



7 | Decision-Support Resources Development and Related Research on Human Contributions and Responses

CCSP Decision-Support Goals

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

Decision-Support 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.

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

Strategic Research Questions

- 9.1 What are the magnitudes, interrelationships, and significance of the primary human drivers of, and their potential impact on, global environmental change?
- 9.2 What are the current and potential future impacts of global environmental variability and change on human welfare, what factors influence the capacity of human societies to respond to change, and how can resilience be increased and vulnerability reduced?
- 9.3 How can the methods and capabilities for societal decisionmaking under conditions of complexity and uncertainty about global environmental variability and change be enhanced?
- 9.4 What are the potential human health effects of global environmental change, and what climate, socioeconomic, and environmental information is needed to assess the cumulative risk to health from these effects?

See Chapter 11 of the *Strategic Plan for the U.S. Climate Change Science Program* for detailed discussion of decision-support resources development and Chapter 9 for these specific research questions.

Decisionmakers, resource managers, and other interested citizens need reliable science-based information to make informed judgments regarding policy and to take relevant action to address the risks and opportunities of changes in climate and related systems. Providing this information is the overall purpose of CCSP. This calls upon research-based resources distributed throughout the program’s research elements and CCSP’s 13 participating departments and agencies. A specialized element of CCSP research described in this chapter focuses on development of resources to support decisionmaking and related research on human contributions and responses to environmental change.

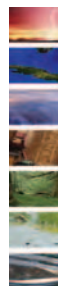
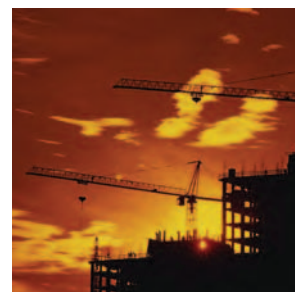
DECISION-SUPPORT RESOURCES

Decision-support resources include 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. This research is especially relevant to CCSP Goal 5: “Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.”

Development of decision-support resources is targeted at three broad categories of uses: (1) input to discussions of climate variability and change by decisionmakers, stakeholders, the media, and the general public; (2) adaptive management and planning; and (3) policy decisions. Each of these categories has a unique set of stakeholders and requires different decision-support tools. However, they share a common reliance on partnerships between scientists and stakeholders to define the problems to be addressed, the nature of decision-support resources to be developed, the expected information to be provided, and the approach for describing levels of confidence and key uncertainties (see the chapter banner for more detail on the goals of decision-support resources development).

Expected outcomes of those CCSP activities focused on the development of decision-support resources 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.



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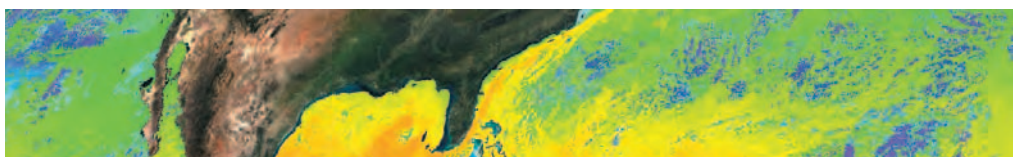
CCSP is encouraging research (described in this chapter) to improve existing assessment methods and to develop new approaches that integrate research from the physical, chemical, biological, medical, engineering, and social sciences. According to the National Research Council (NRC), “In order to address the consequences of climate change and better serve the Nation’s decisionmakers, the research enterprise dealing with environmental change and societal interactions must be enhanced.” Such an enterprise should include “...support of interdisciplinary research that couples physical, chemical, biological, and human systems” (NRC, 2001).

RELATED RESEARCH ON HUMAN CONTRIBUTIONS AND RESPONSES TO ENVIRONMENT CHANGE

Successful development of decision-support resources requires a research base that includes not only research in the natural sciences but that also focuses on human contributions and responses (HCR) to changes in climate and related systems – sometimes known as “human dimensions” research. This research covers a number of questions and is a key – but certainly not the only – part of the foundation for improved decision-support resources, and is also discussed in this chapter (see the chapter banner for more detail on key HCR research questions). HCR research includes studies of the interactions of environmental change with a number of aspects of human systems, including:

- Demography (population evolution and change)
- Economics (e.g., national economic growth, international trade, technology development and diffusion, and economic implications of potential impacts and adaptation or mitigation measures)
- History and anthropology (e.g., response of societies to past environmental changes)
- Political science and sociology (e.g., organizations and their role in the policy process; institutions and their role in shaping decisions and behavior).

This research adds to an understanding of how humans contribute to changes in the global environment, why some societies are more resilient and others are more vulnerable to change, and how attributes of social and economic organization can make it either easier or more difficult to mitigate and to adapt to global environmental change.



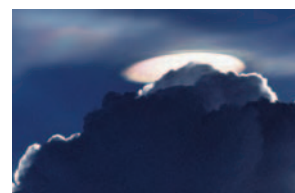
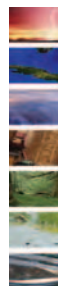
COORDINATING DECISION-SUPPORT AND HUMAN DIMENSIONS RESEARCH

For the first time, this edition of *Our Changing Planet* combines “Decision-Support Resources Development” and “Human Contributions and Responses to Environmental Change” in a single chapter. This reflects the NRC’s recommendation to enhance research on the *connections between environmental change and societal interactions to better support decisionmaking*. It also reflects a commitment on the part of CCSP to improve the interactions between development of decision-support resources and human dimensions research. Improving coordination between decision-support resources development and research on human contributions and responses will be advantageous because both areas share a number of challenges. Both areas require a systematic approach to examining how decisionmakers use information about climate and the environment in decisionmaking. And both depend on the integration of social, economic, and health data with environmental data. Such integration requires that information from diverse disciplines be available at compatible temporal and spatial scales. Geo-referenced data are needed to support investigation of the interactions of environmental and socioeconomic trends in specific places and decision contexts.

There is a risk that treating these topics together will mistakenly imply that decision-support resources development depends solely on this specific area of research, or that the study of human contributions and responses to change is limited to only supporting decisions. Neither statement is correct. Development of decision-support resources cannot be isolated in a single program element, disconnected from research throughout CCSP. Responsibility for developing decision-support resources is distributed across CCSP and success depends on developing strategies for integrating knowledge from the many diverse fields represented in the program. CCSP’s strategy for improving understanding of human-environment interactions recognizes the need for basic research into the human dimensions of global change that may not lead directly to decision-support resources. This chapter describes both sets of activities and begins to explore their interrelationships.

DECISION-SUPPORT RESOURCES GOAL 1: SCIENTIFIC SYNTHESSES AND ASSESSMENTS

The Global Change Research Act of 1990 (P.L. 101-606, section 106) directs the USGCRP 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.” The *CCSP Strategic Plan*



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defines “assessments” as “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.” 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.

The synthesis and assessment products are special cross-cutting products focused on and relevant to a number of science and policy issues (see sidebar for an example). The synthesis and assessment products being generated by CCSP fall under this mandate and focus on a variety of science and policy issues important for public discussion and decisionmaking. CCSP agencies will carry out the analyses with interagency cooperation to ensure the best utilization of resources from the entire program. 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. The 21 synthesis and assessment products are listed in Table 2-1 of the *CCSP Strategic Plan*, aligned with the CCSP goals they address. The scope of a few of these (i.e., 4.3, 4.5, 4.6, and 4.7) has been modified from those listed in the *CCSP Strategic Plan* to make the suite of products more responsive to Section 106 of the Global Change Research Act.

To facilitate preparation of the products, CCSP published a set of guidelines that define a methodology that includes development of a prospectus with open scientific and public comment, reliance on scientific experts to draft the products, scientific peer review followed by open public comment on the drafts, and approval for publication

SYNTHESIS AND ASSESSMENT PRODUCT 5.2

Best-Practice Approaches to Characterize, Communicate, and Incorporate Scientific Uncertainty in

Decisionmaking. Synthesis and Assessment Product 5.2 will address the issue of uncertainty and its relationship to science, assessment, and decisionmaking. Specifically, the product has the following purposes:

- 1) Improve the quality and consistency of information about scientific uncertainty presented to decisionmakers and other users of CCSP’s reports by identifying “best practice” options recommended in the literature on this subject
- 2) Improve communication between scientists and users of the products by providing a simple guide to interpreting information about uncertainty contained in the reports
- 3) Provide a brief overview of the literature on approaches for taking account of uncertainty in decisionmaking.

