Global Change Research Program

MULTI-YEAR PLAN

[Goal 6]

April 2003

Not Yet Externally Peer Reviewed

The Office of Research and Development's (ORD) multi-year plans (MYPs) present ORD's proposed research (assuming constant funding) in a variety of areas over the next 5-8 years. The MYPs serve three principal purposes: to describe where our research programs are going, to present the significant outputs of the research, and to communicate our research plans within ORD and with others. Multi-year planning permits ORD to consider the strategic directions of the Agency and how research can evolve to best contribute to the Agency's mission of protecting human health and the environment.

MYPs are considered to be "living documents." ORD intends to update the MYPs on a regular basis to reflect the current state of the science, resource availability, and Agency priorities. ORD will update or modify future performance information contained within this planning document as needed. These documents will also be submitted for external peer review.

This Multi-Year Plan (MYP) has not been extensively revised since its contents and focus are closely tied to the government-wide Climate Change Science Program (CCSP) draft *Strategic Plan*. The CCSP *Strategic Plan* has undergone initial public and National Research Council (NRC) review. (The NRC review was formally released on Wednesday, February 26, 2003.) The CCSP *Strategic Plan* and the review comments strongly support in its entirety the work contained in the ORD Global MYP. However, it seems prudent to wait until the final CCSP *Strategic Plan* is released before finalizing revisions to the ORD Global MYP. Further details on the status of the government-wide CCSP *Strategic Plan* are contained in the following Preface.

Preface to Revised Version of Global Multi-Year Plan

Joel D. Scheraga
National Program Manager

In February 2002, President Bush announced the formation of a new management structure, the Climate Change Science Program (CCSP), to coordinate and direct the US research efforts in the areas of climate and global change. These research efforts include the US Global Change Research Program (USGCRP) authorized by the Global Change Research Act of 1990, and the Climate Change Research Initiative (CCRI) launched by the President in June 2001 to reduce uncertainties in climate science, improve global climate observing systems, and develop resources to support policymaking and resource management at the national, regional and local levels.

Following the President's announcement, a draft *Strategic Plan* was prepared by the thirteen federal agencies participating in the CCSP and released for public review in November 2002. The draft *Strategic Plan* aims to balance the near-term (2- to 4-year) focus of the CCRI with the breadth of the USGCRP, pursuing accelerated development of answers to the scientific aspects of key climate policy issues (at the national, regional, local and sector levels), while continuing to seek advances in the knowledge of the physical, biological and chemical processes that influence the Earth system. It is noteworthy that the goals of ORD's assessment-oriented program were highlighted throughout the *Plan*, but received particular attention in Chapter 4 ("Decision Support Resources").

A US Climate Change Science Program Planning Workshop for Scientists and Stakeholders was held in Washington, DC, on December 3-5, 2002. The public had an opportunity to comment on the draft *Strategic Plan* during the workshop and during a subsequent public comment period extending to January 13, 2003. At the same time, the National Academy of Sciences was asked by Dr. James Mahoney (Director, CCSP), to undertake a fast-track review of the draft *Strategic Plan*. The NAS review was formally released by Dr. Thomas Graedel, the Review Committee Chair, at a press conference on Wednesday, February 26, 2003.

Development and review of the draft CCSP *Strategic Plan* coincided with the period during which the Executive Council requested revisions of the ORD Multi-Year Plans (MYPs). Given this coincidence of events, updates to the Global MYP have been delayed

Since the advice from the Executive Council (Bill Farland) and the Science Council (Larry Cupitt) was to revise the Global MYP to reflect changes in the USGCRP and CCSP, updates to the Global MYP have been delayed until the CCSP *Strategic Plan* is completed. With the official release of the NRC review this week, ORD's Global Program is now in a position to begin revising the MYP.

Although the revised CCSP *Strategic Plan* will not be released until May 2003, several key

messages and recommendations relevant to ORD's Global Program have emerged from the NAS review and the public comments. In particular, the NAS strongly recommends increased support for activities which are the main focus of the EPA/ORD Global Program: regional assessments of climate impacts, evaluation of adaptation options, and development of decision support tools. The NAS criticized the draft government-wide CCSP *Strategic Plan* for not emphasizing these activities enough, and called for increased emphasis and funding of them by the Climate Change Science Program (CCSP). Dr. Graedel stated that the CCSP needs to move beyond a physical sciences program to one that includes impacts, adaptation and human dimensions. Specifically:

- There is a need for greater emphasis and support of regional impacts assessments.
- There is a need to explicitly acknowledge the importance of the U.S. National Assessment and build upon this assessment effort.
- There is a need for greater emphasis of decision support for international, federal, state, and local decision makers facing environmental problems.
- There is a need to build upon existing programs like EPA/ORD's Global Change Research Program (which was explicitly acknowledged). Greater support needs to be provided to these programs.

In other words, the *Research Strategy* and Multi-Year Plan for the ORD Global Program are still consistent with the goals and objectives of the CCSP *Strategic Plan*. In fact, it is highly likely that the goals of ORD's program will be increasingly highlighted and reflected in the revised CCSP *Strategic Plan*.

In addition to the CCSP *Strategic Plan*, the revised ORD Global MYP needs to account for EPA's (OAR's, ORD's and OIA's) recent commitment to support the US Bilateral Climate Change Agreements and Initiatives, initiated by President Bush. The USG Bilateral Program consists of broad-based, USG interagency activities in countries and regions of the world in support of the US obligations under the UN Framework Convention on Climate Change. ORD has been called upon by the Department of State to support assessments of climate impacts and potential adaptation options in four countries: China, India, Canada, and Italy.

Finally, in addition to the Executive Council's and Science Council's request that the revised MYP reflect changes in the CCSP, additional guidance was given:

- APMs should be revised, as necessary, to reflect evolution of the program's activities;
- Additional effort should be made to identify additional cross-goal APMs; and
- Integration of the intramural research program and the assessment activities should be further elaborated upon.

Some of these revisions have already been made. APMs (*e.g.,* for NCER and the STAR grants program) have been revised to represent advances in the research we are doing. Additional cross-goal APMs are being identified (*e.g.,* Goal 8 APMs related to "invasive species"). And the intramural research program is being better integrated with the ongoing regional assessment activities (*e.g.,* water quality impacts research and the Great Lakes Regional Assessment). The final version of the Global MYP will reflect all of these changes.

In closing, I'd like to emphasize the extent to which the Global Program's *Research Strategy* and draft MYP have already been successfully implemented and guided the work of the program. The Phase 1 Regional Assessments for the Great Lakes, Mid-Atlantic, and Gulf Coast Regions have been completed. Cooperative agreements for the Phase 2 assessments have been awarded and work initiated. The Phase 1 Health Sector Assessment has also been completed, and work has commenced on the development of next-generation scenarios for use in the Phase 2 Health Sector Assessment. The intramural research program's Air Quality Working Group is on track with the planned air quality assessment (*e.g.,* critical downscaling work has been initiated and supporting STAR grants will soon be awarded). The air quality assessment activities truly represent an integrated effort across ORD's labs and centers. The Water Quality Working Group is on track with its planned assessments, and successfully completed its first assessment of the vulnerability of coastal drinking water systems (*i.e.,* surface water) to sea level rise. Assessments of the vulnerability of ground water supplies will soon be completed, on schedule. And the Ecosystem Working Group will soon complete its planned problem formulation report for the planned assessment of global change impacts on aquatic ecosystems. We are delivering on those things we promised to do.

At the same time, the Global RCT is carefully evaluating previously planned activities that may no longer be necessary from our clients' perspective; specifically, support for the UV monitoring network in rural sites. No decisions have been made yet, but any disinvestments in this area will be reflected in investments elsewhere in the intramural research program. Such ongoing reevaluations of different components of the program represent the true nature of the MYP as a "living planning document."

I'd like to thank the Executive Council and Science Council for their helpful reviews of the draft Global MYP. And I'd especially like to thank the members of the Global RCT and the intramural inter-lab Working Groups for their continued hard work and support.

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MULTI-YEAR PLAN
Global Change Research Program (Goal 6)
U.S. Environmental Protection Agency
Office of Research and Development
Washington, D.C. 20460

I. Introduction

Earth's environment is constantly in flux. A complex interplay of natural processes and human activities foster wide-ranging change. Climate change and variability, change in land-use patterns, and change in UV radiation are examples of processes occurring on a global scale. The potential consequences of these global changes include effects on human health, ecosystems, and social well-being.

Policy makers and resource managers recognize that decisions made today may have important long-term ramifications for the Earth system. Providing them with comprehensive assessments of potential consequences allows them to anticipate, avoid, or adapt to coming changes. The purpose of EPA's Global Change Research Program within the Office of Research and Development (ORD) is to provide scientific information to resource managers, policy makers, and other stakeholders in order to support them as they decide whether and how to respond to the risks and opportunities presented by global change.

The activities of EPA's Global Change Research Program are closely coordinated with, and dictated by, the U.S. Global Change Research Program (USGCRP). The USGCRP was established in 1989 and authorized by Congress in the Global Change Research Act of 1990. It is comprised of 11 member agencies. USGCRP activities are coordinated by the Subcommittee on Global Change Research (SGCR), within the National Science and Technology Council's Committee on Environment and Natural Resources (CENR). Coordination of USGCRP activities is done in cooperation with the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB).

The vision of the USGCRP, as articulated in its new Congressionally-mandated *Strategic Plan*, is to provide cutting edge scientific information to help American communities and businesses better understand and manage global environmental changes and their impacts.[1] To fulfill this vision, the USGCRP has three goals for its coordinated interagency program:

- Improve US capacity to project future global change at the regional and local scales relevant to decision making, in light of uncertainties;
- Develop tools and information to project where we are most vulnerable and find

[1] U.S. Global Change Research Program, *Knowledge for Projecting Change, Understanding Vulnerability, and Enhancing Resilience: Strategic Plan for the United States Global Change Research Program, 2002-2010*, OMB Review Draft, 2001.

out how we can become more resilient;

- Provide useful knowledge to American governments, communities, and businesses to help them make decisions that reduce risks and take advantage of opportunities posed by global change.

The USGCRP *Strategic Plan* provides a framework for agency planning; *i.e.,* it is used by the SGCR to identify research and assessment priorities, and year-to-year activities of the members agencies. This *Strategic Plan* defines EPA's unique niche within the USGCRP as an assessment-oriented program with primary focus on understanding the regional consequences of global change (with particular emphasis on climate change and climate variability) for human health and ecosystems.

EPA's Global Change Research Program has developed its own *Research Strategy* to formalize its assessment responsibilities within the USGCRP. The *Research Strategy* articulates a vision of the Program's long-term goals for developing comprehensive assessments of global change issues and the research to support such efforts. The *Research Strategy* complements ORD's Strategic Plan and supports the Agency's mission to protect human health and to safeguard the natural environment.

The purpose of this companion document, the *Multi-Year Plan* (MYP), is to provide an implementation plan for accomplishing the work described in the *Research Strategy*. The MYP outlines a specific strategy for integrating work across ORD's Laboratories and Centers in support of the overall research and assessment goals articulated in the *Research Strategy*. The MYP covers a period of approximately 10 years (beginning with FY02).

Hierarchy of Global Change Research Planning Within the Federal Government and the EPA

USGCRP 10-Year *Strategic Plan*
(Congressionally Mandated)

EPA/ORD Global Change *Research Strategy*

EPA/ORD Global *Multi-Year Plan*

The MYP is composed of two parts. Part 1 provides a narrative that describes the scope of EPA's Global Program, EPA's role in the context of the USGCRP, the EPA Global Program's additional goal of addressing the needs of EPA's Program Offices and Regional Offices, and the integration of research and assessment activities within the Global Program (*i.e.,* a discussion of how EPA's assessments will be made *measurably better* by ORD's research). The narrative addresses specific questions raised by ORD's Executive Council and Science Council in a review of an earlier draft of this document. Part 2 of the MYP presents flow diagrams showing the sequence and interrelationship of annual performance goals (APGs) as they contribute to long-term research and assessment goals (LTG). Part 2 also contains tables describing the APGs and associated annual performance measures (APMs) needed to meet the long-term goals. The

MYP tables relate the APMs/outputs in a particular year with the APGs they support, even if the APG is in an out year.

How is the MYP linked to GPRA? The Government Performance and Results Act (GPRA) requires that programs define specific goals that they plan to achieve in any given year, and the specific measures that they will take to achieve those goals. The annual performance goals (APGs) and the annual performance measures (APMs) contained in the MYP correspond exactly to the goals and measures required by GPRA. All of the APGs and APMs contained in the MYP support the Agency's Goal 6, "Reduction of Global and Cross-Border Environmental Risks," Objective 6.2, "Reduce Greenhouse Gas Emissions," and Sub-Objective 6.2.3, "Conduct Global Climate Change Research."

What are the benefits of having an MYP? The *Research Strategy* articulates the assessment goals (*i.e.,* desired results) for the Global Program during the next decade, and identifies the clients for the assessments. It also provides a rationale (summarized below) for the selection of the assessment goals. The Multi-Year Plan provides an implementation plan for how these objectives can be met by ORD's Laboratories and Centers through a coordinated science program. It lays out a well-coordinated program that is more than a collection of individual Laboratory and Center activities. The program described in the MYP will yield outputs and outcomes that individual Laboratories and Centers, acting alone, would not likely achieve.

Planning tool. The MYP is a science planning tool that can also be used by ORD management for annual budgeting exercises. It enables management to determine whether the right science is being done to support the long-term goals of the Global Program. Because the MYP provides a framework for an integrated Global program, it enables management to identify "critical path" investments that must be made in any given year if longer-term objectives are to be met. It makes clear what capabilities must be developed (*i.e.,* capacity building) if longer term objectives are to be met.

Budget tool. In developing the MYP, it was assumed that annual budgets for the Global Program would be roughly constant at about $23M per year from FY02 through FY10. The MYP presents an integrated program with realistic time lines, given the assumed constant budget. But budgets are uncertain and annual surpluses or shortfalls may occur. If there are budget shortfalls, the MYP enables ORD managers to ascertain what will be lost in the way of performance goals and measures. If there are budget surpluses, it enables management to identify the highest priority research and assessment activities and understand the opportunities for moving more rapidly along a time line of activities leading to long-term goals.

Accountability. The MYP also enables ORD management to hold Laboratories and Centers accountable for their annual activities and expenditures. Since the achievement of the Global Program's long-term goals will depend upon close coordination among the Laboratories and Centers — with output from one lab/center often being input to the activities of another lab/center — failure to deliver products in a timely fashion will be transparent to all participants in the program.

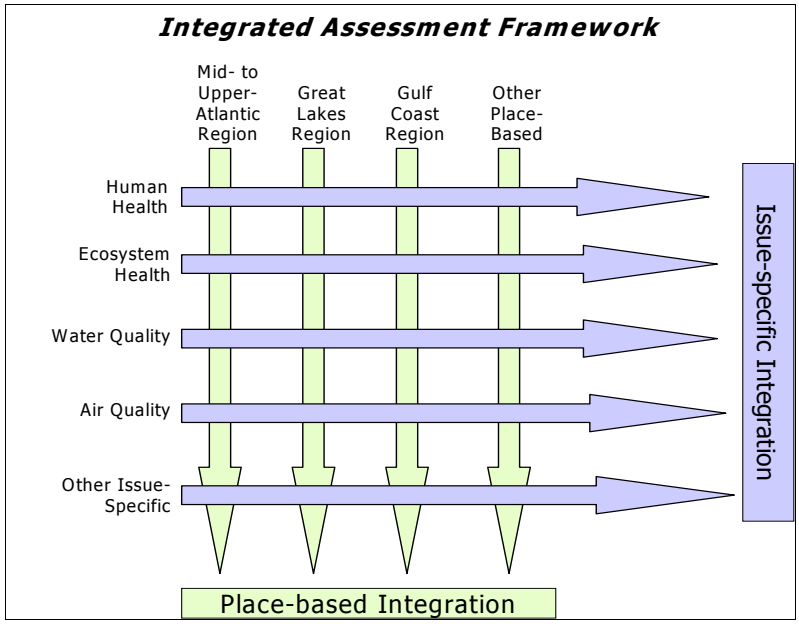
II. SCOPE OF EPA's PROGRAM

The Global Change Research Program is an assessment-oriented program with primary focus on understanding the potential consequences of global change for human health, ecosystems, and social well-being in the United States. This entails: (1) improving the scientific capabilities and basis for projecting and evaluating effects and vulnerabilities of global change in the context of other stressors and human dimensions (as humans are catalysts of and respond to global change); (2) conducting assessments of the ecological, human health, and socioeconomic risks and opportunities presented by global change; and (3) assessing adaptation options to improve society's ability to effectively respond to the risks and opportunities presented by global change as they emerge.

An Integrated Framework of Research and Assessment. The framework of research and assessment in the Global Change Research Program is integrated along intersecting lines of place and issue. The focus areas described in the sections that follow are issue-based efforts, bounded along topical lines (*e.g.*, air and water quality, human health, and ecosystems) rather than according to region or place. Yet, these focused topics invariably overlay region- or place-based contexts (see Figure 1). The integration of place and topical focus means that research and assessment activities in a region like the Mid-Atlantic have a regional focus, but are organized around issues of concern, *e.g.*, ecosystems, human health, and water resources.

A Place-Based Approach. EPA has long emphasized the importance of understanding environmental consequences from a regional perspective. The Global Change Research Program's *Research Strategy* and this MYP are consistent with that view. As the Global Change Research Program strives to understand relative risks in the context of multiple stressors, at multiple scales and multiple levels of biological and institutional organization, a place-based framework provides the means for that integration.

Figure 1. The integration of place-based and issue-based assessment activities.



