CHAPTER 11

Decision Support Resources Development

CHAPTER CONTENTS

The Role of Decision Support

In order to fulfill the scientific assessment requirements of the 1990 Global Change Research Act (P.L. 101-606)[3], and to enhance the utility of the extensive body of observations and research findings developed by the U.S. Global Change Research Program (USGCRP) since 1990, the Climate Change Science Program (CCSP) is adopting a structured approach to match, coordinate, and extend resources developed through the research activities to the support of policy and adaptive management decisionmaking. The USGCRP has made very large investments in research and observing programs since 1990. By comparison, the USGCRP investment in assessment activities and other decision support resources has been much smaller to date. The largest assessment program previously undertaken by the USGCRP was the National Assessment initiated in 1998, which produced overview reports in late 2000 and a series of specialty reports in the period 2001-2003.

The decision support approach for analyses and assessments adopted by the CCSP builds upon the "lessons learned" from earlier USGCRP assessment analyses, as well as other sector, regional, national, and international assessments. The Climate Change Research Initiative (CCRI) will place enhanced emphasis on the extraction of mature scientific knowledge from the core research program for use in assessment and decision support. The principal guidelines for the CCSP decision support approach follow:

- *Analyses structured around specific questions*. This approach enhances consistent communications among all involved scientists and stakeholders addressing designated questions.
- *Early and continuing involvement of stakeholders*. Stakeholder feedback is essential in defining key science and observation questions, and in defining the key issues in each analysis.
- *Explicit treatment of uncertainties*. The CCSP and the general scientific community have the responsibility to define the applicability limits imposed on various projections and other analyses, as related to the uncertainties in the underlying data and analysis methods. The CCSP will consistently address the uncertainties and the limits of applicability (related to underlying uncertainties) associated with the decision support analyses it reports.

[3]"On a periodic basis (not less frequently than every 4 years) the Council, through the Committee, shall prepare and submit to the President and the Congress an assessment which:
1) Integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings
2) Analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity
3) Analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years." (from Section 106).

- *Transparent public review of analysis questions, methods, and draft results.* In the same manner that the CCSP published a *Discussion Draft Strategic Plan* for public review in November 2002, the CCSP will publish drafts of decision support analysis plans for open review. Draft results from the analyses will also be published for review before their completion.
- *Evaluate ongoing CCSP analyses and build on the lessons learned.* The CCSP plans to conduct, through a variety of mechanisms, a limited number of decision support case studies during the next 2 years, and to expand the scope of these analyses only after evaluating scientific and stakeholder community feedback from the initial experiences.

The CCSP activities in Decision Support Resources go beyond what has been accomplished in the past in the breadth of interagency activity and commitment to extend beyond traditional science assessments to new forms of stakeholder interactions that focus development and delivery of information in more effective and credible ways. The CCSP Decision Support Resources activities will build on the science foundation established by the USGCRP, the CCRI, and related international research programs, as well as the lessons learned from other assessments and stakeholder interaction projects conducted during the last decade. The planned decision support resource development will address key recommendations from the National Research Council (NRC), particularly those discussed in *Global Environmental Change: Research Pathways for the Next Decade* (NRC, 1999a), *Climate Change Science: An Analysis of Some Key Questions* (NRC, 2001a), and *The Science of Regional and Global Change: Putting Knowledge to Work* (NRC, 2001e).

Priorities on decision support resources are guided by national and international priorities that have been established with stakeholder partnerships. National priorities include the management of carbon, energy, water, air quality, community growth, disaster, invasive species, and coasts, along with possible negative ancillary impacts associated with health and agricultural efficiency.

The analyses and development of other decision support resources are intended to support the decisionmaking process and to be capacity-building activities. By sponsoring these activities (conducted by government, academic, and other groups), the CCSP will enhance the capabilities of various interdisciplinary research groups to assist in the evaluation of the many different policy and adaptive management questions likely to arise in the coming years. Decision support resources are improved on an iterative basis, requiring a continuous process of incorporating new technologies, processes, and knowledge. The CCSP plan for evaluation is to systematically verify and validate the integration of each new generation of climate change research results into decision support resources and to determine the confidence in using the enhanced tools in a variety of applications.

BOX 11-1

WORKING DEFINITIONS

Decision Support Resources
Decision support resources refers to the set of analyses and assessments, interdisciplinary research, analytical methods (including scenarios and alternative analysis methodologies), model and data product development, communication, and operational services that provide timely and useful information to address questions confronting policymakers, resource managers and other stakeholders.

Policy Decisions
Policy decisions result in laws, regulations, or other public actions. These decisions are typically made in government settings (federal, state, local) by elected or appointed officials. These decisions, which usually involve balancing competing value issues, can be assisted by—but not specified by—scientific analyses.

Adaptive Management Decisions
Adaptive management decisions are operational decisions, principally for managing entities that are influenced by climate variability and change. These decisions can apply to the management of infrastructure (e.g., a waste water treatment plant), the integrated management of a natural resource (e.g., a watershed), or the operation of societal response mechanisms (e.g., health alerts, water restrictions). Adaptive management operates within existing policy frameworks or uses existing infrastructure, and the decisions usually occur on time scales of a year or less.

Planning
Planning is a process inherently important for both policy decisions and adaptive management. It usually occurs in the framework of established or projected policy options.

Stakeholders
Stakeholders are individuals or groups whose interests (financial, cultural, value-based, or other) are affected by climate variability, climate change, or options for adapting to or mitigating these phenomena. Stakeholders are important partners with the research community for development of decision support resources.

Assessments
Assessments are processes that involve analyzing and evaluating the state of scientific knowledge (and the associated degree of scientific certainty) and, in interaction with users, developing information applicable to a particular set of issues or decisions.

Scenario
A scenario is a coherent statement of a potential future situation that serves as input to more detailed analysis or modeling. Scenarios are tools to explore "If …, then…" statements, and are not predictions of or prescriptions for the future.