The report’s “best practice” guidelines will be tailored for different types of products so that the treatment of uncertainty in CCSP products is more systematic and helpful to users. A team of leading experts in decision and risk analysis will draft the report, supported through NSF. Representatives of participating CCSP agencies will work with the authors to ensure that the technical advice developed is useful and appropriate for the CCSP process.

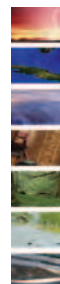
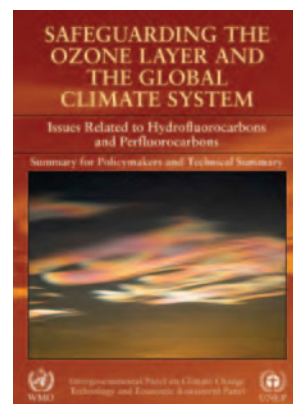
by the interagency governing body of CCSP, including a role for the NRC to provide additional analysis and to bound uncertainty. These guidelines are described more completely in the overview chapter of this report, and are available in their entirety on the CCSP web site (see <www.climate-science.gov/Library/sap/sap-guidelines.htm>).

CCSP agencies and scientists funded by these agencies will continue to participate in international science assessments, including the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* scheduled for completion in 2007, the Arctic Climate Impact Assessment, the Millennium Ecosystem Assessment, the International Research Institute for Climate Prediction, and the World Meteorological Organization/United Nations Environment Programme assessments of stratospheric ozone depletion and associated environmental impacts.

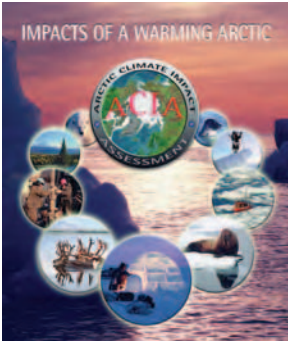
The United States supports these assessments in a variety of ways. For example, the U.S. Government has played an active role in the IPCC process since its inception in 1988. It continues to support the IPCC actively. The United States chairs IPCC's Working Group I (which focuses on the climate system) and provides support for its Technical Support Unit. Working Group I played a lead role in the *Special Report on Safeguarding the Ozone Layer and the Global Climate System* (completed in July 2005, see <www.ipcc.ch/pub/reports.htm>) and is currently leading development of the science volume of the *Fourth Assessment Report* (AR4).

Through participation in the IPCC process, the U.S. Government helps guide development of an important set of international assessments – including the reports mentioned above, the impacts and response option volumes of the AR4, and a Working Group III Special Report on Carbon Capture and Storage. CCSP supports participation of experts to serve as Coordinating Lead Authors, Lead Authors, and Review Editors of the reports and to participate in workshops that contribute to the process. At present, 116 U.S. scientists serve as authors of the five reports under preparation, and 15 as Review Editors. CCSP also coordinates the U.S. reviews of draft reports at the request of the Department of State. Further information on the IPCC can be obtained at <www.ipcc.ch>.

CCSP-supported scientists also participated in the Arctic Climate Impact Assessment (ACIA), which focused on potential impacts of climate variability and change, ozone depletion, and other interacting environmental changes on a broad range of Arctic ecosystems, socioeconomic conditions, and natural resources. ACIA officially started in October 2000 and was completed during fall 2004. The Arctic Council, including its Senior Arctic Officials, provided oversight through progress reports and documentation at Arctic Council meetings. Funding was provided to ACIA through both direct and



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indirect support from each of the eight Arctic nations. As the lead country for ACIA, the United States provided financial support through NSF and NOAA, which allowed the establishment of an ACIA Secretariat at the University of Alaska, Fairbanks. Contributions from the other Arctic countries, as well as from the United Kingdom, supported the involvement of their citizens and provided in-kind support, such as hosting meetings and workshops. Further information on ACIA is available at <www.acia.uaf.edu>.

Related HCR Research on Assessment and Decision-Support Methods

CCSP is encouraging research to improve methods of assessment and decisionmaking under uncertainty. This research examines a number of key issues including: designing processes for assessment that effectively focus scientific analyses on decisionmaking issues; more effectively encouraging public participation in assessments; estimating the costs and opportunities (market and non-market) of environmental changes; improving approaches for representing, analyzing, describing, and communicating uncertainty in assessments; and improving understanding of climate-change related decisions under uncertainty.

One example of this area of research is a project conducted by researchers at Harvard University that seeks to understand and promote the design of effective systems to harness research-based knowledge in support of decisions related to human development and environmental stewardship. The project has found that decision-support systems are likely to be more effective to the extent that they cultivate and protect “bridging” or “boundary” organizations that actively promote two-way connections and dialog between the research and applications communities (RASSP, 2003; NRC, 2005).

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Decision Making Under Uncertainty Program. Under its Decision Making Under Uncertainty (DMUU) program, NSF initiated grants for five interdisciplinary university and private sector research teams to study important aspects of problems associated with understanding climate-related decisions under uncertainty. These teams are expected to produce new insights of interest to the academic community, generate significant educational benefits, and develop new tools that will benefit policymakers, decisionmakers, and different stakeholders. In FY 2006, the DMUU research teams will conduct integrative research on scales larger than normally would be expected through individual research projects. In addition to conducting fundamental research, the teams will develop tools that people, organizations, and governments can use to better understand the risks associated with climate variability and change and the

options they have to address those risks; provide education and research opportunities for U.S. students and faculty; and develop and disseminate tangible products for researchers, decisionmakers, and other relevant stakeholders.

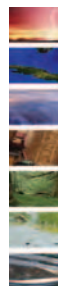
DMUU publications are planned for FY 2006 that will disseminate the outcomes of a set of workshops conducted by economists examining the adequacy of the representation of climate change uncertainties and the development of decision criteria and analytical tools for decisionmaking in the face of these uncertainties. They will place particular emphasis on the formulation of climate change adaptation and mitigation response options. Also appearing in FY 2006 will be publications and web-based products resulting from a series of workshops and seminars that bring together researchers and practitioners for extended examination of especially promising topics that bridge climate change and decisionmaking research and analysis, including alternative methods for uncertainty-based analysis of climate change impacts, vulnerability, and adaptation; analysis of greenhouse-gas emission projections and mitigation policies under uncertainty; and the applicability and limits of the “insurance” analogy for responding to the threat of global climate change.

This research contributes to CCSP Strategic Plan Question 9.1, Goals 11.2 and 11.3, and Synthesis and Assessment Product 5.2.

Evaluating Case Studies of Knowledge for Decisionmaking. The Knowledge Systems project at Harvard University will synthesize insights emerging from case studies through a series of papers addressing the principal challenges of governance and financial arrangements; linking knowledge with decisionmaking; and facilitating adaptive learning. A three-part special issue will be published by the *Proceedings of the National Academies* with case studies and guidelines for designing effective systems to harness research-based knowledge in support of decisions bearing on the joint goals of human development and environmental stewardship. Findings of the Knowledge Systems project are being extended and evaluated through a series of workshops run in collaboration with the National Academies’ Roundtable on Science and Technology for Sustainability, co-chaired by NOAA Deputy Administrator James Mahoney and Stanford University Dean Pamela Matson and engaging high-level decisionmakers from business, government, and civil society.

This research contributes to CCSP Strategic Plan Question 9.1 and Goal 11.2.

Learning from Climate Assessment. In partial fulfillment of CCSP’s commitment to build on the “lessons learned” from earlier assessment activities, CCSP has requested that the NRC carry out an analysis of global change assessments that have addressed topics broadly similar to those encompassed by CCSP. This study will examine which assessment approaches (in terms of geographic scale, scope, assessment entity, and timing) and products are most effective for meeting CCSP’s stated objectives for



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assessments, as outlined in Chapter 11 of the *CCSP Strategic Plan*. The study is described in greater detail in the introduction to this report.

This project contributes to CCSP Strategic Plan Goal 11.1.