Place-based study is naturally suited to the information requirements of decision makers. An environmental

problem and its solution are often unique to a location. Similarly, socioeconomic impacts are likely to be experienced locally and may be best addressed by regional assessments. The best approach for addressing regional problems is one that is responsive to the scientific and political realities that are unique to the locale. By establishing relationships with stakeholders at regional (or sub-regional) scales, the Global Change Research Program is able to engage locally-based decision makers in the assessment process. These partnerships, while useful to the assessment, encourage a sense of ownership in the scientific results and a readiness to employ assessment outcomes to inform decision making.

EPA-led research often begins with a specific problem in a particular place.

Three "places" serve as the regional settings for much of the Global Change Research Program's research and assessment activities: the Mid-Atlantic, the Great Lakes, and the Gulf Coast. The focus on these three regions reflects an ongoing EPA presence and interest in those regions (see, for instance, the *Ecological Research Strategy* [1998][2] which underscores EPA's long-term commitment to the Mid-Atlantic, the Great Lakes, and the Gulf Coast regions) and EPA's responsiveness to the 1997 request of the U.S. Global Change Research Program to support assessments of the potential consequences of climate variability and change in those regions.

In the U.S. National Assessment process (mandated by the Global Change Research Act of 1990), public-private partnerships were established with university assessment teams in each of the regions. While each regional assessment is unique, there are several common issues. Each is managed by a principal investigator who assembled a multi-disciplinary team of experts readied to address stakeholder concerns. Each team developed an approach to initiate and maintain stakeholder involvement. Each team assessed impacts on multiple sectors, such as human health, water quality and quantity, forests, agriculture, and coastal resources. Each team followed guidance established by the USGCRP, including using common scenarios and addressing common questions. All of the regional assessments conducted as part of the First U.S. National Assessment used climate scenarios from two General Circulation Models: the Canadian Climate Center Model (CGCM1) and the United Kingdom Hadley Center Model (HadCM2), and each regional assessment examined possible impacts in several time frames: 2030 to 2050 and beyond 2080.

These place-based assessment efforts continue to evolve. The successes of the initial assessments, and the evidence of sincere stakeholder interest, is leading to broader and deeper involvement in follow-up efforts. These regional assessments also provide a source of information and an audience for research results for EPA's and other agencies' research programs. In developing the research needs and priorities outlined in the Global Change Research Program's *Research Strategy* (and implemented in this MYP), the authors drew from

[2] U.S. Environmental Protection Agency, *Ecological Research Strategy*, Office of Research and Development, draft, 1998.

workshop and assessment reports from all of the USGCRP assessments. The university-led assessments provide regional testbeds for EPA research, as well as giving EPA and others in the assessment community ongoing access to stakeholder communities.

An Issue-Based Approach. The primary emphasis of EPA's activities is on those areas in which it has a comparative advantage relative to other agencies conducting global change research. In coordination with other USGCRP agencies, EPA has decided to focus its work in four issue areas: the effects of global change on *air quality, water quality, ecosystems, and human health*. ORD's Global Change Research Program will be able to build upon a strong research foundation in each of the focus areas to anticipate future opportunities or risks.

The four focus areas are interdependent and are enmeshed in the overall place-based framework. Changes in air or water quality may have important implications for human and ecosystem health. Changes in ecosystems due to climate or land-use change may affect water quality or the spread of infectious diseases. Changes in the frequency or intensity of extreme weather events (*e.g.*, floods, droughts, wildfires) could simultaneously affect public health, air and water quality, and ecosystems. Research and assessment must capture the interactions between the issue-based focus areas and the specific impressions that place imparts on the impacts of global change. Coastal vulnerabilities along the Mid-Atlantic are both similar to and dissimilar from those along the Gulf. The integration of place and issue helps assessors identify common ground while highlighting differences

Major components of EPA's assessment program. Over the next decade, the Global Change Program plans a series of research and assessment activities that will contribute (in FY 2010) to a USGCRP multi-sector, multi-region assessment of the consequences of global change in the United States. The interagency USGCRP assessment activities are described in the new USGCRP *Strategic Plan*, which will soon be delivered to Congress. The activities outlined in the USGCRP plan address those topics that represent the greatest risks to people and their environment, have demonstrated policy relevance, and show promise for extending the research community's assessment capabilities.

The EPA/ORD/Global assessment program has two major thrusts: (1) a major commitment to the ongoing USGCRP National Assessment process; and (2) intramural research and assessments in the four focus areas (see Figure 2). The MYP is structured so that it provides detailed plans for the ongoing assessments sponsored by EPA as part of the USGCRP National Assessment process, and for assessments in each of the four focus areas (air quality, ecosystems, water quality, and human health).

This Global Multi-Year Plan is unique among all ORD Multi-Year Plans in that it is the only one coordinated with other agencies through an interagency federal program. The USGCRP, in collaboration with OSTP and OMB, identifies research and assessment priorities, and the year-to-year activities of the member agencies.

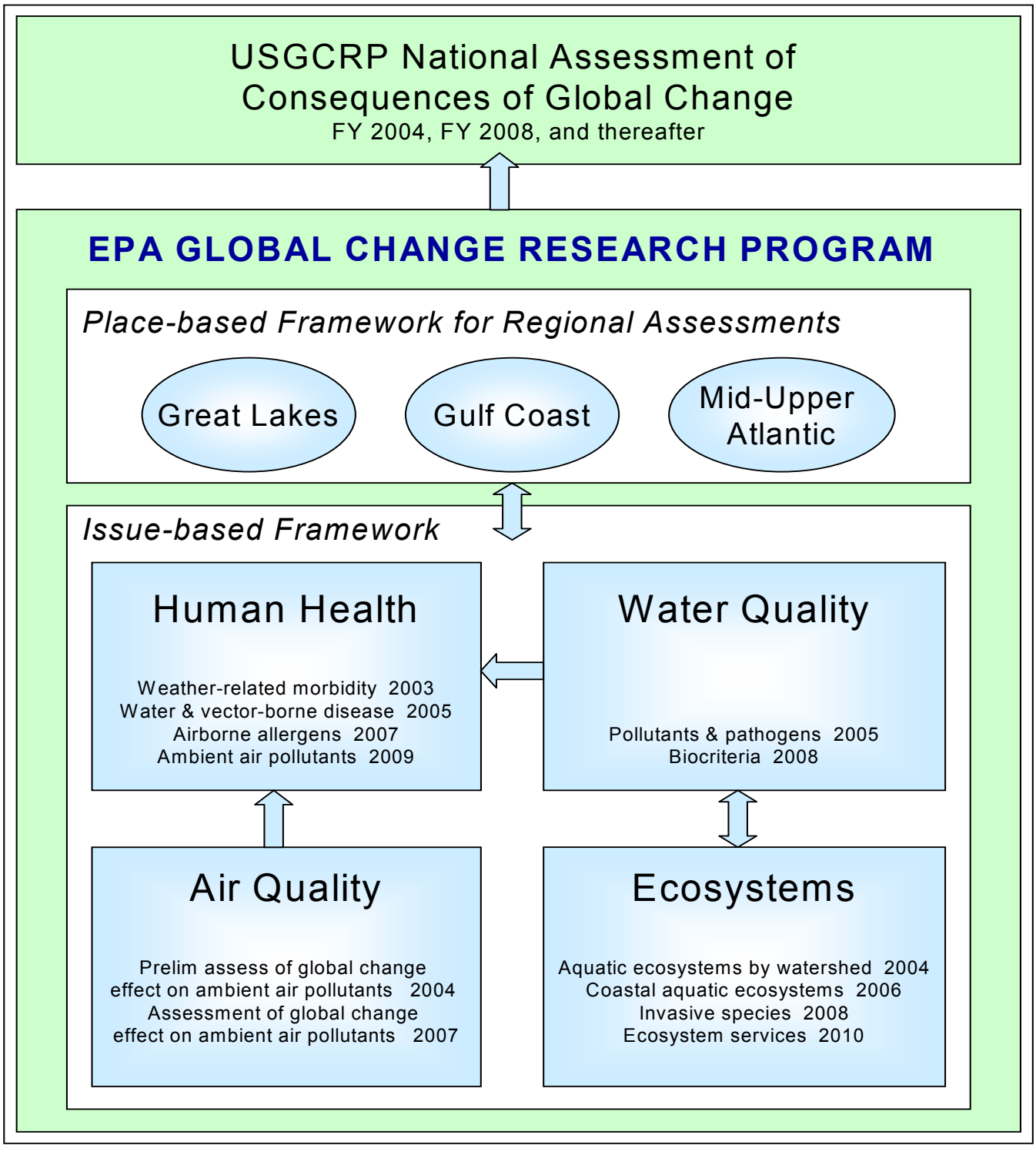


Figure 2: **Major Components of EPA's Global Change Research Program**

Commitment to ongoing USGCRP National Assessment process. EPA's program has made a major commitment to the ongoing National Assessment activities organized through the USGCRP. The Global Change Research Act of 1990 mandates that the USGCRP conduct periodic assessments of the potential consequences of global change for the United States. These periodic assessments are to be conducted not less than every four years. These periodic assessments are reflected in the MYP tables of goals and performance measures as scheduled reports to Congress in FY04 and FY08.

EPA is committed to three Regional Assessments (Mid-Atlantic Assessment, the Great Lakes Regional Assessment, the Gulf Coast Regional Assessment) and an assessment of the Health Sector as part of this ongoing process. These assessments, conducted through public-private partnerships coordinated by the USGCRP, form the basis for designing intramural research within ORD's laboratories and centers, and extramural grants through the STAR program. The regional assessments provide a source of information and an audience for research results for EPA's and other agencies' research programs.

The USGCRP National Assessment emphasizes a process driven by the needs of stakeholders – persons best positioned to identify important information needs and optimal ways of responding. The USGCRP has affirmed that "close collaboration with ... resource managers, decision makers, and other stakeholders is essential to ensure that USGCRP assessments adequately and accurately incorporate and reflect the sensitivities, resilience, and realistic adaptation options of managed and natural systems." One of the lessons from the First U.S. National Assessment, delivered to Congress in November 2000, is that it takes time to conduct the analytic exercises necessary to complete a thorough, complex stakeholder-oriented assessment.

Intramural assessments in the four focus areas. Through integrated, collaborative efforts, ORD's Laboratories and Centers will also conduct research and assessments in each of the four focus areas, often with a place-based focus.

What was the rationale for selecting the particular focus-area assessments that will be conducted? As discussed in the *Research Strategy*, the assessments that will be conducted have been chosen based upon several criteria: (1) their relevance and importance to EPA's Program Offices and Regional Offices; (2) their importance to EPA's overall mission to protect public health and the integrity and resilience of ecosystems; and (3) EPA's comparative advantage vis-a-vis other USGCRP agencies.

Air quality assessment. In the air quality focus areas, an assessment is planned that will examine the potential consequences of global change on urban air quality in the United States. (This assessment will be paired with related human health assessments.) Based upon comments received from the external panel of experts who reviewed the *Research Strategy*, it has been decided to conduct a single air quality assessment that integrates all pollutants in the atmosphere (*i.e.,* a "one atmosphere" approach is being taken). Particular attention will be paid to tropospheric ozone and particulate matter, in order to provide useful insights about the feasibility of attainment of air quality standards under global change to EPA's air regulatory program.

Ecosystem assessments. In the ecosystem focus area, three research and assessment activities are planned that evaluate the effects of global change on: (1) aquatic ecosystems (which may include lakes, rivers, and streams; wetlands; and estuaries and coastal ecosystems); (2) invasive nonindigenous species; and (3) selected ecosystem services. The assessment of aquatic ecosystems will contribute to water quality assessments of pollutants and pathogens and of biocriteria. The ecosystem services assessment will draw on work from the aquatic ecosystems assessment and the invasive nonindigenous species assessment.

Water quality assessments. In the water quality focus area, the program plans two assessments of the possible impacts of global change on water quality; in particular, the consequences of global change for: (1) water quality related to pollutants and microbial pathogens; and (2) water quality related to biocriteria. Both water quality assessments will either contribute to or benefit from human health and ecosystems assessments. In addition, results from the assessment of pollutants and microbial pathogens will be used in the assessment of biocriteria.

Human health assessments. In the human health focus area, assessment activities are planned that focus on the consequences of global change for weather-related morbidity and vector- and water-borne diseases. (These areas were identified as key knowledge gaps by the Health Sector Assessment conducted as part of the First U.S. National Assessment.) In addition, the results from the Global Program's air quality assessments will be used to evaluate health consequences of ambient air pollutants (particularly tropospheric ozone and particulate matter) under conditions of global change.

Sequencing of research and assessment activities. An important feature of this MYP is the flow of work within and across focus areas. Related activities are arranged in a logical sequence. For instance, the assessment of water-borne illnesses is conducted in parallel with assessments of aquatic ecosystems and of aquatic pollutants and microbial pathogens. Likewise, the human health assessment of the effects of tropospheric ozone and particulate matter under conditions of global change occurs after the air quality assessment of the global change impacts on air quality.

This sequencing of activities is reflected in the "flow diagrams" and the tables of goals and performance measures presented in this MYP.

Characteristics of all EPA assessments. The goal of the assessments conducted as part of the Global Change Research Program is to inform policy and resource management decisions (*e.g.,* by EPA's Program and Regional Offices; local and regional stakeholder groups) in a *timely* fashion using the best available scientific and socio-economic information. Such policy-focused assessments are more than just risk assessments or toxicological studies. They also are more than just a synthesis of scientific information or an evaluation of the state of the science. Rather, these assessments are analytic exercises. They involve the analysis of information from multiple disciplines — including the social and economic sciences — to answer the specific questions being asked by stakeholders. In addition, they include an analysis of adaptation options to improve society's ability to respond effectively to risks and opportunities as they emerge.

How are stakeholders included in the design of the assessments (*e.g.,* questions to be answered) to ensure that they lead to useful outputs and outcomes? A successful assessment process entails elicitation from stakeholders of the issues, questions and outcomes of greatest concern to them. The EPA assessments are stakeholder-oriented activities. Stakeholders are engaged throughout the assessment process. At the outset of the assessment process, they can identify the particular issues and questions of interest to them. They are then involved in the analytic process, in the communication of results, and in the use of assessment findings for decision making.

Throughout the assessment *process*, assessment *products* (*outputs*) are produced using the best-available scientific and socio-economic information to inform a particular set of stakeholder-defined policy decisions. Timely production of these products is critical since decisions (*outcomes*), including the decision to do nothing, often must be made before the scientific community has concluded all of its analyses and is prepared to provide input. The continuous involvement of stakeholders (*e.g.,* EPA's Program Offices) helps ensure that assessment products are useful; *i.e.,* that they lead to positive outcomes.

Such a stakeholder-oriented process helps the research and assessment communities ensure the timeliness and usefulness of their work. Significant benefits also accrue to stakeholders, particularly in their understanding of issues and in their use of scientific information in the decision-making processes. Stakeholders should be engaged early in the assessment to assist in developing the plan for the assessment and to identify and frame pertinent research and assessment questions. As the assessment progresses, stakeholders can provide expertise and data to the analytic process. As findings emerge, stakeholders can offer leadership in the development of communication strategies for the dissemination of assessment findings as they explore how information related to global change can be integrated into their own decision and planning processes.

Is it feasible to do the planned assessments given the available scientific information? It is *always* possible to analyze the best-available scientific information at any point in time — despite the existence of uncertainties — to inform policy and resource management decisions. (This has already been demonstrated by EPA's Global Program. One success from EPA's assessment program is depicted in Box 1 [attached at the end of this MYP].) It is also imperative that such assessments be conducted on an ongoing basis since the science may change and policy and resource management decisions are made regularly. It is essential that EPA assessments provide *useful* information to decision makers in a *timely* fashion.

Assessment is an ongoing process. It is likely that assessments will not be able to completely answer all of the questions posed by stakeholders. For example, the Health Sector Assessment that was conducted as part of the First U.S. National Assessment assessed the potential health consequences of changes in air quality in the United States as a result of climate variability and change. This issue had been identified as a major concern by public health officials. The assessment concluded that climate change may affect exposures to air pollutants by affecting weather, anthropogenic emissions, and biogenic emissions and by changing the distribution and

types of airborne allergens.[3] However, the assessment also concluded that it isn't yet possible to draw conclusions about the future effects of climate change on human health. It noted that the specific types of change (*i.e.,* local, regional, or global), the direction of change in a particular location (*i.e.,* positive or negative), and the magnitude of change in air quality that may be attributable to climate change are a matter of speculation, based on extrapolating present understanding to future scenarios. Since public health officials still would like to be informed about the potential health consequences of changes in air quality as a result of climate change, the assessment identified key research gaps that must be filled: basic atmospheric science work on the association between weather and air pollutants; improving air pollution models and their linkage with climate change scenarios; and closing gaps in the understanding of exposure patterns and health effects.

As an assessment process progresses, new questions also will be posed by stakeholders as their needs change and as they learn from ongoing assessments. For this reason, the last step in any particular assessment is the identification and *prioritization* of "key" research gaps, *i.e.,* those knowledge gaps that must be filled in order to answer stakeholder questions. This MYP includes Value of Information exercises that are periodically conducted to identify key research gaps, new research questions for the intramural and STAR research programs, and new assessment questions.

[3] Bernard, Susan M., Jonathan M. Samet, Anne Grambsch, Kristie L. Ebi, and Isabelle Romieu, "The Potential Impacts of Climate Variability and Change on Air Pollution-Related Health Effect in the United States," *Environmental Health Perspectives*, Vol. 109, Supplement 2, May 2001, 199-209.

Value of Information Exercises

The last step in any particular assessment is the identification and *prioritization* of "key" research gaps, *i.e.,* those knowledge gaps that must be filled in order to answer stakeholder questions. Some of the stakeholder questions will be the same as those asked at the outset of the assessment process. But the stakeholders may have new questions they wish to pose, either because of the insights they have already gained from the assessment process or because of changes in other factors unrelated to the assessment process.