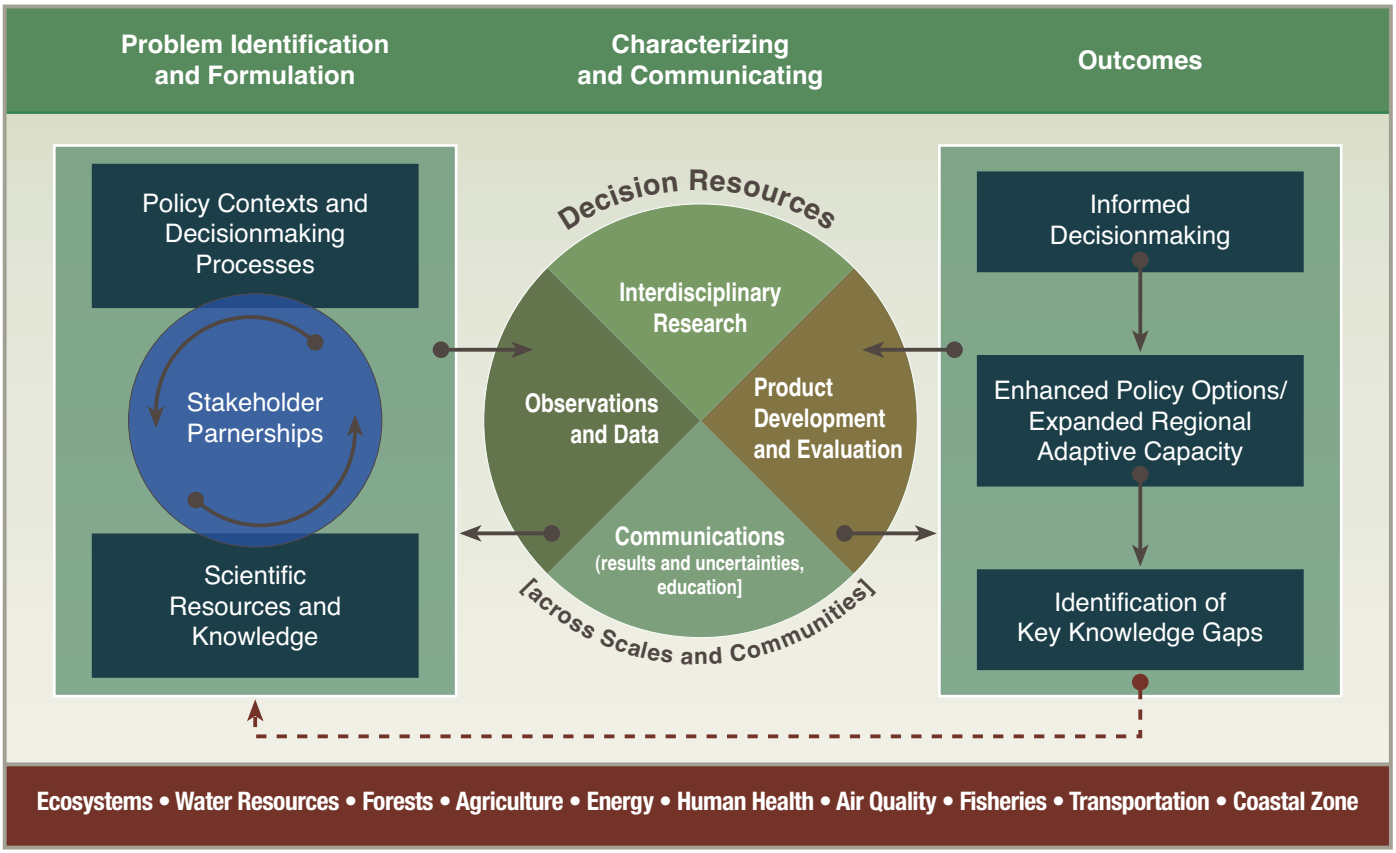

Figure 11-1: Schematic representation of decision support framework illustrating components of problem identification and formulation, development of decision resources, and final outcomes.

The planned CCSP Decision Support Resource activities respond to the following three goals:

1) *Scientific syntheses*. Prepare scientific syntheses and assessments to support informed discussion of climate variability and change issues by decisionmakers, stakeholders, the media, and the general public.
2) *Adaptive management for resources and infrastructure*. Develop information resources to support adaptive management and planning for responding to climate variability and climate change, and transfer these resources from research to operational application.
3) *Support for policymaking*. Develop and evaluate methods (scenario evaluations, integrated analyses, alternative analytical approaches) to support climate change policymaking and demonstrate these methods with case studies.

Management and advisory processes (involving both government and non-government reviewers) will be developed to ensure implementation of a coordinated CCSP decision support effort using review and feedbacks to identify and set priorities.

Three decisionmaking categories will be addressed by the CCSP: (1) public discussion and planning based on state-of-science syntheses and assessments; (2) operational adaptive management decisions undertaken by managers of natural resources and built infrastructure (i.e., "climate services applications"); and (3) support for policy formulation. Each of these decisionmaking categories has a unique set of stakeholders and requires different decision support tools. A common framework of activities will be used where appropriate for all three categories as shown in Figure 11-1. The figure illustrates stakeholder partnerships with scientists to identify and formulate the problems to be addressed, the development of decision support resources, and expected outcomes. Key elements in this framework include:

- Involvement of stakeholders in question identification and formulation
- Science syntheses and assessments focused on the identified question(s)
- Formation of interdisciplinary research teams that interact with the decisionmaking communities, and that integrate the natural and social sciences
- Development, with users, of a decision support "toolbox" (a collection of validated and verified products and processes that can be used by decisionmakers)
- Quantification and communication of the level of confidence in reported findings
- Evaluation and review processes for the decision support analyses that engage the relevant decisionmaking communities.

The "decision support toolbox" refers to the collection of decision support products [including communication methods, integrated maps, geographic information system (GIS)-based analysis products, targeted forecasts for particular sectors, "decision calendars," scenarios, etc.] that have been validated, verified, and evaluated from the perspective of users. In its mature state, decisionmakers will be able to assess the extent to which analytical tools applied in a particular sector or circumstance could be applied or modified in their particular setting. The toolbox depends upon the physical,

natural, social science, and, now, assessment foundations of the CCSP, including Earth observation networks and systems, Earth system models, the data and data-handling infrastructure of the CCSP research activities, and an evolving network of socioeconomic data.

