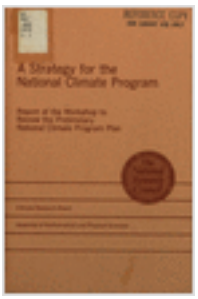

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A Strategy for the National Climate Program

Report of the Workshop to
Review the Preliminary National Climate Program Plan
Woods Hole, Massachusetts
July 16–21, 1979
to the
Climate Research Board
Assembly of Mathematical and Physical Sciences
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1980

NOTICE The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Climate Research Board
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Preface

The Climate Research Board, at the request of the National Climate Program Office of the National Oceanic and Atmospheric Administration, organized a Workshop to review the status of the Plan for the National Climate Program called for in Public Law 95-367, the National Climate Program Act, enacted in September 1978. The Act [Section 5d (9)] calls for the preparation of a five-year National Climate Program Plan to be submitted to the Congress within one year of the date of its enactment. It also calls for submission of a Preliminary Climate Program Plan to be submitted to the Congress within six months of the enactment date. Specifically, the Act reads as follows:

A preliminary 5-year plan, to be submitted to the Congress for review and comment, not later than 180 days after the enactment of this Act, and a final 5-year plan to be submitted to the Congress not later than 1 year after the enactment of this Act, that shall be revised and extended biennially. Each plan shall establish the goals and priorities for the Program, including the intergovernmental program under section 6, over the subsequent 5-year period, and shall contain details regarding (A) the role of federal agencies in the programs, (B) federal funding required to enable the Program to achieve such goals, and (C) Program accomplishments that must be achieved to ensure that Program goals are met within the time frame established by the plan.

It is this preliminary plan that was reviewed by the Climate Research Board Workshop and is referred to hereafter as the Plan.

The Plan represents a conscientious effort to respond to the provisions of the Climate Program Act, the views of the federal agencies, the recommendations of the Climate Research Board, and comments and suggestions elicited

in special seminars and workshops convened by the National Climate Program Office during the past year.

The July 1979 version of the Plan, the subject of a hearing by the Subcommittee on Natural Resources and Environment of the House Science and Technology Committee on July 10, 1979, was delivered to the Workshop participants only as they assembled. As a result, the time available to the participants for examination of this version of the Plan was quite short. The participants, however, had had the opportunity to study three earlier versions. Participants' preparation for the Workshop and much of the deliberation during the Workshop focused on the June 1979 version. The final version differed in significant ways. In addition to the Plan, the Workshop participants also had available other supporting documentation as well as several agency plans. For example, they examined in some detail planning guidelines for the research component of the Program and the plan for carbon dioxide research of the Department of Energy. It was not possible to make an up-to-date version of this plan available to participants before the opening day of the Workshop.

The Workshop was organized into six principal working groups corresponding to individual chapters or sections of the Plan. Although there was considerable interaction among members of the six working groups, there was no detailed review by all participants during the course of the Workshop of the specific recommendations of the individual working groups. This overall review was accomplished after the Workshop through review by all participants of the draft report as a whole.

To ensure that experts broadly representative of scientific and applied interests relevant to all aspects of the Plan were present to conduct the review, it was necessary to augment the expertise of members of the Climate Research Board with that of participants from many different fields, especially from applied climatology. These individuals and their affiliations are noted in the list of participants in the Workshop (see Appendix A).

The six working groups were:

Working Group on Climate Data, Information, and Services,
Working Group on Climate System Research,
Working Group on Climate Impact Assessment,
Working Group on International Climate Activities,
Working Group on Intergovernmental Climate Programs,
Working Group on Carbon Dioxide and Climate.

In addition to these six main working groups, an *ad hoc* group was convened to examine the issue of program management and its impact on program execution. Most participants were members of at least two Working Groups.

This report is the second to be issued by the Climate Research Board on the status of the planning for the National Climate Program. A similar Workshop was held in July 1978 to review the status of the National Climate Program planning just before the enactment of the Climate Program Act. Its report, entitled *Toward a U.S. Climate Program Plan* (National Academy of Sciences, Washington, D.C., 1979), provided extensive background information and a series of recommendations for the development of the five-year National Climate Program Plan. The Climate Research Board presented these recommendations as a reservoir of suggestions that could be drawn on by executive department agencies in preparing the five-year plan. Although we are pleased that the Plan incorporated some of these suggestions, we also note that significant parts of the Plan, such as the section on international aspects, do not reflect many of the earlier recommendations. We continue to believe that the previous Climate Research Board report provides a range of useful recommendations that could contribute to the development of the final five-year National Climate Program Plan.

This report deals with priorities within the scope of the National Climate Program as defined by the Congress. It does not consider relative priorities between the problems of climate and the many other problems of society. Hence our recommendations should not be interpreted as narrow advocacy for climate programs. The report necessarily reflects the expertise and experience of its authors and their perception of gaps in the Plan under review. Thus, for example, the chapter on international aspects draws on the experience of the concerned Working Group to present a large array of potential initiatives that could give substance to an aspect of the Program deemed important by Congress but neglected in the Plan. Congress also emphasized that the Program must be designed to meet user needs. In this and in last summer's reports we have stressed this concern. However, a week's work by a handful of people could not achieve this goal. Vigorous and extended efforts by the planners of the National Climate Program will be needed. The advisory committee called for in the enabling legislation will, we hope, play an important role in this process.

The most serious deficiency of the Plan was believed to be its lack of specification of priorities for action. The Workshop therefore concentrated on program priorities and on a possible strategy for the National Climate Program that could serve to shape these priorities. This strategy is outlined in Chapter 1. Chapter 2 contains some general comments and recommendations for the Plan as a whole. The specific comments and priority recommendations of each of the Working Groups are presented in subsequent chapters. In a few instances, more-detailed discussions believed to be important by Workshop participants have been included in the Appendixes.

We hope that the strategy and priority recommendations of this Workshop will be useful to the executive department agencies and the Congress as they

consider the final versions of the five-year plan of a program that is of such great importance to the nation.

Robert M. White, *Administrator*
National Research Council
Workshop Study Director

Contents

1
A Strategy for the National Climate Program

The impacts of climate and its changes on our lives are ubiquitous. The National Climate Program, as a result, draws the interest of many affected groups for different but valid reasons. Not only are climate and its changes important to the conduct of our daily lives and to the nation's industrial and agricultural activities, but they also affect the formulation of national policies, for example, those for food and energy. Moreover, climate has broad international ramifications.

It is not surprising, therefore, that different groups see different values in a national climate program and look to different outputs to serve their needs. Some see in the National Climate Program a new opportunity for increasing our national economic productivity through more-effective application of existing climate knowledge. Others see the program as the vehicle for undertaking the research necessary to understand better the possible consequences of man's activities on the climate itself. Still others see in the Program an opportunity to develop reliable predictions of seasonal and interannual anomalies in climate. Great consequent economic benefits could flow from an enhanced ability to make longer-range plans.

These values are in fact closely interrelated. For example, Congress believed that a demonstration of improved productivity through use of climate information would increase the demand for new data and new research results. This demand for information would motivate research and facilitate the provision of necessary resources. Similarly, improved data and knowledge would permit better services.

The National Climate Program Act addresses all of these values and specifies several mechanisms and institutional arrangements through which its

objectives might be achieved. For example, the Act specifies that experimental climate-forecast centers be established and that a federal-state cooperative program be instituted as a means for delivering climatic services responsive to needs at state and local levels.

The Plan reflects these diverse interests. It seeks to be responsive to the requirements of the Act as well as to the values that various constituencies attach to the National Climate Program. However, although some elements of an overall strategy are to be found in the Plan, a clearly stated strategy for implementation of the National Climate Program to meet the needs of those who will be served by the Program's output is lacking.

Developing a strategy means making difficult choices, but these choices must be made. An agreed-on strategy is essential to provide an overall working framework within which program activities can be related one to another, program balance can be assessed, and funding allocations can be made. Such a strategy would be equally helpful to those who plan the program and to those who carry it out.

Within the organizational framework of the National Climate Program, which visualizes three principal components—climate-system research, provision of data and services, and climate-impact studies—we propose a *general strategy* to permit selection of the types of activity that will be pursued within each component.

GENERAL STRATEGY

The National Climate Program should emphasize early production of useful outputs on the basis of our present knowledge of climate while simultaneously expanding the understanding of climate and its relationship to society.

Within this strategy, the program must focus on *types of activities* classified by their expected times of payoff and on *priority program areas*. The first we designate as *streams* of activity; the second, *themes*. To clarify the strategic approach that we recommend, the relationships between the types of activity (streams) and the priority program areas (themes) are shown schematically in Table 1.

Types of Activity (Streams)

The following three basic streams of activity should be pursued concurrently as part of the overall strategy:

1. *The first stream of activity would provide for the improved use of existing climate knowledge and for the exploration of the economic benefits*

TABLE 1 Relationship between Types of Activity and Program Areas

Types of Activity (Streams)	Program Areas (Themes)[a]		
	Energy	Food	Water Resources
1. Improved use of existing knowledge: more-effective use of climate information in decision making and improved delivery of climatic information to users	Priority projects	Priority projects	Priority projects
2. Research in natural and man-made climate change and in the accompanying impacts on society	Priority projects	Priority projects	Priority projects
3. Research in the prediction of climate fluctuations and in the societal needs for and consequences of such predictions	Priority projects	Priority projects	Priority projects

[a]Program areas are designed to influence priority decisions in applications and impact studies.

that might be derived from more-effective use of climate information in decision making and from improved systems for the delivery of climatic information to a wide range of users. The climatological record contains data and information on what nature has done and, in the actuarial sense, is likely to do in the future. Thus, even without any climatic-forecasting skill in the meteorological sense, there is a basis for much better use of existing climate information and for delivery of this information to users. The first element of our strategy is therefore to provide the mechanisms and the tools needed to tap and apply this reservoir of climate information. We are reasonably sure that this stream of activity will demonstrate and yield economic benefits at an early date. We see no technological or scientific barriers to the successful undertaking of this stream of activity. An adequate program might well provide useful outputs within one to two years.

2. *The second stream of activity would encompass the research necessary for the determination of the sensitivity of climate to man-made and natural perturbations and the impact of such possible climate changes on society.* We feel that an adequate program of research can provide significant improvements in our knowledge of critical climate processes, in our ability to construct models of the climate's long-term response, and in our ability to assess

the consequences for human society. In about five years, through vigorous programs of climate-system research and climate-impact studies, it should be possible to sharpen significantly our estimates of the consequences for climate and society of such issues as the increasing atmospheric concentration of carbon dioxide (CO_2) resulting from deforestation and the burning of fossil fuels. The record of human history gives many examples of small and large climate surprises that have had significant social and economic consequences. Societies that experienced these changes might have coped better had they been forewarned.

3. *A third concurrent stream of activity should enhance the present national and international research effort to develop an ability to predict the fluctuations of climate on seasonal and interannual time scales* and to assess the related societal implications. Reliable predictions could significantly benefit management of agriculture, energy, and water-resource activities. This difficult scientific problem can only yield to a long-term, sustained effort with frequent reassessment of progress and prospects. Research is needed not only into the means for providing predictive information but also into the needs for prediction, optimum means for utilizing predictive information, and the quantitative impacts of predictive capabilities on the various sectors of the economy. There is no way to estimate when or to what degree the objective of improved climate prediction can be achieved, but we believe that there is sufficient scientific promise and societal importance to warrant a strong commitment to this stream of activity.

Priority Program Areas (Themes)

The Program, within any reasonable level of funding, cannot immediately meet the needs of all groups that have interest in its possible outputs. There is, therefore, a pressing need to establish priorities. The expectations for the National Climate Program must be realistic, and it should be recognized that most objectives cannot be met within an initial five-year period. The Plan, therefore, must be viewed as a road map into the future with priority targets carefully chosen so real progress can be made toward a limited number of objectives.

As a second dimension in the recommended strategy, we propose the adoption of a limited number of themes based on major national and international issues; priority decisions in applications and impact study areas should then be influenced by these themes. When basic research in any of the streams is involved, priority judgments must, of course, be based primarily on needs for fundamental knowledge.

The interlocked and mutually supporting themes of *energy*, *food*, and *water resources* suggest themselves as priority program areas. *We urge that*

such policy themes be selected soon and that the general character of the National Climate Program for the next five years flow from them.

Program Implementation

The priority recommendations in the subsequent sections of this report are responsive to the strategy outlined above. This implies that some areas of activity that are significantly affected by climate may not be given major attention during the early years of the National Climate Program. Although we do not propose the elimination of climatic activities other than those related to energy, food, and water resources, we believe that a sharp initial focus for the climate program is vital to its success. It should be noted, however, that energy naturally relates to transportation, heating, and cooling, whereas food encompasses both conventional land agricultural and marine food resources.

If this strategy is adopted, then the planning for the first stream of activities needs strengthening. Tasks need to be made more specific, priorities need to be assigned, and outputs need to be described. Our suggestions for priorities and improvements are described in the chapters on data, information, and services and the Intergovernmental Climate Program (Chapters 3 and 7). Funding of this stream of activity will need significant augmentation if the strategy is to be followed.