Since the resources available for conducting research related to an assessment process are scarce, research needs must be prioritized. Research dollars that are used to support assessments need to be directed to their highest-valued uses, *i.e.,* toward producing timely research products that fill key knowledge gaps that are needed to answer stakeholders' questions. This requires that *value of information* calculations be done (either explicitly or implicitly). Such calculations yield insights into the incremental value to stakeholders of information expected to be derived from an investment in a particular research activity. The results of these calculations depend on changing stakeholder needs and values, and the timeliness and relevance of information. Value of information exercises can be expensive to undertake, but need to be part of any assessment process.

There are a variety of techniques available for calculating the value of information. A useful approach that will be used by the Global Change Research Program is decision analysis. Fundamentally, the "decision" the Program faces is to choose among alternative investments in research, each of which has an uncertain outcome (*i.e.,* an uncertain value). Sensitivity analysis techniques of decision analysis will be used to compute the difference in value obtained by changing the decisions about which research to undertake. Influence diagrams will be used to graphically represent the decision problems under uncertainty. Efficient algorithms that have been developed to solve decision problems represented as influence diagrams will then be used to calculate the value of information from alternative research activities. (These algorithms build an auxiliary structure called a rooted cluster tree or strong junction tree. Previous work has suggested that value of information calculations can be performed efficiently on such a tree.)

III. EPA ROLE IN THE CONTEXT OF OTHER USGCRP AGENCIES

It is the mission of EPA to protect human health and to safeguard the natural environment – air, water, and land – upon which life depends. Other federal agencies also have responsibility for investigating global environmental change as members of the USGCRP. However, EPA has a unique role that goes beyond resource management to the protection of human health, air quality, water quality, and entire ecosystems from environmental risks.

EPA's unique niche within the USGCRP. It is recognized that within the USGCRP, EPA has a limited role. However, as noted earlier, EPA has a unique niche within the USGCRP

as the assessment-oriented program with primary focus on understanding the regional consequences of climate change and climate variability for human health and ecosystems. EPA's intramural and extramural research program is improving the scientific basis for determining and evaluating effects of global change on ecosystems and human health in the context of multiple stressors. This scientific information is used in carrying out EPA's assessment responsibilities which responsibility include: (1) ongoing support for Regional Assessments in the Mid-Atlantic, Great Lakes, and Gulf Coast; (2) ongoing support for the Health Sector Assessment; and (3) place-based/regional assessments of the consequences of climate variability and change (in the context of multiple "global" stressors) for air quality, water quality, ecosystems, and human health.

The USGCRP is developing new ways to transform scientific information into products for routine use by government, commercial organizations, and others for reducing risks and taking advantage of opportunities resulting from global change. EPA's assessment orientation is a key mechanism for accomplishing this objective.

Contributions from other USGCRP agencies' research programs to EPA assessments. EPA's Global Program also benefits from research conducted in other USGCRP agencies. As noted by the external panel that peer reviewed the Global Program's *Research Strategy*, it is impossible for EPA to conduct all of the research necessary to complete its assessments. (For example, the panel noted that it is impossible for ORD to assess the consequences of global change for aquatic ecosystems, without benefitting from the work being done in other USGCRP agencies on terrestrial ecosystems and marine ecosystems.) The panel noted that EPA must invest in those areas in which it has a comparative advantage, given EPA's mission and the strengths of its research program. As noted in the *Research Strategy*, specific contributions by other USGCRP agencies to EPA's intramural focus-area assessments have been identified:

Related USGCRP work supporting EPA ecosystem assessments:

- Understanding terrestrial ecosystems: DOI/USGS
- Understanding marine ecosystems: NOAA
- Biology and biogeochemistry of ecosystems: DOE, DOI/USGS, NSF, SI, USDA

Focus of Overall Coordinated USGCRP Ecosystem Research and Assessment Program

How do natural and human-induced changes in the environment interact to affect ecosystems (from natural to intensively managed), their ability to provide natural resources and commodities, and their influence on regional and global climate? Coordinated USGCRP research will:

- examine the structure and functioning of ecosystems, including cycling of nutrients, and how these nutrients interact with the carbon cycle;
- seek to identify and understand the key processes that link ecosystems with change;
- determine the vulnerability of ecosystems to global change **(includes EPA contributions)**;
- identify options for enhancing resilience and sustaining ecosystem goods and services **(includes EPA contributions)**; and
- provide a scientific underpinning for improved interactions with resource managers. **(includes EPA contributions)**.

Related USGCRP work supporting EPA air quality assessment:

- Modeling long-range transport of pollutants: NASA
- Atmospheric composition and chemistry: DOC/NOAA, DOE, NASA, NSF, USDA
- Understanding the Earth's Climate System (including the development of Global Circulation Models): NASA, NSF, DOE, DOC/NOAA, DOI/USGS

Focus of Overall Coordinated USGCRP Atmospheric Composition Research and Assessment Program

How is the composition of the global atmosphere altered by human activities and natural phenomena, and how do such changes in composition influence climate, ozone, ultraviolet radiation, pollutant exposure, ecosystems, and human health? Coordinated USGCRP research will:

- processes affecting the stratospheric ozone layer and its recovery;
- the properties and distribution of greenhouse gases and aerosols;
- long-range transport of pollutants and implications for air quality; and
- integrated assessments of the effects of these changes for the nation and the world. **(includes EPA contributions)**.

EPA's reliance upon ongoing research, models, and assessments at other Agencies, including NOAA, DOE, DOT, NSF, NSF and NASA, for the conduct of its air quality assessment, is discussed in greater detail in the air quality section of this MYP.

Related USGCRP work supporting EPA water quality assessments:

- Global water cycle: NASA

Focus of Overall Coordinated USGCRP Global Water Cycle Research and Assessment Program

How do human activities and natural processes that affect, for example, climate variability, influence the distribution and quality of water within the Earth system? To what extent are changes predictable, and how will these changes affect climate, the cycling of carbon and other nutrients, and other environmental properties? Coordinated USGCRP research will:

- assess trends in the water cycle and determine the causes of these changes (including feedback effects of clouds on the water and energy budgets as well as the global climate system);
- predict precipitation and evaporation on time scales of months to years and longer and spatial scales from local to regional to global;
- model physical and biological processes and human demands and institutional processes, to facilitate efficient water resources management **(includes EPA contributions)**; and
- conduct the research required for reports on the state of the global water cycle and national water resources.

Related USGCRP human dimensions research in areas not covered by EPA: NOAA, DOE, HHS/NIH, SI

Overall Coordinated USGCRP Human Dimensions Research and Assessment Program

Improving our scientific understanding of how humans cause changes in the Earth system – an dhow society, in turn, is affected by the interactions between natural and social processes – is an important priority for the USGCRP. Coordinated USGCRP research will address the following key questions:

- What are the major human drivers of changes and how do they vary temporally, spatially, and across economic sectors and social groups?
- What are the human consequences of global environmental change? **(includes EPA contributions)**
- How might global change affect key life-support systems (water, health, agriculture), economies, and political systems? **(includes EPA contributions)**

Other related USGCRP general "climate science" support for EPA assessments:

- Carbon cycle science: DOC/NOAA, DOE, DOI/USGS, NASA, USDA

Overall Coordinated USGCRP Carbon Cycle Research Program

How large and variable are the reservoirs and transfers of carbon within the Earth system, and how might carbon sources and sinks change and be managed in the future? The coordinated USGCRP program will provide the scientific underpinning for carbon management by focusing on:

- North American and ocean carbon sources and sinks;
- the impact of land-use change and resource management practices on carbon sources and sinks;
- projecting future atmospheric CO_2 and methane concentrations and changes in land-based and marine carbon sinks; and
- reporting periodically (starting in 2010) on the global distribution of carbon sources and sinks and how they are changing.

The interactions between EPA's program and the research programs of other federal agencies is discussed in detail in the USGCRP's new *Strategic Plan*. Specific *Implementation Plans* (*e.g.,* a Carbon Cycle Implementation Plan) have been developed by the USGCRP to describe interagency efforts in the specific areas listed above. More detailed descriptions of other USGCRP agency programs can be found in the FY2002 USGCRP report to Congress entitled, *Our Changing Planet*.[4]

In some cases, USGCRP agencies (including EPA) jointly sponsor assessments that focus on particular topics of mutual concern. For example, one successful collaborative effort between EPA, NOAA, NASA, NSF – and EPRI, in the private sector – has focused on specific consequences of climate change for the spread of infectious diseases in the United States. EPA, in partnership with other USGCRP agencies, will continue to explore such jointly-funded assessment activities – as described in the USGCRP *Strategic Plan* report to Congress.

[4] U.S. Global Change Research Program, *Our Changing Planet: The FY 2002 U.S. Global Change Research Program*, A report by the Subcommittee on Global Change Research, Committee on Environment and Natural Resources of the National Science and Technology Council, A Supplement to the President's Fiscal Year 2001 Budget, Washington, DC, September 2001.

It is noteworthy that EPA has already made significant disinvestments in its Global Change Research Program since 1997. In 1997, ORD's Executive Council restructured the Global Change Program resulting in a redirection of resources to higher-priority research and assessment activities more consistent with EPA's particular area of emphasis within the USGCRP program — to avoid duplication of efforts between USGCRP agencies. For example, EPA's Global Program disinvested in the development of Global Circulation Models, carbon cycle analysis, forest research, and landscape characterization research.

Management of Agency Programs Within the USGCRP

The USGCRP has coordinate research on complex global change issues for more than a decade, While existing agency expertise and approaches used in the past help provide a good foundation for the future, new mechanisms for closer coordination and integration within the USGCRP's distributed, multi-agency structure are being implemented. These include:

- New mechanisms for increasing involvement of the external research community in planning and oversight;
- Enhanced coordination through interagency working groups responsible for preparation of detailed implementation plans that identify how the contributions of the agencies will be brought together to meet research needs and produce deliverables; and
- A new budgetary capability to identify and carry out integrative research and activities under the direction of the interagency committee responsible for the program. This will include strong mechanisms for budgetary review and compliance (*e.g.,* by OMB).

How will EPA's Global Program contribute to the overall USGCRP and to other USGCRP agencies? The overall USGCRP, as well as specific USGCRP agency programs, also benefit from EPA's Global Program. Specifically:

- Assessment of Consequences: Among the USGCRP member agencies, EPA is responsible for assessing the potential consequences of global change on human health, the environment, and social well-being in the United States. The involvement of the EPA Global Change Program in the USGCRP is consistent with the National Academy of Sciences' recommendation to engage in a formal process to identify and coordinate areas of research that are supported by multiple agencies.[5] ORD's Global Change Program responded with a redirection towards a more assessment-oriented program focused on

[5] National Research Council, *Global Environmental Change: Research Pathways for the Next Decade*, National Academy of Sciences, Washington, DC, 1999; National Research Council, *Our Common Journey: A Transition Toward Sustainability*, National Academy of Sciences, Washington, DC, 1999.

consequences of global change in 1998.

- Contributions to USGCRP National Assessment Process: EPA contributes to the larger USGCRP National Assessment activities through its support for the Mid-Atlantic, Great Lakes, and Gulf Coast Regional Assessments, and the Human Health Sector Assessment.

- Contributions to USGCRP Multi-Sector, Multi-Region Assessment in 2010: As noted earlier, the EPA research and assessment activities over the next decade will contribute (in FY 2010) to a USGCRP multi-sector, multi-region assessment of the consequences of global change in the United States. The interagency USGCRP assessment activities are described in its new *Strategic Plan.*

- Contributions of Focus Area Assessments to Other USGCRP Agencies: Specific EPA "focus area" research and assessment products are "handed off" to other USGCRP agencies that have statutory and regulatory authority in specific areas. For example, it is expected that EPA's assessment of the potential morbidity effects from motor vehicle crashes associated with climate change and variability will be delivered to the Department of Transportation for incorporation into their policy and regulatory programs.

- UV-B Monitoring Network: EPA supports the USGCRP Interagency UVB Monitoring Network. Concerns over increased levels of potentially harmful ultraviolet-B (UV-B) radiation reaching the Earth's surface prompted the USGCRP in 1995 to set up a U.S. Interagency UV Monitoring Plan. The Interagency Plan outlined the coordinated efforts to be undertaken by USDA, NASA, NOAA, NSF, EPA, the Smithsonian Institution, and the National Institute of Standards of Technology (NIST).

  Each agency was given the task of providing different but complementary information about UV reaching the Earth's surface. The role of EPA's Global Program is to measure UV-B in urban areas to support human health effects research. (NIH also plays a leading role in the health effects area.) EPA's Global Program also maintains a rural UV-B monitoring network at U.S. National Park sites located around the country.

  Analysis of the data collected from EPA's UV-B monitoring network is also required to support the ecosystem assessments. This MYP captures this contribution in the form of APGs and APMs in the ecosystem focus area. Also, information derived from the UV-B monitoring network can also inform the air quality assessment.

IV. ADDRESSING PROGRAM AND REGIONAL OFFICE NEEDS

Emphasis is placed on the expected utility of the research and assessment products for addressing both short- and long-term global change risks. EPA's Office of the Administrator, Office of Air and Radiation (OAR), Office of Water (OW), Office of Prevention, Pesticides, and Toxic Substances (OPPTS), and Office of Policy, Economics, and Innovation (OPEI), as well as

EPA Regional Offices, are the primary internal clients for these products. Assessments conducted by the Global Change Program should help these clients meet their strategic goals and objectives by supplying information on the potential consequences of global change on the resources for which they have oversight.

The assessments described in the *Research Strategy* support EPA's Program and Regional Offices by providing insights regarding possible future conditions of the resources within their oversight. The goal is to have EPA's Program Offices understand their media and programmatic responsibilities in light of climate change and variability. For example, a 1°F increase in average nighttime temperature – which has already been observed during the past century and is expected to occur more rapidly as the climate changes – has a major impact on weed growth and insects, items controlled with pesticides. Increased use of pesticides may make it more difficult for the OPPTS to meet its regulatory responsibilities. Also, when combined with expected increases in the frequency and intensity of rainfall as the climate changes, an increased use of pesticides can lead to greater runoff into rivers and streams. This will pose further challenges to the Office of Water.

Similarly, the Office of Air and Radiation (OAR) has a strategic goal of bringing all areas of the country into attainment with the National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter (PM) by 2020. The Global Change Program plans an assessment of the consequences of global change on tropospheric ozone and PM under climate change. This assessment will include an evaluation of how potential technology and policy changes, in the context of climate change, may affect the ability of communities to achieve the NAAQS. Health assessments will build on the air quality assessments to project potential health effects. The Global Change Program will work with the Program and Regional Offices to ensure that the assessments address issues of concern to them.

The EPA Program Offices (particularly OAR) and EPA Regional Offices have been involved in the development of this MYP. As key users of ORD research products, it is critical that their perspectives are addressed. It is also planned (as described below) that the Program Offices and Regional Offices will be involved in the *Value of Information* exercises periodically conducted as part of the National Assessment process.

V. INTEGRATING EPA's RESEARCH AND ASSESSMENT ACTIVITIES

Assessment and research are viewed as *complementary* and *parallel* activities in the Global Change Program. The research program is guided by the assessment activities and, in turn, provides a steady flow of new scientific and socio-economic information necessary for conducting assessments. The research and assessment activities proceed concurrently. This ongoing process of research and assessment ensures that the Program addresses relevant topics in a timely manner while remaining responsive to stakeholder needs. As outlined in this MYP, research to support assessments will be provided through intramural efforts in ORD Laboratories and Centers and by extramural funding of STAR grants. In turn, the assessments identify and prioritize key research gaps, *i.e.,* those knowledge gaps that must be filled in order to answer

stakeholder questions.

Timing and sequencing of research and assessment activities. As noted earlier, an important feature of this MYP is the flow of work within and across focus areas. Related activities are arranged in a logical sequence. For instance, the assessment of water-borne illnesses is conducted in parallel with assessments of aquatic ecosystems and of aquatic pollutants and microbial pathogens. Likewise, the human health assessment of the effects of tropospheric ozone and particulate matter under conditions of global change occurs after the air quality assessment of the global change impacts on air quality. This sequencing of activities is reflected in both the "flow diagrams" and the tables of goals and performance measures.

Standard approach for identifying cross-goal opportunities and cutting-edge research needs. At the outset of each planned Global assessment, it is critical that our understanding of the following be refined (beyond this MYP):

- stakeholder needs and issues of concern;
- key research questions that need to be addressed in order to complete the planned assessment;
- opportunities for cross-ORD goal collaboration; and
- specific research needs to be addressed through STAR Requests for Assistance (RFAs).

This is necessary to ensure that EPA's Global assessments are made "measurably better" by the work done in its intramural research program and by the work done through its STAR grants program.

The Global Program follows a standard "workshop approach" for meeting these objectives when an assessment commences. Workshops are held at the outset of each assessment effort to identify the issues of concern to stakeholders, to share the best-available scientific and socioeconomic information relevant to the assessment topic, to identify key knowledge gaps, and to identify available data and information. These workshops present an opportunity for ORD Laboratories and Centers to work together to refine the intramural Global research activities, finalize planned RFAs for the STAR grant program, and identify work being done in other Goals that can contribute to the specific assessment being undertaken.

The Global Program has already had success conducting such workshops. A research planning ("Research Needs") meeting was held in December 2001 to support the Global air quality assessment. Participants in the meeting included representatives from all of ORD's Laboratories and Centers, clients and researchers from the Office of Air and Radiation, and researchers and modelers from the outside academic community. This workshop successfully:

> Workshops are held at the outset of each assessment that provide ORD Laboratories and Centers to refine the intramural Global research activities, finalize planned RFAs for the STAR grant program, and identify work being done in other Goals that can contribute to the specific assessment being undertaken. These workshops are a critical step towards ensuring that the EPA Global assessments are made *measurably better* by the intramural research program and the STAR grant program.