The expected outcomes from the CCSP Decision Support Resources activities include:

- Improved science syntheses and assessments for informing public discussion of climate change issues
- Expanded adaptive management capacity to facilitate the responses of resource managers to climate variability and change
- Assessment information for evaluating options for mitigation of and adaptation to climate variability and change
- Identification of information needs to guide the evolution of the CCSP science agenda.

Goal 1: Prepare scientific syntheses and assessments to support informed discussion of climate variability and change issues by decisionmakers, stakeholders, the media, and the general public.

The Global Change Research Act of 1990 (P.L. 101-606, Section 106) directs the USGCRP to support research to "produce information readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating, and adapting to the effects of global change" and to undertake periodic science assessments. Assessments are an effective means for integrating and analyzing CCSP research results with other knowledge, and communicating useful insights in support of a variety of applications for decision support. Assessments also help identify knowledge gaps and thus provide valuable input to the process of focusing research.

During the next decade, CCSP will continue to support assessment analyses. Given the broad set of policy, planning, and operational decisions that would benefit from climate and global change information, there are a wide variety of candidates for CCSP assessment analyses. A focused, systematic approach for selecting and producing a practical number of assessments—and for continuously addressing the "lessons learned" from each assessment analysis—will be developed and published by the CCSP.

Objective 1.1: Produce scientific synthesis reports

The CCSP participating agencies will coordinate their work to produce a number of synthesis reports that integrate research results focused on identified science and decision issues. These reports will provide current evaluations of the science foundation that can be used for informing public debate, policy, and operational decisions, and for defining and setting the future direction and priorities of the program.

The CCSP agencies and scientists funded by these agencies will also continue to participate in the principal international science assessments including the Intergovernmental Panel on Climate Change (IPCC) fourth assessment scheduled for completion in 2007, and the World Meteorological Organization (WMO)/United Nations Environment Programme (UNEP) assessments of stratospheric ozone depletion and associated environmental impacts.

Objective 1.2: Plan and implement designated assessment analyses in collaboration with the stakeholder and research communities

The CCSP will produce a set of assessments that focus on a variety of science and policy issues important for public discussion and decisionmaking. The assessments will be composed of syntheses, reports, and integrated analyses that the CCSP will complete by the third quarter of 2006. CCSP cooperating agencies will sponsor or carry out the analyses with interagency oversight to ensure that resources from the entire program are best utilized. This approach will cover the full range of CCSP goals and will provide a "snapshot" of knowledge concerning the environmental and socioeconomic aspects of climate variability and change. A list of the planned CCSP scientific synthesis and assessment reports is provided in Box 11-2. This list reclassifies the product summary in Table 2-1 (Chapter 2) by primary decision support purpose.

Goal 2: Develop resources to support adaptive management and planning for responding to climate variability and climate change, and transition these resources from research to operational application.

Adapting to climate variability and potential change poses challenges to management of resources, infrastructure, and the economy. The pressures of increased population densities and intensified land use, common throughout much of the United States and other nations, increase the demand for effective management of resources sensitive to climate in many regions. For example, information on short-term climate variability (i.e., weekly, monthly and seasonal projections) is relevant for the development of state and regional drought action plans, agricultural operations management, water resource system management, and fishery management. Much of the information from CCSP research is relevant to these decisions, but often is insufficiently focused on management applications to be directly useful. Thus, the CCSP decision support resource activities will play an important role in the "transition from research to operations" for major elements of the underlying research. In the transition process, particular attention will be placed on the establishment of validation and verification guidelines for the extension of the research, analyses and assessments, model and data products, and other resources into operational decision support.

CCSP research results, data products, forecasts, and model results are already being applied to adaptive management decision support in a limited number of regional and sectoral case studies. Elements of climate and associated ecosystem observations from satellite, ground-based, and *in situ* platforms are also being synthesized into useful data products for decisionmakers. Examples include a variety of maps for crop management, water quality management, and urban planning, and integrated products illustrating snowpack, precipitation, streamflow, and potential for drought conditions. Climate projections, especially those from El Niño-Southern Oscillation (ENSO) analyses (which have demonstrated elements of seasonal- to biennial-scale forecast skill), have provided information for state and local emergency preparedness organizations; water resource management plans for the western regions; agricultural planning for the southeast; and fire management for drought-stricken

BOX 11-2

CCSP TOPICS FOR INTEGRATED SYNTHESIS AND ASSESSMENT PRODUCTS CATEGORIZED BY PRIMARY END USE

Science Reports to Inform Evolution of the Science Research Agenda

- Temperature trends in the lower atmosphere—steps for understanding and reconciling differences
- Past climate variability and change in the Arctic and at high latitudes
- Updating scenarios of greenhouse gas emissions and concentrations, in collaboration with the Climate Change Technology Program (CCTP); review of integrated scenario development and application
- North American carbon budget and implications for the global carbon cycle
- Climate models and their uses and limitations, including sensitivity, feedbacks, and uncertainty analysis
- Climate projections for research and assessment based on emissions scenarios developed through the CCTP
- Climate extremes including documentation of current extremes; prospects for improving projections
- Relationship between observed ecosystem changes and climate change
- State of the science of socioeconomic and environmental impacts of climate variability

Synthesis and Assessment Products to Inform Adaptive Management Decisions

- Risks of abrupt changes in global climate
- Coastal elevation and sensitivity to sea-level rise
- Within the transportation sector, a summary of climate change and variability sensitivities, potential impacts, and response options
- Preliminary review of adaptation options for climate-sensitive ecosystems and resources
- Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions
- Best practice approaches for characterizing, communicating, and incorporating scientific uncertainty in decisionmaking
- Decision support experiments and evaluations using seasonal-to-interannual forecasts and observational data

Synthesis and Assessment Products to Inform Policy Decisions

- Re-analyses of historical climate data for key atmospheric features; implications for attribution of causes of observed change
- Aerosol properties and their impacts on climate
- Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure and climate change
- State-of-knowledge of thresholds of change that could lead to discontinuities (sudden changes) in some ecosystems and climate-sensitive resources
- Scenario-based analysis of the climatological, environmental, resource, technological, and economic implications of different atmospheric concentrations of greenhouse gases

regions. Decision support tools are also employed by federal agencies to serve the public in local and regional decisionmaking and include applications in the management of carbon, water, disasters, invasive species, and coastal ecosystems along with information on public health, agriculture efficiency, and energy use. All of these products have been co-developed by scientists and users after extensive dialogue and are potential resources for a "decision support toolkit."