DECISION-SUPPORT RESOURCES GOAL 2: ADAPTIVE MANAGEMENT/PLANNING DECISIONS

“Adaptive management decisions” are operational decisions, principally for managing infrastructure (e.g., wastewater treatment systems), natural resources (e.g., a watershed), or societal response mechanisms (e.g., health alerts). They occur within existing legal and institutional frameworks, usually recurring on annual (or shorter) time scales. “Planning” focuses on these and additional sectors (e.g., urban or regional planning), typically involving development of infrastructure and institutions with long lifetimes (several decades or more), and with decision processes over long time scales (years to decades). CCSP has adopted a distributed approach to developing these decision-support resources that draws on ongoing activities in contributing departments and agencies in many sectors and settings.

CCSP research results, data products, forecasts, and model results are already being applied to adaptive management and planning in a number of regional and sectoral case studies. Specific examples include climate observations and projections for crop management, water quality management, and urban planning, as well as integrated products illustrating snowpack, precipitation, streamflow, and the potential for drought conditions. El Niño Southern Oscillation forecasts (which have demonstrated 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. Federal agencies also employ decision-support tools to serve the public in local and regional decisionmaking, including applications in the management of carbon, water, disasters, invasive species, and coastal ecosystems along with information on public health, agricultural efficiency, and energy use.

Developing the sophisticated types of information (integrating physical, hydrological, ecological, demographic, and economic information) in the sustained fashion that is often needed to make complex adaptive management and planning decisions requires that scientists work side-by-side with managers and other stakeholders in the context of specific decisionmaking processes. These interactions are more effective when they occur through long-term partnerships in which targeted information is produced through research, incrementally incorporated into decisionmaking, then updated or



SYNTHESIS AND ASSESSMENT PRODUCTS 5.1 AND 5.3 DEVELOPING TOOLS AND METHODS TO SUPPORT ADAPTIVE MANAGEMENT/PLANNING

Uses and Limitations of Observations, Data, Forecasts, and Other Projections in Decision Support for Selected Sectors and Regions. Synthesis and Assessment Product 5.1 will inventory and characterize the types, capacity, and reliability of observational and other information accessible for decisionmaking as a result of U.S. investments in climate change research. It will result in a catalog of demonstration projects and experiments for international, national, regional, and local decision-support objectives. The product will provide detailed profiles of projects selected from among those implemented by CCSP agencies deemed to be of significant regional or national societal benefit. The report will analyze the capacity and performance of demonstration projects that incorporate observations from remote sensing and *in situ* instrumentation (including measurements related to atmospheric conditions, climate, land-use/land-cover change, hydrology, ecosystems, and human activity) into decision-support tools. The focus of the assessments will be expanded in a subsequent phase to include a profile of the capacity of decision processes and tools to assimilate forecasts and projections resulting from climate change science.

Decision-Support Experiments and Evaluations using Seasonal-to-Interannual Forecasts and Observational Data. Synthesis and Assessment Product 5.3 will provide an evaluation of selected decision-support experiments that use seasonal-to-interannual climate information to support water management decisions. The product will explore the extent to which multidisciplinary research, conducted in consultation with water resource managers, can be designed and implemented to result in expanded decision options and improved management. The product will focus on the issue of water resources as an initial case study because of its inherent importance, the broad array of ongoing projects in the field, and the maturity of interactions between researchers and water resource managers. This product will document the experiences garnered in partnerships among scientists and stakeholders and thus contribute to knowledge of how to effectively integrate the insights of science with the information needs of decisionmakers.

extended through new research and information gathering. CCSP agencies are exploring development of these sorts of research and decision-support partnerships in diverse settings ranging from bi-national watershed planning to management of fisheries and other biotic resources.

Related HCR Research on Adaptive Management and Planning

Research on tools to support adaptive management and planning focuses on a variety of topics including factors that affect the ability of societies to respond to changes in climate and related systems and that thus influence their resilience or vulnerability. For most types of impacts, this field of inquiry has extended scenario-based modeling of potential impacts on natural and human systems (e.g., crops, forests, water flows, coastal infrastructure) by integrating additional information on sensitivity and adaptability from many sources, including operational entities, to support evaluation of responses. For example, a high priority for research and assessment of the potential implications of sea-level rise for the United States involves examining the interaction of sea-level rise, elevation, and approaches in different locations to zoning and planning. Reporting on this work is the focus of one of the CCSP synthesis and assessment products, on coastal elevation and sea-level rise.



SYNTHESIS AND ASSESSMENT PRODUCT 4.1

Coastal Elevation and Sensitivity to Sea-Level Rise. Data on the implications of sea-level rise are needed to inform decisions about both greenhouse gas emissions and how best to prepare for and adapt to sea-level rise. This product focuses on developing tools to support shore-protection and land-use decisions that are mostly made at the local level or on a parcel-specific basis. Many institutions and groups are developing data that can provide insights regarding the implications of sea-level rise, but this information is fragmented and needs to be integrated. The *CCSP Strategic Plan* includes two related geographic information system (GIS) products: maps of coastal elevations relative to sea level, and planning maps depicting how State and local governments could respond to sea-level rise. The Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and several States are developing elevation data for floodplain management. Local governments and major coastal conservancies are developing GIS land-use data for managing ecosystems and economic growth. The Department of Interior develops wetland and shore-erosion data. NOAA and USGS are developing technologies to produce digital elevation models using a common vertical reference frame, thus producing true topographic/bathymetric map products. This report will bring together these ongoing mapping efforts by Federal and non-Federal researchers. Because of time, data, and resource limitations, the synthesis will focus on a contiguous subsection of the U.S. coastal zone. The report will also develop a plan for a sea-level rise research program to answer the questions that are most urgent for near-term decisionmaking. Questions regarding the magnitude of past and future global sea-level rise are outside the scope of this report.

Highlights of Recent Research

Selected examples of recent CCSP-supported research to develop decision-support resources for adaptive management and planning follow.

Resources to Improve Drought Management.^{2,21} Drought is an episodic natural disaster of potentially major proportions. Annual economic losses for the United States can be in the range of several billion dollars. As the recent prolonged drought in the western United States illustrates, drought impacts extend well beyond direct effects on water quantity and quality, with potentially significant consequences for energy generation (hydropower), agriculture, ranching, recreation and tourism, and the health of forests, range lands, fisheries, and other ecosystems.

CCSP has been working to increase partnerships with stakeholder groups to bring advances in climate science to bear on how society can better anticipate, prepare for, and respond to the challenge of drought. A major focus for these efforts is a cooperative effort led by the Western Governors' Association (WGA), with leadership on the Federal side from NOAA in partnership with several other CCSP agencies including USGS, Bureau of Reclamation, and USDA. Other participants include the National Interagency Fire Center, the Western States Water Council, the Interstate Water Council, The Nature



Conservancy, and the Office of Science and Technology Policy. As a result of this collaboration, in 2004, the WGA produced a report with unanimous approval of the governors that describes key steps necessary to develop and implement the National Integrated Drought Information System and what is required to move the Nation from a reactive to a proactive approach to anticipating, preparing for, and responding to drought and its attendant impacts (see Figure 24). CCSP-supported research is expected to play a fundamental role in developing this new national capability, with particular needs for improved observational, monitoring, and prediction capabilities, and the development of new tools for decision support.

In addition, CCSP has been examining the potential implications of regional drought on crop production. Using radar altimetry data from NASA's TOPEX/Poseidon and Jason-1 Earth observation spacecraft, researchers from NASA, USDA, and the University of Maryland estimated reservoir height and water volume in approximately 100 lakes and reservoirs across the world's major agricultural regions to determine irrigation potential in agriculture-sensitive regions, and as a general indicator of drought or high-water condition. The reservoir height data are used now by analysts in

the Production Estimation and Crop Assessment Division of the USDA Foreign Agriculture Service. The World Agricultural Outlook Board uses these condition estimates in forecasts of global agricultural commodities that they regularly publish.