- identified the key questions that OAR (the client office) would like addressed in the Global air quality assessment;
- reviewed and finalized a workplan for conducting the assessment;
- identified key research questions that need to be addressed by ORD's Laboratories and Centers before the assessment can be completed;
- identified key research and modeling questions that need to be addressed by the STAR grants program to help build capacity for future air quality assessments;
- identified opportunities for ORD Laboratories and Centers to contribute work being done in other Goals to the specific air quality assessment;
- identified relevant ongoing research and models being developed by OAR;
- identified relevant ongoing research, models, and assessments at international organizations (*e.g.,* the Intergovernmental Panel on Climate Change); and
- identified ongoing research, models, and assessments at other federal Agencies (including NOAA, DOE, DOT, NSF, and NASA) that will contribute to the air quality assessment.

Will the EPA assessments be made measurably better by the planned research activities? As noted earlier, it is always possible to conduct an assessment at any point in time using the best available scientific and socio-economic information. At a minimum, EPA's assessments can draw upon research being done elsewhere in the scientific community. However, a key question for the EPA Global Program is whether the planned assessments be made measurably better because of the planned EPA/ORD research.

The answer is unequivocally yes. As noted above, EPA's research program fills a particular niche that other USGCRP agencies don't fill. *EPA is doing research in each of the four focus areas -- and integrating across the focus areas -- that is not being conducted elsewhere within the USGCRP.* EPA's unique research contributions include its focus on:

- Air quality: Modeling and integrating the combined effects of global atmospheric process (*e.g.,* long-range transport of pollutants; changes in the stratospheric ozone layer) and regional and local processes (*e.g.,* local emissions of pollutants from transportation; changes in land-use patterns).

- Water quality: Modeling physical and biological processes (*e.g.,* salt water intrusion due to sea level rise; more runoff due to increased levels and intensity of precipitation), combined with human demands (*e.g.,* due to changes in land-use patterns) and institutional processes, to facilitate efficient water resources management.

- Ecosystems: Understanding and modeling the vulnerability of aquatic ecosystems (as opposed to marine or terrestrial ecosystems) to global change; identifying options for enhancing resilience and sustaining ecosystem goods and services.

- Human health: Understanding the consequences of global change for weather-related morbidity and vector- and water-borne diseases (issues identified as key knowledge gaps

by the Health Sector Assessment conducted as part of the First U.S. National Assessment).

- Integration: Understanding and modeling the interactions between air quality, water quality, ecosystems, and human health (*e.g.,* implications of changes in water quality for the sustainability of ecosystem services).

- Human dimensions: Modeling the human consequences of global change, particularly for the key life-support systems of air, water, and ecosystems.

- Adaptation: Researching opportunities to cope with a changing climate to preserve air quality, water quality, ecosystem resilience, and human health.

The peer-reviewed Global *Research Strategy* identifies the specific research questions and modeling exercises needed to support the assessments that will be addressed by ORD's intramural research program. The *Research Strategy* identifies research questions and modeling exercises that critical to the conduct of the planned EPA assessments, but are not being addressed by other federal agencies. The *Research Strategy* also identifies activities being conducted in other federal agencies that are critical inputs to EPA's assessments.

As noted earlier, the workshops held at the outset of each assessment are a critical step towards ensuring that the EPA Global assessments are made *measurably better* by the intramural research program and the STAR grant program. (These workshops build off of the framework already established in the *Research Strategy*.) They provide ORD Laboratories and Centers an opportunity to refine the intramural Global research activities, finalize planned RFAs for the STAR grant program, and identify work being done in other Goals that can contribute to the specific assessment being undertaken.

Future EPA assessments (beyond those planned by 2010) will be enhanced by the research program. The STAR grants program will help build capacity for future (improved) assessments. For example, the air quality section of the MYP stipulates that a first assessment will be completed by FY2007. However, additional model and tool development (*e.g.*, downscaling modeling exercises) conducted through the STAR program will build the capacity for EPA to conduct more complex and comprehensive assessments in the future.

It is noteworthy that some of the individual research projects produced as inputs to broader assessments could also be beneficial as stand-alone products. For example, while data on market penetration and diffusion of new technologies is needed to project future emissions, the information generated on this could be useful to policy officials for other reasons and could have multiple uses.

Finally, it is recognized that the key research gaps and questions will change over time – as the science improves and stakeholder needs change. EPA's Laboratories and Centers will be involved in the *Value of Information* exercises that will be conducted as part of the National Assessment activities, and will help address new research questions as they emerge.

STAR's "capacity building" role within the Global Program. EPA's assessments are also made measurably better by the STAR grant program. In order to capitalize on expertise in the academic community, a significant portion of the Global Program's resources is dedicated to extramural research grants administered through the STAR grants program. The STAR Program's support of long-term research promotes work in high-priority areas of science. Extramural grants help the Global Change Program attain its long-term objectives and encourage scientific work supporting global change assessments. STAR plays an important role in *building the capacity* necessary to permit the conduct of future (improved) Global assessments.

The STAR Program's role consists of competitively awarded grants offered through Requests for Applications (RFAs) and written to be consistent with and responsive to the Global Change Program's *Research Strategy*. As noted by the external panel that peer reviewed the Global *Research Strategy*, because of the nature of the grants process, grants cannot be used to conduct assessments themselves. ORD has no authority to compel grantees to respond to stakeholder input (a key component of the assessment process), and the timing or needs of specific assessments cannot determine the requirements of grant-sponsored research. For this reason, the STAR grants program focuses on two principal areas of global research *not covered by other USGCRP agencies*: (1) science to support assessments of consequences; and (2) human dimensions research.

Identifying specific topics for STAR RFAs: As noted earlier, the workshops held at the outset of each assessment are a critical step towards ensuring that the EPA Global assessments are made *measurably better* by the intramural research program and the STAR grant program. Amongst other objectives, they provide ORD an opportunity to refine and finalize planned RFAs for the STAR grant program that are needed to support the assessment activities. (The contributions from STAR that are identified in this MYP -- particularly in the areas of air quality and ecosystems – are a starting point for all workshop discussions.) The proposed RFAs will then be vetted and endorsed in the standard ORD Research Coordination Team (RCT) process.

Specific contributions required from STAR: This MYP identifies very specific contributions required from the STAR program to support the conduct of research in the focus areas – particularly in the areas of air quality and ecosystems. (See those sections for listings of potential STAR RFA topics). Examples of specific needs identified in this MYP include:

- Air quality focus area: Topics identified in this MYP for RFAs in the air quality focus area include:
  - downscaling global meteorology to regional meteorology;
  - developing models and methodology to address temporal and spatial scale issues for regional emissions drivers; and
  - development of techniques to link technological change to changes in regional and local emission inventories

  (The "Research Needs" workshop that took place in December 2001, which was coordinated with an OAR meeting on global modeling of ozone and particulate matter, refined the research topics to be pursued in the STAR program. Based upon discussions with the NCER, participants in the workshop assumed that some

of this work would be conducted by the STAR program using competitively awarded cooperative agreements.)

- Ecosystems focus area: ORD will work cooperatively with the academic community through NCER's STAR program to supplement ORD's internal research program.. The multi-year plan includes four APMs that reflect NCER's plans to review research supported under FY 1999 to FY 2002 STAR solicitations and to develop reports that will directly support APGs 2 and 5. RFAs will be developed in future years to address scenario development and tools to support them and to support other assessments of the impacts of global change on aquatic ecosystems. STAR RFA topics may address the following research gaps:
  - Ecologically relevant scenarios of land use change;
  - Pathways from ecological functioning to aquatic ecosystem goods and services;
  - Human responses to global change;
  - Effects of global change on the distributions of invasive species; and
  - Effects of changing temperature, precipitation, land use, UV radiation and sea level rise on multiple aquatic ecosystems.

- Production of reports. Production of reports by the National Center for Environmental Research (NCER) that review research supported under various STAR solicitations. For example, the ecosystem section of this MYP calls for NCER:
  - to review the research supported under the FY99 STAR solicitation to develop a report on the vulnerability of aquatic ecosystem services to climate change and variability;
  - to review the research supported under the FY00 STAR solicitation to develop a report on the interactions among human factors, climate, and physical processes on fire regimes, and the consequent impacts on aquatic ecosystem health; and
  - to review the research supported under the FY01 STAR solicitation on the interactions among land use change, UV radiation, and climate change/variability on aquatic ecosystems.

Opportunities to integrate across ORD goals and OAR activities. The goal of the Global Change Program is not to study current conditions and processes, but rather *to build upon ongoing research* -- some of which is conducted within other Goals -- to examine scenarios of future global change and the influence of climate, land use, and other factors on issues that are important to the public. ORD's air, water, ecosystems, and human health research programs provide monitoring, modeling, and process information that the Global Change Program can use to develop baseline scenarios to assess possible impacts of changes in climate and land use on human health, ecosystems, and socio-economic well-being in the United States. For example, ORD's Environmental Monitoring and Assessment Program (EMAP) program provided valuable data on baseline conditions of resources in the Mid-Atlantic region that contributed to the Mid-Atlantic Regional Assessment conducted as part of the First U.S. National Assessment. (Specifically, it enabled the assessors to answer the question, "What is the current status of resources in the region?", before examining how climate change might affect those conditions.)

Contributing ORD programs. ORD programs that contribute to the work conducted within the Global Program are EMAP[6], the Regional Vulnerability Assessment (REVA) land-use characterization work, and the research described in the new Water Quality MYP. The Global Program also draws upon work being conducted within the Program Offices (*e.g.,* OAR/OAQPS air quality data sets).

Examples of specific linkages to Goal 8: This MYP has already identified specific products from other ORD Goals that will contribute to the planned assessments. For example, as noted in the ecosystem section of this MYP, the ecosystem assessments will benefit if Goal 8 is responsive to Goal 6 needs by providing the following products:

- Assess the effects of global change on patterns and severity of marine (coastal) diseases.
- Report on the effects of land use change on aquatic ecosystems in the Mid-Atlantic region using linked water resources and land use change models.
- Investigate effects of land use change on aquatic ecosystems in the western U.S. and the Mississippi River Basin using linked water resource and land use change models.
- Investigate the effects of plant invasions on Laurentian Great Lakes wetlands.

Research being done on "public health outcomes" and "asthma" (Goal 8.2)[7] may have some relevancy to the work planned in health section of this MYP. Goal 8.3 Research planned on human behavior (social and economic) that will be supported through the STAR grants program may have some relevancy to the human dimensions research planned in this MYP.

Contributing OAR programs. Research conducted by OAR to improve emissions of ozone precursors and particular matter, and to develop and validate air quality models (Models-3/CMAQ) used to predict future concentrations of ozone and PM, also contribute significantly to the goals of the Global Change Research Program.

It is important to note that other ORD programs and Goal areas will, in turn, benefit from the work done within the Global Change Research Program (Goal 6). In addition to supporting Goal 6 (Global Risks), the Global Program's assessments will address issues outlined in Strategic Goal 1 (Clean Air), Goal 2 (Clean Water), and Goal 8 (Sound Science). The assessments will also support regulatory requirements of the Clean Air Act and Amendments, the Clean Water Act and Amendments, the Safe Drinking Water Act and Amendments, the Food Quality Protection Act, and the Federal Insecticide, Fungicide, and Rodenticide Act.

Consistency with ORD's Ecological Research Strategy. It is also important to note that conducting assessments of the consequences of global change at regional scales is consistent with ORD's *Ecological Research Strategy*. ORD's ecological research program strives to understand relative ecological risks in the context of multiple stressors, at multiple scales and multiple levels of biological organization. The integrative techniques articulated in the

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[6] See for example, the draft Ecology MYP for a discussion of the Environmental Monitoring and Assessment Program (EMAP) National Coastal Assessment.

[7] See the ORD Human Health *Research Strategy* and MYP.

Ecological Strategy suggest that research be conducted at "places" or regional-scale settings, such as the Mid-Atlantic, the Great Lakes or the Gulf Coast. EPA has long emphasized the importance of understanding environmental consequences from a regional perspective. Thus, the Global Program's *Research Strategy* and this MYP remain consistent with the Agency's strategic direction.

VI. FLOW DIAGRAMS AND TABLES OF GOALS AND MEASURES

❑ National Assessment Activities

Background

The Global Change Research Program has made a major commitment to and plans continued involvement in the National Assessment activities organized through the USGCRP. The National Assessment is an ongoing process with scheduled reports to Congress in FY04 and FY08 as mandated in the 1990 Global Change Research Act. The National Assessment emphasizes a process driven by the needs of stakeholders – persons best positioned to identify important information needs and optimal ways of responding.

EPA will continue to sponsor, on an ongoing basis, the Mid-Atlantic Regional Assessment, the Great Lakes Regional Assessment, the Gulf Coast Regional Assessment, and the Health Sector Assessment as part of the National Assessment process. This entire process is described in the new USGCRP *Strategic Plan*.

Long-term Goal: The long-term goal of the USGCRP National Assessment process is to determine the regional and national implications of climate change and variability for the people, environment, and economy of the United States in the context of other, non-climate (environmental, economic, and social) stresses.

National Assessment Activities ANNUAL PERFORMANCE GOALS AND MEASURES		**Fiscal Year**	**Lab/Center**
APG 1: Conduct a Health Sector Assessment and Regional Assessments of the potential consequences of climate change and variability in the Mid-Atlantic, Great Lakes, and Gulf Coast of the United States.		**2004**	**NCEA**
APM	Conduct 3 Regional and Health Sector Assessments	2002, 2003, 2004	NCEA
APM	Conduct "Lessons Learned" workshop to ascertain lessons from previous Regional and Health Sector Assessments about the conduct of a policy-focused assessment.	2002	NCEA

National Assessment Activities ANNUAL PERFORMANCE GOALS AND MEASURES		Fiscal Year	Lab/Center
APM	Conduct stakeholder workshops to elicit key assessment questions	2002	NCEA
APM	Develop common scenarios for use by all Regional Assessments and Health Sector Assessment – as well as the EPA intramural "focus-area" assessments.	2002, 2003	NCEA
APM	Conduct Value of Information exercise to identify key remaining research gaps.	2004	NCEA

National Assessment Activities ANNUAL PERFORMANCE GOALS AND MEASURES		Fiscal Year	Lab/Center
APM	Sponsor joint USGCRP Health Sector Assessment of potential consequences of climate change for the spread of infectious diseases.	2002, 2003, 2004	NCEA
APG 2: Conduct a Health Sector Assessment and Regional Assessments of the potential consequences of climate change and variability in the Mid-Atlantic, Great Lakes, and Gulf Coast of the United States.		**2008**	**NCEA**
APM	Conduct 3 Regional and Health Sector Assessments	2005, 2006, 2007, 2008	NCEA
APM	Conduct "Lessons Learned" workshop to ascertain lessons from previous Regional and Health Sector Assessments about the conduct of a policy-focused assessment.	2005	NCEA
APM	Conduct stakeholder workshops to elicit key assessment questions	2005	NCEA
APM	Develop common scenarios for use by all Regional Assessments and Health Sector Assessment – as well as the EPA intramural "focus-area" assessments.	2005, 2006	NCEA
APM	Conduct Value of Information exercise to identify key remaining research gaps.	2008	NCEA
APM	Sponsor joint USGCRP Health Sector Assessment of potential consequences of climate change for the spread of infectious diseases.	2005, 2006, 2007, 2008	NCEA

❑ Air Quality Activities

Background

EPA administers the Federal Clean Air Act, which requires the Agency to develop regulations and guidance to protect public health and ecological systems from the adverse effects of air pollutant emissions from stationary, mobile and fugitive sources. Title I of the Act requires EPA to establish National Ambient Air Quality Standards (NAAQS) for six pollutants including tropospheric ozone and particulate matter, and to revisit the standards every five years. EPA's Office of Air and Radiation (OAR) has the lead responsibility to implement and enforce the provisions of the Clean Air Act and to monitor and track air quality. ORD supports OAR's efforts to implement these standards by performing research to provide new information and tools that can be used to assess the effects of air pollutants and to identify, develop, and compare risk management strategies.

Improving air quality is a major goal of the Agency (see Goal 1) and there is increasing recognition that climate and air quality are closely coupled through atmospheric chemical, radiative, and dynamic processes. However, our understanding of many climate-chemistry linkages is limited and a better understanding is needed in order to improve the accuracy and confidence in estimates of future changes in climate and air quality, options for reducing adverse effects, and assessments of impacts.

While few studies have explicitly investigated the effects of global change on air quality, available evidence (e.g., weather-ozone studies, basic atmospheric chemistry, sensitivity of emissions to weather and land use, etc.) raises concerns that global change could adversely affect air quality. These studies suggest that global change (climate change and variability, UV-radiation, land use change) could have significant impacts on ambient air quality. Global climate change will likely result in changes in regional and local weather. Changes in meteorology may affect air pollution levels by altering 1) rates of atmospheric chemical reactions and transport processes; 2) anthropogenic emissions, including adaptive responses involving increased fuel combustion for power generation; and 3) biogenic emission rates from natural sources. UV radiation affects chemical activity in the troposphere and can have either positive or negative effects on ambient concentrations of air pollutants. Finally, patterns of land use can influence biogenic and anthropogenic emissions (e.g., increased urban sprawl may result in higher emissions from transportation sources or construction that lead to fugitive dust).

The focus of the Global Change Program from now through at least 2008 will be on ozone and particulate matter, although other pollutants will also be investigated as data and modeling capability permit. Ozone and particulate matter were selected as the focus as they are likely to be affected by global change, are of significant interest to the Agency, and are driven by processes that also drive emissions of greenhouse gases, allowing an examination of potential co-benefits.