Making use of information on variability and potential future changes in climate requires that decisionmakers be directly involved in shaping their key questions, and not passive consumers of general scientific information. User partnerships that actively engage scientists provide the opportunity for understanding where scientific resources and knowledge can best be used and what new research may be needed. Outputs from such interactions include decision calendars and assessments that frame the context in which the science will be used, determination of what products need to be developed using the science information base and experiential knowledge of stakeholders, and determination of the limits of existing knowledge to be applied to the problem.

Decision support for adaptive management requires advances in basic knowledge and progress in applying scientific information within adaptive management settings. Conducting research within a decision support framework can provide multiple benefits for both practitioners and scientists. Ideally, users of research information are served so that new options exist for minimizing negative impacts or pursuing opportunities, and researchers benefit from refinement and prioritization of research agendas through the identification of the uncertainties most relevant to decisionmaking.

CCSP will play an important role in generating processes and products relevant to adaptive management decision options. Examples of pilot products include historical data analyses and products; forecasts for particular sectors at key time periods; probabilistic climate variability and change information integrated with decision models; "decision calendars;" geo-referenced maps of critical climate and associated environmental parameters; and specific model runs or data sets. The CCSP will also develop mechanisms to sustain interactions between users and researchers in order to better understand how to optimize the delivery of research results, data products, and forecasts.

Objective 2.1: Conduct research to extend the uses and identify the limits of existing decision support resource capabilities for adaptive management

The CCSP's approach for accelerating and enhancing decision support for adaptive management will be based on the following:

- Enhancement of existing case studies of adaptive management decision support using a variety of approaches sponsored by CCSP agencies
- Implementation of evaluation processes to address (1) the role of scientific uncertainties in the analyses and (2) feedback information to help frame future research agendas
- Development and demonstration of elements of a decision support toolkit.

CCSP research will target adaptive management issues and information use, including the potential entry points and barriers to using climate information as well as the types of new information that would provide the greatest benefit to decision processes. This research will integrate natural and social systems within an application context of managed resources or infrastructure, utilizing climate and environmental observations, model outputs, socioeconomic data, and decision models. It will incorporate elements of regional/ sub-regional climate science and associated environmental processes, socioeconomic impacts, technological capabilities, management institutions and policies, and decision processes including evaluation.

CCSP will integrate lessons learned from current adaptive decision support case studies sponsored by CCSP participating agencies. These lessons will provide a mechanism for evaluating how scientific information is currently used by decisionmakers (to help frame problems) and for evaluating the quality of the scientific resources available to be applied to the problems.

Within a case studies framework, CCSP will support development of resources for decision support, and will develop methods to quantify uncertainty and its effect on the adaptive management process in a range of example cases. Illustrative resources to be developed are listed in Box 11-3.

CCSP will periodically organize workshops and forums to gather information on lessons learned from adaptive management decision support activities, and will prepare summary reports that help transition knowledge and resources across regions and sectors. The resources (processes and tools) that emerge from this research in decision support are the foundation for a "tool kit," a term that describes a range of products useful to individuals and institutions responding to the effects of climate variability and change. The CCSP will support the mechanisms to help users identify and use the capabilities in the tool kit, including web-based tutorials, workbooks, and interactive forums.

Objective 2.2: Promote the transition of resources from research to operations for sustained use

Once decisionmakers begin using new products, there is a need to ensure the continuity of that product through services entities. While the CCSP itself does not have a service mission, many of the CCSP collaborating agencies do. The CCSP will work to facilitate the successful transitioning, verification and validation, and maintenance of newly developed decision support products within its collaborating agencies or other non-federal service entities. CCSP will work to support collection of data, information, and other resources utilized by the decision support products and will aid in the transition of this collection to operational entities when appropriate. In the transition process, it is important to benchmark

BOX 11-3

ILLUSTRATIVE RESOURCES TO BE DEVELOPED FOR ADAPTIVE MANAGEMENT DECISION SUPPORT

New experimental long-lead (12-month) streamflow forecasts for major watersheds of the United States, coupled with improved decision-support for water managers and users [2-4 years].

Experimental to operational decision support systems for agriculture and ranching in selected regions (Southwest and Southeast) of the United States [2-4 years].

Prototype regional (Western and Southeastern) integrated "multi-stress" and multi-jurisdiction decision support systems for forest and wildfire management [2-4 years].

Development of a blueprint for the improved regional climate, hydrologic, and ecological observing systems needed for enhanced decision support, particularly in mountainous regions [2-4 years].

Tests of existing regional modeling capabilities, and definition of the improved regional modeling capabilities needed for enhanced decision support [2-4 years and beyond].

Improved public health decision support for major climate-modulated infectious disease threats in the United States, including mosquito-borne viral disease, Hantavirus, and Valley Fever [2-4 years].

Analysis of historical records in target areas to gain a better understanding of past and current climate variability across all time-scales for use in sensitivity analyses of existing and planned physical infrastructure [2-4 years and beyond].

Assessments of potential effects of climate change and land-use change on water and vector-borne diseases [2-4 years].

Assessment of the potential effects of climate change, land-use change, and UV radiation on aquatic ecosystems [2-4 years].

the improvement in performance of solutions that result from integrating research-quality observations with research-quality predictions and outlooks into operational decision support tools.

Two case studies of adaptive management decision support, summarized in Boxes 11-4 and 11-5, illustrate the transition of decision support analyses into the type of operational management resources anticipated by the CCSP Decision Support Resource development goals.