The second stream of activity is better formulated. In particular, the detailed plans of the Department of Energy for the carbon dioxide research program are generally sound. In the physical sciences, they are sharply focused, and preliminary priorities have been specified. Funding for many important projects has been committed. The Department of Energy's plans, however, need strengthening in their multiagency approach to the societal impacts of climatic changes caused by increases in carbon dioxide on society and on the biosphere. Our recommendations for priorities and other ways to improve this part of the Plan are included in our chapters on research, impacts, and carbon dioxide (Chapters 4, 5, and 8).

The planning for the third stream of activity aimed at achieving the basic understanding of climatic processes necessary for seasonal and interannual climate prediction has many good features but also needs strengthening. Our proposals for ways in which this can be done are set forth in the chapter on research (Chapter 4).

The strategy recommended here has direct implications for funding allocations among the parts of the Climate Program. It is our understanding that the Carbon Dioxide Effects Research and Assessment Program of the Department of Energy (DOE) is satisfactorily funded and has support at the policy levels of that department, although it may not completely cover all the needs

of the broad and diverse DOE program. Funding for the DOE program increased by $2.1 million from a fiscal year 1979 base of $4.1 million. The National Aeronautics and Space Administration (NASA) part of the Climate Program, especially as it pertains to the earth radiation budget experiments and some aspects of ocean monitoring by satellite, appears to have adequate funds and policy-level support. Funding for the NASA program increased by $25.5 million from a fiscal year 1979 base of $13.7 million. Moderate amounts of new funding have been allocated to the National Oceanic and Atmospheric Administration (NOAA) program. Funding for the NOAA program increased by $6.2 million from a fiscal year base of $19.4 million. Only small increases were made for programs of the National Science Foundation (NSF) and other agencies. However, no major increases are evident in funding for NOAA and the Department of Commerce despite their responsibilities to lead the national effort. This manifests itself most clearly in the lack of funding support for climate data, information, and services. These three agencies account for $33.8 million of the $35.1 million 1980 fiscal year increment in the government-wide funding for the National Climate Program.

The Workshop was pleased to see such policy-level support in NASA and DOE. However, it appears that other segments of the program have not received substantial new funding. Elements such as the climate data, information, and services component and its related Intergovernmental Climate Program have received very little new funding. No funding for the experimental climate forecast centers has been explicitly identified. This has resulted in a funding imbalance relative to the program strategy we recommend. *Therefore, if this program strategy is adopted, some funding changes will be necessary.*

2
A General Appraisal of the Plan

In light of the strategy proposed in the previous chapter and because of the inherent complexity in drafting a comprehensive climate plan, the Workshop participants believe that the preliminary plan must be regarded as only a first step in a continuing planning process. This preliminary plan requires extensive refinement and modification before it can become the Five-Year National Climate Program Plan called for in the Act. For all the effort that has gone into its preparation, and despite the excellence of some of its parts, there are still shortcomings.

The Plan has been improved by successive revisions, but it remains *more essay than plan.* It lacks sharp focus. In earlier versions, an Executive Summary attempted to communicate a sense of importance and priority for some of the proposed undertakings. This sense of priority is lacking in the July version. *An Executive Summary should be restored to provide a concise summary of objectives, planned accomplishments, and priorities.*

The Plan presents only some general statements of priority, and a sense of priorities to be assigned to the various tasks does not emerge strongly. The Act itself does not explicitly suggest priorities. It authorizes work in each of nine elements of the program, which together encompass virtually all areas of climate research, impact studies, information, and services. Clearly Congress expected some selection of priorities. No two groups are likely to establish exactly the same priorities, but the strategy suggested in the previous chapter may be helpful. Clearly stated priorities are essential for apportioning resources among the components of the Program and among individual activities within these components.

We believe that the Plan does not accord international climate activities the special attention that they deserve. In our previous report we emphasized that the U.S. National Climate Program cannot be carried out in isolation and should be viewed as an integral part of the World Climate Program. The Plan as presented to the Workshop fails to identify program content and priorities. For this reason the Workshop gave special emphasis to this aspect of the Plan. Recommendations are given in the chapter on international climate activities (Chapter 6).

The Plan is unclear about how it will actually attempt to accomplish its objectives. The Plan needs to be more specific about the participation of various agencies and organizations. With the level of detail provided, it is not possible to identify gaps and redundancies that may exist in internal agency plans and priorities and that may result from the limitations of financial and intellectual resources. In this connection, the Workshop is concerned about the adequacy of the present management structure for further developing and then carrying out the Plan. The National Climate Program Office appears to lack the necessary authority to discharge its responsibilities. It has little budgetary flexibility. It does not have the necessary stature within the Department of Commerce or among the other agencies to bring about a coherent government-wide effort. There is some question about whether the Department of Commerce is facing up to its lead-role responsibilities. The policy-level interagency apparatus established to guide the Program needs to provide much stronger policy guidance and to become a real forum for agency commitments to the program. *This concern leads us to recommend that* NOAA *and the Department of Commerce review the adequacy of the management structure for the National Climate Program.*

The July 1979 version of the Plan does not provide information on the costs required to carry out the Plan. Given the nature of the annual federal budgetary and appropriation process, it is understandable that commitments of funding cannot be made for five years in advance. Funding requests for the Climate Program must undergo the same scrutiny as those for all other programs in the federal government. However, funding estimates need not represent commitments, and they are essential to any appraisal of the realism of the Plan. The lack of such data in the Plan has therefore seriously impaired the Workshop participants' ability to make judgments of this kind. At the very least, the Plan should present comparative expenditure information for fiscal year 1979 and fiscal year 1980, so programs and priorities can be related to associated budgetary decisions.

In budget estimates, a clear distinction must be made between the continuing costs of ongoing programs and the costs of new initiatives and between the resources directly and indirectly supporting the National Climate Program. As suggested in the previous report of the Climate Research Board,

indirect activities are those that would be funded even in the absence of a National Climate Program, whereas direct activities and associated costs are those primarily justified by the climate effort itself. The Workshop participants had no clear indication in the Plan of the ongoing work and associated costs as opposed to efforts proposed for implementation with new funding. Setting priorities in the absence of such data is difficult.

With respect to overall program costs, it is clear that the development and continued operation of a dedicated global climate-observing system could cost an order of magnitude more than the funding that is likely to be available. Thus the achievement of the program goals within reasonable funding levels must depend on the use of existing and planned observing systems and related facilities developed for other purposes that can be adapted to the needs of the Climate Program with relatively modest cost increments. This applies to ships, aircraft, buoys, ground-based observing networks, communications, data-processing and -management facilities, and especially satellites. It is particularly important that all atmospheric, ocean, and earth resources satellites now in the planning stages by NOAA, NASA, and the Department of Defense be designed with the view of their contributing to the climate program to the maximum possible extent.

The National Climate Program Plan should provide a basis for evaluation of progress toward the objectives of the National Climate Program Act. The tasks as outlined in the Plan are so broad that evaluation of progress would be difficult. The Workshop recommends that during the first year a small number of well-planned priority projects be undertaken while planning for the remainder of the program continues. This would permit the advisory committee called for in the Act to participate in the planning process and ensure that user interests are represented adequately. This proposal recognizes that, although the planning process is only in its beginning stages, those parts of the effort for which sound plans exist should move ahead without delay.

Finally, we note that *little attention has been given to the question of the education and training implications of the Program.* In our previous report we suggested that this question be addressed in the Plan. We continue to stress this need.

3
Data, Information, and Services

This component of the National Climate Program involves the functions of observation, data management, and provision of useful products and services related to current and potentially changing climates. These functions not only serve users directly but also support the research and impact-assessment components of the Program. *We consider the service function to be of great importance at the outset of the National Climate Program because of the early benefits that can flow from it.* We are aware of the wide range of excellent climate data, information, and services now provided by agencies of the federal government. We believe, however, that the agencies could more fully exploit the potential for improved services if they had adequate support and if they employed feedback from users to formulate priorities.

We believe that the Program will ultimately be evaluated on the extent to which climate information is used to increase the effectiveness and productivity of our nation's enterprises, both public and private. This perceived need for greater use of climatic information provided important motivation for passage of the National Climate Program Act by the Congress. Further, in these times of energy shortage, increasing water-resource scarcity, and potential food shortages, it is important for the diverse elements of the scientific community to organize their efforts to alleviate or mitigate these serious problems. Also, we believe that applications of existing climate knowledge, properly organized and incorporated in planning and decision making, can contribute substantially to the national response to these problems. *Finally, we believe that the improved provision of climate services will require a relatively small incremental investment of resources.*

Experience developed in provision of climate services can, additionally, serve as an effective guide to other elements of the Program by helping to answer such questions as: What research should be done? What are the appropriate parameters and scales for new observational networks? What data should be extracted from the record? In what form or forms can these data be made most useful?

In formulating our priority recommendations given below, we have not considered costs, about which we had little data. Obviously the cost implications of our recommendations will have to be considered before final decisions about priorities are made. Our priorities are based on meeting overall Program objectives as stated in the Plan, some reasonable balance between short-term and long-term beneficial results, and the manner in which the tasks conform to the energy, food, and water themes. Little correlation may exist between our priority order-of-action recommendations and their resource requirements. Further, this section is related closely to the Intergovernmental Climate Program discussed in Chapter 7. Finally, it is not our intent to suggest that actions entirely be carried out sequentially; many of the items enumerated should proceed concurrently.

OBSERVATIONS

Observations provide the basic data for all aspects of the Program. The data serve many purposes of farmers, designers, engineers, planners, ecologists, climate researchers, and others.

Many agencies are now engaged in collecting basic climate data, generally to meet the needs of their own programs. There exist a number of data-collecting networks of different age, scale, and purpose. *Yet there are important data and information gaps relative to important needs in the fields of energy, food production, environmental monitoring, water supply, and climate prediction.*

We sought to identify priorities after an extensive discussion of a wide range of possibilities and by obtaining a consensus of the members of the Working Group about the importance they attached to a number of high-priority activities. We list them below in approximate order of importance by groups. All elements in the same group received approximately the same ranking.

Group 1

(a) Assure the integrity of the NOAA cooperative climatological network and the quality of its observations; assess the possibilities of automation in

the network, and take steps to speed the collection; processing, and dissemination of the data collected. This network has not received care and attention commensurate with its value as the source of data essential to many local applications in agriculture, site selection, and construction.

(b) Improve and expand the network of solar and terrestrial radiation measurements. The quality and quantity of existing records fall seriously short of what is needed in view of the emerging importance of solar radiation as an energy source, as a driving mechanism of climate, and as a complement to the Earth Radiation Balance Experiment.

(c) Assure the continuity of existing climatic benchmark reference stations and increase their number to provide an objective set of data against which to observe climatic change. This is essential to our long-term ability to monitor climatic fluctuations, trends, or changes independently of changes in station location or environment.

(d) Conduct the Earth Radiation Balance Experiment (ERBE) to provide knowledge critical to an understanding of climate processes and climate change. This experiment is also important for possible prediction of medium-range and longer-term climate fluctuations [also see priority (b) above].

(e) Establish a global monitoring system to detect possible climatic effects of the increasing atmospheric CO_2 concentration; consider, in planning this effort, the possibility that thermal effects may first be measurable in the stratosphere and polar regions. This is a basic data need for verifying theoretical calculations of a global warming resulting from increased CO_2. (Further details are given in Chapter 6.)

(f) Activate programs for satellite and other types of observation of conditions in the upper layers of the ocean for purposes of climate monitoring and research in climatic processes; design systems to assure adequate coverage of the southern hemisphere. In the case of satellites, immediate attention should be given to the modification of the design of planned operational and research satellites to optimize their use for climatic purposes before their designs are frozen. Proposals for an internationally coordinated program are presented in Chapter 6 of this report.*

Group 2

(g) Establish in appropriate regions a network of towers (30–50 m in height) to measure wind characteristics pertinent to the siting and elevation of wind-power-generation systems. Such information is at present lacking as a

*This priority was moved into Group 1 from Group 2 on the basis of a proposed initiative by the Working Group on International Climate Activities and because of the importance attached to this effort by the Working Group on Climate System Research.

basis for the possible use of wind energy as a power source and for the design of energy-efficient buildings.

Group 3

(h) Establish temperature-observing networks in urban areas to provide information needed in heating, air conditioning, and energy-distribution applications. Data are needed from urban areas to establish significant climatic differences over small distances, especially in metropolitan areas located along shorelines.

(i) Improve existing networks and develop improved methods for the observation of precipitation. Both the spatial distribution of rain gauges and their inherent accuracy are inadequate for modern requirements.

(j) Develop improved methods for soil moisture detection and monitoring. This is particularly critical in predicting agricultural productivity for effective management of freshwater resources, which are predominantly used in irrigation in food-production systems.

DATA MANAGEMENT AND INFORMATION

Intermediate between the observation of climatic events and the applications of the data are the processes of data management, quality control, processing, retrieval, and dissemination to users. Indeed, planning for these functions should precede and guide the development of the observing system itself. In considering the Program's data-management and information functions, we were guided by concern that data management be efficient and cost effective and, most importantly, that it be made as sensitive and responsive as possible to the needs of user groups. Hence, in the following *recommended actions* we emphasize realistic assessment of the quality of existing data, rapid adoption of new data-handling technologies, easy interchange of data resources among federal and state archives, integration of nonclimatic data sets needed in assessment and impact studies, and easy access to the data by user groups.