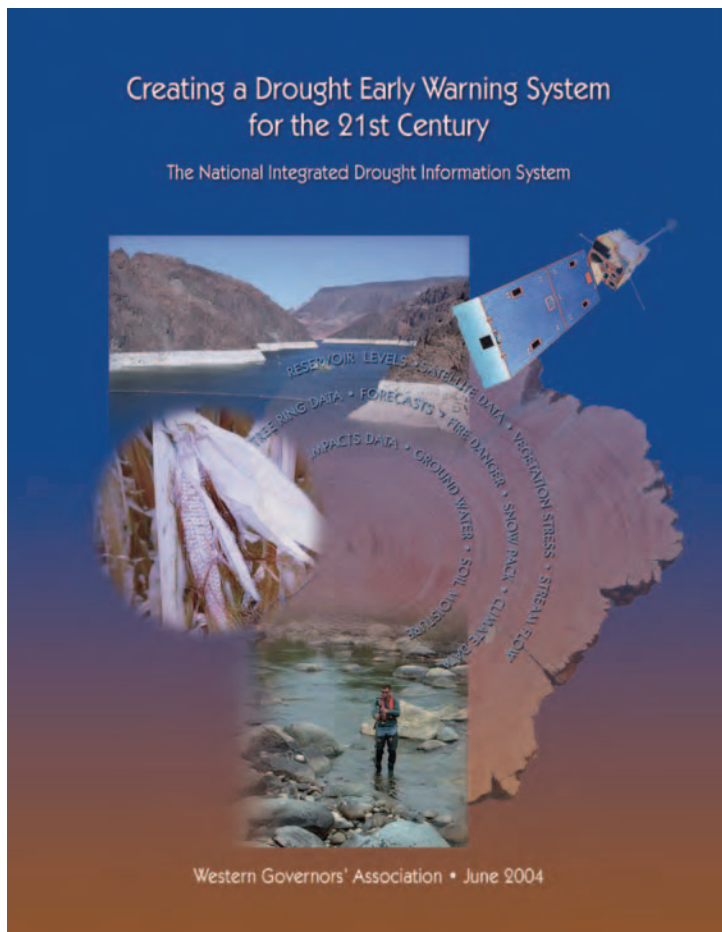
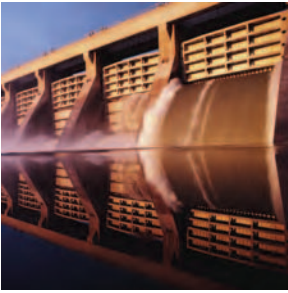


Figure 24: The National Integrated Drought Information System. The report of the Western Governors' Association describing the components necessary for a National Integrated Drought Information System. Credit: Western Governors' Association.





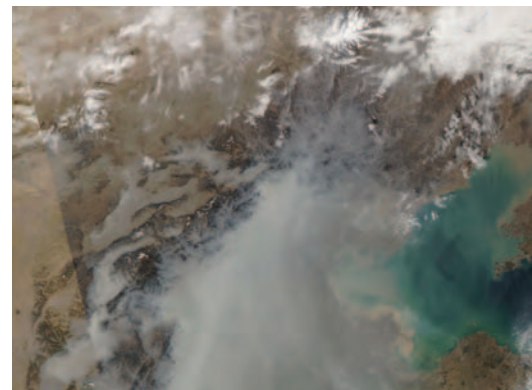
Climate Change Scenarios for Water Resource Managers.⁶ Water resource planners are beginning to ask how climate change might affect specific water resource systems. Reductions in mountain snowpack, which provide large amounts of natural storage for water resource systems in regions such as the Pacific Northwest, are likely at risk from future warming (see the “Climate Variability and Change” and “Global Water Cycle” chapters). Estimates of future warming rates are by themselves of little use to planners, who require watershed-specific information that they typically obtain from simulation models based on historic streamflow data. CCSP-supported university research scientists have found a way to bridge the gap between climate science and traditional water planning practices, providing useful information to water managers regarding river flow projections. These scenarios have allowed planners to compare the impacts of warming-adjusted streamflows with those of a portion of the historic record to see how climate change would affect their ability to meet various water resource objectives such as urban water supply, irrigation, and hydropower.

Climate Change and Coral Bleaching: Understanding Reef Resilience for Management Planning.^{19,22} Large-scale coral bleaching events have been increasing in severity and extent over the past 2 decades. These events cannot be fully explained by localized stressors such as pollution, and instead appear to be linked to the presence of increased sea surface temperatures (Wilkinson, 1998; West and Salm, 2003). While reef managers cannot directly address increases in sea surface temperature linked to climate variability and change, they can engage in adaptive management that takes advantage of knowledge of why some reef areas are less affected by temperature anomalies than others. Three collaborative projects are providing information to assist coral reef managers in the strategic design, placement, zoning, and management of networks of marine-protected areas that maximize reef resilience in the face of climate change. These include: (1) a project to identify environmental factors that may increase resilience by conferring protection from bleaching or enhancing recovery after bleaching; (2) a monitoring project in American Samoa that examines the effects of changes in water quality and different levels of reef protection on coral bleaching and recovery; and (3) a multi-agency cooperative that synthesizes research information to promote adaptive management of coral reefs in response to climate change

Use of Climate Variation to Forecast Mosquito Abundance and Encephalitis Risk in California.^{1,4} The amplification of encephalitis viruses to levels that place human populations at risk of infection depends in part on temperature-related factors. Research is underway that uses climate forecasting at various spatial scales to alert local and state public health officials to changing risks of encephalitis infection. A risk model has been developed that characterizes climate factors related to encephalitis outbreaks (e.g., indicators for rainfall, runoff, and temperature). The

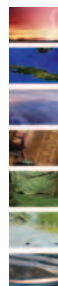
model demonstrates that mosquito abundance patterns and associated patterns of encephalitis risk vary spatially across the different biomes of California and show strong links to climate variations (Barker *et al.*, 2003). The California Mosquito-Borne Virus Surveillance and Response Plan provides a means for estimating the risk from two endemic encephalitides [western equine encephalomyelitis (WEE) and St. Louis encephalitis (SLE)] and describes intervention guidelines for mosquito control that public health agencies can use during periods of heightened risk for human infection. These risk models provide a means for calculating a risk estimate for WEE and SLE infection and a basis for prescribing appropriate response strategies to protect public health.

Improved Air Quality Forecasts. EPA has partnered with NASA and NOAA to improve its air quality index for current conditions (“nowcasts”) and forecasts for the next 30 hours by assimilating data from NASA’s Moderate-Resolution Imaging Spectroradiometer (MODIS) instrument flown on the Terra and Aqua spacecraft (see <idea.ssec.wisc.edu/index.php>). EPA and NOAA signed a cooperative agreement in May 2003 to coordinate the development of air quality forecast guidance. The improved forecasts of air quality and pollution are integrated into a prototype tool that is delivered via the internet (see <www.epa.gov/airnow>). EPA recently integrated the prototype tool into its AIRNow Forecaster Training Workshops, providing training to over 200 air quality forecasting professionals throughout the country. Air quality information is not only important for health-advisory purposes; aerosols (fine particles), tropospheric ozone, and other short-lived air pollutants are also recognized as potential climate forcing agents.

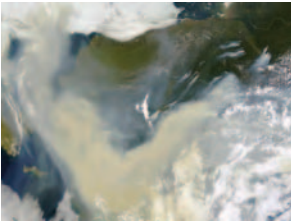


Decision-Support Resources for Ecosystem and Carbon Management

Applications.¹⁵ Researchers evaluated results from an integrated model and decision-support tools that help inform decisions related to ecosystem and carbon management. Using vegetation data from MODIS instruments on board the Terra and Aqua spacecraft, NASA’s Carnegie-Ames-Stanford Approach (CASA) model predicts photosynthesis rates, the amount of vegetation and living organisms within a unit area, and estimates of organic matter that forms the litter layer in soil. The Carbon Query and Evaluation Support Tools (CQUEST) tool provides Internet access for decisionmakers to display, manipulate, and save CASA model estimates of carbon sinks [reservoirs that absorb and store carbon dioxide (CO₂) from the atmosphere] and CO₂ fluctuations in agricultural and forest ecosystems for locations anywhere in the United States (see <geo.arc.nasa.gov/website/cquestwebsite>). USDA Forest Service is currently evaluating CQUEST for monitoring carbon sequestration and loss through forest disturbance and regrowth.