Goal 3: Develop and evaluate methods (scenario evaluations, integrated analyses, alternative analytical approaches) to support climate change policymaking and demonstrate these methods with case studies.

Policy-related questions regarding climate change typically arise from numerous sources, for example from:

- Consideration of climate change policy within federal government

BOX 11-4

HANTAVIRUS PULMONARY SYNDROME IN THE SOUTHWESTERN UNITED STATES

This case study describes research and assessment activities undertaken to better understand the cause of outbreaks of hantavirus pulmonary syndrome (HPS) in the southwestern United States in the 1990s. The research and assessment efforts led to pilot production and evaluation of risk maps, which were then used by public health officials for on-the-ground interventions to prevent disease outbreaks and protect public health. This study illustrates how multidisciplinary, place-based research and assessment, conducted in response to questions raised by a particular user group (public health officials), can lead to the development of products (risk maps) that successfully increase regional adaptive capacity (enhanced public health care).

Problem Formulation

In 1993, a disease characterized by acute respiratory distress with a high death rate (greater than 50%) among previously healthy persons was identified in the southwestern United States. This disease, HPS, was traced to a virus maintained and transmitted primarily within populations of a common native rodent, the deer mouse (*Peromyscus maniculatus*). Public health officials wanted to understand the cause of the outbreak so they could develop effective techniques for intervening and preventing the disease.

Researchers hypothesized that the outbreak was due in part to the unusual weather in 1991-1992 associated with the El Niño-Southern Oscillation. Unseasonable rains in 1991 and 1992 during the usually dry spring and summer, and the mild winter of 1992, were thought to have created favorable conditions for an increase in local rodent populations. It was suggested that a cascading series of events from weather—through changes in vegetation, to virus maintenance and transmission within rodent populations—culminated in changes in human disease risk from HPS.

The Assessment

A study explored this hypothesis by comparing the environmental characteristics of sites where people were infected with those sites where people were not infected. The study used a retrospective epidemiologic approach to risk assessment. Satellite imagery (Landsat Thematic Mapper images), combined with epidemiologic surveillance, retrospectively identified areas at high risk for HPS associated with *Peromyscus* populations over broad geographic regions during the 1993 outbreak. Thematic Mapper data identified environmental conditions approximately 1 year before the outbreak that were measurably different near HPS sites than in rural, populated sites where the disease did not occur.

Pilot Production and Evaluation of Risk Maps as a Decision Support Tool

The assessment revealed that environmental conditions near HPS sites varied with the presence or absence of ENSO. The geographic extent and level of predicted HPS risk were higher during ENSO, supporting the view that El Niño may increase the likelihood of HPS outbreaks.

It was then determined that high-risk areas for HPS can be predicted more than 6 months in advance based on satellite-generated risk maps of climate-dependent land cover. Predicted risk paralleled vegetative growth, supporting the hypothesis that heavy 1992 rainfall due to El Niño was associated with higher rodent populations that triggered the Hantavirus outbreak in 1993. Landsat satellite remote-sensing images from 1995, a non-El Niño "control" year, showed low risk in the region, whereas the images from the 1998 strong El Niño again showed high risk areas as in 1992-1993. Trapping mice in the field validated the satellite-generated risk maps with mouse populations directly related to risk level, with a correlation factor of over 0.90. Risk classification also was consistent with the numbers of HPS cases in 1994, 1996, 1998, and 1999.

Next-Generation Integrated Knowledge

This information was used to develop an early warning system, with intervention strategies designed to avoid exposure. These strategies, developed in partnership with the Centers for Disease Control and Prevention (CDC) and the Indian Health Service, are already being implemented by the U.S. Department of Health and Human Services for disease prevention in the southwest.

BOX 11-5

CLIMATE-ECOSYSTEM-FIRE MANAGEMENT

Wildland fires burn millions of acres each year and major resources are committed to fuel (live and dead vegetation) treatment, fire prevention, and fire suppression. Effective decision support products and tools can improve resource allocation decisions and maintain a high standard of safety for firefighters and the public. The fire-climate assessment tool, which is in essence a structured process, allows fire and fuels specialists and fire weather meteorologists in each of the National Interagency Fire Center's eleven Geographic Area Coordination Centers (GACCs) to work with climatologists to develop GACC-level assessments of fire risk at seasonal to shorter time scales. The tool also allows Predictive Services staff to develop and update a national map and discussion of fire potential for the fire season each year.

Problem Formulation

- La Niña conditions prompted the first climate-fire-society stakeholder workshops in 2000. These annual workshops have established a dialogue between stakeholders (fire managers and decisionmakers) and climatologists.
- The workshops evolved over 3 years, refining the contribution of climate information to seasonal fire outlooks at the regional level and focusing on "fire science," including the nature of the fire regime (frequency, size, intensity); conditions in the natural system (adaptive ecosystems, vegetation, fuels, watershed, soil, wildlife); and characteristics of the human systems (property, economic sectors affected, policy and land-use planning, multi-agency jurisdictions).
- The workshop process is supported by interdisciplinary teams of research scientists interested in focusing climate impacts research on information and insights essential to decision challenges influenced by climate variability and change.

Research Modules

- Design and communication of climate information and forecasts useful for fire management involves collaboration between decisionmakers and scientists in the conduct of research to improve institutional capacity to integrate scientific information and predictions into planning and operations; analysis of individual stakeholder perceptions of fire risk and of their capabilities and willingness to use scientific information in their decision processes; and identification of the factors (environmental, economic, and public health) that are most relevant in the context of overall public good, as viewed across geographic and agency boundaries.
- Climate and ecological processes including improving understanding of the spatial variability of fire. Recent investigations have found strong associations between the Palmer Drought Severity Index (PDSI) several months to 2 years earlier and fire season severity. Correlating anomalous wildfire frequency and extent with the PDSI illustrates the importance of prior and accumulated precipitation anomalies to future wildfire season severity.
- Risk assessment and mitigation including strategic planning for fire use (i.e., prescribed burns and allowing selected fires to burn) and fire suppression; improving predictive capabilities based on improved understanding of relationships between wildland fire and climate before, during, and after events; and determination of how science can inform development of wildland fire objectives important to interagency preparedness planning.
- Development of an integrated model called Fire-Climate-Society (FCS-1) to provide a planning tool, accessible to fire managers and community members, that would integrate the climate, fuels, fire history, and human dimensions of wildfire behavior for strategic management.