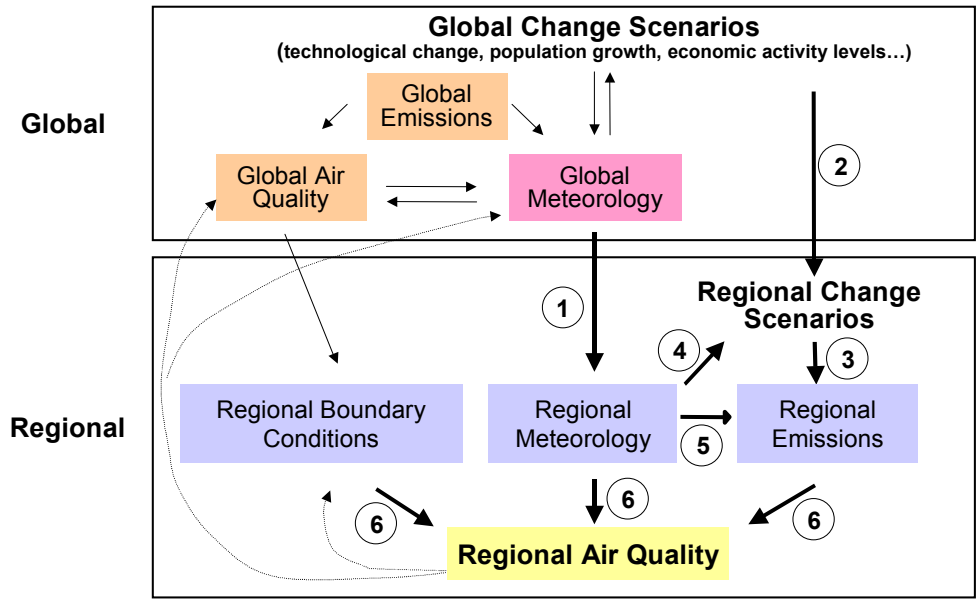
Long Term Goal

One of the long term goals of the Global Change Program is to provide the approaches, methods and models to quantitatively assess the effects of global change (climate change, land use change

and UV radiation changes) on regional air quality, identify technology advancements and adaptive responses and quantify their effect on, and feedback from, emissions and air quality, and develop and apply tools to integrate global change effects across environmental media. This goal will be accomplished through a series of projects building towards the ability to analyze the relationship between global changes and air quality. The research and assessments will initially focus on changes in the medium term (2040-2060) in order to allow for a strong climate signal (i.e., a relatively large change in climate). For each time period, a world without global change will be compared to a world with global change and these differences assessed. Further, the research must take into account other changes that would be expected to occur regardless of whether global change occurs. For example, the U.S. population and economy will continue to grow and change, technologies will continue to evolve, and human behaviors will continue to change over time and these changes must be included in the research and assessments. The research and assessments will also consider potential adaptation strategies and potential co-benefits and costs. Finally, as these assessments are completed, key knowledge gaps will be identified and will help guide consideration of research efforts in the following years.

The major components needed to conduct assessments of air quality changes due to global change, which forms the basis for the multi-year plan, are illustrated in Figure 3. The numbered

Figure 3. Components of an Integrated Air Quality Assessment Framework



components comprise the elements of the 10-year plan for EPA's GCRP. Reflecting the Program's emphasis on place-based regional assessments, the research and assessment activities will focus on "downscaling" to the regional level and developing regional-scale inputs (e.g., regional meteorology, regional emissions) for the air quality simulations. These regional-scale inputs also must take into account regional-scale interactions and changes through time (e.g.,

technological advancements).

The table below lists Annual Performance Goals and Measures for the air quality focus area. APMs that contribute to APG1 are represented by items 1 (meteorological downscaling) and 3 (technology assessment) of the Framework (Figure 1), as estimating regional emissions over longer time scales will require an evaluation of technological change (transportation sector) and how it affects regional emissions. APMs that contribute to APG2 include items 5 (e.g., regional emissions estimates need to be adjusted to account for changes in temperature) and 6 (e.g., regional inputs must be configured for input into an air quality modeling system and the air quality modeling system may need refinement and adjustment to accept these inputs). Finally, APMs that contribute to APG3 include refinement of items 1 (downscaling), 5 (adjusting regional emissions estimates for increased temperature) and 6 (air quality simulations). A second technology assessment focusing on the energy sector (item 3) will also be conducted. The three APGs will involve reporting results from research and assessment activities. The APMs are discussed in greater detail below, including the overarching question that the APM seeks to address.

Flow Chart of Annual Performance Goals

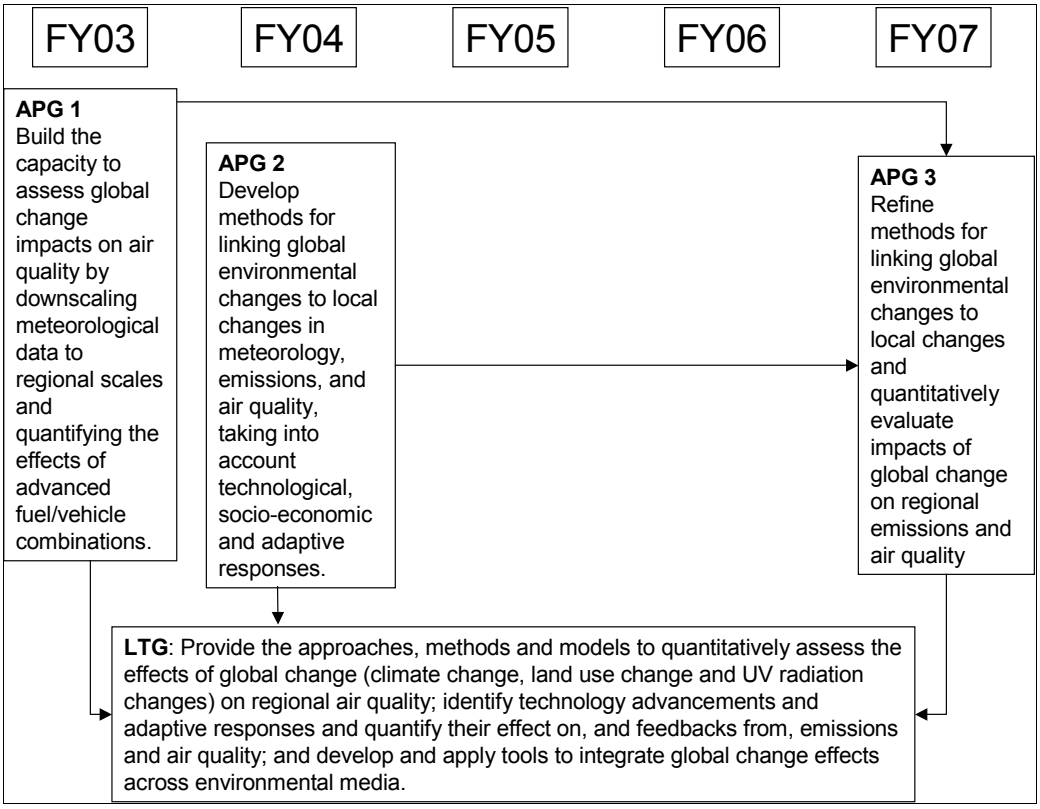


Figure 4 Air Quality

Discussion of Annual Performance Goals and Measures

Air Quality ANNUAL PERFORMANCE GOALS AND MEASURES		Fiscal Year	Lab/Center
APG 1: Build the capacity to assess global change impacts on air quality by downscaling meteorological data to regional scales and quantifying the effects of advanced fuel/vehicle combinations.		**2003**	**ORD**
APM	Meteorological Modeling: Report on research results of downscaling global climate scenarios (from Global Circulation Models) and development of database for input into emissions and air quality modeling.	2003	NCER/NERL
APM	Technology Assessment - Transportation: Investigate alternative fuels and vehicle technology scenarios to determine their influence on emission rates, including the time profile for the market penetration of these technologies. Report on results and development of database for input into emissions modeling systems (e.g., MOBILE6) to estimate future emissions.	2003	NRMRL
APG 2: Develop methods for linking global environmental changes to local changes in meteorology, emissions, and air quality, taking into account technological, socio-economic and adaptive responses (Preliminary Assessment)		**2004**	**ORD**
APM	Research Workshop Report: Convene a workshop of experts to review the framework and approaches proposed for assessing global change effects on air quality, identify key research needs, and develop a research agenda to address those needs.	2002	NCEA
APM	Statistical Analysis of Weather and Air Quality: Examine monitored concentrations of air pollutants and meteorological variables to identify possible relationships and generate hypotheses regarding the effects of global climate change on ambient concentrations.	2003	NCEA
APM	Emissions Model Development: Refine emission processor models so that estimates of future year emissions from point, area, and mobile sources based on global trends (e.g., population growth, economic growth, technology) and that take into account regionally-specific information can be made.	2003	NRMRL/NERL

Air Quality ANNUAL PERFORMANCE GOALS AND MEASURES		Fiscal Year	Lab/Center
APM	Air Quality Modeling: Prepare and refine CMAQ for linkage with global scale models (i.e., through regional boundary conditions and regional meteorology) and conduct scoping studies, and pursue relevant related modeling research questions.	2003	NERL
APG 3: Refine methods for linking global environmental changes to local changes and quantitatively evaluate impacts of global change on regional emissions and air quality.		**2007**	**ORD**
APM	Emissions Modeling Report: Refine estimates of future year emissions from point, area, and mobile sources for baseline and global change conditions.	2006	NRMRL/NERL /NCER
APM	Technology Assessment - Energy Sector: Examine changes/improvements in fossil fuel energy generation, alternative energy technologies, and market penetration of these technologies and incorporate into emissions modeling.	2006	NRMRL
APM	Air Quality Simulations: Conduct numerical air quality simulations using as input regional climate modeling, emissions modeling, and driver scenarios.	2007	NERL

Discussion of Performance Measures: Major Components

2003 Meteorological Modeling APM

Key Question: How will global climate change affect local and regional weather patterns which influence air quality? The impact of climate change on regional and local weather will be analyzed through the refinement of Global Circulation Model (GCM) output to the appropriate temporal and spatial scales. These results are needed for developing emissions inventories and as inputs to air quality modeling. For air quality simulations, the amount of input data necessary overwhelms statistical techniques and as a result, it will be necessary to have physically based, regional climate models which will take GCM outputs and produce results that can be used as air quality model inputs.

About 30 GCMs were evaluated in the most recent IPCC Working Group I report and results for several of them are available through the IPCC Data Distribution Centre. The Global Program will use existing GCM results developed by the international climate modeling community, including those used for the US National Assessment. The selection of GCM runs will be based on a number of criteria including peer review, assumptions about future emissions, whether the model has previously been used for downscaling, and whether the model runs have been archived and readily accessible. Several groups including Battelle Pacific Northwest National Laboratory, Argonne National Laboratory, the National Center for Atmospheric Research, and Pennsylvania State University have developed Regional Climate Models (RCMs) and have used

them to downscale Global Circulation Model (GCM) results.

2003, 2006 Emissions Modeling APMs
Key Question: What is the effect of global change on emissions, especially ozone precursors and particulate matter? Existing emissions inventories will be used to develop a reference (current) case scenario. Future baseline and global change emission scenarios will be developed using the reference case and emission projection systems, accounting for trends in driver scenarios, land use changes, and technology advances in transportation and energy systems. EPA's Office of Air and Radiation will be engaged as partners in developing scenarios for future air pollution programs and emission scenarios. Emissions models, such as MOBILE6 (for mobile source emissions) and BEIS3 (for biogenic emissions) will be used as appropriate to generate emissions scenarios. SMOKE, the emissions component of the air quality modeling system may also be used to investigate the effect of temperature on emissions.

2003, 2007 Air Quality APMs
Key Question: What is the quantitative effect of global change on ambient concentrations of ozone, fine particulates and other pollutants? EPA's Community Multiscale Air Quality (CMAQ) model will be used to explore the extent of the influence of global change on U.S. air quality in 2040-2060. CMAQ is not a single model or modeling system but rather contains three types of environmental modeling systems: meteorological, emission, and chemistry transport. The meteorological modeling system (Penn State/NCAR Mesoscale Model 5 (MM5)) provides descriptions of atmospheric motions; fields of pressure, moisture, and temperature; fluxes of momentum, moisture, and heat; turbulence characteristics; clouds and precipitation; and atmospheric radiative characteristics. The emission modeling system simulates trace gas and particulate emissions from point, mobile and area sources depending on surrounding meteorological conditions and socioeconomic activities. The chemistry transport modeling system simulates various chemical and physical processes that are thought to be important for understanding atmospheric trace gas transformations and distributions. CMAQ modeling system can treat multiple pollutants simultaneously at multiple scales (urban, regional and up to continental scales).

The focus of the 2003 APM is on scoping studies and CMAQ model preparation and refinement for linkage with global scale models. Relevant research needs will be identified and research activities initiated to the extent possible.

For the 2007 APM, CMAQ will be run for reference, baseline and global change simulations and results analyzed for air quality impacts. Model evaluation will be carried out for the reference case simulation using 1 x CO_2 climate runs and comparing to ambient observational data. Simulations of the medium term 2040-2060 air quality for the baseline and global change scenarios will be conducted and results compared to determine global change impacts on air quality.

Attention will also be paid to understanding and modeling the interactions of changing UV radiation on concentrations of tropospheric oxidants (ozone, etc.) and PM.

2002 Research Needs Workshop APM
Key Question: What are the key unknowns regarding climate change and air quality and which are the most important for assessing impacts? Assessing the effect of global environmental change on regional air quality poses new and unique challenges. The goal of the workshop is to review the proposed approach to assessing regional air quality in the US, identify research needs within each of the components and in linkages between components, and priorities for conducting the research. Examples of questions include:

- Are the boundary layer process representations in regional climate models sufficiently developed for driving air quality models, or will they need to be refined?
- With what accuracy and spatial resolution must regional climate information be provided to be useful for air quality simulations?
- How will potential changes in vegetation (e.g., CO2 enhancement, geographic distributions) due to climate change affect biogenic emissions?
- What are the likely changes in the spatial distribution in economic activities and how will this affect anthropogenic emission?
- What chemical species are provided by the global chemical models? How will regional models handle coarser species/spatial/temporal resolution from the global models? What if key species are missing from the global simulations?

Although many of these uncertainties are the subject of ongoing research at EPA or other federal agencies, there is not a specific focus on the effect of global change on these processes and how these in turn affect regional air quality. A workshop to bring together a diverse community including air quality modeling experts, regional climate modelers, biogenic emissions experts, etc. from government and academia to identify key research needs will be held to guide research activities in the longer term.

2003 Statistical Analysis APM
Key Question: What can air quality and climate monitoring data tell us about possible relationships and potential impacts? Measured concentrations of air pollutants and meteorological variables will be examined to identify possible relationships and generate hypotheses regarding the effects of global climate change on concentrations of tropospheric ozone and fine particulates. Relationships will be evaluated for several cities representing a range of climate and atmospheric conditions. This work will be done in collaboration with OAQPS.

2003, 2006 Technology Assessment APMs.
Key Question: How would technology advancements influence emissions of ozone precursors and particulates? Understanding the ongoing changes within technological systems is necessary to provide a solid foundation for the emissions modeling. The Country's technological infrastructure will be evolving dynamically over the next 50 years and these changes will influence emission rates, land use patterns, human system resilience and ecosystem health. In addition, our infrastructure may change to adapt to climate warming by using more resilient or reliable technology and methods. The focus of the technology assessment will be on two economic sectors that impact air quality – transportation and energy production. These two sectors account for roughly two-thirds of the pollutants that impact air quality for tropospheric

ozone and particulate matter and are areas where technological changes can be expected over the next few decades in response to fuel availability, fuel mix, higher cost of fuels, highway congestion, and other factors.

For the 2003 APM, technological change in transportation will be the major focus (although some work will be done on energy production). Alternative fuels and vehicle designs will be investigated to estimate their influence on emission rates. The time profile for the market penetration of these technologies will also be determined. This information will be incorporated into emissions models (e.g., MOBILE6) to estimate future emissions. (These emissions inventories will not be developed until a later date.) For the 2006 APM, there will be a greater emphasis on energy production. Changes/improvements in fossil fuel energy generation, alternative energy technologies, and market penetration of these technologies will all be examined and incorporated into emissions modeling.

Interactions with other Agencies and Offices

For several components in the figure, EPA's GCRP will rely on ongoing research, models, and assessments at other Agencies, including NOAA, DOE, DOT, NSF and NASA; EPA's OAR (e.g., for air programs, emissions inventories, etc.) and international organizations (e.g., IPCC) so that Global Program resources can be used most effectively. For example, the IPCC recently completed a Special Report on Emission Scenarios which includes information on global emission drivers. Similarly, DOE provides energy use forecasts to the year 2020 in the *Annual Energy Outlook* and EPA's Office of Air and Radiation develops inventories of air pollutant emissions for policy analyses and has recently begun work linking global air quality to regional boundary conditions. Future scenarios for a number of driving factors also were developed for the National Assessment. These existing analyses will be examined and used as a starting point for developing forecasts of emissions inventories. As appropriate, working relationships will be developed with these agencies and EPA offices.

ORD will also rely on research programs at other agencies on global climate (NOAA, NASA), global chemistry research (NOAA, NASA, NSF), and regional climate modeling (NCAR), especially for components in the Global section of the diagram. These agencies are members of the USGCRP, which will be the main vehicle for coordinating this effort with their ongoing research efforts. That is, EPA is a client for these agencies as we intend to use their research results and data in our applications research/assessments. EPA focus on regional air quality complements, but does not duplicate these efforts.

OAR is engaged in a number of efforts to better understand the linkages between climate change, international transport of air pollutants, and regional air quality. While the scope of OAR's interest is similar to the scope of ORD's work, OAR is focusing more on the effect of regional air quality control strategies on climate change and international transport (i.e., on the global air quality to regional boundary conditions linkages and feedback loops in Figure 1), as opposed to the effect of climate change on regional air quality. Furthermore, OAR is focusing on addressing short-term assessment needs using existing tools and methods. By focusing on long-term research and capacity building needs, ORD's efforts will complement and support those of OAR.