Highlights of Recent Research and Plans for FY 2006



Climate Variability and Fires.^{3,7,10,17,18,20} Climate connections to fire severity appear to occur through the effects of varying moisture patterns in producing higher or lower than normal amounts of grass in the preceding 2 years, and from the dryness of the vegetation. CCSP-supported scientists are studying these climate and wildfire interactions on a regional scale for the western United States (Roads *et al.*, 2004; Reinbold *et al.*, 2004), and developing long-lead forecasts for use by wildfire managers (Brown *et al.*, 2003). Westerling *et al.* (2002) compiled a comprehensive 21-year fire history for the western United States to facilitate climate-based predictions of the potential severity of the fire season several months in advance. Numerous steps are being taken to bring this scientific information to relevant decisionmakers. For example, two workshops are held each year – one focused on eastern and southern states and the other on western states and Alaska – involving climate scientists and wildfire managers (e.g., the National Interagency Fire Center) to provide and discuss the climate outlook for the upcoming fire season (Lenart *et al.*, 2005; Garfin *et al.*, 2004). Further information on these workshops may be obtained from <www.ispe.arizona.edu/climas/conferences/NSAW/index.html>.

Famine Early Warning System Network. The United States supports the innovative application of science to alleviate risks related to existing climate variability or the potential for climate change through the Famine Early Warning System Network (FEWS NET; see <www.fews.net>). FEWS NET provides decisionmakers with the information to respond effectively to drought and food insecurity by analyzing remote-sensing data and ground-based meteorological, crop, and rangeland observations to identify early indications of potential famine. In addition to using data produced by host governments for its analyses, FEWS NET uses data from satellite imagery [Normalized Difference Vegetation Index (NDVI) or “greenness” images and Meteosat Rainfall Estimation images] that it receives every 10 days throughout the year. FEWS NET operates in 20 countries in Africa, three countries in Central America, and in Haiti and Afghanistan.

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In FY 2006, CCSP participating agencies will sponsor research to develop decision-support resources for adaptive management and planning for responding to climate variability and change, and develop collaborations to apply these research-based resources in operational settings. Selected examples follow.

Use of Seasonal-to-Interannual Climate Information. Research on the use of seasonal-to-interannual climate information will focus on mitigating the impacts of short- and long-term droughts, as well as assessing risks involved in upcoming wildfire

DECISION-SUPPORT RESEARCH: BRIDGING SCIENCE AND SERVICE THE REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS PROGRAM

The Regional Integrated Sciences and Assessments (RISA) Program is composed of eight teams of researchers who investigate the potential impacts of seasonal-to-interannual and longer term global change, and collaborate with local, State, and Federal agencies tasked with specific resource management mandates. Through a process of interaction with key regional stakeholders – such as public health agencies, water resource managers, fishers, extension agents, and farmers – researchers address climate-sensitive issues relevant to a variety of policy and natural resource management goals. Findings from RISA activities and the development of experimental decision-support tools are proving highly valuable in a range of practical settings. Examples of research-based products include:

- The incorporation of model-based climate information into the production of regional maps for fire risk and forest management (Lenart *et al.*, 2005)
- Snow-water equivalent forecasts for the San Francisco Bay Delta watershed that have been used by CALFED – a consortium of 23 Federal and State agencies that are collaborating to restore the San Francisco Bay estuary and an adjacent major inland delta – in efforts to determine trends in water supply and demand (Dettinger *et al.*, 2004)
- Long-lead streamflow forecasts for water resource planning associated with the Columbia River (Hamlet *et al.*, 2002)
- AgClimate, a web-based decision-support system to help farmers manage risks associated with climate variability (<agclimate.org>)
- University curricula for the multidisciplinary study of climate impacts and policy response, used to educate the next generation of students of public policy and resource management (<www.cses.washington.edu/cig/outreach/classes.shtml>).

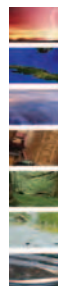
Meeting the climate information needs of decisionmakers is a major challenge. In addition to mastering the ability to observe, understand, and simulate continental- and global-scale processes, the ultimate utility of this work hinges on making the connection between regional variability and humans or ecosystems. Regionally based programs, such as RISA, utilize studies of the application of climate information and rely on human-dimensions research to strengthen the theoretical foundations of decision support.

These activities address Question 9.2 and Goal 11.2 (Objective 2.1) of the CCSP Strategic Plan.

seasons. Work will be aimed at water management, wildfire management, and drought planning, and will emphasize how scientific information about climate and drought impacts can be used to inform decisionmaking at State, regional, and national levels. Through the Regional Integrated Sciences and Assessments (RISA) Program, two workshops with researchers and fire managers will be held in 2006 to assess upcoming fire seasons and plan more effectively. Several workshops with local and State water managers will also be held in the western United States in 2006. In addition, the recently initiated NOAA Climate Transition Program will review a round of proposals in early FY 2006 to address the increasingly important challenge of applying decision-relevant climate research in operational settings. Operational settings include, but are not limited to, water management agencies, fisheries councils, disaster management offices, and weather service field offices.

These activities will address Question 9.2 and Goal 11.2 (Objective 2.2) of the CCSP Strategic Plan.

Early Snowmelt Discharge and its Effects on Water Resources in the Western United States. Research in the USGS Earth Surface Dynamics Program will address the implications of climate-induced early snowmelt discharge and its effects on water resources in the western United States. A decision-support system



Highlights of Recent Research and Plans for FY 2006

(DSS) will be developed to evaluate the risks associated with management choices in the face of climate variability, with a focus on sample reservoir systems on the western slope of the Sierra Nevada. The research will compare the economic efficiency of managing reservoirs with and without better data, models, and predictive capacity, and will estimate the value of improved forecasts of water resource availability in the Sierra Nevada under changing climatic conditions using the DSS. Further research will evaluate the tradeoff between the cost to a decisionmaker of an inaccurate climate policy, management, or investment decision and the cost to the decisionmaker of seeking a better decision.

These activities will address Questions 4.2, 4.5, 5.5, and 9.3 of the CCSP Strategic Plan.

Decision Support for Public Health Decisionmakers. Several 3-year research projects will address how climate change and health impact studies can be transformed into information useful to public health decisionmakers. The studies will employ partnerships between researchers and decisionmakers in the public health arena (see es.epa.gov/ncer/rfa/2005/2005_decision_support_sys.html). Additional studies will address two priority research areas: (1) heat- and cold-related illnesses, and (2) waterborne diseases. A better understanding of the consequences of climate variability and change for human health will be useful for State and local public health agencies' efforts to ameliorate these effects (see es.epa.gov/ncer/rfa/2005/2005_hsa_impacts_research.html).

These activities will address Question 9.4 of the CCSP Strategic Plan.

Coastal Elevation Maps and State and Local Plans for Sea-Level Rise.

Coastal elevation maps that depict areas vulnerable to sea-level rise are being produced by the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, EPA, NOAA, USGS, and several States. Planning maps are being created by EPA that synthesize current State and local baseline plans for sea-level rise along the U.S. Atlantic Coast. This work improves understanding of the sensitivity and adaptability of coastal ecosystems and human systems and provides resources to support coastal zone environmental and infrastructure-related decisionmaking. These maps will synthesize current State and local coastal policies along the U.S. Atlantic and Gulf Coast. Conservation officials will be able to use the maps to determine whether current policies ensure sufficient wetland migration, and identify areas where additional wetland migration is feasible. Local governments can focus infrastructure in areas where shores are certain to be protected. Ecologists studying potential environmental consequences of climate change will have a better idea whether tidal habitat will shift inland or be replaced with seawalls. During FY 2005-2006, existing draft maps that have already been reviewed by local stakeholders in mid-Atlantic cities and counties will be peer-reviewed and published, and new maps will be created along the south

Atlantic and New England Coasts, as well as the Gulf Coast of Florida. This work will support preparation of CCSP Synthesis and Assessment Product 4.1.