Next-Generation Integrated Knowledge

The objective is to develop an understanding of the interactions among climate, ecology (e.g., fuel load), and human factors (e.g., real estate, land use, recreation, conservation, jurisdiction, law) such that decision support insights reflect the true "multiple-stressor" realities of wildland fire risk and management. Particularly important are questions such as:

- What federal/state policies and programs increase fire risks and severity; what policies pose barriers to adoption of innovations such as new decision support tools?
- What are the scales of impacts (temporal and spatial) that influence fire regimes?
- What are the connections between multi-year drought and fire risk?

Pilot Product Development and Evaluation

- A new Predictive Services program has been launched to anticipate where fires are most likely to occur in order to allocate the appropriate firefighting resources to these areas. Geographic area predictive services units, established by the 2000 National Fire Plan, are tasked with integrating information about climate, weather, fire danger, and firefighting resources to provide decision support to fire managers on the location, timing, and severity of fire potential.
- The National Wildland Fire Outlook is the compilation of the 11 geographic area outlooks generated at the National Seasonal Assessment Workshop, and provides the first national-level, interagency, climate-based seasonal fire outlook.

In the spirit of the adaptive learning approach built into many of the regional projects, pilot products are inspiring a new round of research into understanding decision structures and constraints in order to transfer knowledge gained in this particular decision support experience.

- Proposals advanced by private and non-governmental organizations
- Preparation for international negotiations
- Consideration of legislative proposals
- Priority-setting processes for science and technology programs.

The CCSP will work in close collaboration with the Climate Change Technology Program (CCTP) to develop evaluations of relevant policy questions that incorporate up-to-date knowledge of both scientific and technology issues. The CCSP will focus on two objectives in this area: (1) developing scientific syntheses and analytical frameworks ("resources") to support integrated evaluations, including explicit characterization of uncertainties to guide appropriate interpretation, and (2) initially conducting a limited number of case studies with evaluation of the lessons learned, to guide future analyses.

Objective 3.1: Develop scientific syntheses and analytic frameworks to support integrated evaluations, including explicit evaluation and characterization of uncertainties

One of the challenges of developing scientific syntheses is providing a systematic way of integrating knowledge across disciplines, each having their own methodologies, resolutions, and degrees of certainty of scientific information. Meeting this challenge requires defining and meeting information needs across these borders, and developing methods and approaches to put information from different disciplines in compatible formats. Integrated models are an important tool for synthesis and comparative evaluation because they impose stringent standards of cross-disciplinary consistency and intelligibility. The CCSP supports the development of a number of integrated modeling frameworks that are useful for exploring many dimensions of climate and global change. The CCSP will also adopt other approaches for synthesis, including integration of expert knowledge across the relevant fields.

The CCSP will structure its syntheses and integrated analyses of policy questions related to climate variability and change using four types of approaches and drawing on research results produced throughout all areas of the program. These four approaches are:

1) Evaluations of net greenhouse gas flux and uptake using a variety of methods
2) Climate system analyses to study sensitivities and quantify ranges of climate variability and change
3) Analyses of the effects of climate variability and change
4) Integrated analytic frameworks.

Evaluation of net greenhouse gas flux and uptake in the Earth system (including human activities, the land surface, ecosystems, the atmosphere, and the oceans). The CCSP will use several methods to evaluate historical, current, and projected future patterns of greenhouse gas flux uptake, and consequent concentrations. These methods include state-of-science syntheses for emissions and carbon cycle information, evaluation of the effects of future technology adoption in the United States and globally (in collaboration with the CCTP), use of expert working groups (including both government and non-government specialists) to evaluate historical and projected greenhouse gas emission information and uncertainties (including uncertainties arising from different assumptions about human driving forces), and various inverse-calculation methods to verify greenhouse gas flux rates compared to recent and current observations of greenhouse gas levels. Consistent with overall CCSP guidelines, these analyses will be developed in response to specific questions, and will be released for public review prior to publication in final form.

Climate system analyses. The CCSP will examine the range of natural variability (short- and long-term), responsiveness of the climate system to changes in net greenhouse gas fluxes and concentrations, and the potential for abrupt climate changes. CCSP analyses will use analytic approaches to improve the evaluation of uncertainty in important variables. It is well-recognized that there are significant questions about climate model sensitivity, as well as questions about verification of climate model projections when compared to long-term observation records. The CCSP will prepare an updated analysis on the uses and limitations of climate models for various policy support applications, and this CCSP analysis will guide the use of climate models in other CCSP analyses. In addition to computer-based climate models, several other analytical techniques will be used by the CCSP in developing policy-support analyses. These include atmospheric and oceanographic process research, historical and analog evaluations, and various data analysis and projection techniques. The CCSP supports a major program of climate model development and verification (see Chapter 10), and results from this program will be used in support of syntheses as appropriate.

Analyses of the effects of climate variability and change. Evaluation of the potential impacts associated with different atmospheric concentrations of greenhouse gases and aerosols is an important input to weigh the costs and benefits associated with different climate policies. Further research is required to integrate our understanding of the range of effects of different concentration levels and to develop methods for aggregating and comparing those impacts across different sectors and settings. Working with external advisory groups and the broad range of CCSP scientists, the CCSP-supported research will analyze a range of possible climate change impacts determined from climate system modeling and arising from different assumptions about natural and human influences, including (among many others) implications for agriculture, forestry, drought, fire, water resources, fisheries, coastal zones, and built environments such as ports. It will also address (to the extent possible given uncertainties) the potential implications of various response options for both the climate system and the economy.