Group 1

(a) Establish a Climate Data and Information Clearinghouse to identify, inventory, and standardize climate data resources and to refer users promptly and effectively to the sources of needed information. The clearinghouse should encourage the registration of data sets useful for impact assessment and should convey information on user requirements for data products and

formats to supplying agencies. Such a clearinghouse is an essential mechanism to link the highly dispersed users of climatic information and the producers through a versatile and responsive system. Beginnings of such a clearinghouse have been established in NOAA, but the NOAA facility would require considerable expansion to meet the needs of a growing National Climate Program.

(b) Develop advisory mechanisms to ensure that modes of data storage and retrieval are responsive to the evolving needs of users in agriculture, industry, public programs, and research. The availability of basic data sets is of critical importance. The statutory Climate Program Advisory Committee should undertake this urgent task, considering carefully the assignment of priorities among users.

Group 2

(c) Develop mechanisms to assure that (i) existing climate data sets are accompanied by statements of characteristics and limitations, (ii) new sets added to archives are strictly monitored with respect to quality, integrity, and accessibility, and (iii) a custodian is designated for management of each set of data in state as well as federal archives. The cost of minimizing loss of data, reducing misunderstanding of data, and correcting internal inconsistencies in data sets is low compared with the cost of the observations themselves, but the return on investment is high.

(d) Improve climate data-processing capability, retrieval, and accessibility through introduction of advances in data-base management methods, storage technology, and methods for improved communication of data sets to and from users. The vast amount of data and their somewhat unpredictable combination into information sets mandate the flexibility and economy available through evolving technology.

Group 3

(e) Consider (i) the costs versus benefits of storing high-volume satellite data for climate-related purposes, (ii) the merits of consolidation or decentralization of data repositories, and (iii) the adequacy of protection against catastrophic loss of climate data. Each item entails substantial continuing cost and raises accessibility questions, with the last item having special significance to potential future national-defense requirements.

SERVICES

The provision of improved climate-related services is mandated in the National Climate Program Act. Previous reviews of the Climate Research Board

indicated that a potential exists for much greater use of climate information in support of various sectors of the national economy, such as agriculture; fisheries; trucking; construction; energy production, distribution, and conservation; and the general public. Specific examples of such proven uses appear elsewhere in this report. As we indicated in our previous report, the private sector, as well as governmental units, has an important role to play in the provision of useful services. In view of these considerations, we recommend the following activities as candidates for high priority in the implementation of the National Climate Program.

Group 1

(a) Conduct or contract for a small number of operational demonstrations of the utility of climate information products and services in key sectors of the national economy, preferably food, energy, and water resources. These demonstrations should be carefully monitored with respect to costs involved and benefits derived and their distribution; an example of one such demonstration on climatic support for irrigation, judged to have a high likelihood of success, is described in Appendix B. Only through demonstration programs can a fair test of one of the basic premises of the Program–its ability to improve national productivity–be assured.

(b) Conduct intensive analyses of the costs and benefits of operational climate services now being provided to a wide range of industries and constituencies. This can be a further test of the utility of climatic services. Some examples of the economic benefits that can be derived are given in Chapter 7, The Intergovernmental Climate Program.

(c) In concert with knowledgeable representatives of user groups, conduct or contract for studies of the potential for new applications of climate information and services. These studies should consider the potential costs and benefits, both economic and social, and their distribution. We suspect that there are many new ways and different human endeavors in which climatic knowledge can be usefully applied.

(d) In implementing the Intergovernmental Climate Program, provide (i) decentralization needed to assure effective management of local data sets, (ii) professional assistance responsive to local conditions and users, and (iii) mechanisms to convey information on local needs to central agencies. A discussion of this matter is presented in Chapter 7.

Group 2

(e) Provide surveillance and reports in quantitative terms on mesoscale and regional climatic phenomena (e.g., drought, extreme rainfall, snow

accumulations), using data assembled on appropriate scales of time and space. Serious climatic fluctuations may occur on the scale of a few counties to a few states; the monitoring and early-warning systems should be designed accordingly.

(f) Determine the specialized needs of major sectors of the economy for long-range forecasts and develop products appropriate to those needs within the limitations of present forecast capability. This may be a task for the experimental climate-forecast centers discussed in Chapter 4. Knowledge of extreme conditions is important: for some decisions it may be necessary to know only, for example, that average temperature in a region is expected to be in the highest or lowest 10 percent ever observed for the following month; attention could then be focused on the specialized problem rather than on a much broader one (see also Sections 3.8 and 3.9 of *Toward a U.S. Climate Program Plan*).

(g) Develop policies to encourage and facilitate greater involvement of the private sector in the provision of climate services to the nation. Both the basic economic philosophy of the United States and the limitations of resources within the government dictate a large role for the private sector, especially in meeting specialized user needs.

Group 3

(h) Increase awareness in the Department of Commerce that climate information and services can be of benefit to U.S. business and industry through improvements in productivity. The entire Department of Commerce, not just NOAA, should actively participate in the National Climate Program.

(i) Conduct information programs to increase the awareness of decision makers in government, industry, and public affairs to the potential benefits of climatic services.

(j) Initiate analyses that will permit (i) a critical assessment of the contents of existing climatic publications, (ii) improvement in the timeliness of issue and distribution of publications, (iii) application of new technology in the publication process, (iv) evaluation of new channels of information dissemination, and (v) provision for a reasonable division of cost and effort between publications for a general audience and information provided to meet specific user needs. The existing publications system appears to have evolved over a long time on an *ad hoc* decision basis, and a thorough analysis of the system should result in some improved modes of operation.

4
Climate-System Research

The climate-system research section of the Plan contains most of the ingredients necessary for a successful program of climate research. Nevertheless, the organization of these ingredients in terms of objectives and tasks makes it difficult to discuss specific activities and to assign priorities. The tasks identified do not relate to clear research objectives and do not address those disciplinary groups expected to perform the work.

A supporting document, *Planning Guidance for Climate Systems Research* (Draft Appendix to the National Climate Program 5-Year Plan, National Climate Program Office, NOAA, June 1979), was made available shortly before the Workshop. It presents a more complete rationale for the research component and a rich reservoir of topics for research. Moreover, its organization is better attuned to our perception of the scientific problems and the means by which they should be addressed. This excellent document, however, is not in itself a research plan. It is a catalog of what could and should be done, not a prescription of what will be done. Within the broad and many-fingered streams of research outlined in this document, many priorities are identified. However, even this reduced list could hardly be pursued in its entirety. Our purposes here are thus to suggest how the storehouse of possibilities represented by this document may be drawn on to develop a sharply focused plan that can be successfully implemented within the constraints of time, resources, and talent. To this end, we will present suggestions on the organization of a research plan, and we will extract from the *Guidance* document a limited group of research activities of the highest priority and greatest feasibility.

ESSENTIAL ELEMENTS OF A RESEARCH PLAN

The scope of possible climate research is exceedingly broad. A clear rationale is therefore required and should include:

- A clear statement of *research goals* in terms related to the objectives of the climate program as a whole.
- Identification of *research approaches* to be used in achieving these goals.
- A set of well-defined *priority research tasks* necessary to implement the approaches and to build basic knowledge and capabilities. Priorities for these research tasks must be based on some hypothesized level of resources.
- *Milestones* that can reasonably be expected to be achieved.

Here we suggest an outline for the development of a climate-system research program that meets these criteria.

Research Goals

The successful experience of the Global Atmospheric Research Program (GARP) has demonstrated the importance of simple and clearly stated objectives. These must be both scientifically meaningful and directly related to the practical goals of the program and the strategy adopted for its implementation. It is recommended that the following be adopted as a statement of the goals of the climate-system research program:

1. *To achieve a more-detailed knowledge of the characteristics of the present climate of the earth.* This information is necessary to support improvements across a wide spectrum of research and climate-related activities.
2. *To improve our understanding of the physical basis of climatic variations on time scales from several weeks to several years.* This would lead to a capability to assess the predictability of the seasonal and interannual variations of climate that are of great concern to humanity.
3. *To improve our understanding of the nature of fluctuations of climate over decades to centuries.* This would lead to an improved capability to assess the longer-term influences of human activities on climate.

Research Approaches

Research directed toward these goals should focus on the diagnosis of the structure of the present climate and on the development and application of empirical and dynamical models for the diagnosis and prediction of climatic variations. The principal approaches or areas of research activity should be

consistent with the program's goals and with the resources of the participating scientific disciplines. This will permit the realistic planning of research by specialist groups and the definition of coherent research projects.

The definition of research areas evolved for the World Climate Research Program is a useful example of such an approach. It is recommended that the climate-system research program be structured in a similar fashion in order to facilitate coordination between the national and international efforts; the organization of the *Guidance* document referred to above is in fact closely related to this structure.

On this basis we recommend that the principal approaches or areas of activity in the climate-system research program be defined as follows:

Research Data Acquisition and Empirical Studies

- Specification of data needs for climate research,
- Development of observing and monitoring systems for climate research,
- Reconstruction and diagnosis of selected past climates,
- Diagnostic studies of the present climate,
- Statistical-empirical studies of climatic variation,
- Development of high-quality comprehensive data sets from the First GARP Global Experiment,
- Enhancement of existing and development of new global climate data sets from past and continuing satellite observations.

Studies of Physical Climate Processes and Their Parameterization

- Cloud-radiation interactions,
- Ocean-heat storage and transport and sea ice,
- Atmospheric latent- and sensible-heat transport,
- Hydrological cycle,
- Land-surface processes,
- Biogeochemical processes,
- Aerosol-radiation interactions,
- Sun-climate effects.

Climate Modeling and Model Applications

- Model development and testing,
- Model validation against present and past climates,
- Numerical experiments on the predictability of seasonal and interannual climate changes,
- Numerical experiments on the longer-term sensitivity of climate to natural and man-made influences.

Priority Research Tasks

To merit priority, we believe that an activity must be both scientifically important and tractable in terms of costs and resources. Also relevant in some cases is the long lead time required for development of the required knowledge or capability. In determining priorities, we have assumed that the substantial current level of effort in climate research will continue and that increases of the order of 10–20 percent per year in total research funding (in real terms) will be available over the next few years. There are substantial climate research efforts under way in NOAA and NASA as well as in the university community and at the National Center for Atmospheric Research (NCAR) through NSF. Since we did not review these efforts in detail, we identify here only those activities that we judge to be in particular need of *additional* resources. In doing so, we do *not* imply a diversion of resources from ongoing research programs.

Another major limitation, which we recognized but did not address in detail, is manpower. The Climate Research Board identified this matter in its previous report, and its recommendation that this problem needs some treatment in the Plan remains valid. Recommendations for increased research necessarily imply increased manpower, which, in fields such as physical oceanography and boundary-layer meteorology, is already in short supply.

From among the elements of the research approaches outlined above, the following are identified as priority research tasks:

Research Data Acquisition and Empirical Studies (see also Chapter 3)

- Further development of the technology for satellite measurement of selected climate parameters, especially the incoming solar radiation, precipitation over the ocean, sea-surface temperature, snow cover, and sea ice.
- Improvement in the coverage, accuracy, and accessibility of climate data bases for research.
- Further global and regional diagnostic studies of the observed behavior of the climate system, including studies of the annual cycle, seasonal climate anomalies, longer-period climatic fluctuations, and past climates.

Studies of Physical Climate Processes and Their Parameterization

- Further studies of cloud-radiation interaction to clarify the relationships among large-scale atmospheric conditions, cloudiness, and cloud-influenced atmospheric radiation.
- Studies of methods for parameterizing standing-eddy and Hadley-cell transports in simplified models.

- Focused ocean process studies to clarify the mechanisms responsible for the production and maintenance of sea-surface temperature anomalies, sea ice, and the roles of oceanic heat storage and transport (see Chapter 6, International Climate Activities).
- Concerted international pilot studies to relate vegetation and soils data and improved satellite information to albedo, surface roughness, hydrologic processes, and ecosystem patterns.

We believe that these tasks are necessary in order to show how the climate system actually works. There are so many potentially interacting climate variables that diagnostic and process studies are essential to provide guidance for focused model studies. To be of maximum value, these studies should span a wide range of climatic states and include the use of paleoclimatic data.

Climate Modeling and Model Applications

- Improvement in the simulation of the characteristic annual variation of the distribution of such climatic variables as temperature, wind, cloudiness, and precipitation, along with the associated seasonal variances, covariances, and statistics of derived parameters, such as heat transport and storage.
- Intensified studies of the predictability of seasonal climate anomalies with a variety of atmospheric models and with data sets similar to those used for simulation of the mean annual cycle.
- Additional studies of the climate's response to changes in the external parameters of the climate system, especially changes in the atmospheric CO_2 concentration.
- Further development of ocean models and a hierarchy of coupled ocean–atmosphere models for climate studies.

