

information needed for formulating adaptive management strategies is identified and provided to decisionmakers and policymakers?

(3) *The Global Water Cycle*

Question 1: To what extent does the water cycle vary and change with time, and what are the internal mechanisms and external forcing factors, including human activities, responsible for variability and change?

Question 2: How do feedback processes control the interactions between the global water cycle and other parts of the climate system (e.g., carbon cycle, energy), and how are these feedbacks changing over time?

Question 3: What are the key uncertainties in seasonal to interannual predictions and long-term projections of water cycle variables, and what improvements are needed in global and regional models to reduce these uncertainties?

Question 4: How do the water cycle and its variability affect the availability and quality of water supplied for human consumption, economic activity, agriculture, and natural ecosystems; and how do its interactions and variability affect sediment and nutrient transports, and the movement of toxic chemicals and other biogeochemical substances?

Question 5: What are the consequences of global water cycle variability and change, at a range of temporal and spatial scales, for human societies and ecosystems? How can the results of global water cycle research be used to inform policy and water resource management decision processes?

(4) *Land Use and Land Cover Change*

Question 1: What are the primary drivers of land use and land cover change?

Question 2: What tools or methods are needed to allow for better characterization of historic and current land use and land cover characteristics and dynamics?

Question 3: What advances are required to allow for the projection of land use and land cover patterns and characteristics 10–50 years into the future?

Question 4: How can projections be made of potential land cover and land use change over the next 10–50 years for use in models of impacts on the environment, social and economic systems, and human health?

Question 5: What are the combined effects of climate and land use and land cover change and what are the potential feedbacks?

(5) *The Global Carbon Cycle*

Question 1: What are the magnitudes and distributions of North American carbon sources and sinks and what are the processes controlling their dynamics?

Question 2: What are the magnitudes and distributions of ocean carbon sources and sinks on seasonal to centennial time scales, and which processes control their dynamics?

Question 3: What are the magnitudes and distributions of global terrestrial, oceanic and atmospheric carbon sources and sinks and are they changing over time?

Question 4: What are the effects of past, present, and future land use change and resource management practices on carbon sources and sinks?

Question 5: What will be the future atmospheric carbon dioxide and methane concentrations, and how will terrestrial and marine carbon sources and sinks change in the future?

Question 6: How will the Earth system, and its different components, respond to various options being considered by society for managing carbon in the environment, and what scientific information is needed for evaluating these options?

(6) *Ecosystems*

Question 1: What are the most important linkages and feedbacks between ecosystems and global change (especially climate), and what are their quantitative relationships?

Question 2: What are the potential consequences of global change for ecosystems and the delivery of their goods and services?

Question 3: What are the options for sustaining and improving ecosystem goods and services valued by societies, given projected global changes?

(7) *Human Contributions and Responses to Environmental Change*

Question 1: What are the magnitudes, interrelationships, and significance of the primary human drivers of change in atmospheric composition and the climate system, changes in land use and land cover, and other changes in the global environment?

Question 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?

Question 3: How can the methods and capabilities for societal decisionmaking under conditions of complexity and

uncertainty about global environmental variability and change be enhanced?

Question 4: What are the potential human health effects of global environmental change, and what tools and climate and environmental information are needed to assess and address the cumulative risk to health from these effects?

In addition, the final chapter in Part II is devoted to Grand challenges in modeling, observations, and information systems. Modeling, observations, and data and information dissemination are crosscutting, “enabling” activities and are tightly coupled to the seven research elements. These are needs that are particular to a given research area and must be planned and implemented in close association with the research that they support or draw on. However, they also need to be managed in a focused manner because they provide essential infrastructure that must serve multiple purposes within the CCSP-enabling fundamental research, as well as supporting assessment and decisionmaking—and because they depend on the distributed assets of CCSP agencies, some of which were originally developed to serve other needs.

Part III of the plan describes communication, cooperation, and management issues that cut across all areas of the program. The specific topics addressed are:

(1) *Reporting and Outreach*

Inventory of Existing Agency Activities
Reporting and Outreach for
Decisionmakers
Reporting and Outreach for the Public
Outreach for K–12 Education

(2) *International Research and Cooperation*

Goals of International Cooperation in
Climate Science
The International Framework
Bilateral Cooperation in Climate Change
Research and Technology
Multilateral International Cooperation
in Research and Observational
Programs
Regional Cooperation In Global Change
Research
U.S. Plans And Objectives For Future
International Cooperation

(3) *Program Management and Review*

Scientific Guidance
Interagency Planning and
Implementation
Program Integration

References

NRC, 1999a. Committee on Global Change Research, National Research Council, Global