ORD also will work cooperatively with the academic community through NCER's STAR program. Topics for RFAs include downscaling global meteorology to regional meteorology, developing models and methodology to address temporal and spatial scale issues for regional emissions drivers, and development of techniques to link technological change to changes in regional and local emission inventories. The "Research Needs" workshop that took place in December 2001, which was coordinated with an OAR meeting on global modeling of ozone and particulate matter, refined the research topics that could be pursued in the STAR program. The following list includes topics of STAR program RFAs for air quality topics tentatively planned over the next ten years.

Tentative STAR RFAs for Air Quality Activities

FY 2002 **Anthropogenic Emissions Modeling —** Future US/state/regional development will have important implications for future air pollutant emissions. This RFA seeks proposals addressing one or both of the following two issues: 1) The effects of regional development, land use changes, and technological change in transportation on regional transportation systems, demands, and emissions; and 2) The effect of US/state economic development patterns (e.g., high/low growth, spatial relocation, decentralized, sector specialization, etc.) on emission sources (e.g., types, amounts, location, etc.).

FY 2003 **Global-Regional Chemistry and Climate Modeling** — Regional air quality simulations will need to account for the effects of global chemistry and global climate on regional chemistry and regional climate. This RFA seeks proposals addressing one or both of the following two issues: 1) The effect of future economic growth globally, especially regional development patterns for countries experiencing rapid change, on chemical boundary conditions for North America; and 2) The effect of future changes in global climate on regional climate (including an intermodel comparison of multiple downscaled GCM scenarios and uncertainty analyses).

FY2004 **Biogenic Emissions Modeling —** Biogenic emissions are important emission sources and are affected by global change. These changes should be incorporated into air quality simulations. This RFA seeks proposals addressing the effect of land use changes (e.g., due to regional development) and/or vegetation changes due to climate change on biogenic emissions.

FY2005 **Climate Change and Emissions Drivers —** Climate change may have important "feedback" effects on emissions through its impact on human behaviors. For example, warmer summers will likely increase use of air conditioners, resulting in increases in energy demands and (in the absence of additional controls) air pollutant emissions. This RFA seeks proposals addressing the effect of climate change on energy demands, population migration and development patterns, recreational travel, and resource flows for solar, wind, and hydropower, with subsequent effects on air pollutant emissions.

FY2006 **Spatial Diffusion of Technological Change —** There is a wealth of research on technological change and how it can affect emissions. However there has been little work on spatial diffusion patterns of technological changes. While unimportant for greenhouse gases, the spatial distribution of criteria air pollutants is critical for regional air quality. This RFA seeks proposals addressing the spatial diffusion of technologies, including barriers to diffusion and the role of economic incentives and growth, and the effect of differing patterns on criteria air pollutants emissions.

❑ **Ecosystem Activities**

The EPA Global Change Research Program will conduct assessments of the effects of global change on aquatic ecosystems. Human dimensions and the impacts of multiple stressors (including climate variability & change, land use change, and UV radiation) will be addressed in order to improve society's ability to respond to the future consequences of global change.

Ecosystem Focus Area Long Term Goal:
Build capacity to assess and respond to global change impacts on fresh water and coastal ecosystems. Ecosystem research and assessment activities are focused on four areas: aquatic ecosystems in selected watersheds, coastal aquatic ecosystems, climate change effects on invasive species distributions, and coastal and freshwater ecosystem services. These four activities are associated with five APGs:

- ❑ 2002 APG (APG 1): Complete problem formulation phase of an assessment of the consequences of global change on aquatic ecosystems at a regional level.

- ❑ 2004 APG (APG 2): Build the capacity to assess and respond to global change impacts on **aquatic ecosystems** by developing and applying methods for linking global changes to local changes in physical, chemical, biological and ecological conditions **in selected watersheds**.

- ❑ 2006 APG (APG 3): Build the capacity to assess and respond to global change impacts on **coastal aquatic ecosystems** by developing and applying methods for evaluating the effects of altered temperature and flow regimes, pollutant loads, sea level rise and altered UV exposure on estuaries and coral reefs.

- ❑ 2008 APG (APG 4): Build the capacity to assess and respond to risks posed by invasive species to aquatic ecosystems by exploring potential **impacts of climate change on invasive species distributions** through the application of different methods.

- ❑ 2010 APG (APG 5): Build the capacity to assess and respond to global change impacts on aquatic ecosystems by reviewing methods for evaluating **global change effects on coastal and freshwater ecosystem services** and exploring potential regulatory applications.

In addition, the Global Program maintains a UV-B monitoring network in urban and rural areas in partnership with the Office of Air and Radiation. As noted earlier, analysis of the data collected from EPA's UV-B monitoring network is required to support the ecosystem assessments (as well as informing the air quality assessment). The contributions of the UV-B monitoring network are captured in a sixth APG:

- ❑ 2010 APG (APG 6): Maintain UV-B monitoring network and evaluate data for UV-B impacts.

These annual performance goals are supported by research and assessment being conducted by NCEA, NHEERL and NERL, and under the STAR program (managed by NCER). ORD

scientists will develop and apply conceptual models that describe the mechanisms by which climate variability & change, land use change, and UV radiation affect freshwater and coastal aquatic ecosystems. These models will link global forces (e.g., climate variability and change, land use change, and UV radiation) to physical and chemical changes in these systems (e.g., altered water temperatures, changes in pollutant loads, altered flow regimes) and these physical and chemical changes to biological and ecological responses (e.g., coral bleaching). For example, watershed case studies being conducted by NCEA will link global change to changes in local processes such as altered stream temperature, streamflow, riparian vegetation, macro invertebrate communities, and fish. Research being conducted or supported by NHEERL, NERL and NCER will also contribute to this 2004 APG (see listing of APMs supporting the APGs, below). Research and assessment activities of at least 2 labs and centers form critical components for attaining each of the four goals. The leadership for the assessments under each of these goals is shared across labs and centers with NCEA leading the 2004, 2008 and 2010 assessments, and NHEERL leading the 2006 assessment, respectively. NERL research contributes to all 6 APGs. See the diagram below for a display of the projected outcomes and actions needed to reach the Ecosystem Focus Area Long Term Goal.

Flow Chart of Annual Performance Goals

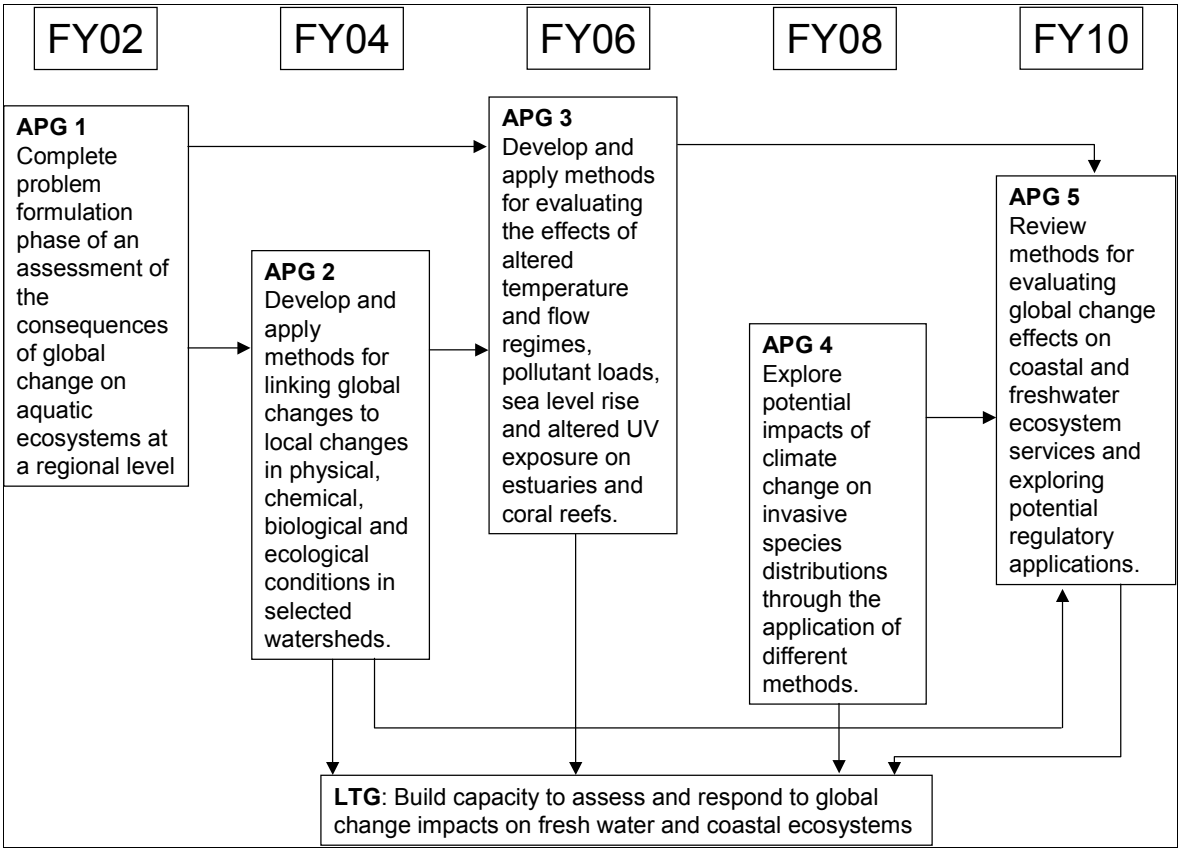


Figure 5 Ecosystem Health Focus Area

Discussion of Annual Performance Goals and Measures

Ecosystems ANNUAL PERFORMANCE GOALS AND MEASURES		**Fiscal Year**	**Lab/Center**
APG 1 - Complete problem formulation phase of an assessment of the consequences of global change on aquatic ecosystems at a regional level		**2002**	**ORD**
APM	Problem formulation report	2002	NCEA
APM	Publish reports supporting analysis of the comparative risk of UV radiation and habitat quality to amphibian populations across North America in support of USGCRP assessments.	2002	NHEERL
APG 2 - Build the capacity to assess and respond to global change impacts on aquatic ecosystems by developing and applying methods for linking global changes to local changes in physical, chemical, biological and ecological conditions in selected watersheds.		**2004**	**ORD**
APM	Build the capacity to assess global change impacts on aquatic ecosystem health by reviewing the research supported under the FY99 STAR solicitation to develop a report on the vulnerability of aquatic ecosystem services to climate change and variability.	2003	NCER
APM	Apply molecular tools to evaluate global change impacts on aquatic ecosystem health in selected watersheds.	2003	NERL
APM	Review the literature on the effects of climate variability and change, UV radiation and land use change to inform the assessment of the consequences of global change for aquatic ecosystems.	2003	NCEA
APM	Conduct research on global change impacts on fish in natural aquatic ecosystems by assessing the risks to fish from UV-mediated toxicity of polyaromatic hydrocarbons.	2004	NHEERL
APM	Report on the interactions among climate and human factors on fire regimes, and the consequent impacts on ecosystem health.	2005	NCER-
APM	Prepare a final report that summarizes the findings of selected watershed case studies of the vulnerability of aquatic ecosystems to global change and options available to managers to increase ecosystem resilience to these stressors.	2004	NCEA

Ecosystems ANNUAL PERFORMANCE GOALS AND MEASURES		Fiscal Year	Lab/Center
APG 3 - Build the capacity to assess and respond to global change impacts on coastal aquatic ecosystems by developing and applying methods for evaluating the effects of altered temperature and flow regimes, pollutant loads, sea level rise and altered UV exposure on estuaries and coral reefs.		**2006**	**ORD**
APM	Investigate the interactive effects of UV exposure and increasing temperature on coral bleaching.	2003	NHEERL
APM	Evaluate the exposure of coral ecosystems in the Florida Keys to UV radiation.	2003	NERL
APM	Assess the effects of global change on patterns and severity of marine (coastal) diseases - Goal 8 MYP	2006	NHEERL
APM	Assess the effects of changing temperature and flow regimes on aquatic communities in watersheds of the Great Lakes and/or Great Rivers.	2006	NHEERL
APM	Study the effects of changes in nutrient loadings on South Florida coral ecosystems.	2006	NHEERL
APM	Provide tools for assessing vulnerability of coastal ecosystem services in the Southeastern U.S. to changes in UV and global climate change.	2006	NERL
APM	Prepare a final report on the current and potential future impacts of global change (including UV radiation, temperature, and nutrient loadings) on coastal aquatic ecosystems.	2006	NHEERL
APG 4 - Build the capacity to assess and respond to risks posed by invasive species to aquatic ecosystems by exploring potential impacts of climate change on invasive species distributions through the application of different methods.		**2008**	**ORD**
APM	Review the literature on the effects of climate variability and change on the potential future distribution of nonindigenous invasive species, and consequent impacts on aquatic ecosystem health.	2005	NCEA
APM	Investigate the effects of plant invasions on Laurentian Great Lakes wetlands. Goal 8 MYP.	2006	NERL
APM	Conduct an expert workshop to identify critical research needs and to develop methods to build capacity to assess the effects of climate variability and change on the potential future distribution of nonindigenous invasive species, and consequent impacts on aquatic ecosystem health.	2006	NCEA

Ecosystems **ANNUAL PERFORMANCE GOALS AND MEASURES**		**Fiscal Year**	**Lab/Center**
APM	Prepare a final report on the impacts of global change on the potential future distribution of nonindigenous invasive species, and consequent impacts on aquatic ecosystem health.	2008	NCEA
APG 5 - Build the capacity to assess and respond to global change impacts on aquatic ecosystems by reviewing methods for evaluating global change effects on coastal and freshwater ecosystem services and exploring potential regulatory applications.		**2010**	**ORD**
APM	*Report on the effects of land use change on aquatic ecosystems in the Mid-Atlantic region using linked water resources and land use change models - Goal 8 MYP*	*2005*	*NERL*
APM	*Assess range changes of aquatic plants and animals accompanying climate, land use, and other changes in the Mid-Atlantic region using climate scenarios for the year 2050 .*	*2005*	*NERL*
APM	Build the capacity to assess global change impacts on aquatic ecosystems by reviewing the research supported under the FY01 STAR solicitation on the interactions among land use change, UV radiation, and climate change/variability on aquatic ecosystems.	2005	NCER
APM	Build the capacity to assess global change impacts on aquatic ecosystem services by reviewing the research supported under the FY02 STAR solicitation.	2006	NCER
APM	*Investigate effects of land use change on aquatic ecosystems in the western U.S. and the Mississippi River Basin using linked water resource and land use change models - Goal 8 MYP*	*2007*	*NERL*
APM	Provide molecular indicators for evaluating vulnerability of aquatic ecosystem services to global change.	2008	NERL
APM	Describe and validate coral index of biotic integrity (IBI) methodology that is sensitive to global change stressors.	2008	NHEERL
APM	Assess coral reef condition using IBI as indicator of effects of global change and local stressors.	2010	NHEERL
APM	Prepare a final report that reviews methods for evaluating global change effects on coastal and freshwater ecosystem services and exploring potential regulatory applications.	2010	NCEA
APG 6 - Maintain UV-B monitoring network and evaluate data for UV-B impacts.		**2010**	**ORD**

Ecosystems ANNUAL PERFORMANCE GOALS AND MEASURES		Fiscal Year	Lab/Center
APM	Complete Level 2 corrections and quality assurance for the UV network data. The data collected from the National UV monitoring network in the period 1996-2002 will have been screened, corrected where necessary, and made available to researchers on a centralized data base.	2003	NERL
APM	Report on geographic and seasonal variability in biologically effective UV reaching the surface of aquatic ecosystems in the US.	2004	NERL
APM	Assessment of the impacts of clouds and haze on UV exposure in Mid-Atlantic aquatic ecosystems.	2005	NERL
APM	Recommendations for optimization of the UV network for achieving environmental research goals. Includes analysis of the power to detect the effect of the Montreal Protocol and assessment of exposure at the regional scale.	2006	NERL

The FY02 APG - the problem formulation - establishes assessment endpoints, conceptual models, and analysis plans that will guide APGs 2, 3, 4 and 5. The problem formulation is geared toward developing information products that can be used to improve decision-making with respect to aquatic ecosystems.

The FY04 goal is to assess and respond to global change impacts on aquatic ecosystems by developing and applying methods for linking global changes to local changes in physical, chemical, biological and ecological conditions in selected watersheds. NCEA will contribute to this goal by conducting case studies in specific river basins and specific states, and by drawing from EPA-sponsored regional assessments to evaluate the effects of climate, land-use change, and UV radiation on different types of aquatic ecosystems. NCER will contribute through its support of the FY99 STAR awards and its review of the research conducted under this solicitation. The final product for this assessment will be a report that synthesizes the results of an overarching conceptual model of climate, land-use, and UV effects on aquatic ecosystems, and quantitative results from the individual case studies.

The FY06 goal is to assess and respond to global change impacts on coastal aquatic ecosystems by developing and applying methods for evaluating the effects of altered temperature and flow regimes, pollutant loads, sea level rise and altered UV exposure on estuaries and coral reefs. Activities that will support this goal include NHEERL's research on watersheds and coastal receiving waters in the Northeast region, NHEERL's research on the effects of temperature, UV radiation and nutrient loading on coral ecosystems (an important ecosystem sensitive to global change factors), and NERL's studies of impacts of global change on coastal ecosystem services. The final product for this goal will be an assessment report that evaluates the impacts of global change on coastal aquatic ecosystems.

The FY08 goal is to examine the potential impacts of climate change on invasive species distributions through the application of different methods. The activities that support this APG include a synthesis of the literature on the effects of climate change and variability on nonindigenous invasive species, a workshop, and NERL's research on plant invasions. The final product for this goal will be an assessment report on the impacts of global change on the potential future distribution of nonindigenous invasive species, and consequent impacts on aquatic ecosystem health.