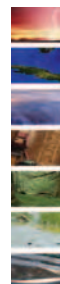
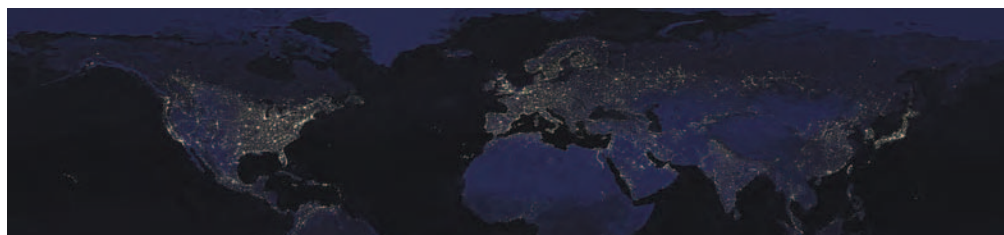
These activities will address Question 9.2 of the CCSP Strategic Plan.

Early Warning System for the Rapid Identification of Health Threats.¹²

Scientists plan measurable enhancements to the Centers for Disease Control and Prevention (CDC) Environmental Public Health Tracking Network/Health and Environment Linked for Information Exchange (EPHTN/HELIX) decision-support system using NASA Earth-Sun System research results. This epidemiological surveillance decision-support system is designed to establish a national network of local, State, and Federal public health agencies that tracks trends in priority chronic diseases. Planned to be fully functional around 2009, the EPHTN will be a national early warning system for the rapid identification of health threats, such as toxic chemical releases. Earth science results provide valuable information on the environmental contribution to chronic diseases, and forecasts based on coupled Earth system-chronic disease models. The plan for 2006 includes determining the performance of the EPHTN/HELIX decision-support tool configured to assimilate observations from NASA Earth-observing sensors MODIS and ASTER, and forecasts of Earth system processes from the Large Scale Eddy Simulation Model. This work will enhance the ability of the EPHTN/HELIX surveillance system to assimilate observations and predictions of weather, climate, and environmental risk factors to predict disease events and to more accurately represent environmental risk factors.

This activity addresses Questions/Goals 9.3, 9.4, 11.1, and 11.2 of the CCSP Strategic Plan.

Mesoamerican Biological Corridor. NASA, USAID, the World Bank, and the Central American Commission for Environment and Development are partnering to develop a regional visualization and monitoring system. The Central America Monitoring and Visualization System (SERVIR) is a decision-support tool that will assist the seven nations of Central America in developing a Mesoamerican Biological Corridor extending from southern Mexico to the Colombian border. SERVIR uses assimilated remote-sensing Earth observations of environmental and other geophysical parameters in a geographic information system that generates visualization products



Highlights of Recent Research and Plans for FY 2006

for decisionmakers to aid in ecosystem management. SERVIR's users are government policymakers and natural resource managers, nongovernmental organizations, teachers, students, and the general public. Specific decision-support products include fire detection, red tide location, hurricane tracking, food security early warning system, and climate change modeling. These products reach users through a series of information nodes located in each of the participating countries. More information on SERVIR is available at <servir.nsstc.nasa.gov/home.html>.

*This activity supports Questions 8.1, 8.2, and 8.3,
as well as Goals 11.1 and 11.2 of the CCSP Strategic Plan.*

DECISION-SUPPORT RESOURCES GOAL 3: POLICY DECISIONS



“Policy decisions” can result in laws, regulations, and other public actions. These decisions are typically made in government settings by elected or appointed officials. Policy-related questions regarding climate change typically arise from numerous sources, for example from:

- Consideration of climate change policy within the Federal government
- Proposals advanced by private and non-governmental organizations
- Preparation for international negotiations
- Consideration of legislative proposals
- Priority-setting processes for science and technology programs.

As described in the *CCSP Strategic Plan*, CCSP is focusing on two objectives in this area: (1) developing scientific syntheses and analytical frameworks to support integrated evaluations, and (2) initially conducting a limited number of case studies with evaluation of the lessons learned to guide future analyses.

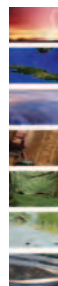
CCSP supports the development of a number of integrated modeling frameworks that are useful for exploring many dimensions of climate and global change. Integrated analysis of climate change is essential for bringing together research from many contributing disciplines and applying it to gain comparative 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 economic and environmental implications of changing greenhouse gas concentrations and various technology portfolios. Development and use of techniques for scenario and comparative analysis are useful for exploring the implications of different hypothetical

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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 is encouraging innovation and development of approaches to integrated analysis.

An integrated assessment of climate change analyzes the human (including economic), physical, and biological aspects of climate change, from the forces that give rise to greenhouse gas emissions or land-cover/land-use change (such as economic activity, population and demographic change, and technological advance), through emissions, to impacts (such as changes in unmanaged ecosystems, sea-level rise, and altered growing conditions for crops). The primary emphasis in an integrated assessment is to represent all three aspects in such a way that the costs and benefits of climate change can be evaluated. Integrated assessments are commonly based on scenarios simulated using a computer model. Integrated assessment models are used to evaluate, for example, specific climate change policy options, including those for reducing greenhouse gas emissions.

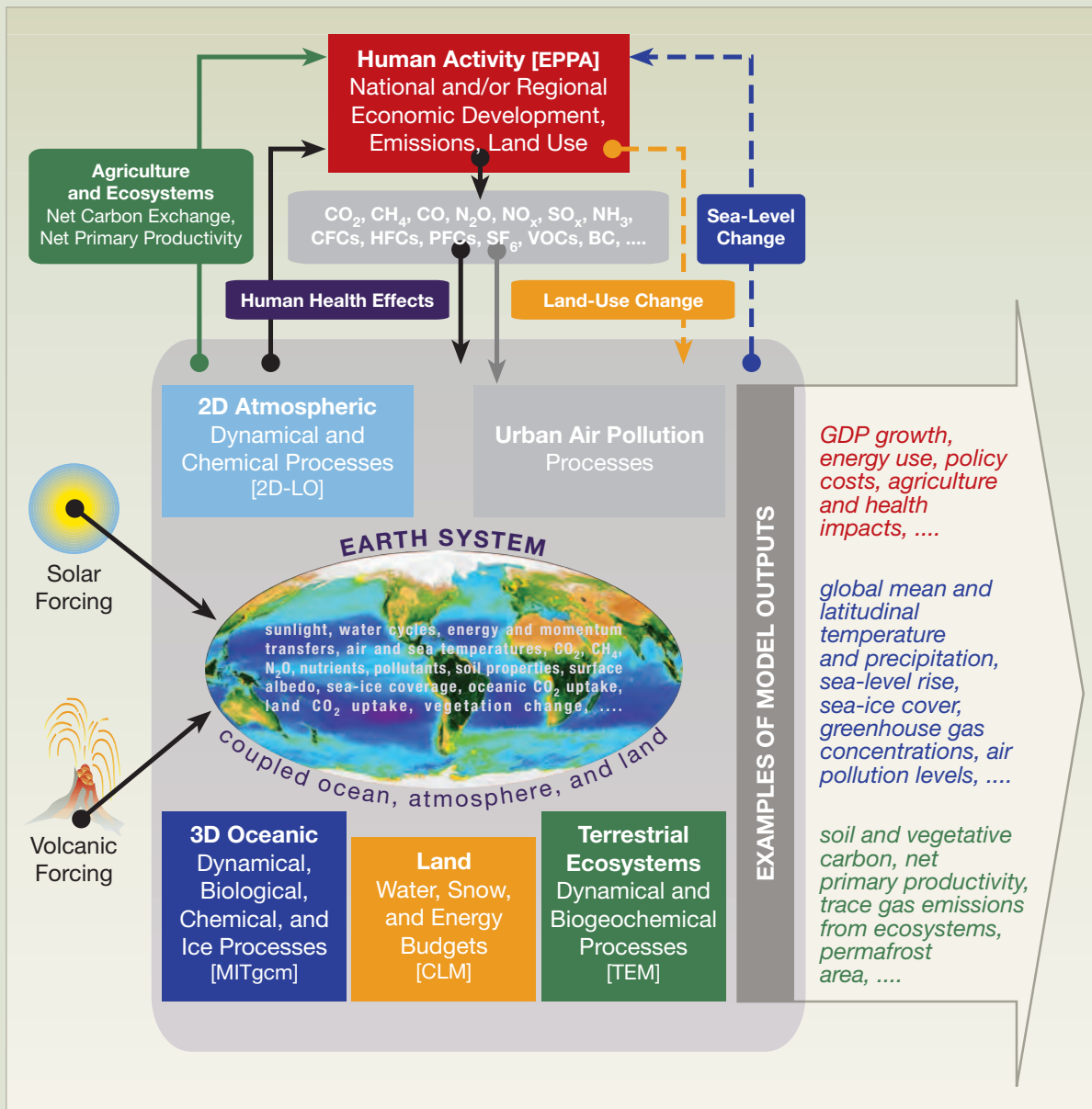
Under CCSP, the DOE Integrated Assessment of Climate Change Research Program sponsors academic investigators who examine individual research topics using integrated assessment models. DOE sponsors the development of several integrated assessment models, and EPA, NOAA, and NSF sponsor additional studies that improve aspects of models and allow for the use of the models for particular investigations. Two major integrated assessment modeling teams are supported – one at the Massachusetts Institute of Technology and the other at the Pacific Northwest National Laboratory. CCSP does not make policy recommendations. Instead, it supports fundamental research that provides necessary objective background understanding for others to analyze policy questions and make policy recommendations.