We believe that these tasks are necessary to facilitate understanding of the operation of the climate system. The models should be validated against the observational results of the Global Weather Experiment to the fullest extent possible. The periodically varying factors influencing the annual cycle are large and well known, and the resulting atmospheric signal is the largest known climatic change. Analysis of these simulations will provide valuable clues about model behavior and will therefore be a guide to model improvement. Seasonal climate anomalies are also large, and the necessary models and data are available for their experimental prediction. We urge that such predictions be made, using all suitable models and data, and that the work of the experimental climate-forecast centers be considered an integral part of this activity. Analysis of these predictions will help to determine the predictability of different climate variables as functions of location and season and

will also provide valuable guidance for model improvement. Studies of the climate's sensitivity to external effects should also include the response to volcanic aerosols, changes in land-surface character, and changes in solar radiation. Such studies will improve our understanding of long-term climatic variations and the human influences on climate.

Experimental Climate Forecast Centers

The National Climate Program Act mandates the establishment of "experimental climate forecast centers." Although no plan has been suggested by the National Climate Program Office (NCPO) for implementing this requirement, we do agree with the rationale presented in the Plan. In December 1978 an informal meeting arranged by the Climate Research Board to consider this problem indicated that *three to five centers should be established utilizing strengths of existing groups, operating with differing scientific approaches, and having specialized concerns for different major sectors of our economy.* It was further suggested that these experimental climate-forecast centers should be initiated gradually, beginning under the second year of the National Climate Program. Although these suggestions for the development of the Plan still appear reasonable and timely, they were not discussed further at the Workshop.

Milestones

From these priority research tasks the following specific goals are considered feasible to be addressed within the five-year scope of the Plan:

- Improved validation of models with the aid of new global observations.
- Design of a feasible and effective global climate-observing system through the use of climate models.
- Development of research-quality climate data sets from existing and planned satellite and conventional observing systems.
- Preparation of provisional estimates of the role of forests and soil organic materials as sources or sinks for CO_2, using available data sets on major ecosystem-cover classes.
- Use of the climate-observing system to monitor indices of global and regional climate and use of the resulting data for climate analysis, "now-casting," and impact assessment.
- Improvements in statistical and deterministic general-circulation models, including validation of coupled ocean–atmosphere models, suitable for use by the experimental climate-forecast centers.

- Development of a well-defined strategy for testing theories of climate change.
- Conduct of sensitivity tests to determine the climate's response to critical parameter changes and conduct of model simulations to determine how the climate responds to anomalies in forcing mechanisms.
- Significant progress toward an understanding of the key factors influencing interannual climate variability, including an improved understanding of the limits of climate-anomaly predictability.
- Extension of historic climate records through use of tree rings, pollen, and other paleoclimatic (preinstrumental) proxy records of climate for improved understanding of space-time anomalies of climate.

5
Climate-Impact Assessment

The National Climate Program Act states that climate-related impact assessments

. . . shall be conducted to the maximum extent possible by those Federal agencies having national programs in food, fiber, raw materials, energy, transportation, land and water management, and other such responsibilities, in accordance with existing laws and regulations.

Such assessments are a mechanism for linking scientific studies of climate to decision making at all levels of government and society. They provide the crucial justification for the study of climate and climate variability, that is, the potential impacts of climate on human welfare. These assessments depend on the ability to analyze correctly societal responses to climatic variations on many different time scales.

In the report of the 1978 Climate Research Board study, a variety of points relating to this problem were suggested:

- The concept of climate as a resource,
- The need for multiagency involvement,
- The need for clearly stated objectives in terms of immediate impacts, societal implications, and formulation of policy options,
- The need to explore different methodologies,
- The desirability of attempting at least partially integrated assessments,
- The need to involve the nongovernmental scientific community and the user groups affected by climatic variability.

We believe that those recommendations remain valid. Our comments below are designed to supplement these points.

Although difficulties with the development of a climate-impact assessment program are recognized and discussed in the preliminary five-year plan (July 1979), the program itself is not defined much better than it was a year earlier. Climate-impact assessment remains poorly structured.

An organized framework or outline is clearly needed as a prerequisite for development of this program. As essential elements, a definition of climate-related impacts and a set of criteria for setting priorities must be established. Commonly accepted and clearly understood definitions of climate-related impacts and impact assessments must be established. Standardized definitions are especially important in this area because impact studies cut across many disciplines and the jurisdictions of many agencies. Criteria embodying a holistic perspective must be developed and applied in determining the priorities among climate-related assessment tasks. Such considerations would guide agencies away from priorities based on narrowly defined criteria.

We note also that the Plan identifies certain studies related to climate impacts in progress in various agencies. However, we are aware of many other such efforts that are not mentioned in the Plan. These apparent gaps give the impression that little progress has been made in this area. Also, this lack of information on agency efforts has made it difficult for us to discern the priorities implicitly employed by agencies in their current programs.

Because of the deficiencies in the present Plan, *climate-impact studies risk being undernourished at a time when they require the greatest infusion of support.* In developing the multidisciplinary National Climate Program envisaged in the Plan, there has been a natural tendency to emphasize those disciplines that have strong, ongoing programs. In the case of climate, this has meant an emphasis on the physical and to a lesser extent the biological sciences. To redress this imbalance, *it is important that an adequately funded, well-structured climate-impact assessment program drawing on the resources of the social sciences be established as an integral part of the National Climate Program.*

It would be a mistake to presume that assessment research will be less expensive than climate-system research or that funds cannot be used so efficiently in underdeveloped programs as they can in well-organized and well-articulated programs. It would also be a mistake to permit delay in the development and implementation of a climate-impact assessment program. Thus, *immediate and concerted efforts should be undertaken to develop a national capability to conduct impact assessments.*

We recommend the following steps as a way to proceed:

1. Thorough analysis of ongoing activities in all agencies, with careful evaluation of methodologies, quality of work, etc. It is obvious that impact

studies in several agencies have not yet been brought into the program. For example, a considerable body of relevant experience in environmental-impact assessment has been developed as a result of studies of the ozone-depletion problem. Also, the Bureau of Land Management has conducted a national assessment of desertification.

2. Evaluation of the institutional arrangements for past national and international climate-related impact-study efforts for the purpose of improving the organization and efficiency of similar future endeavors and the dissemination of their findings. Particular attention should be given to relevant political considerations in addition to structural constraints. The Climatic Impact Assessment Program of the U.S. Department of Transportation might be one good case study.

3. Development of commonly accepted and clearly understood definitions of climate impacts and impact assessments. Some preliminary views on the latter topic are to be found in the 1978 Climate Research Board study. An important related task will be to develop an approach to integrated impact assessment that is feasible in terms of existing institutional capabilities.

4. Development of criteria to determine priorities among climate-related impact-assessment tasks. The themes of energy, food, and water resources that we have suggested provide one type of guideline. But other criteria could include, for example, socioeconomic importance, the urgency of policy decision, the immediacy of social benefits, and the opportunities for synergistic federal-state cooperation.

5. Development of an overall outline for the organization of the impact-assessment program, i.e., an outline of all the biological and physical systems involved and of the various socioeconomic sectors.

6. Development within each agency of the capacity to carry impact assessment beyond the physical-biological level into socioeconomic effects. We agree with Congress that mission agencies should undertake the studies that fall within their mission, but we note that most agencies will need to hire new personnel with new skills in order to accomplish this. Developing analytic capability in socioeconomic areas within the agencies should receive appropriate attention. This long-term effort must be initiated without delay.

7. Development within the National Climate Program Office of the capacity to do integrated assessments. These studies usually exceed the missions of agencies but remain essential to the broader policy implication of climate. This program should be built carefully, not on a crash basis; personnel with broad, interdisciplinary experience and abilities will be needed.

8. Simultaneous development of the impact program on several levels. At the local or regional level, the state agencies and local representatives of federal agencies will work on area-specific problems (see Chapter 7). A central national capability is needed to provide inputs to national policy, and a

strong international capability is needed at the level of global policy (see Chapter 6). Information must flow among levels by way of aggregation and disaggregation.

9. Development of descriptors relating to climate, its variability, and its impact on society that will be useful in policy formulation and decision making. These should be consistent over time and space; thus they will become familiar to users. Examples might include standardized direct measures of climate (such as heating-degree days) or indices (such as crop-production indices) whose origins are explicitly understood. These descriptors are fundamental in the language of communication between science and policy.

10. Early initiation of exploratory impact studies in critical problem areas. Such studies could well include

- Assessment of the impact of climate fluctuations on agricultural production on a hierarchy of scales (state, national, global) and associated societal impacts.
- Assessment of the effects of a variety of large-scale, long-term climatic changes, since large climatic changes might result from increasing atmospheric concentrations of CO_2.

An adequate program of climate-impact studies is an integral and vital part of our national climate effort. Despite the inherent complexity and difficulty of its definition, organization, and execution, we see no reason for delay. We hope that this component of the Plan will receive appropriate priority for attention, planning, and funding.

6
International Climate Activities

In this chapter we elaborate our rationale and recommendations to a greater extent than in other chapters. This more-extensive treatment is provided because the Plan fails to address the international aspects of the U.S. National Climate Program in any significant manner. Our emphasis is a reflection of the importance that we attach to this part of the National Climate Program.

The United States has a strong national interest in the international dimensions of climate as described in our 1978 report, *Toward a U.S. Climate Program Plan.* The Plan would benefit from the incorporation of this rationale into its discussion of international activities. The following points might be included:

- By its intrinsic nature, climate is globally interconnected, even though its impacts are felt most acutely on local and regional scales. Thus international cooperation is essential in collecting and disseminating climate data, undertaking the necessary climate research, and assessing climate impacts. The United States cannot manage this enormous task alone but must take advantage of the scientific knowledge and financial resources of other nations.
- Regional and global climatic events, whether caused by nature or man, may have a major impact on food supply, water resources, and the use of energy in individual countries or regions. The economic and political consequences of such events may give rise to significant foreign-policy or humanitarian concerns in the United States.
- Of special importance to this country is the vulnerability of many developing countries, particularly those whose economies and social structures are centered around agriculture, to climate variability. They may not

have the resources, the technical skill, or the knowledge to mitigate the impact of climate fluctuations. Hundreds of millions of people now live on the margin of subsistence, and adverse climatic conditions may threaten their ability to adapt. It is thus in the national interest of the United States to assist the developing countries, through either bilateral or multilateral mechanisms, to understand and to deal with potential climate change.

- The United States, despite its vast size, great productivity, especially in agriculture, and advanced socioeconomic infrastructure, is by no means impervious to climate variations. Moreover, as a major consumer of imported resources and a major source of pollutants that may affect climate, the United States has special responsibilities. Thus, as a matter of self-interest, it has an obligation to cooperate internationally in dealing with the climate issue and to exhibit sensitivity to the problems of other nations.
- The possibility of significant effects on global climate resulting from human activities is a subject of growing international concern. Other governments must be involved from the outset in the assessment process if global consensus on responses at the national and global levels is to be reached.

APPRAISAL

The Preliminary Plan does not give an emphasis to the international dimensions of the climate program commensurate with its importance. It focuses principally on organizational and institutional matters and does not identify or suggest programmatic actions. It merely outlines existing international climate activities of the United States. *We recommend that the Plan highlight the international aspects by devoting a separate chapter to them.* The material in the present international section of the Plan should be updated in the light of recent international developments.

Initiatives and Priorities

The United States can play a key role in stimulating international interest in climate-related problems. Experience in the Global Atmospheric Research Program (GARP) suggests that strong advocacy by a large nation that is prepared to commit resources to an international undertaking can be a unifying focus and catalyzing force for commitments by other nations. The emergence of the World Climate Program has provided a new arena for U.S. leadership. Later in this chapter, we discuss the modalities for U.S. participation in the components of this effort. But first, we wish to highlight a limited number of U.S. initiatives around which the entire World Climate Program might be galvanized. *We recommend the following initiatives.*

A Global-Ocean Circulation Experiment (GOCE)

The heat stored and transported by oceans is central to controlling climate variability over time scales ranging from weeks to millenia. Future improvements in monthly, seasonal, and interannual climate forecasting will therefore depend on the systematic monitoring of the circulation and thermodynamic structure of the ocean, particularly in the strong-current regions and the upper (heat-storage) layers.

Moreover, the rate of increase of carbon dioxide and its climatic effects depend fundamentally on the capacity of the ocean reservoir as a thermal and chemical buffer and the mixing processes between the upper layers and the deeper waters. Indeed, gaps in our knowledge of the ocean may well be the primary barriers to improved assessments of the carbon dioxide question. It is important, therefore, that a global ocean-observing system ultimately be developed to monitor the relevant processes and provide the basis for improved understanding.

Monitoring, once undertaken, requires long-term commitments. Thus expensive monitoring programs should be mounted only when their scientific validity and their utility have been established. The routine monitoring of many oceanic variables important to climate must still await scientific and/or technical advances. However, the idea of a Global Ocean Circulation Experiment as an organizing concept and a target to be achieved by the end of the decade of the 1980's is meaningful.

There is an encouraging precedent for such an approach. Two decades ago the task of observing the weather on a global scale in the atmosphere was thought to be almost impossible. Thanks to technological developments, such as meteorological satellites, and after a series of carefully designed regional experiments, a Global Weather Experiment (GWE) was designed and is now under way. The time from conception of the idea to actual field implementation was about one decade. The analogy is by no means perfect—we knew much more about the atmosphere and the requirements for its observation. Thus monitoring the ocean might better be termed an exploration than an experiment. But the GARP Global Weather Experiment at least indicates that a task of this magnitude can be planned and executed.