In FY10, the APG is to assess and respond to global change impacts on coastal and freshwater ecosystem services and explore potential regulatory applications. NHEERL, NERL and NCEA will contribute to this goal through research on the effects of climate variability and change, land use change, and UV radiation on ecosystem services. Place-based ecological assessments will be conducted in the Northeast region, in watersheds of the Great Lakes and/or Great Rivers, in the Mississippi River Basin and the western U.S., in the Chesapeake Bay and its watersheds (see listing of APMs supporting this APG, above). Research to be conducted in response to NCER's FY01 and FY02 STAR solicitations will be reviewed and summarized by NCER to contribute to the final assessment report. In addition, activities in the Water Quality Focus Area contribute to the FY10 APG for the Ecosystem Focus Area. For example, activities to support the FY05 and FY08 APGs in the Water Quality Focus Area include an evaluation of the impacts of global change on pollutants and pathogen concentrations in surface and groundwater and a report providing states with a framework to evaluate whether global change could pose risks to their ability to meet biocriteria. The final product for this goal will be an assessment report on the impacts of global change on coastal and freshwater ecosystem services and potential regulatory applications.

Interface of Ecosystem Focus Area Activities with STAR Grants Program. ORD will work cooperatively with the academic community through NCER's STAR program to supplement ORD's internal research program.. The multi-year plan includes four APMs that reflect NCER's plans to review research supported under FY 1999 to FY 2002 STAR solicitations and to develop reports that will directly support APGs 2 and 5. RFAs will be developed in future years to address scenario development and tools to support them and to support other assessments of the impacts of global change on aquatic ecosystems. STAR RFA topics may address the following research gaps:

FY 2002 **Ecologically Relevant Scenarios of Land Use Change** — We need scenarios of sufficient resolution to project impacts at fine scales (e.g., watersheds). The detailed projections need to include critical variables that affect ecosystems. Knowing an area will have an "agricultural" land use is not sufficient. To model effects on aquatic ecosystems, knowledge of the amount and timing of fertilizer & pesticide applications, cultivation methods and other factors is critical. To understand impacts on critical small-scale habitats (such as riparian zones), you need to know about land use decisions immediately adjacent to those habitats. Projecting land use change into the distant future (20-50 or 100 years) is particularly difficult, and an important research gap. Research is needed to develop land use and land management projections that can be used to project impacts on freshwater and coastal aquatic

ecosystems. This RFA seeks proposals that will develop methods and information products in the Great Lakes, Gulf Coast, and Mid & Upper Atlantic regions of the U.S. Priority will be given to proposals that develop methods that can also be applied in other regions, and to proposals that produce ecologically relevant scenarios of land use change that can be used in assessments of the impacts of global change on aquatic ecosystems. Multiple spatial and temporal scales will need to be considered, with attention to cross-scale issues.

FY 2003 **Pathways From Ecological Functioning to Aquatic Ecosystem Goods and Services**— Humans depend upon aquatic ecosystems for a variety of ecosystem goods and services, but research is needed to fully elaborate the linkages between ecological functioning and ecosystem services. This RFA seeks proposals that (1) identify goods and services provided by aquatic ecosystems in particular places, (2) describe how investigators will trace these valued services back to the elements of ecosystem structure and functioning that support them, and (3) identify methods or models (quantitative or conceptual) for linking changes in ecosystem structure and functioning to changes in services.

FY 2004 **Human Responses to Global Change** — Humans will adapt to changing environment after change occurs (reactive adaptation) or in anticipation of changes (anticipatory adaptation). Modeling future impacts of global change on aquatic ecosystems requires an understanding of reactive adaptation. Providing decision-makers with useful information to protect aquatic ecosystem services requires evaluation of the effectiveness of anticipatory adaptation options. For example, will a changing climate result in redistributions of population, changes in land use and management, or adaptive strategies to protect human infrastructure from sea level rise or extreme events? How will changes in agricultural practices affect water quality? How will humans respond to changes in water availability and quality? What effects will these changes in human behavior have on aquatic ecosystems? Will current stresses from human activities be exacerbated or ameliorated? What options are available to protect highly-valued ecosystem services, are they likely to be adopted, and how effective would they be? This RFA seeks proposals that develop plausible scenarios of potential reactive responses and that evaluate the effectiveness of potential anticipatory strategies.

FY 2005 **Effects of Global Change on the Distributions of Invasive Species**— There are many sources of uncertainty to consider in projecting future distributions of invasive species. Because some invasives are tolerant of a wider range of climate and land use conditions than some native species, global change is an important factor to consider in developing projections. High levels of uncertainty make definitive predictions impossible, but scenario-based approaches for looking at the range of possible outcomes could be valuable to decision-makers. This RFA seeks proposals for evaluating the range of potential future distributions of invasive species that include using a common set of driver scenarios to compare performance (internal mechanisms, modeled outcomes, and characterization of uncertainty) of models

depending upon representation of underlying processes.

FY 2006 **Effects of Changing Temperature, Precipitation, Land Use, UV Radiation and Sea Level Rise on Multiple Aquatic Ecosystems**— Research is needed on specific aquatic ecosystem types (e.g., lakes, variety of freshwater and coastal wetlands, coral reefs, estuaries, rivers and streams) to understand the implications of global change for ecological structure and functioning. How will global change affect freshwater hydrology, water quality, and aquatic organisms? How will changes in upstream watersheds affect estuaries, and what will be the cumulative effects of upstream changes, changes in temperature & precipitation regimes and sea level rise? How will different types of wetlands respond to changes in hydrology, pollutant loads, and in the case of coastal wetlands - to sea level rise? Will wetlands be more susceptible to invasion by non-indigenous species as environmental conditions change? This RFA seeks proposals that will address existing gaps in knowledge of the pathways from global change to changes in ecological structure & functioning, and develop the linkages to explicitly model these pathways.

❑ Water Quality Activities

The objective of the Clean Water Act is "To restore and maintain the chemical, physical, and biological integrity of the Nation's waters."

Long Term Goal for Water Quality:
Determine the possible impacts of global change on water quantity and quality and the consequences for aquatic ecosystems and drinking water and wastewater systems. Develop adaptation strategies to increase the resilience of those systems.

Water quality is currently threatened by pollutants and pathogens (*e.g.*, nutrients, sediments, microbial pathogens, pesticides, and other toxic pollutants) and alterations in freshwater habitats, streamflow, and water temperatures. These threats to water quality could be exacerbated or ameliorated by climate change, climate variability or land-use change. The Global Change Program will assess the effects of global change on water quality, thus helping the Agency to fulfill its commitment to safeguard the Nation's waters. Specifically, the Program plans to assess the consequences of global change for:

1. water quality related to pollutants and microbial pathogens (2005), and
2. water quality related to biocriteria (2008).

The effects of global change on water quality and on aquatic ecosystems are interdependent. Assessments in these areas will be coordinated to leverage overlap in data, techniques, and assessment results. The **Biocriteria** assessment will build on the **Pollutants and Pathogens** assessment in the *Water Quality Focus Area*, and also on assessments completed in the *Ecosystem Focus Area* between 2002 and 2006. The **Ecosystem Services** assessment in the *Ecosystems Focus Area* will in turn build on this **Biocriteria** assessment.

Flow Chart of Annual Performance Goals

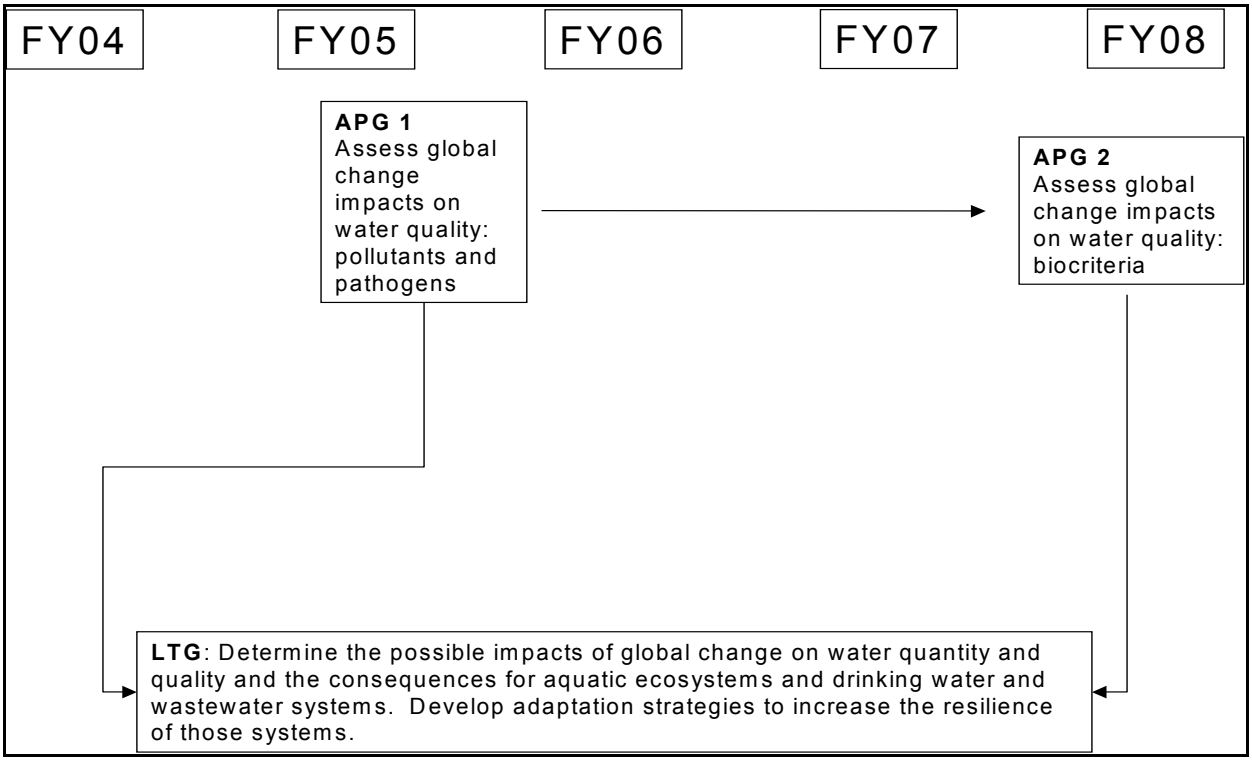


Figure 6 Water Quality

Discussion of Annual Performance Goals and Measures

Water Quality ANNUAL PERFORMANCE GOALS AND MEASURES		**YEAR**	**LAB/ CENTER**
APG 1: Assess global change impacts on water quality: pollutants and pathogens		**2005**	**ORD**
APM	Assessment: Drinking Water Infrastructure	2001	NCEA
APM	Assessment: Sea Level Rise	2001	NCEA
APM	Assessment of adaptation strategies for drinking water infrastructure	2002	NRMRL
APM	Assessment of pollutants and pathogens in surface waters	2003	NCEA
APM	Assessment of impacts on waste water treatment	2003	NCEA
APM	Report on relative impacts of land-use change and climate change	2004	NRMRL
APM	Final Report	2005	NCEA
APG 2 - Assess global change impacts on water quality: biocriteria		**2008**	**ORD**
APM	A peer-reviewed report on the impacts on water quality of interactions between land use change, UV radiation, and climate change & variability. This research is supported under the FY 01 solicitation.	2005	NCER
APM	Report on biocriteria: potential sensitivity to global change and adaptation strategies	2005	NCEA
APM	Case studies for rivers and streams	2006	NCEA
APM	Case studies for 2nd aquatic ecosystem type (e.g., lakes or coral reefs)	2007	NCEA
APM	Case studies for rivers and streams	2008	NRMRL
APM	Final report: describe framework for states to evaluate biocriteria vulnerability to global change, options for adaptation	2008	NCEA

APG 2005: Pollutants and Pathogens. Global change could alter the concentrations of pollutants and pathogens in surface and ground waters. These changes could have ramifications for aquatic ecosystems, human recreational uses, and drinking water. The Global Change Program will examine the ability of public water systems to respond to altered drinking water and waste water treatment needs due to global change. In addition, the availability of adaptation options to protect surface waters for aquatic ecosystems and for recreational uses will be explored.

Nutrients, microbial pathogens, pesticides and other toxins pose a variety of risks to humans and aquatic life. In addition, saltwater intrusion poses a risk to coastal drinking supplies. In 1999, about 10% of public water failed to meet health-based drinking water standards. Many of these violations were related to microbial pathogens. EPA's Science Advisory Board concluded in 1990 that exposure to microbial contaminants such as bacteria, viruses, and protozoa (e.g., *Giardia lamblia* and *Cryptosporidium*) was likely the greatest remaining health risk management challenge for drinking water suppliers (http://www.epa.gov/OGWDW/mdbp/mdbp.html). In 2000, the EPA reported that over 20,000 water bodies have been identified as polluted. Nutrient pollution is a particularly serious problem.

The Global Change Program's assessment of pollutants and pathogens will focus on four aspects of water quality: drinking water infrastructure, wastewater treatment, surface water quality, and surface water/groundwater interaction. The Global Change Program's assessment will assess the consequences of global change for these aspects, and will examine the potential for adaptive responses to protect drinking and surface waters for human and ecosystem uses. The interconnectedness of the four aspects may provide opportunities to look at multiple benefits associated with watershed protection strategies.

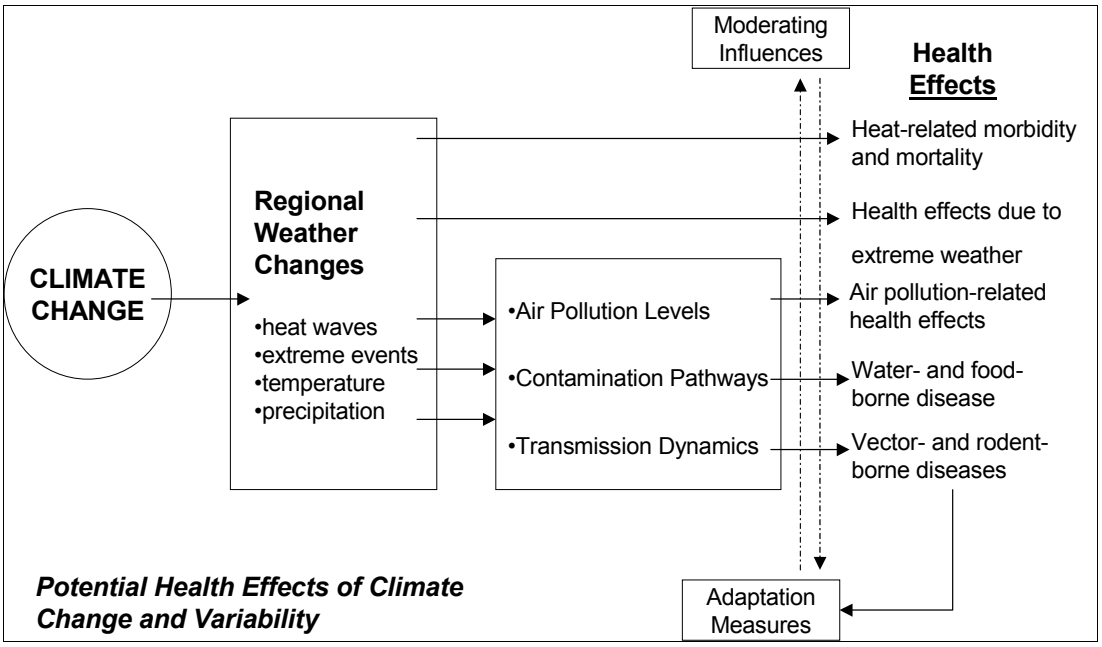
APG 2008: Biocriteria. To comply with the Clean Water Act's requirement that state water quality standards shall consist of designated uses and the criteria for protecting such uses (Section 303(c)(2)(A)), and with the Clean Water Act objective (Section 101(a)) of restoring the biological integrity of the nation's waters, EPA is working with states to develop biocriteria. The Water Quality Criteria and Standards Program is pursuing the development of biocriteria as an improved basis for aquatic life protection because "biocriteria and bioassessments will help to identify ... the cumulative impacts of all stressors within a water body" (EPA 1998a, p. 33).

The ability of states to attain biocriteria will be influenced by changes in climate, climate variability, land-use and UV radiation. These global changes could alter water temperatures, stream morphology, stream flow and lake levels, UV effects on aquatic life, pollutant concentrations in water bodies, and sedimentation. The Global Change Program will develop a framework that states can use to assess the effects of global change on their ability to meet biocriteria and to identify adaptation strategies to cope with global change. Detailed studies will be conducted in 2-4 states that have established biocriteria for streams and wadeable rivers. Later detailed studies will expand the framework to a second aquatic ecosystem. The final step of the analysis will evaluate the applicability of the framework to states that were not included in the detailed studies.

❑ Human Health Activities

Health is affected by a variety of social, political, economic, environmental, and technological factors. The health effects associated with global change (such as changes in climate or in land use) may be wide-ranging and occur via pathways of varying directness and complexity and against a backdrop of shifting demographics, new technologies, changes in human behavior, and evolving medical care and public health protection systems. All of these factors affect human health, either directly or indirectly through interactions with other stresses.