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INTEGRATED ASSESSMENT MODELS

The schematic illustrates the framework and components of a typical integrated assessment model. This particular model was developed by the Massachusetts Institute of Technology (see <mit.edu/globalchange/www/if.html>). An economic model (often a general equilibrium model) provides emission scenarios, which are used as inputs to atmospheric chemistry and climate models. Outputs from the atmospheric models are used as inputs to models that evaluate the impact of potential future climate change on agricultural, ecosystem, and other sectors. For example, in the schematic the climate model outputs drive a terrestrial ecosystems model projecting land vegetation changes, land CO₂ fluxes, and carbon storage, which feed back to the coupled chemistry/climate and natural emissions models. There are a variety of feedbacks between the component models. In view of the large number of analytical elements in an integrated assessment model, each with its own uncertainties, the outcomes of these models must be carefully evaluated for their overall uncertainties.



SYNTHESIS AND ASSESSMENT PRODUCT 2.1

Updating Scenarios of Greenhouse Gas Emissions and Concentrations, in Collaboration with the Climate Change Technology Program (CCTP): Review of Integrated Scenario Development and Application. Scenario analysis is a widely used intellectual device for decisionmaking in complex and uncertain situations. Scenarios have been applied extensively in the climate change context. Examples include emissions scenarios, climate scenarios, and technology scenarios. Scenarios are not predictions; they are “what ifs?” – sketches of future conditions (or alternative sets of future conditions) – used as inputs to decisionmaking or analysis exercises.

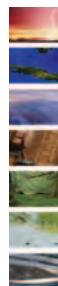
Synthesis and Assessment Product 2.1 has two components. Part A will use integrated assessment models as the foundation for a small group of new global emissions scenarios leading to long-term stabilization of greenhouse gas concentrations. These new scenarios will incorporate lessons from previous scenario efforts and will be based on the evolving state-of-the-art in integrated assessment modeling. The scenarios are intended for policymakers and analysts, such as the technology analysts in the CCTP, who may benefit from enhanced understanding of the role of technology in stabilization; other decisionmakers or analysts, such as climate modelers, who may use the data outputs of the scenarios as inputs to analyses (e.g., climate modelers might use the emissions trajectories as inputs to climate models); and analysts or decisionmakers who may use the participating integrated assessment models to generate additional analyses, using the scenarios as a foundation (e.g., using the integrated assessment models to explore the implications of various additional scenarios of technological advance). Part B will review and evaluate how the science and stakeholder communities define, develop, implement, and communicate scenarios in the global climate change context, and how this process might be enhanced or improved. This will include a review of past scenario development and application efforts. The intent of the review is to inform preparation and application of future scenarios by CCSP, the IPCC, the CCTP, and other global change research and assessment organizations.

An initial case study of the application of integrated assessment tools is being undertaken in Synthesis and Assessment Product 2.1. Other case studies focus on practices to increase soil carbon levels and transportation policy options for responding to climate change, as follows.

Alternative Incentive Designs for Practices to Raise Soil Carbon Levels.¹¹

Atmospheric concentrations of greenhouse gases can be reduced by withdrawing carbon from the atmosphere and sequestering it in soils and biomass. Research analyzed the performance of alternative incentive designs and payment levels if farmers were paid to adopt land uses and management practices that raise soil carbon levels.

Transportation Policy Options for Responding to Climate Change. Under a new study, *Climate Change and U.S. Transportation*, the Transportation Research Board (TRB) and the Division of Earth and Life Sciences of the National Academies will evaluate transportation policy options for adapting to the potential impacts of climate change, and examine strategies to mitigate future climate impacts. DOT, EPA, the U.S. Army Corps of Engineers, and TRB (including the American Association of State and Highway Officials and the Transit Cooperative Research Program) are sponsoring the study, which will include as a centerpiece a major conference with commissioned papers that is designed to foster and expand dialog and awareness about the potential risks and consequences of climate change. A committee of experts assembled for this effort will issue a report with findings and recommendations regarding needed research and actions.



SYNTHESIS AND ASSESSMENT PRODUCT 4.7

Impacts of Climate Variability and Change on Transportation Systems and Infrastructure. A sound transportation system is vital to the Nation's social and economic future. Investments in transportation are substantial, and result in infrastructure that lasts for decades. This product will investigate the potential impacts of climate variability and change on transportation infrastructure and operation, and provide guidance as to how transportation planners and decisionmakers may incorporate this information into transportation planning, design, engineering, and operational decisions to ensure a reliable and robust future transportation network. Implications for all transportation modes – surface, marine, and aviation – will be addressed. This initial study will focus on the potential effects of climate variability and change on transportation infrastructure and systems in the central U.S. Gulf Coast. It will also include a review of knowledge of the potential impacts of climate change on national transportation systems.

The three-phase study will:

- Develop knowledge about potential transportation infrastructure sensitivities to climate variability and change through an indepth synthesis and analysis of existing data and trends
- Assess the potential significance of these sensitivities to transportation decisionmakers in the central U.S. Gulf Coast region
- Identify potential strategies for adaptation that will reduce risks and enhance the resilience of transportation infrastructure and services
- Identify or develop decision-support tools or procedures that enable transportation decisionmakers to integrate information about climate variability and change into existing transportation planning and design processes.

HCR Research on Human Contributions to Global Change: Relevance to Informing Policy Inquiries

Research on human contributions to global change can have direct bearing on the development of decision-support resources and methods for informing climate change policymaking (i.e., Decision-Support Goal 3; see chapter banner). This work draws upon analyses of fundamental socioeconomic processes and spans a range of disciplines and topics, including demography, economics, history, anthropology, political science, and engineering. This research examines factors affecting greenhouse gas emissions (e.g., energy use) and changes in land use and land cover. Recent research has also focused on the factors that affect environmentally significant consumption at the household level, as well as on understanding trends in innovation, efficiency, and living standards, and their implications for energy use, emissions, and land-use/land-cover change.

For example, research on demographic and energy data in China, the United States, and Indonesia used household surveys and disaggregated energy use data to improve the prediction of energy use by fuel type. The research is designed to provide data and information on the demographic and technology factors that drive energy use and the associated emissions of greenhouse gases in three case-study countries that have large populations and are currently or will soon become major global sources of greenhouse gas emissions. One example of results from this research to date is evidence that the shift in rural China and elsewhere from the use of traditional fuels such as firewood for home heating and cooking to commercial fuels such as fossil fuels may not be as

sensitive to income level as previously assumed and therefore may occur somewhat more slowly than commonly thought (Jiang and O'Neill, 2004).

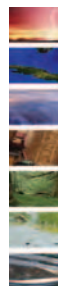
In another example, researchers from the Center for the Study of Institutions, Population, and Environmental Change at Indiana University working in Brazil have extended consideration of the role of household demography in land-use decisions (Deadman *et al.*, 2004). They used a household life-cycle model that examined the relationships between household age and land use and between time since acquisition of the property and land use in regions around the Brazilian cities of Altamira and Santarém. The researchers found that in Altamira, younger households deforest at higher rates, whereas older households, which may have undergone earlier episodes of deforestation, tend to consolidate into perennials and pasture. In Santarém, a study area with a much longer but less planned settlement history, the age of the household showed no relationship with land use. In both locations, the time since acquisition of the lot was more strongly related to deforestation than household age (even in Altamira), suggesting that lot turnover is in fact a key driver of land-use change in both locations.