Integrated analytic frameworks. Integrated analysis of climate change is essential for bringing together research from many contributing disciplines and applying it to gain comparative insight into policy-related questions. Full integration of information including research on human activities, greenhouse gas and aerosol emissions, land-use and land-cover change, cycling of carbon and other nutrients, climatic responses, and impacts on people, the economy, and resources is necessary for analysis of many important questions about the potential implications (both economic and environmental) of different greenhouse gas concentrations and various technology portfolios. Development and use of techniques for scenario and comparative analysis is useful for exploring the implications of different hypothetical policies for curbing emissions growth or encouraging adaptation. Answers from integrated analysis can only reflect the existing state of knowledge in component studies, but it

is important to develop frameworks and resources for integration, exercise them, and learn from analysis of the results. CCSP will encourage innovation and development of approaches to integrated analysis, and test these approaches in case study evaluations.

Evaluation of uncertainty. For all four of the analytical approaches described above, the issue of evaluation and communication of uncertainty and levels of confidence is fundamental. Uncertainties can arise from lack of knowledge; from problems with data, models, terminology, or assumptions; and from other sources. Integrated models are strong tools for examining uncertainty through repeated model runs with variation of key parameters. Use of scenarios, sensitivity analysis, and the specification of probability distributions for many inputs coupled with model runs are among the ways in which integrated models can be used to explore uncertainty. CCSP will use these and other techniques to evaluate uncertainty, and couple this analysis with its commitment to reporting levels of confidence and uncertainty clearly and transparently. The approaches to uncertainty evaluation and communication will enable users of CCSP analyses to understand the uses and limits of the information. As indicated elsewhere in this plan, broad guidelines for consideration of scientific uncertainty by the CCSP include the following:

- Uncertainty by itself (i.e., without regard to its magnitude in each specific case) should not prevent the development of analyses that may provide useful information for policy considerations.
- The magnitude (or importance) of uncertainty should be directly reported as a key element of analytical results in all cases where policy-supporting analyses are conducted.

Analytic approaches. Within the four analytical domains described above, a variety of approaches will be used and tailored to the study of a particular set of policy questions. The approaches are a means for examining proposed courses of action that incorporate knowledge of important key factors and uncertainty. In addition to development of decision support-related resources, the CCSP will also support research that furthers development of resources for integrated and comparative analysis, including:

- Use of historical climates (climate analogs)
- Techniques for posing and analyzing "If …, then…" questions, and reporting analytical results in the form of probability distributions of possible outcomes, thereby incorporating uncertainty information directly in the projected outcomes
- Models and qualitative frameworks for integrating scientific and technical information to compare environmental and socioeconomic effects of alternative response options
- Techniques for developing and analyzing scenarios using only a few of the most important variables (parametric analysis techniques)
- Techniques for "inverse analysis" that start from the study of temperature, precipitation, and other climate inputs required to maintain a system or activity, then identify rates or levels of climate change that would lead to discontinuities or thresholds.

An emphasis will be placed on the development of the greenhouse gas net flux scenarios through collaboration with CCTP. The distinctive feature of scenarios is that they integrate knowledge from the full range of relevant sources into a consistent description of potential future events. The specific variables incorporated in scenario development depend on the question being addressed. Scenarios for atmospheric chemistry, climate, impacts, adaptation, and mitigation models all require different techniques and variables. Scenarios will be constructed using up-to-date information on projections for key variables (e.g., demography, technology characteristics and costs, and economic growth and characteristics) and the relationship of key driving forces to environmental change (e.g., land use and land cover). CCSP will coordinate its scenario development plans with CCTP plans for analysis of different plausible technology portfolios and with the scenario efforts of the IPCC.

Objective 3.2: Conduct a limited number of case study analyses and evaluate the lessons learned in order to guide subsequent analyses

During the next 2 years, CCSP will conduct a limited number of case study integrated analyses using the approaches described above. For each case study analysis, a project team will be established that is responsible for design and implementation of the decision support methodology and products. Diverse input will be solicited to frame the questions, determine analytic methodologies to be used, identify needed observations to address the problem, and determine what resulting analyses and products are to be prepared. Stakeholder involvement will be sought throughout the case studies to aid in question development, selection of analytical methods, review of products, and guidance for communication of results. CCSP will provide support and coordination of the scientific community, stakeholder, and public interactions. End products of each case studied will include appropriate assessment reports, as well as the related "lessons learned" documents.

The lessons learned during the decision resource case studies conducted in the next 2 years will be used to guide the definition of a wider set of analyses to be completed in a 2- to 4-year time period. Both the initial and subsequent case studies will be specified (e.g., by choice of technical issues addressed, and by parameters selected for analysis) to reflect relevant climate variability and change issues. An illustrative case study demonstrating the application of the policy decision support process to an examination of technology mitigation is summarized in Box 11-6. Note that this illustration does not constitute a specific plan for analysis. As mentioned previously, CCSP will present specific plans for decision support analyses in separate announcements when ready, and will solicit public comment on each proposed plan.

Other case studies being considered for short-term (within 2 years) or longer term (2-4 years) analysis include:

- Possible climate and ecosystem responses to long-term greenhouse gas stabilization at various specified levels
- Projected climate, socioeconomic, and environmental outcomes of various carbon sequestration initiatives adopted both in the United States and globally
- Application of scientific information on the carbon cycle, ecosystems, and other research elements for the development of guidelines for crediting carbon sequestration activities—for example, as related to land use and soil type, cover species type, management practices, and so on
- Possible outcomes (in terms of projected greenhouse gas concentrations and climate system response) projected for various scenarios of new energy technology penetration both in the United States and globally
- Risk analyses related to various examples of abrupt climate change

BOX 11-6

TECHNOLOGY SCENARIO CASE STUDY: AN ILLUSTRATIVE CASE STUDY (IN CONJUNCTION WITH THE CCTP)

Evaluate Two Categories of Scenarios

1) What combinations of technologies can be expected to provide energy consistent with different emission levels between now and 2050?
2) What are the range of plausible consequences (on the climate system and socioeconomic parameters) of different emission scenarios reflecting the technology options responsive to the previous question?