Already, some efforts, such as the Pilot Ocean Monitoring Study (POMS), aimed at developing certain aspects of an ocean observing system for climatic purposes are being planned. The United States should move to support these efforts vigorously as part of the larger concept envisaged here. Also, there is much ongoing ocean monitoring that can be expanded to serve as a base for the larger experiment, just as the World Weather Watch served as a base for the Global Weather Experiment. The island tide-gauge network for monitoring sea level, the ship-of-opportunity program, and present satellite observations form an initial base.

We are now beginning to see new technological developments that offer promise of making a GOCE possible. The drifting buoy program, part of the GWE observing system, has been an outstanding success. Costs are lower, lifetimes are longer, performance is better, and international participation higher than the most optimistic estimates had predicted. A similar system of drifting buoys specifically designed for oceanographic measurements could be an important part of a Global Ocean Circulation Experiment. Radar altimetry from the satellite SEASAT, despite its short lifetime, has clearly demonstrated a capability to monitor sea levels to accuracies of 10 cm in areas where the geoid is known. For the long term, comprehensive system studies for the design of an integrated constellation of atmospheric, oceanic, and earth resources satellites to meet the needs of the climate program will be necessary. Oceanographic instrumentation is also advancing rapidly with developments in solid-state circuits, effective power supplies, long-lifetime deep-mooring techniques, and advances in underwater acoustic communication. These technological developments could form the basis of a Global Ocean Circulation Experiment within the next decade.

We recommend:

a. *Study of the requirements for and feasibility of a Global Ocean Circulation Experiment.* This study should include the observational, technological, and theoretical aspects of the problem and should take into account the need for understanding the oceanic aspects of the CO_2 issue. This study will also be valuable in developing the international consensus needed as a basis for a meaningful international program.

b. *If needs and feasibility are established, proposal by the United States of a Global Ocean Circulation Experiment as a major international initiative.* Such an experiment could be under way by the end of the 1980's.

A Global Carbon Dioxide Effort

The CO_2 issue is of special international importance because all countries inject CO_2 into the atmosphere through fossil-fuel combustion, deforestation, and other land-use changes and because all countries will be affected by global climate changes and the remedial actions that may be required. The relationship between increases in airborne CO_2 and climate change is thus a central question in the complex of issues relating to future energy production. To address this question successfully will require the facilities, data resources, and scientific talents of many countries. Moreover, the global consensus required for coordination of effective responses can be reached only through the active participation of all countries.

Knowledge of CO_2 emissions and the functioning of the carbon cycle and assessment of climatic change resulting from increased atmospheric CO_2

concentration are specifically required for resolution of the CO_2 issue. However, the development of climate models to project CO_2-induced climate changes and the assessment of impacts of these changes are fundamentally the same tasks as for the general study of climate and its variability.

The CO_2 question is now receiving attention by several international organizations. The Scientific Committee on Problems of the Environment of the International Council of Scientific Unions (SCOPE-ICSU) assigned high priority to research in biogeochemical cycles in the mid-1970's and is receiving support from the United Nations Environment Program (UNEP). More recently, this multidisciplinary program has been expanded to include the carbon cycle as a central focus. The Scientific Committee on Oceanic Research (SCOR-ICSU), for example, through the Committee on Climate Change and the Oceans (CCCO), is studying the oceanic component of the carbon cycle. The World Meteorological Organization (WMO) is coordinating selected aspects through its Project on Research and Monitoring of Atmospheric Carbon Dioxide. Other governmental and nongovernmental international organizations also contribute to knowledge on the CO_2 question. These organizations include the Man and the Biosphere Program (MAB) and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Food and Agriculture Organization (FAO), the International Institute for Applied Systems Analysis, and the International Atomic Energy Agency.

We urge that a paramount goal of the U.S. international climate activities be to foster and strengthen these efforts. In accomplishing this objective the United States should:

- Support research on biogeochemical cycles, including the carbon cycle, on the basis of the interdisciplinary approach developed by SCOPE.
- Recognize that the development of climate models and studies of possible climatic impacts of increasing atmospheric CO_2 concentrations, being analogous to other aspects of the World Climate Program, should be the responsibility of WMO-ICSU and UNEP, respectively.
- Propose a global monitoring system for detecting the climatic effects of increasing atmospheric CO_2. A monitoring system specifically designed to detect those changes expected to be associated with increasing atmospheric concentrations of CO_2 is required to validate and to calibrate model-based predictions of climatic effects. For example, it has been suggested that equatorial lower-stratospheric temperatures and polar-region climate may be sensitive indicators. Data from such a system would increase our confidence in climatic projections even though such indicators are not of direct societal relevance. Design and implementation of the monitoring system must be car-

ried out in coordination with related efforts, such as the WMO Project on Research and Monitoring of Atmospheric Carbon Dioxide, the UNEP Global Environmental Monitoring System program, and the emerging UNEP Plan of Action for Carbon Dioxide.

- Support a companion monitoring system for ground-surface changes (e.g., with SCOPE) to measure CO_2 sources and sinks and to observe surface changes (e.g., albedo, roughness, hydrologic balance, and ecosystem characteristics) that may be associated with CO_2-induced climate changes.
- Encourage international participation by supporting research and other CO_2-related activities at competent foreign institutions.

An International Climate Data Referral and Exchange System

As a matter of high priority, an International Climate Data Referral and Exchange System needs to be established in coordination with the domestic Climate Data and Information Clearinghouse recommended in Chapter 3; no such system exists at present. The existing WMO catalog of data for research and similar WMO undertakings might be used as a basis for development of this data referral system.

It is not necessary or desirable that all data actually reside in one center, but some data gathering will be necessary. The United States should cooperate in defining arrangements to continue and strengthen existing programs to gather and prepare data sets and to publish data (e.g., programs of World Data Center A for monthly world weather records, of Canada for ground-based ozone data, of the Soviet Union for selected surface-radiation data, and of the United Kingdom for monthly tide-gauge data). In addition, it is important that greater attention be given to the inventory and exchange of proxy data as part of this new system. For some types of data (such as precipitation from relatively dense station networks), regional subcenters could be used to share the tasks of gathering the data. This method is now used to gather world cooperative ship data.

PARTICIPATION IN THE WORLD CLIMATE PROGRAM

The preceding initiatives are meant to highlight a small number of possible proposals for international action that the United States can bring to the international arena. In addition to such major proposals for new international action, we recommend a number of priority activities in the various segments of the World Climate Program.

Data, Information, and Services

The Plan should indicate the intent of the United States to participate in the Climate Data and Climate Applications Programs of the World Climate Program in the following ways:

- Full cooperation in the making and exchange of observations. It is important that the weather and climatological data from existing networks, such as the World Weather Watch, be maintained and expanded. They represent the backbone of the global observation system.
- Facilitation of access by U.S. scientists to information in data banks of other nations.
- Expansion of the WMO Voluntary Cooperation Program to help developing nations in their climate-related activities.
- Funding by the United States for the education and training of personnel for climate programs in developing countries.
- Arranging for assembly and rapid dissemination of current information on existing or developing climatic anomalies on a worldwide basis. Monthly and seasonal projections of climate anomalies on a global basis prepared by various countries should be widely disseminated. Such projections would be especially useful to those developing countries that do not yet have this capability. The international experimental climate forecast center proposed in the next section could be a vehicle for this function.

Climate Research

In 1979, WMO and ICSU agreed that there should be only one World Climate Research Program (WCRP) and established a Joint Scientific Committee, which is to be regarded by both organizations as the main scientific organ for the formulation of the overall scientific concepts and the coordination of research efforts on the international level. This research program will focus on the extent to which climate can be predicted and on the nature and extent of man's influence on climate.

The research program is primarily concerned with time scales from several weeks to several decades and space scales from regional (about 1000 km) to global, spanning time and space scales that are both tractable and important. Further details are given in the WMO-ICSU agreement on the WCRP as described in the previous Climate Research Board report.

The research component of the U.S. National Climate Program Plan is essentially consistent with the World Climate Research Program. We recommend that the highest priority be given to the following activities:

- Develop a strong international program in climate aspects of oceanic research, associated with the proposed GOCE. Such a program should focus on both the seasonal–interannual forecast problem and climate sensitivity to human activities. The considerable ongoing activity in oceanographic research needs improved coordination on the national and international levels. We believe that the joint SCOR–IOC Committee on Climate Change and the Ocean, which cooperates with the Joint Scientific Committee for the World Climate Research Program, should be asked to undertake this function.
- Explore possible new approaches to the study of land-surface processes. Scientists from various disciplines should decide jointly what new observations and observational programs are needed. There is a need to establish channels for finding out what existing data are available and how they can be obtained. It is recommended that the United States explore ways in which World Climate Program activities can contribute to the world community's efforts to combat desertification and deforestation.
- Designate one or more national groups to act as an international experimental climate-forecast center. Such a center could develop statistical and/or dynamical techniques for seasonal and interannual forecasts over the globe. This center could involve scientists of many nations and might even be located at some meteorological research center outside the United States.
- Develop a vigorous program of scientist exchange. This might place emphasis on furthering the participation of non-U.S. scientists in the research of U.S. mathematical modeling groups. This exchange program should help facilitate the validation of models and interpretation of results.
- Support and encourage other nations to support efforts to determine past climates in order to diagnose global patterns and processes of past climate variations.

Impact Assessment

In developing the international aspects of an impact-assessment program, the United States should work toward involving a wide group of international organizations, both intergovernmental and nongovernmental. A discussion of these organizations and their possible functions in the impact-assessment effort is given in Appendix C.

Although it is highly desirable to arouse the consciousness of intergovernmental agencies to the range and importance of climate-impact problems and to the possible roles they might play in addressing them, the nongovernmental bodies must also have a key role. We regard the development of the necessary arrangements between governmental and nongovernmental bodies as a matter to which the United States should give immediate attention.

We believe that the international impact-assessment program would be strengthened if the United States, in addition to supporting those impact studies related to key economic sectors, could give support to studies of the following kind as part of the impact-assessment program (see also Chapter 5):

- *Historical Impact Studies* Historical studies of the impact on man of periods of climatic stress would be illuminating, and most countries could participate easily in such a program. Studies could be accomplished by examining the past climatic record for periods of marked variability or anomaly. Once those periods were identified, the accompanying political, social, and economic conditions could be analyzed for the impact on man. Much of this work could be done by social scientists, with some input from physical and biological scientists. UNESCO could well be the sponsoring intergovernmental agency for these studies.
- *Classification of Climate and Impacts* Consideration should be given to the development of new kinds of impact-related climate classifications on a worldwide basis to facilitate the understanding and study of climatic impacts. By an impact-related climate classification is meant the compilation and categorization by geographic areas of those available climatic data that can be helpful in making decisions in a particular sector of human activity. Special climatic classifications of land areas are needed for agriculture (specialized for individual crops), soil conservation, forestry, hydrology, energy sources and uses, health effects, fire hazards, relations between human activities and ecological systems, and many other purposes. For example, maps and statistical tables of the geographical and time distribution of variations in wind speeds are needed for evaluation of the potential for use of windmills as primary energy sources. Similarly, global ocean maps of seasonal averages and variability of vertical temperature distributions, depth of the low-oxygen layer, and extent and intensity of upwelling would be of great value in fishery management.
- *Research on Climatic Impacts* International research programs on agricultural aspects of climatic-impact studies should be developed in cooperation with the international agricultural research centers.

Institutional Matters

Extensive comments on international institutional matters were presented in last year's report. However, we believe that these are so critical to the success of the World Climate Program that we have provided an extensive discussion of many institutional issues in Appendix D. We have many concerns. For example, we believe that multilateral arrangements among nations will be of

greater importance than those of a bilateral nature in the conduct of the World Climate Program and that this has been inadequately emphasized. We believe that more recognition must be given in the Plan to the opportunity for cooperation with developing nations. There are potentially serious impediments to the free access and exchange of data that need to be addressed. We believe that the flexibility inherent in the present arrangements for individual U.S. government agencies and nongovernmental bodies to interact with counterparts abroad on matters of climate is a strength but that there should be more conscious coordination by the NCPO and the U.S. Department of State. Lastly, there is a need to examine various mechanisms for funding the international aspects of the U.S. National Climate Program so the climatic concerns of the United States can be accommodated.

7
The Intergovernmental Climate Program

The Intergovernmental Climate Program (ICP) has not been funded for fiscal year 1980. We rationalize that the Executive Branch believes that the need for the information and services from such a state-federal cooperative climate program has not been demonstrated. We propose that the ICP as its first task demonstrate its worth through an exploratory program that can be terminated if the economic benefits that many believe will flow from the program are not forthcoming. Our recommendations attempt to outline such an approach.

Congress expressed its interest in this program in some detail in Section 6 of Public Law 95-367. The House conference report accompanying this legislation made it clear that the National Climate Program is intended to be not only a research program but also a program to bring the results of research and data analysis to the people through an effective intergovernmental program. The realization of economic benefit, increased productivity, and the reduction of the effects of hazards need not await breakthroughs in climate prediction. Analyses of typical climate and probabilities of extremes from archived climatic data are already contributing significantly in some sectors of our economy and national defense. The issue is whether a greatly enlarged outreach and educational effort, coupled with increased availability and accessibility of climate services, can achieve better marginal utilization and conservation of the nation's natural resources and labor sufficient to warrant an increased national investment.