Highlights of Plans for FY 2006

Integrated Assessment of Aerosol Production, Effects, and Control. In FY 2006, Argonne National Laboratory will develop new estimates of future aerosol emissions for sulfur and carbonaceous aerosols. This work will address technology types not often considered in forecasting models, such as cookstoves in developing countries. Other researchers at the Massachusetts Institute of Technology will investigate aerosol effects on radiation absorption and reflection and on the hydrologic cycle by analyzing the economics of aerosol production and control, the atmospheric chemistry and radiation effects of these substances, and the interaction with terrestrial systems (including hydrological effects). These studies are supported by the DOE integrated assessment (IA) program.

This work will address Question 9.1 of the CCSP Strategic Plan.

Representation of Uncertainty in Emission Scenarios for Integrated Assessment of Climate Change. In FY 2006, researchers at the University of North Carolina, as a part of the DOE IA program, will contribute data and methods to support improved representation of uncertainty in the future development of emission scenarios for integrated assessment of climate change and other purposes. Historical data on energy use will be used to characterize uncertainties in measures of substitution between energy and other inputs such as capital and labor. Probabilistic scenarios of emissions will be explored by propagating uncertainty in emissions



Highlights of Recent Research and Plans for FY 2006

through a climate-chemistry model and testing various criteria for selecting a small number of emissions scenarios that span the scenario probability space.

This work addresses Question 9.3 of the CCSP Strategic Plan, and will support Synthesis and Assessment Product 2.1.



Integrated Assessment of Climate, Land and Water Resources, and Economic Activity. Throughout the last decade, USDA's Economic Research Service (ERS) has analyzed how global changes might affect long-term agricultural and environmental sustainability. For much of this research, ERS has relied on the Future Agricultural Resources Model (FARM), an integrated modeling framework. FARM has been used primarily to analyze the impacts of greenhouse gas emissions on agriculture, but has also been used to explore other topics such as costs of sea-level rise, the effects of trade deregulation and population growth on tropical forests, the costs of protecting global ecosystem diversity, and the impacts of technological advance in agriculture on land use. ERS has initiated the Economic Evaluation of Changes in Earth's Land and Water Resources Project to revise the FARM modeling framework. A revised, documented database and a user manual for a prototypical revised model will be available to the public in FY 2006. The new modeling framework itself will assist researchers and decisionmakers in addressing questions from the *CCSP Strategic Plan* related to water resources, land-use and land-cover changes, ecosystems, and human contributions and responses to environmental change.

This activity will directly address Goal 11.2 of the CCSP Strategic Plan.

DECISION-SUPPORT RESOURCES CHAPTER REFERENCES

- 1) **Barker**, C.M., W.K. Reisen, and V.L. Kramer, 2003: California state Mosquito-Borne Virus Surveillance and Response Plan: A retrospective evaluation using conditional simulations. *American Journal of Tropical Medicine and Hygiene*, **68(5)**, 508-518.
- 2) **Birkett**, C. and B. Doorn, 2003: A new remote-sensing tool for water resources management. *EOM*, **13(6)**, 20-21.
- 3) **Brown**, T.J., A. Barnston, J.O. Roads, R. Martin, and K.E. Wolter, 2003: 2003 Seasonal consensus climate forecasts for wildland fire management. *Experimental Long-Lead Forecasts Bulletin*, **12(1)**, 6 pp.
- 4) **California Department of Health Services**, 2004: *California State Mosquito Borne Virus and Surveillance Response*. <http://westnile.ca.gov/website/publications/ca_mos_res_6_04.pdf>
- 5) **Deadman**, P.J., D.T. Robinson, E. Moran, and E. Brondizio, 2004: Effects of colonist household structure on land use change in the Amazon rainforest: An agent based simulation approach. *Environment and Planning B: Planning and Design*, **31**, 693-709.
- 6) **Dettinger**, M.D., D.R. Cayan, M.K. Meyer, and A.E. Jeton, 2004: Simulated hydrologic responses to climate variations and change in the Merced, Carson, and American River basins, Sierra Nevada, California, 1900-2099. *Climatic Change*, **62**, 283-317.

DECISION-SUPPORT RESOURCES CHAPTER REFERENCES (CONTINUED)

- 7) **Garfin**, G.M., T. Brown, R. Ochoa, and H. Hockenberry, 2004. *National Seasonal Assessment Workshop: Western States and Alaska, Phoenix, AZ, March 30-April 2, 2004. Final Report*. CLIMAS/ISPE, Tucson, 18 pp.
- 8) **Hamlet**, A.F., D. Huppert, and D.P. Lettenmaier, 2002: Economic value of long-lead streamflow forecasts for Columbia River hydropower. *ASCE Journal of Water Resources Planning and Management*, **128(2)**, 91-101.
- 9) **Jiang**, L. and B.C. O'Neill, 2004: The energy transition in rural China. *International Journal of Global Energy Issues*, **21(1/2)**, 2-26.
- 10) **Lenart**, M., T. Brown, H. Hockenberry, and G. Garfin, 2005: *National Seasonal Assessment Workshop: Eastern and Southern States, Shepherdstown, WV, January 19-21, 2005. Final report*. CLIMAS/ISPE, Tucson, 31 pp.
- 11) **Lewandrowski**, J., C. Jones, R. House, M. Peters, M. Sperow, M. Eve, and K. Paustian, 2004: *Economics of Sequestering Carbon in the U.S. Agricultural Sector*. U.S. Department of Agriculture, Economic Research Service Technical Bulletin No. 1909, Washington, DC.
- 12) **NASA**, 2005: *Earth-Sun System Applied Sciences Program: Public Health Program Element FY 2005-2009 Plan*, National Aeronautics and Space Administration, Washington, DC, 23 pp. Available at <aiwg.gsfc.nasa.gov/esappdocs/progplans/ph_ver1-0.doc>
- 13) **NRC**, 2005: *Knowledge-Action Systems for Seasonal-to-Interannual Climate Forecasting: Summary of a Workshop* [Cash, D. and J. Buizer (eds.)]. National Research Council, National Academies of Science, National Academies Press, Washington, D.C., 32 pp.
- 14) **NRC**, 2001: *Climate Change Science: An Analysis of Some Key Questions*. Committee on the Science of Climate Change, National Research Council, National Academy Press, Washington, DC, USA, 42 pp.
- 15) **Potter**, C., S. Klooster, V. Genovese, and R. Myneni, 2003: Satellite data helps predict terrestrial carbon sinks. *EOS Transactions*, **84**, 502-508.
- 16) **RASSP**, 2003: Science and technology for sustainable development (Research and Assessment Systems for Sustainability Program). *Proceedings of the National Academy of Sciences. Special Feature*, **100(14)**, 8059-8091.
- 17) **Reinbold**, H.J., J. Roads, and T.J. Brown, 2004: Evaluation of ECPC's fire danger forecasts using RAWs observations. *International Journal of Wildland Fire*, **14**, 19-36.
- 18) **Roads**, J., F. Fujioka, S. Chen, and R. Burgan, 2005: Seasonal fire danger forecasts for the USA. *International Journal of Wildland Fire, Special Issue: Fire and Forest Meteorology*, **14(1)**, 1-18.
- 19) **West**, J.M. and R.V. Salm, 2003: Resistance and resilience to coral bleaching: implications for coral reef conservation and management. *Conservation Biology*, **17(4)**, 956-967.
- 20) **Westerling**, A., A. Gershunov, D. Cayan, and T. Barnett, 2002: Long lead statistical forecasts of area burned in western US wildfires by ecosystem province. *International Journal of Wildland Fire*, **11**, 257-266.
- 21) **Western Governors' Association**, 2004: *Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System*. Western Governors' Association, Denver, Colorado, USA. Available at <www.westgov.org/wga/publicat/nidis.pdf>.
- 22) **Wilkinson**, C. (ed.), 1998: *Status of Coral Reefs of the World: 1998*. Australian Institute of Marine Science, Queensland, Australia, 184 pp.