Analysis Planning

A project workshop—with expert stakeholders including climate scientists, energy technology engineers and scientists, energy economists, and industry, government, and non-government organization representatives would be held (late 2003/early 2004) to gain alignment and organize cooperative research on deliverables. Additional project working groups would be formed for continued dialogue throughout the project time frame. A draft study plan, including competitive proposal processes and federal in-house research assignments, and a timeline for completion of tasks would be prepared by early 2004. CCSP would post the draft plan for public comment on its website, <www.climatescience.gov>.

Scenarios for Technology Performance with Alternative Profiles

Each profile would include technologies that are presently part of the global energy system and that are expected to have their performance improved over time, as well as new technology options presently under development (e.g., carbon capture and disposal, hydrogen systems, fusion energy, and biotechnology). Performance improvements with alternative technology options would also be explored. Estimates of potential benefits in terms of greenhouse gas emissions, energy security, and oil dependence would be assessed. The scenarios would also explore the potential for unintended consequences—both positive and negative. For example, if wind energy were extracted over large areas, it could reduce conventional air pollution as well as reduce greenhouse gas emissions, but it could also conceivably affect regional atmospheric circulation. Interaction with CCTP would be essential in developing these baseline scenario profiles. Incorporation of current scientific information about socioeconomic, technological, climatic, and environmental factors would be undertaken, with a characterization of the uncertainty in the scenarios. The scenarios would be completed by the end of 2004.

Modeled Climate Change for Each Greenhouse Gas Scenario, including Dynamic Carbon Cycle and Reasonable Projections of Land Use

This climate modeling task would be the responsibility of the large U.S. modeling groups. The model runs would also estimate the uptake of greenhouse gases by natural systems. This modeling must be informed by the results of carbon cycle research. The veracity of the model simulations for carbon sources and sinks needs to be tested ahead of time by comparisons to historical observations of the carbon cycle and the contribution of land-use changes. The model results would likely be presented in probabilistic form, and would be required to achieve agreed confidence limits to be considered usable for decision support. The large baseline computer modeling would be completed by mid-2005.

Modeled Environmental Impacts on Soil Moisture, Streamflow, and Vegetation

It is likely that one or both of the high-end U.S. climate models used for these studies would include fully interactive hydrologic-carbon-biogeochemical cycles (i.e., the major natural systems being impacted by climate). Workshops would be held to engage the broader community of researchers studying climate impacts in the analysis of these experiments, and provide guidance as to how process-driven impacts models can be interfaced with these simulations. The baseline global impacts modeling would be completed with probability distributions of projected outcomes by the end of 2005. Higher resolution (50-km or greater) simulations may be available for portions of the baseline scenarios starting in FY06, but only if such higher resolution models are shown to have useful confidence limits by that time.

Analyses, Assessments, and Reports

Throughout the process, several interim analyses, assessments, and reports would be generated. Example products for this case could include the following:

- Synthesis report on the scenario development and the characterization and evaluation of the uncertainties in the scenarios (2005).
- Evaluation of the impacts on the climate system for the baseline and alternative technology pathways. Report on the analysis of the scenarios of response of the climate system to various emission scenarios with emphasis on intercomparison of the different pathways (2006).
- Analysis of the scenarios of environmental responses to those response scenarios of the different climate states. Reports on the inter-comparison of those responses to the different climate states. One example may be an evaluation of the potential for carbon sequestration in different ecosystems and agricultural systems, including initial greenhouse gas accounting analyses and guidelines for agriculture and forestry (2006).
- Final synthesis report on the inter-comparison of different technology pathways with the baseline pathways including an analysis of potential environmental benefits and associated costs of each scenario (2007).

- Projected climate and ecosystem outcomes related to significant changes in land use and land cover, both in the United States and globally
- Analysis of adaptation strategies related to specified changes in climate or ecosystem parameters.

Decision Support Management Strategy

CCSP management and advisory processes will ensure implementation of an open and credible process for development of decision support resources.

Management Structure

Leadership and direction will be provided by the CCSP interagency governing body, working with representatives of the Interagency Working Group on Climate Change Science and Technology (IWGCCST) and CCTP to:

- Select syntheses or assessments to be conducted by the program, and provide oversight for these activities
- Review needs for decision support focused on adaptive management and promote development of CCSP research and resources to respond to these needs
- Periodically identify and define topics of importance to national decisionmaking to be addressed by the CCSP case studies of integrated analyses and scenario evaluations
- Establish external advisory mechanisms.

CCSP decision support activities will be implemented through an interagency working group with management and coordination support from the Climate Change Science Program Office (CCSPO). Specific responsibilities of the working group include:

- Carry out approved activities (e.g., identify resource requirements, develop implementation plans) under supervision of the CCSP interagency governing body
- Evaluate program needs and develop initiatives that respond to these needs
- Maintain an inventory of ongoing decision support and assessment activities within the CCSP agencies
- Coordinate agency activities
- Support advisory mechanisms as directed by the CCSP, including workshops, committees, or NRC activities.

CCSPO will support development of decision support activities, under the supervision of the CCSP interagency governing committee. CCSPO will be responsible for helping to coordinate the preparation of assessment and synthesis products; connecting the assessment activities, lessons learned, and decision tools development to broader interests and communities; and evaluating, reporting, and communicating results from the decision support activities.

Stakeholder Input and Evaluation

CCSP decision support activities will be conducted openly with input from external technical experts and other stakeholders. Advisory processes will be structured to meet specific requirements for each activity. Past experience has indicated that open framing of the questions to be addressed and methods to be adopted are crucial to establishing an open process and credible product. Ongoing advisory processes will provide independent review and oversight and ensure that products developed bring in all relevant perspectives. Independent evaluation of both products and processes will be included as a component of decision support efforts to ensure that future activities are improved by consideration and application of experience garnered through initial case study activities.

A first step that will be taken in developing stakeholder input is to hold a focused workshop to provide comments on (1) initial selection of topics/questions for policy decision support activities; (2) possible structures of "If …, then…" scenario analyses and other approaches for providing insight into the identified topics; (3) suggestions regarding the appropriate role of CCSP-supported research in fostering problem-oriented/solution-based adaptive management decision support; and (4) suggestions for ongoing external advisory and review mechanisms.

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