We also note that the National Climate Program Plan indicates that "the Federal financial assistance role will be primarily limited to assisting in efforts that would be of benefit to more than one State." This is a view different

from that of the Congress. Section 6 of the Act specifically calls for state and regional programs and consultation at the local level. We believe that the lack of emphasis on the climate information services in the Plan reflects a lack of appreciation of the degree to which these services can contribute to the nation's economy and the degree to which the success of a National Climate Program depends on feedback from users.

We are deeply concerned over delay of the start of the ICP. A key output mechanism of the National Climate Program is missing. *We recommend that*:

1. *The Intergovernmental Climate Program be activated without further delay.*
2. *Exploratory programs be started immediately, using fiscal year 1980 funds.*
3. *A fully developed program be in place within five years if its worth can be demonstrated.*

Our justification of these recommendations is summarized in this section.

The major functions of the Intergovernmental Climate Program should be to:

- Assemble, analyze, and make available local climate data of high quality,
- Inform sectors of the community about the importance of climatic impacts and the availability of data and methods of analysis,
- Assist state and local governments with climate-related issues,
- Identify needs for research and services,
- Act as a focal point for local and regional activities of diverse federal agencies and for studies of climatic impacts and the value of climate services.

For an effective program, all these functions should be closely linked, accountable to state governments or regional entities as well as federal authorities, and evaluated in terms of the demonstrable value of the services provided. The program must be built around highly qualified professionals, sensitive to the users and familiar with data and information sources, who will provide climate-information services.

A basic purpose of the National Climate Program Plan is to increase productivity and to conserve the nation's resources. It is our belief that if these goals of the climate program are to be achieved, *a strong, vigorous, and effective intergovernmental component will prove to be essential.*

Decisions on resource use are made in substantial part by state and local governments, private firms, and individuals. Therefore, delivery of services and information must be through a network accessible to these units and responsive to the needs of individual industries or regions.

A network reaching to the local level can serve as a two-way conduit, providing a means by which local needs can be communicated to the federal government. This is seen as a means to stimulate research that is more responsive to local needs and to help identify areas in which basic research is needed. The two-way nature of this conduit, or delivery–feedback mechanism, is an essential feature of the overall National Climate Program that can in large part be provided by the ICP. It needs to be emphasized that, in establishing this delivery system, it is desirable to utilize as fully as possible existing institutions (such as the state climatologists and the U.S. Department of Agriculture's Cooperative Extension Services) that have effective mechanisms for providing public services and means for communicating local needs and feedback on the quality and utility of services to the state and federal levels.

Many current and past cases illustrate the productive use of climatic information. A few examples are:

- The nationally published base for calculating cooling degree-day units is 65°F, without regard to humidity. The cooling degree-day values for 50 communities in arid Arizona were revised to the base of 80°F. This information is now the basis for the design of structures and systems for the desert region and results in substantial savings in capital costs.
- In Maryland, a public utility was prepared to construct a multimillion-dollar system to diffuse hot water into the Chesapeake Bay on orders from a regulatory commission. Calculations based on an erroneous interpretation of climatic data by nonprofessionals indicated that a violation of thermal-pollution regulations would occur. A climatologist noted the error in interpretation of the wet-bulb temperature data, and millions of dollars were saved, along with the energy necessary to construct the system and operate it for the lifetime of the power plant.
- Climatic data on soil temperatures in a midwestern state are monitored daily in the spring. These are coupled, on a weekly basis, with historical frequencies of daily-precipitation data to develop probability prospects for the planting of corn. An annual benefit-to-cost ratio of 80 is estimated, based on savings in worktime, energy, and seed–fertilizer loss.
- Climate information was used in the early 1970's by a commercial firm to design and market a pollution-control system including a special air-quality monitoring network. A power company was able to meet pre-1977 clean-air standards and realized annual fuel savings of $5 million to $15 million at a cost of 10 percent of the savings.
- Climatology of winds and ocean waves are used by a commercial firm to design and market a system to optimize the routing schedule of trans-oceanic shipping. A 40-ship fleet can save roughly $4 million annually at a cost of about 10 percent of the savings.

The important point is that for each use of climate information cited above, there are many others showing waste and loss of resources because of lack of use of climate data in planning, design, and operational decision making.

The Air Weather Service of the U.S. Air Force has operated for years a tailored climatological service that may serve as an example of a prototype intergovernmental program. This service is discussed more fully in Appendix E.

THE ROLE OF THE ICP IN RESEARCH

Although the Intergovernmental Climate Program is not concerned with climate-system research as such, there are important ties between its projected activities and those of the research segment of the national program. Primary among these are the physical effects that link local and large-scale climate (see Chapter 4).

The local scale is that on which the effects of climate are felt in man's climate-sensitive activities. The nature of local climate is determined in part by the site's location with respect to the large-scale circulation of the atmosphere and in part by the local topography. Research on the structure and behavior of large-scale climate typically uses only generalized information concerning local conditions, as represented in the parameterization of small-scale processes onto the scale resolved by conventional climate models. The turbulent transfer of heat through the atmospheric surface boundary layer is an example of a small-scale process that plays a critical role in the dynamics of large-scale climate. The successful treatment of such processes requires information on the detailed local distribution of such properties as vegetative cover, soil type, and surface moisture, as well as the distribution of local wind and temperature. Such study is addressed under the Plan's Climate System Research section and is a consideration in the Plan's carbon dioxide and international activities as well.

A second aspect of the relationship between large-scale and local climate that is supportive of research is the question of translating a change of climate on the large scale into the effects to be expected locally. This question is in some respects the inverse of the parameterization problem, in that here the transition is from large to small scales rather than the other way around. As empirical and theoretical climate research succeeds in providing even a limited capability to predict future large-scale climate anomalies, there will emerge the problem of translating such information into forecasts of the anomalies to be expected at varied local sites (which were necessarily smoothed out in the

large-scale picture). Solution of this problem will require an extensive knowledge of the structure of local climates. It is in this connection that the ICP will serve as an essential mechanism for the delivery of large-scale climate information and forecasts to the local user community.

THE ROLE OF THE ICP IN DATA MANAGEMENT AND OBSERVATIONS

Certain national activities related to management of climatic data, observation systems, and related services can best be met by the decentralization intrinsic to the ICP. These activities include the improvement of the cooperative observing network, the inventory of nonfederal weather networks, the establishment of a climate data and information clearinghouse, the management of local data sets, monitoring data quality in these and the national networks, study of available data on values of climate services, development of a system for climate monitoring, and information transfer to users and educational programs to reach decision makers.

The rapid increase in the availability of small computers and data-storage capability is certain to increase greatly the amount of data available at any point in a climate-information system. These developments should be encouraged. However, unless accompanied by professional knowledge and judgment at the user level, the result could well be a continued misuse of climate information.

IMMEDIATE IMPLEMENTATION OF EXPLORATORY PROGRAMS

The demonstration aspects of the Intergovernmental Climate Program can be initiated immediately by funding a limited number of exploratory projects that emphasize and document the benefits of climatological services at the regional and state levels. These climate projects should involve existing governmental agencies, institutions, and private businesses; depend primarily on existing data and information; and show favorable impact on public well-being within three years of approval.

The objectives of an exploratory program are:

- To gain knowledge necessary for the design and conduct of the National Climate Program through experience with local users of climatological information,
- To provide models of climatological services that quickly demonstrate favorable benefit-to-cost ratios in relevant sectors of the economy or that otherwise contribute to public well-being,

- To point to the potential markets for climatological services so private climatological organizations will enter these sectors and create or expand self-sustaining businesses in cooperation with federal, state, and local climatological entities,
- To adapt intergovernmental processes to the evaluation of climate-information services, data acquisition and analysis, and climate-effects activities as part of the National Climate Program.

Projects activated as exploratory programs should have the following characteristics (in decreasing order of priority):

1. A clearly defined service component that produces favorable economic benefits or otherwise contributes to the public welfare in a cost-effective manner.
2. A clear illustration of the relationships among climatological and impact-assessment variables and processes that contribute to the benefits of the project.
3. An ability to raise public understanding of the utility of climatological data in a wide range of activities.
4. A recognition or application of advances in climate research and/or a documentation of requirements for additional research.
5. A reliance on existing observation networks, collection technologies, and information services.

A FIVE-YEAR PROGRAM TARGET

The National Climate Program should set as its target a fully developed and functioning Intergovernmental Climate Program at the end of five years. Development of the ICP can be a sequential process involving three phases: exploratory projects, development of selected state or regional climate programs, and the operation of the fully developed state or regional climate programs.

Phase I would provide for the implementation of selected exploratory projects with 100 percent federal funding beginning in fiscal year 1980. These projects could be initiated under other provisions of the Act. The aim of these projects has been discussed above.

Phase II would provide for initiation of joint federal–state climate programs so they can meet criteria for acceptance as a State Climate Program as part of the ICP. Activities in this phase should be generally supported by joint federal–state funding.

Phase III of the program would provide for accepting qualified State Climate Programs into the ICP with joint federal–state funding.

The five-year target should be to have all 50 states participating. Activities would center in the areas of climate information services, climate data acquisition and analysis, and climate effects studies. The most important contributions to the NCP are likely to be in the provision of climate information services. The role of data acquisition, analysis, and climate effects studies is to support the provision of services, identify needed research, and to complete a two-way transfer of data and information between the ICP and the NCP.

As the ICP matures, decisions on federal, state, or private funding can be made on the merits of the individual situations. As we see it, climate information services should be largely free of federal funding. A combination of state and private-sector support would provide the necessary resources. This will ensure that only those activities are continued that can be sustained on the basis of their local value and that the federal government is not expected to support these kinds of activities in perpetuity. The data-collection, data quality, and clearinghouse activities of the ICP would be the responsibility of both federal and state governments. Both benefit from and both should support this resource for the ICP and the NCP. Support for the climate effects studies would be provided from both federal and local sources.

8
Carbon Dioxide and Climate

We had available to us both the Carbon Dioxide chapter of the Plan and a supplementary DOE document entitled *Carbon Dioxide Effects Research and Assessment Program–Research Issues* and dated July 4, 1979. The two documents were in striking contrast. The first was diffuse and generalized, the second detailed and precise. The Carbon Dioxide chapter of the Plan does not demonstrate clearly the need for balanced and coordinated efforts to address the CO_2 issue nor any specific ways to foster or guide such efforts, for example, through the setting of priorities. On the other hand, the DOE document does describe significant progress in initiating a broad program of research and assessment and in setting preliminary funding priorities and goals. In what follows, therefore, it is important to distinguish between our comments on the two documents reviewed.

AN APPRAISAL OF THE CARBON DIOXIDE CHAPTER OF THE NATIONAL CLIMATE PLAN

The question of carbon dioxide and climate provides an opportunity to test the applicability of the Plan to an issue of current concern, one that cuts across the Plan's three main components. We found deficiencies in the following areas:

- *Program Objective* The goal of the program, as stated by DOE and incorporated into the Plan, is "to develop the ability to predict the environmental, economic, social, and political costs and/or benefits of the increasing

atmospheric concentrations of carbon dioxide with sufficient confidence to permit policy decisions to be made on the future global use of fossil fuels." We do not believe that any foreseeable level of knowledge will ever be considered unequivocally "sufficient" for such policy decisions. Rather, we envisage that policies will evolve through a continuing dialogue between the scientific and political communities based on steadily improving knowledge. We therefore suggest that the goal of the CO_2 aspect of the National Climate Program be restated as: "to predict the agricultural, environmental, and societal consequences, national and international, of increasing atmospheric concentrations of carbon dioxide, with the objective of providing a better knowledge base for making informed policy decisions concerning the use and development of energy and other natural resources."

- *Program Balance* Emphasis is given to well-defined research problems in the physical sciences, particularly those concerning the global carbon cycle and climate studies, but comparatively little attention is paid to the environmental, biological, and societal impacts of CO_2-related climate change.
- *Management Arrangements* The relationships between the DOE and the NCPO as well as between the NCPO and other agencies are not clearly defined. Although informal arrangements that appear to work have been developed, some formal interactive process designed to preserve the leadership of the NCPO in climate-related activities appears to be desirable. This process should attempt to resolve important differences in goals and priorities among the NCPO and mission agencies, including, for example, DOE's naturally greater emphasis on energy policy implications than are necessarily warranted for the NCP as a whole.
- *Scope* Greater recognition should be given to the following important aspects of the CO_2-climate issue: its long-term global nature—irreversible within our lifetimes; the possibility of natural fluctuations of climate; the consequences of human activities on the biosphere; distinctions between environmental effects on the "less-managed" biosphere versus those on the "managed" biosphere; the diverse and unequally distributed impacts of climatic change; and the potential importance of adaptive societal responses, in addition to possible "technological fixes" for prevention or amelioration of climatic-change effects.

The Plan should indicate that the usefulness of the program's results could be considerably improved by fostering broad international cooperation, as suggested in more detail in Chapter 6, addressing questions of the application of scientific knowledge to policy decisions, with specific treatment of uncertainty; examining other available impact-assessment techniques developed for technological, environmental, and natural hazard assessments; and distinguishing further between the two types of assessment functions, the "policy"

assessment of the CO_2-climate issue itself and the appraisal of the status of CO_2-climate research.