The Global Change Program will develop integrated health assessment frameworks that incorporate the effects of multiple stresses, their interactions, and potential adaptive responses. In addition to assessment activities, scientific research on the relationships between climate change, climate variability, land-use change, and health outcomes will be required to inform the assessment process. All of the research and assessment activities will be conducted as part of the USGCRP's Health Sector Assessments and will be organized around public-private partnerships. Assessments also must account for human responses to global change impacts. Adaptive

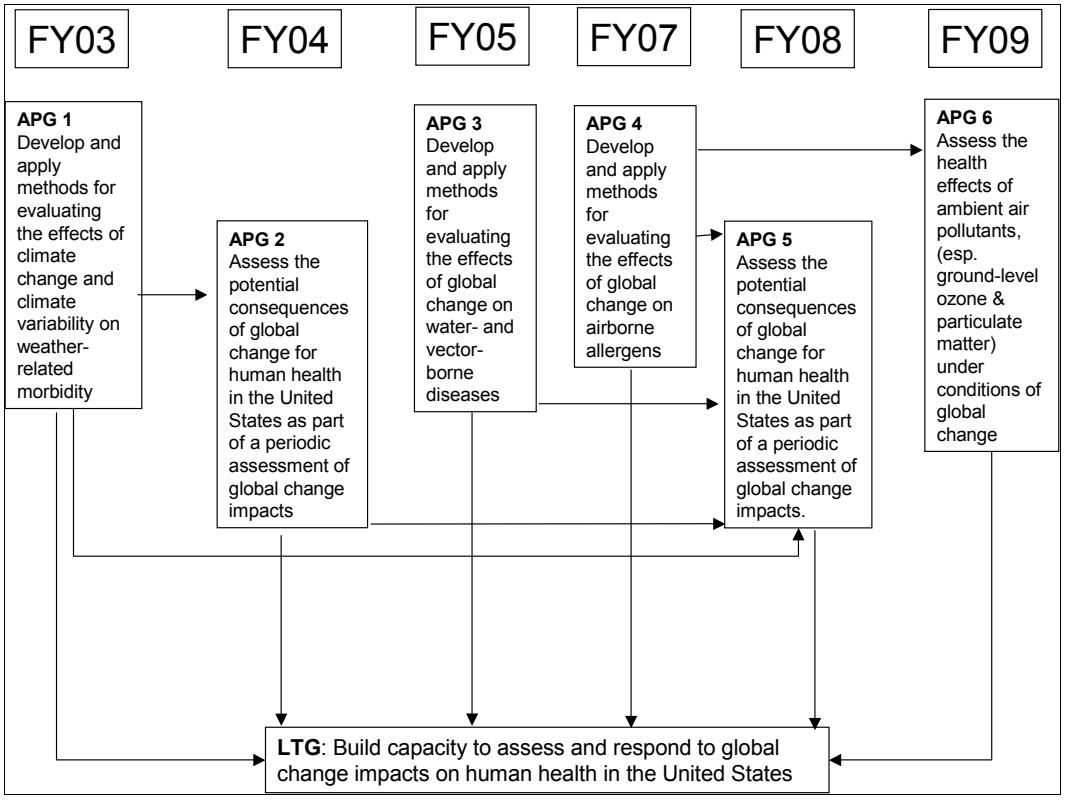


measures — such as better ecosystem management; improved public health monitoring, surveillance, and control programs; disaster preparedness; and the wider use of protective technologies (e.g., sun screen, water purification, and vaccination) — may mitigate the effects of global change. Risks to health from technological advancements also must be considered. For example, increased use of air conditioning protects against heat stress but also may increase emissions of greenhouse gases and criteria air pollutants that have adverse health effects. Some adaptation strategies will yield ancillary benefits, which also must be understood.

The Global Change Program's research and assessment activities will focus on the following analyses of potential health impacts associated with global change. These activities form the APGs for the human health portion of the Global Program. The reporting year for each APG is indicated in parenthesis. The reporting year is not intended to signal the conclusion of work related to the APG but rather marks the time when synthesis reports are produced.

- Assessment of the consequences of climate change and climate variability on human health and subsequent assessments of the impacts of global change on human health through the Second (FY 2004), and Third (FY 2008) USGCRP National Assessments of the Consequences of Global Change for the United States;
- Develop and apply methods for evaluating the effects of climate change and climate variability on weather-related morbidity (FY 2003);
- Develop and apply methods for evaluating the effects of global change on water- and vector-borne diseases (FY 2005);
- Develop and apply methods for evaluating the effects of global change on airborne allergens and associated morbidity (FY 2007);
- Assess the health effects of ambient air pollutants, especially ground-level ozone and particulate matter, under conditions of global change. (FY 2009).

Flow Chart of Annual Performance Goals



Discussion of Annual Performance Goals and Measures

Human Health Annual Performance Goals and Measures		Lab/Center	Fiscal Year
APG1: Develop and apply methods for evaluating the effects of climate change and climate variability on weather-related morbidity		**NCEA**	**2003**
APM	Assess the effects of heat and cold morbidity in vulnerable populations (children, elderly)	NCEA	2003
APM	Examine the impact of inclement weather on accidental injuries, especially from slips and falls and from motor vehicle crashes, and assess the impact of climate change on injury incidence	NCEA	2002
APM	Estimate the effects of extreme heat on emergency department and hospital admissions	NCEA	2003
APM	Evaluate the relationship between violent crime and weather variability and project the impact of climate change on that relationship	NCEA	2002
APG2: Assess the potential consequences of global change for human health in the United States as part of a periodic assessment of global change impacts.		**NCEA**	**2004**
APM	Compile a review of the direct and indirect impacts of global change on human health in the U.S. and evaluate the feasibility of adaptation strategies	NCEA	2004
APG3: Develop and apply methods for evaluating the effects of global change on water- and vector-borne diseases		**NCEA**	**2005**
APM	Assess the effects of global change on vector-borne diseases	NCEA	2003
APM	Assess the effects of global change on water-borne diseases	NCEA	2004
APM	Examine the effects of global change on the quality of life (or nuisance) impacts of vectors. Estimate the costs of those nuisance effects.	NCEA	2005

Human Health Annual Performance Goals and Measures		Lab/Center	Fiscal Year
APG4: Develop and apply methods for evaluating the effects of global change on airborne allergens and associated morbidity		**NCEA**	**2007**
APM	Estimate the impact of airborne allergens, especially associated with medical expenditures and lost productivity.	NCEA	2005
APM	Evaluate the mechanisms through which global change may effect the presence and severity of airborne allergens.	NCEA	2006
APG5: Assess the potential consequences of global change for human health in the United States as part of a periodic assessment of global change impacts.		**NCEA**	**2008**
APM	Compile a review of the direct and indirect impacts of global change on human health in the U.S. and evaluate the feasibility of adaptation strategies	NCEA	2008
APG6: Assess the health effects of ambient air pollutants, especially ground-level ozone and particulate matter, under conditions of global change.		**NCEA**	**2009**
	Update dose-response function in 812 health effects model	NCEA	2007
	Run model simulations on ambient air pollutants, especially ozone and particulate matter change, to estimate changes in health effects	NCEA	2008

APG1 in 2003: Develop and apply methods for evaluating the effects of climate change and climate variability on weather-related morbidity

Preliminary analyses of weather-related mortality have been conducted. Though certain issues associated with weather-related **mortality** require further study (for example, the degree to which people can acclimatize to increased warmth), important progress is expected in the study of climate change and weather-related **morbidity**. A number of heat-related morbidity effects need to be investigated, including: heat-related symptoms that do not require a visit to a medical provider (e.g., nausea, cramps, headache, and syncope) and emergency room visits or hospital admissions for heat-related illnesses.

The direct effect of weather on human health goes beyond temperature extremes. Climate change may also affect precipitation (rain and snowfall), precipitation intensity (flash flooding), and extreme events such as severe ice storms and hurricanes. Land use changes, such as increased urbanization in flood plains and coastal areas, may exacerbate vulnerability to climatic change. Potential health effects from inclement or extreme weather include deaths, injuries, and illnesses (e.g., increased mortality associated with blizzards and snowfalls). Secondary health effects resulting from economic losses and natural resource devastation in the aftermath of extreme weather can be significant and are largely unexplored.

Key questions related to weather-related morbidity have been identified, including:

- What is the quantitative relationship between heat stress and cold stress and illnesses, particularly in vulnerable populations (e.g., children)?
- How will the incidence of these illnesses change as the earth warms?
- How are temperature-related illnesses modified by personal characteristics and behaviors?
- How are changes in weather patterns (e.g., inclement weather, snowfall, storms) associated with accidents and injuries?

The assessment of weather-related morbidity will consists of four component activities or APMs, including evaluation of

(1) heat-related morbidity in children;
(2) the relationship between weather variability and violent crime and projected changes in incidence related to climate change;
(3) the effects of inclement weather on accidents and injuries and projected changes in incidence associated with climate change; and
(4) the effects of extreme heat on emergency room visits and hospital admissions.

APG2 in 2004 and APG5 in 2008: Assess the potential consequences of global change for human health in the United States as part of a periodic assessment of global change impacts.

All proposed research and assessment tasks related to human health endpoints support the USGCRP National Assessment process. The first National Assessment's Health Sector work identified a number of research needs that have been incorporated in the selection of health impacts slated for study by EPA. The National Assessments will be conducted as a public-private partnership involving multiple institutions and multiple disciplines.

APG3 in 2005: Develop and apply methods for evaluating the effects of global change on water- and vector-borne diseases.

Water-borne Diseases. An assessment of water-borne diseases will focus on two topics: (1) water-borne diseases spread through contaminated drinking water or recreational water; and (2) coastal/marine health issues, including harmful algal blooms. The goal is to understand the role that global change, such as land use change and climate change, plays in water-borne diseases. There are many determinants of these types of diseases, including poor sanitation, poor erosion control, application of agricultural fertilizers, and coastal sewage release. In addition, many cases of water-borne diseases go unreported. This contributes to the lack of understanding of the full extent of problems caused by contaminated water. Nonetheless, water contamination appears to be an important environmental risk and poses a risk management challenge for water suppliers.

Global change may further exacerbate the health risks associated with these factors through more intense precipitation events, more droughts, and increased water temperature. Increases in flooding and water shortages can impair local sewerage, degrade water quality, and alter the potential risks of diarrheal and dysentery epidemics. Other environmental factors — including sunlight, pH, ocean currents, winds, sea surface temperatures, and nutrients — can influence algal production. Algal blooms can effect the transmission of some bacterial diseases such as *V.*

vulnificus and *V. parahemolyticus*. Algal blooms also are associated with biotoxin contamination of fish and shellfish.

Key questions identified for water-borne diseases include:
- Which water-borne diseases are sensitive to climate and land-use change?
- Which aspects of climate and land-use change exert the most important effects on water-borne disease risks?
- Based on what we know about potential changes in the hydrological cycle, water temperatures, frequency of extreme conditions, sea-level rise, and land-use changes, how are water-borne disease risks likely to be affected?
- How effective and costly are adaptive measures designed to manage adverse health impacts associated with water-borne diseases?

Vector-borne Diseases. There is an extensive literature on the relationship between meteorological variables, especially temperature, and various aspects of vector-borne disease transmission (e.g., parasite development, biting behavior, reproduction rates, bioclimatological thresholds). There also have been efforts to develop integrated systems-based models, including theoretical constructs that describe the various components in the system, relationships between components (e.g., vectorial capacity), and the best available information from field and laboratory studies to estimate parameters describing these relationships. With a few exceptions, existing models have not been linked to global changes, such as climate scenarios from General Circulation Models (GCMs). Few models include human dimensions or explicitly consider costs and the implications of medical interventions.

Key questions identified for vector-borne diseases include:
- Based on what we know about changes in climate and land use, how are habitats of disease-carrying vectors (terrestrial, freshwater, marine) likely to be altered?
- How can existing models be utilized to estimate potential changes in future disease risks?
- How effective and costly are adaptive measures designed to manage adverse health impacts associated with vector-borne diseases?
- How is quality of life or nuisance effects impacted by variations in vector populations mediated by changes in climate or land-use?

The assessment of global change on vector- and water-borne diseases consists of three component activities, including examining the effects of global change

(1) on vector-borne diseases;
(2) on quality of life impacts associated with human exposure to vector populations; and
(3) on water-borne diseases.

APG4 in 2007: Develop and apply methods for evaluating the effects of global change on airborne allergens and associated morbidity

Precipitation change, temperature, and land use change all impact the growth and circulation of airborne allergens. People with allergic asthma who are sensitive to tree, grass or weed pollen may have trouble during peak pollen seasons. Meteorological or land use factors that change the extent and severity of the pollen season may prove problematic. For instance, rain can impact

the pollen season in a good or a bad way. Rain can be bad as it helps everything grow, including pollen-generating plants. While a slow, prolonged rain can wash the pollen out of the air and reduce pollen counts. Warm, humid weather is also associated with increased asthma attacks, probably related to increased growth of molds. Clearly, asthma and other pulmonary conditions are vulnerable to airborne allergens that may be affected by global change-related stressors. The assessment of global change on airborne allergens consists of two component activities:

(1) Evaluation of the mechanisms through which global change may effect the presence and severity of airborne allergens.

(2) Estimation of the impact of airborne allergens on medical expenditures and productivity.

APG6 in 2009: Assess the health effects of ambient air pollutants, especially ground-level ozone and particulate matter, under conditions of global change.

Global change may affect exposures to air pollutants by affecting: (1) weather, and thereby local and regional pollution concentrations; (2) UV radiation, and thereby local and regional pollution concentrations, especially tropospheric ozone; (3) anthropogenic emissions through adaptations involving increased fuel combustion for power generation; and (4) biogenic emissions. In addition, global change may increase or decrease the amount of time individuals spend indoors, resulting in changed exposure to indoor pollutants that are, in some cases, more hazardous than ambient conditions. Health impact assessments of global change-induced changes in air pollution levels will rely on the substantial body of scientific literature, on ORD expertise, and on the air quality assessments of the effects of global change on tropospheric ozone and particulate matter conducted by the Air Quality Working Group in the Global Change Research Program.

The key research and assessment questions for air pollution-related health effects (especially for tropospheric ozone and particulate matter) under conditions of global change include:

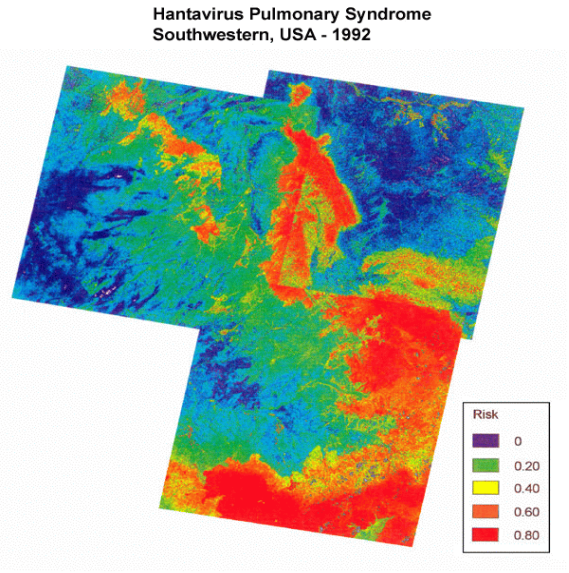
- How do changes in climatic conditions and changes in anthropogenic and biogenic emissions associated with climate and land-use change affect human exposures to ground-level ozone and particulates?
- What health effects are associated with ambient air pollutant exposures mediated by climate and land-use changes?
- How would societal changes and technology advancements adopted either to respond to climate change or reduce harmful ambient levels of air pollutants affect health risks? What combinations of these human adaptive responses would provide the greatest combined risk reduction (co-benefits) at the lowest cost?

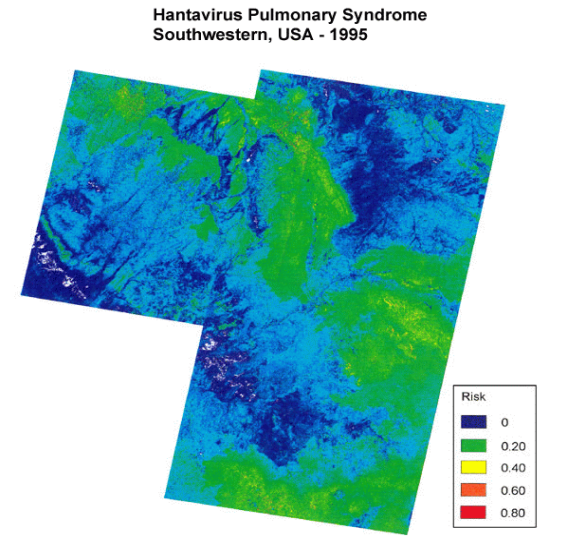
BOX 1

Developing Methods for Disease Prevention: Hantavirus Pulmonary Syndrome in the Southwest U.S.

In 1993, a disease characterized by acute respiratory distress with a high death rate (>50%) among previously healthy persons was identified in the southwestern United States. This disease, hantavirus pulmonary syndrome (HPS), was traced to a virus maintained and transmitted primarily within populations of a common native rodent, the deer mouse.

After the outbreak occurred, researchers hypothesized that it was due to environmental conditions and increased rodent populations caused by unusual weather associated with the El Niño Southern Oscillation (ENSO) in 1991-92. It was suggested that a cascading series of events from weather (unseasonable rains in 1991 and 1992, and the mild winter of 1992), through changes in vegetation, to virus maintenance and transmission within rodent populations, culminated in changes in human disease risk from HPS.





An EPA-sponsored study at The Johns Hopkins School of Hygiene and Public Health explored this hypothesis by comparing the environmental characteristics of sites where people were infected with those at sites where people were not infected.

This research found that high risk areas for Hantavirus Pulmonary Syndrome can be predicted based on satellite generated risk maps of climate-dependent land cover over 6 months in advance. Predicted risk paralleled vegetative growth, supporting the hypothesis that heavy rainfall from El Niño in 1992 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 1992-93. Trapping mice in the field (collectors blinded to risk category), validated these satellite generated risk maps with mouse populations directly related to risk level, with a correlation factor over 0.90. Risk classification also was consistent with the numbers of HPS cases in 1994, 1996, 1998, and 1999. These methods, developed in partnership

with CDC and the Indian Health Service are already being implemented for disease prevention in the southwest by the U.S. Department of Health and Human Services.