AN APPRAISAL OF THE DOE DOCUMENT, CARBON DIOXIDE EFFECTS RESEARCH AND ASSESSMENT PROGRAM—RESEARCH ISSUES

This document is an excellent overview of the proposed or ongoing research in the following areas: the carbon cycle; climate studies; environmental effects of climate change and CO_2 increase; social, economic, and political costs and/or benefits of global environmental change; amelioration and adaptation; assessment; and program development.

The document summarizes existing and projected financing and assigns priorities to the component projects on the carbon cycle and climate studies. Parts 3 and 4 are based on a preliminary version of the report of the American Association for the Advancement of Science-Department of Energy Workshop on Environmental and Societal Consequences of a Possible CO_2-Induced Climate Change held at Annapolis, Maryland, April 2-6, 1979. DOE has not yet had time to assign priorities to the activities suggested at this Workshop; the final report should make this possible. Area 5 is not yet developed. Area 6 will become the highest-priority activity by 1981-1982 since it includes assessment of the nature and magnitude of the problems posed by the CO_2 issue. Area 7 is concerned only with the support required for the development of the Program.

We found this document very valuable and urge DOE to continue the process of orderly prioritization that it represents. We have considered the priorities that should be assigned within the DOE carbon dioxide program to activities in carbon-cycle research and climate studies, and we generally concur with those assigned by DOE, as indicated in Table 2. Although priorities were not assigned to environmental, biological, and socioeconomic impacts studies, these areas are nonetheless important. We urge DOE to plan high-priority tasks in these areas as soon as possible.

STRENGTHENING THE PLAN

Our analysis of the Carbon Dioxide chapter of the Plan suggests that it could be strengthened in the following ways:

1. *Global carbon cycle.* Understanding of the global carbon cycle is crucial to addressing policy questions raised by the carbon dioxide and climate issue. The priorities and projects developed by DOE in its Research Issues

TABLE 2 A Partial List of Suggested Priorities for CO_2-Related Activities

Major Area	Component	Subcomponent	Incremental Priority[a]	Comments
Carbon cycle studies	Net sources for atmospheric CO_2	Past industrial sources	Medium	Ongoing effort elsewhere; needed for assessment
		Future industrial sources	High	Some present funding
		Terrestrial biosphere	Very high	Much uncertainty, which must be resolved for prediction of future CO_2 levels
		Other natural sources	Low	Includes volcanic and cryospheric sources, probably minor and well covered elsewhere
	Atmospheric CO_2 monitoring	CO_2 observing systems	Medium	Proposed network of 25 monitoring stations will allow some analysis of transport processes–high priority. Medium priority for other monitoring methods, e.g., denser station network, satellite observations, aircraft soundings. These are NOAA-funded items
	Net sinks for atmospheric CO_2	Air–sea exchange	Low	Worthwhile work difficult, but existing activities should be continued
		Concentrations in upper oceans	High	Only worthwhile if very high accuracy of measurement possible
		Exchange between upper and deeper ocean layers	Very high	The heart of the CO_2 problem is exchange between upper and intermediate ocean water
		Ocean sediments	High	High for all calcareous sediments, provided that scientific feasibility can be demonstrated
		Biosphere	Very high	Concerns CO_2 enhancement of growth, especially in major possible sinks, such as tropical forests. Very high priority only if feasible; experimental design has to be established

	Past record	Geological record	Low	Refers to older record
		Recent (last glacial cycle) records	High	Overlaps with studies of terrestrial biosphere; studies of agricultural land use, forest changes are important
	Modeling	Development of models of cycle, modification of atmospheric models	High	Immediate need is for some new funding to modify atmospheric models
Climate studies	Reconstruction of past climates	Paleoclimatic research	High	Such reconstructions focus on such cases as warm periods (e.g., hypsithermal, last interglacial) for insights about possible CO_2-induced future changes
	Climate models		High	Rides on the back of much larger general-circulation modeling exercises–but large effort required for hierarchy of models applicable to climate problems
	Evidence of change in future climate		High	Vital to learn how to distinguish change in signal from noise, probably by identification of suitable precursor symptoms as well as monitoring of ordinary parameters
	Construction of scenarios of future climate		High	This is major part of *assessment* program and will be major objective by 1981–1982

[a]Incremental priority refers to the extra effort needed specifically for the purposes of the National Climate Program.

document for research on the global carbon cycle thus appear well justified and well defined. A summary of them should be incorporated in the Plan and should be supplemented by explicit consideration of the role of human activities, including economic development in different countries and different scenarios of world energy policies. The Plan should emphasize that our knowledge of the natural carbon cycle needs to be improved, especially in the following areas:

- The rate of transfer of CO_2 (and other trace substances, such as tritium) from the surface layers of the oceans into intermediate waters.
- The rate of assimilation of CO_2 by the major ecosystems as a function of the availability of water, CO_2, and other nutrients.
- The modes and rates of decomposition of soil organic matter.
- The response of ocean sediment to enhanced concentrations of inorganic carbon in seawater.

This knowledge needs to be integrated into internally consistent models that can predict future carbon dioxide concentrations in the atmosphere, given human perturbations. Such models will require careful validation to be of use in policy decisions. The following observations may be particularly valuable for model development and validation:

- Atmospheric CO_2 concentrations globally as a function of time,
- The isotopic composition of carbon dioxide in the atmosphere in the past as revealed by tree rings and in the present as obtained by direct atmospheric measurements,
- Determination of soil and vegetative carbon changes in the present and past by such methods as remote sensing accompanied by ground-truth verification and historical records of land use,
- Total amount and isotopic composition of inorganic carbon in surface and intermediate ocean waters.

2. *Effects of increased atmospheric carbon dioxide on climate.* Further development of the ability to model CO_2-related climate changes is clearly a high-priority activity, in which special attention should be devoted to the geographic and temporal nature of such changes. Consideration should also be given to the reconstruction of past climates as an important ingredient for model calibration. Monitoring of the present climate is necessary for the detection of any climate change resulting from CO_2 changes (or other perturbations) and should be continued on a priority basis. Scenarios of possible future climates should also be developed in order to integrate the results of climate research into a useful form for assessments of impacts.

3. *Effects on climate change and carbon dioxide increases on the environment.* We believe that the two classes of environmental effects detailed in the Plan (environmental features versus environmental processes not resolved in geophysical simulations) are not clearly defined and should be restructured. Direct changes in physical characteristics of the oceans and the cryosphere should be treated as one class and examined closely for possible feedback mechanisms that may accentuate or moderate climate changes. A second class of effects should encompass impacts in the biosphere, both unmanaged and managed. The second category should include study of the direct effects of increased atmospheric CO_2 (e.g., on plant productivity) since these could be important factors balancing adverse environmental consequences of climatic change. It should also examine ways to ameliorate undesirable impacts, in conjunction with the research category on societal response.

4. *Societal impacts of carbon dioxide-related environmental change.* This research category requires considerable methodological development, as recognized by the Plan. However, the lack of well-defined methodologies should not preclude the development of an overall research strategy for addressing the societal impacts of CO_2-related change. One immediate goal of such a strategy would be to foster working relationships among the mission agencies and the social science community to ensure at the outset mutual understanding and productive consideration of the issues of interest. A first step in this direction would be to apply existing social science techniques in order to characterize the magnitude of societal impacts (economic, political, legal, social, psychological) as much as possible. Even a broad characterization of impacts would be useful in guiding further research and providing input into policy decisions.

5. *Societal response to carbon dioxide-related environmental change.* Much greater recognition should be given to potential adaptive responses of societies to climate changes. Adaptive as well as preventive and ameliorative measures should be closely examined within the context of global perceptions and constraints.

6. *Carbon dioxide-effects assessment.* A clear distinction should be made between an assessment of CO_2-relevant knowledge as it applies to specific policy issues at any time and an assessment of the current research program (whether U.S. or global) and its direction and expectations. The former performs the necessary integration of the results of each of the previous research categories, carried from human influences through environmental effects and back to human impacts and responses. The latter focuses on the research process itself, with a possible need for an independent review. Although both functions are necessary and interdependent, some confusion could arise from their association.

GENERAL CONCERNS

The successful execution of the CO_2 aspect of the Plan and indeed of the entire National Climate Program Plan will require the integrated efforts of many governmental agencies. We are not convinced that such efforts are taking place. We had hoped that the technical integration could be accomplished through a formal interactive process under a lead agency, extending from the initial development of the Plan through its actual accomplishment. In the present situation, the success of the effort depends on the ability of each agency to carry its own priorities and projects through the funding process. Obviously, the risk of disjointed and uneven results is significant.

We are puzzled about what recommendations to make to solve this problem. Solutions would require all CO_2 efforts and indeed the entire climate program to be viewed as a whole by the Congress in both its authorization and appropriation process and by the Office of Management and Budget in its budgetary review in the Executive Branch. We appreciate the difficulty in bringing this about. We can only urge that all agencies give this program adequate policy and budgetary attention and cooperate among themselves as much as possible. We are grateful that some indeed are doing so.

Appendix A: Participants in the Workshop to Review the National Climate Program Plan

Robert M. White, Administrator, National Research Council, *Workshop Study Director*

CLIMATE RESEARCH BOARD MEMBERS

Verner E. Suomi, University of Wisconsin, Madison, *Chairman*
Francis P. Bretherton, National Center for Atmospheric Research
Dayton H. Clewell, Mobil Oil Corporation (retired)
Herbert Friedman, Naval Research Laboratory
Charles W. Howe, University of Colorado
John Imbrie, Brown University
John E. Kutzbach, University of Wisconsin, Madison
Cecil E. Leith, National Center for Atmospheric Research
Roger R. Revelle, University of California, San Diego
Joseph Smagorinsky, National Oceanic and Atmospheric Administration
Frederick E. Smith, Harvard University
Karl K. Turekian, Yale University
John Waelti, University of Minnesota
Sylvan H. Wittwer, Michigan State University

INVITED PARTICIPANTS

D. James Baker, University of Washington
Werner Baum, University of Wisconsin, Milwaukee

Bert Bolin, University of Stockholm
Stanley A. Changnon, Illinois State Water Survey
Howard Critchfield, Western Washington University
Robert E. Dickinson, National Center for Atmospheric Research
Bo R. Döös, World Meteorological Organization
Robert W. Durrenberger, Arizona State University
W. Lawrence Gates, Oregon State University
W. J. Gibbs, Australian Meteorological Service (retired)
Michael Glantz, National Center for Atmospheric Research
Stanley M. Greenfield, Teknekron, Inc.
F. Kenneth Hare, Trinity College, Toronto
Christian A. Herter, Department of State (retired)
Charles L. Hosler, Pennsylvania State University
Paul Janota, Environmental Research and Technology, Inc.
Helmut E. Landsberg, University of Maryland
Michael MacCracken, Lawrence Livermore Laboratory
Lester Machta, National Oceanic and Atmospheric Administration
Syukuro Manabe, National Oceanic and Atmospheric Administration
Thomas McKee, Colorado State University
Charles Mosher, American Association for the Advancement of Science
Jerry S. Olson, Oak Ridge National Laboratory
Giulio Pontecorvo, Columbia University
Norman J. Rosenberg, University of Nebraska
Stephen H. Schneider, National Center for Atmospheric Research
Robert W. Stewart, Institute of Ocean Sciences, Sidney, British Columbia
George M. Woodwell, Woods Hole Oceanographic Institution

FEDERAL GOVERNMENT AND CONGRESSIONAL REPRESENTATIVES

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David Atlas, National Aeronautics and Space Administration
Ian Bartky, National Oceanic and Atmospheric Administration
William C. Bartley, Department of Energy
J. Christopher Bernabo, House of Representatives
Eugene W. Bierly, National Science Foundation
Albert Bridgewater, National Science Foundation
Radford Byerly, Subcommittee on Natural Resources and Environment, House of Representatives
Edward S. Epstein, National Oceanic and Atmospheric Administration
Robert Etkins, National Oceanic and Atmospheric Administration
Steven Flajser, Committee on Commerce, Science and Transportation, U.S. Senate

Galen Hart, Department of Agriculture
Alan Hecht, National Science Foundation
Howard Hill, National Oceanic and Atmospheric Administration
Roy L. Jenne, National Oceanic and Atmospheric Administration
Ronald Lavoie, National Oceanic and Atmospheric Administration
Edward Mainland, Department of State
Dudley McConnell, National Oceanic and Atmospheric Administration
Douglas H. Sargeant, National Oceanic and Atmospheric Administration
Robert A. Schiffer, National Aeronautics and Space Administration
David Slade, Department of Energy
George I. Smith, Department of the Interior
William Sprigg, National Oceanic and Atmospheric Administration
Thomas W. Waltz, National Oceanic and Atmospheric Administration
Herbert L. Wiser, Environmental Protection Agency

STAFF

John S. Perry, National Research Council, *Executive Secretary*
Fred D. White, Consultant
Robert S. Chen, Resident Fellow, National Academy of Sciences
Barbara Neff, Assistant to the Administrator, National Research Council
Noreen Prather, National Oceanic and Atmospheric Administration
Doris Bouadjemi, National Research Council

Appendix B: Irrigation Demonstration Project

Irrigation provides an important degree of stability to the food-producing industry of the United States. More than 60 million acres of land are now irrigated in the United States. Of these, 51 million are in the 17 western states. Growth of irrigation has been rapid in the recent past. In the Great Plains region, irrigation has risen at an exponential rate since the 1950's. In Nebraska more than 6.8 million to 7.0 million acres are now irrigated.

The greatest increase in irrigation in recent years in the Plains region has been through sprinkling systems–primarily the center-pivot system, which permits irrigation of from 135 to 152 acres in each quarter section of land (160 acres) irrigated.

Center pivots are expensive to install–upward of $60,000–75,000 per system (including well preparation and pump installation). Most of these systems operate at high pressure (60–80 pounds per square inch) and are powered by electric motors or by engines that utilize diesel fuel, liquefied petroleum gas, or natural gas.

At current prices, a single irrigation cycle costs between $4 and $6 per acre. In all, during an average year in Nebraska, for example, fuel consumption may range from 4500 to 10,800 gallons of diesel equivalent. Since existing pivot systems in the United States now number over 50,000 and irrigate more than 7 million acres, the fuel consumption involved approaches half a billion gallons diesel equivalent per year.

Excessive irrigation–more-frequent and more-intense application of water than is needed–wastes fuel, degrades soil quality, depletes groundwater supplies more rapidly than necessary (thus increasing pumplifts and further increasing fuel requirements), and may degrade groundwater quality. Excessive irrigation can actually reduce crop yield. Most farmers tend to apply excess water; many overirrigate by 50 to 100 percent.

Irrigation can be scheduled rationally on a field-by-field basis if certain knowledge is available:

1. Soil type, moisture-holding capacity, and antecedent soil moisture content;
2. Crop type, stage of development, and water requirement at each stage;
3. Irrigation system characteristics and efficiency;
4. Cumulative evaporation since the last irrigation or rainfall event and probable evapotranspiration and precipitation in the forthcoming week to 10-day period.
5. Forecast information made available on a timely basis as the irrigation approaches.

Since two to four days are normally required for irrigation of a 160-acre field, forecasts must provide for an appropriate lead time or rapid updating.

Climatological and weather information must be entered daily or, minimally, twice weekly into the decision matrix in order to facilitate scheduling of each irrigated field. Scheduling services are currently being provided by many small companies scattered through irrigation regions. These services often rely on rough estimations of evapotranspiration or on observation of a few soil moisture samples. A few larger companies make use of computer technology to monitor conditions in large numbers of fields. The AGNET interactive computer-information system, in use in Nebraska and adjacent states, is already used to provide scheduling advice to a large number of irrigators. But here, too, climate and weather information is not received in a manner permitting maximal efficiency and accuracy.

Hence it is suggested that NCPO undertake to develop a demonstration project, in conjunction with private and/or state organizations involved in irrigation scheduling, to improve scheduling services through the rational use of climatological and weather information. NCPO would undertake to provide a continuous and timely flow of climatic analyses and current weather and short-term forecast information for use in support of a selected number of irrigators. Data on benefits, in terms of water saved, energy conserved, and yields achieved, should be evaluated before any expansion of this service is effected.

Appendix C: International Organizations and Climate-Impact Assessment Functions

Among the intergovernmental organizations are the United Nations (UN) itself, several of its subsidiary bodies and specialized agencies, and regional organizations outside the UN system to which the United States adheres, e.g., the Organization of American States and the Organization for Economic Cooperation and Development. Among nongovernmental organizations are the International Institute for Applied Systems Analysis, the International Social Science Research Council, and the International Council of Scientific Unions (ICSU) and several of its constituent groups, especially the International Geographical Union, the International Union of Geodesy and Geophysics, the International Union of Biological Sciences, the Scientific Committee on Problems of the Environment (SCOPE), the Scientific Committee on Oceanic Research (SCOR), the Committee on Space Research, and the Consultative Group on International Agricultural Research.

We see intergovernmental agencies as having the following functions:

- UNEP. Overall coordination and support of the climate impact studies component of the WCP. The Plan might acknowledge UNEP's Earthwatch program of global environmental assessment and suggest that climate impact assessment is an aspect of environmental assessment that might provide a useful model for other environmental assessment methodologies. For example, multilateral and bilateral international arrangements in oceanography have already demonstrated their effectiveness. SCOR and IOC have now established the Committee on Climate Change and the Oceans (CCCO) to facilitate international cooperation in climate-related ocean matters and to cooperate with the Joint Scientific Committee of WMO and ICSU for the

World Climate Research Program. We believe that the international oceanographic activities of the U.S. Climate Program can be most effectively coordinated through this new body.

- WMO. Coordination of the collection and dissemination of climatic data for all purposes, including impact studies.
- World Health Organization. Study of health impacts of climate and of spatial and temporal climatic variability.
- FAO. Study of impacts of climate and climatic variability on agriculture, forestry, and fisheries, at local, regional, and global levels.
- UNESCO. Conduct of historical studies of societal impacts of climate and climatic variability.
- UNESCO-MAB. Relating of Man and Biosphere (and SCOPE) studies of ecosystem production, decomposition, and burning to more widely representative data on the carbon and nitrogen cycling, hence CO_2 and modeling, that would help evaluate system and social responses to climatic changes before these occur, with UNEP and United Nations Development Program (UNDP) support.
- UNESCO-IOC and WMO. Coordination of ocean monitoring, including pollution monitoring.
- International Energy Agency. Study of availability of and demand for different energy sources (wind, hydro power, direct solar conversion, biomass, fossil fuels, and nuclear) as related to climate and climate variability.
- UNDP. Support of climate-impact research in developing countries.
- International Bank for Reconstruction and Development, Inter-American Development Bank, Asian Bank. Evaluation of climatic impact of development projects funded by these agencies.

Appendix D: International Institutional Issues

BILATERAL AND MULTILATERAL AGREEMENTS

The language of the Plan implies a precedence for bilateral arrangements in the conduct of international climate activities. We believe that equal or greater emphasis should be placed on the development of multilateral mechanisms to enlist the participation of many nations. The key climatic problems requiring international collaboration, such as data acquisition, have global dimensions. For example, observation of the ocean will require the participation of many countries in an organized fashion. We see supplementary bilateral arrangements as playing special roles. For example, the still-developing Law of the Sea will apparently require in many cases individually negotiated agreements between nations conducting oceanographic research and the coastal states concerned. The roles of bilateral and multilateral arrangements should be clarified and compared in the Plan.

COOPERATION WITH DEVELOPING NATIONS

More recognition should be given in the Plan to the opportunity for cooperation with developing nations. Studies have shown that the components of the climate system with the greatest potential predictability are in the tropical regions where the noise from day-to-day weather fluctuations is the least. However, many developing nations in these regions have had difficulty in supporting the data acquisition necessary to develop methods for analysis and prediction of these large-scale components. As noted in the 1978 Climate Research Board review, it is clearly in the interests of both the NCP and the

World Climate Program to develop cooperative programs to alleviate this difficulty. The Voluntary Cooperation Program of the WMO can be an effective mechanism for achieving this objective. Transfer of technology in acquisition, management, and application of climate information should be a major goal of this effort.

FREE ACCESS AND EXCHANGE OF DATA

For standard meteorological observations, the international data collection and exchange system is well established and functionally effective, although it still needs attention and improvement. The exchange of precipitation data is often inadequate. Difficulties for climate research and climate-impact studies have arisen or are likely to arise in two areas:

1. Collection and dissemination of oceanographic data within the 200-mile-wide "economic zones" of coastal states. Collection of oceanographic data in these waters requires the consent of the coastal states, which may be withheld at their discretion.
2. Socioeconomic, agricultural, demographic, and environmental data needed for climate-impact studies. In many less-developed countries, as well as in states having centrally planned economies, such data are often not accessible even when they exist.

It may be possible for oceanographic ships and personnel of developed countries to obtain the needed oceanographic data through arrangements made by such agencies as the Intergovernmental Oceanographic Commission or other "competent international organizations," defined in the negotiating text for the UN Law of the Sea Conference. Similar arrangements for obtaining socioeconomic and related data needed for climate-impact studies could conceivably be made by UNEP. The United States should take necessary steps to obtain access to essential data.

U.S. AGENCY INVOLVEMENT IN INTERNATIONAL PROGRAMS

Even before the establishment of a unified National Climate Program, there have been several instances of U.S. participation in international climate-related enterprises, through the auspices of both intergovernmental and nongovernmental organizations as well as through bilateral and multilateral agreements. Very often the U.S. government agency most intimately involved programmatically has been authorized to deal directly with the international

organization or other nations on behalf of the United States. Examples are NOAA vis-à-vis WMO and EPA vis-à-vis the U.S.-U.S.S.R. bilateral agreement on the environment. In such instances the designated agency is required to coordinate the involvement and interests of other agencies, including the U.S. Department of State. In other instances the Department of State itself is the primary interfacing agency, as with UNEP. Still another *modus operandi* is for the National Academy of Sciences (NAS) to be the contact point. An example of such a nongovernmental interface is that with ICSU. But the NAS also communicates and enters into agreements with the academies of sciences of other nations, which are sometimes government units.

This large variety of means for the United States to participate internationally provides great flexibility and minimizes bureaucratic and pyramidal obstacles. It is highly recommended that it be continued, taking due account of the coordinating role of the NCPO and the statutory responsibilities of the Department of State in intergovernmental agreements. Furthermore, full advantage should be taken of possible assistance by scientific attachés at major U.S. embassies. To improve communications in the area of international climate activities, it is recommended that the director of the National Climate Program Office be added to the federal Committee on International Environmental Affairs as a member *ex officio*.

FUNDING INTERNATIONAL EFFORTS

During the last 10 to 15 years, there has been a marked shift in the nature of the UN specialized agencies. Whereas they were formerly dominated by developed countries, they are now more responsive to the objectives of developing nations. Thus there may be instances in which the priorities of the National Climate Program do not coincide with those of the UN agencies. To assure adequate attention to U.S. climate concerns, the United States should consider the following possibilities:

1. Apart from persuasive argument in the councils of the agencies, advantage can be taken of the Trust Fund system, whereby funds granted to the agencies may be earmarked for particular purposes.
2. An appropriate ICSU body or other nongovernmental organization can be used as a channel for funding.
3. Individual scientists can be seconded from the United States, at U.S. expense, to participate in international tasks of particular concern to the United States.
4. *Ad hoc* arrangements, including financing, can be made between countries when a problem requiring a high order of scientific or technical expertise needs to be addressed.

Appendix E: An Example of a System to Deliver Applied Climatological Services

The Air Weather Service of the U.S. Air Force (USAF) has provided systematic climatological support to the research and development and operational elements of the USAF and to the operational elements of the Army for many years. The service system successfully combines decentralized staff elements working locally with worldwide users and certain centralized facilities to provide intensive studies and data services. These are then distributed through the local entities. It is useful to examine this system in some detail because both the decentralized and the centralized components are essential to achieving the documented highly beneficial impact on the design, development, and employment of military resources. User-documented value analysis studies show that the benefit-to-cost ratios of these services vary over a wide range, but a comfortable average is on the order of 10 : 1.

Several dozen specially trained staff meteorologists and staff weather officers are stationed worldwide as essential members of development laboratories, project offices, and operating units. These officers interact continuously at the local level with their military clients in order to help formulate user needs in meteorological terms, educate the users about the value of climatological support, interpret and deliver climatological products and services in a timely manner in terms that the user understands, generate requirements for applications studies and climatological research, and perform quick response services using on-hand resources.

The more-intensive studies, when required by the various users, are generally requested by the local weather officers of the scientific and technical staffs at the USAF Environmental Technical Applications Center (ETAC). There, 200 personnel produce about 400 climatological studies and analyses

each year and process thousands of internal and external data searches and information referrals each month. Virtually *none* of these studies involves climate prediction, and they rarely require special observing programs. They are, however, distinctly in the category of applied climatology and are usually based on existing data sets of operational quality. Needs for research are referred to the Air Force Systems Command.

This system succeeds because it provides tailored services in a distributed manner through specialists who work closely with the users in their local environment. A few major facilities, such as USAFETAC, various Air Force laboratories, and private contractors provide intensive studies, analyses, and specialized data services. USAFETAC acts as a clearinghouse at the global level. The primary communication network is the telephone, although some specialized communications links are in place.

Appendix F: Abbreviations Used in Text

AGNET	Agricultural Network
CCCO	Committee on Climate Change and the Oceans
CO_2	Carbon dioxide
DOE	Department of Energy
ERBE	Earth Radiation Balance Experiment
ETAC	Environmental Technical Applications Center, U.S. Air Force
FAO	Food and Agriculture Organization
GARP	Global Atmospheric Research Program
GOCE	Global Ocean Circulation Experiment
GWE	Global Weather Experiment
ICP	Intergovernmental Climate Program
ICSU	International Council of Scientific Unions
IOC	Intergovernmental Oceanographic Commission
MAB	Man and the Biosphere Program, UNESCO
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCP	National Climate Program
NCPO	National Climate Program Office
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
POMS	Pilot Ocean Monitoring Study
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee on Oceanic Research

UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAF	United States Air Force
WCRP	World Climate Research Program
WMO	World Meteorological Organization