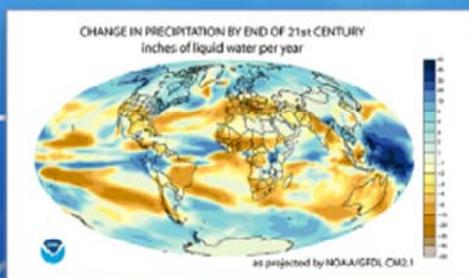


# Integrated Modeling to Characterize Climate Change Impacts and Support Decision Making

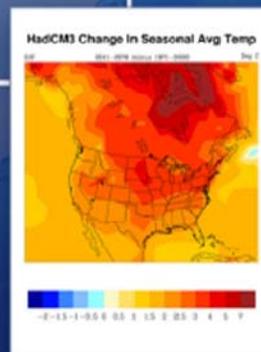
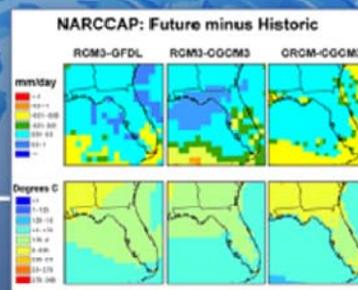
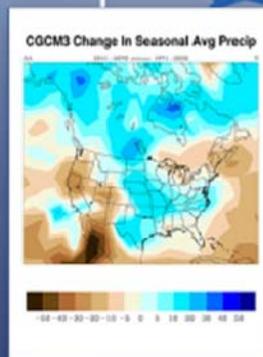
February 1 - 2, 2011

Atlanta, GA



“We envision a resilient, healthy, and prosperous Nation in the face of a changing climate.”

- Progress Report of the Interagency Climate Change Adaptation Task Force, October 5, 2010



### Overview:

This report provides a summary of the discussions and proceedings of the workshop on “Integrated Modeling to Characterize Climate Change Impacts and Support Decision Making” The workshop took place on February 1-2, 2011 in Atlanta, GA and attracted approximately 120 participants. This workshop is the second of a series of symposia and workshops in the Council for Regulatory Environmental Modeling (CREM) Integrated Modeling Forum. The goals of the workshop were to: (1) bring together empirical scientists, modelers, economists, social scientists, and public policy experts to help ensure that model development aligns with climate change policy design, management, and decision making needs; (2) connect the climate change data producers with the climate change data users and make existing resources accessible to stakeholders in the field; and (3) highlight successful case studies of intra-Agency, interagency, academic, public, and private sector systems analysis and integrated modeling for climate change impacts. Discussions were designed to identify the challenges and opportunities represented by specific decision making needs and will chart a path forward for the development and use of integrated modeling to respond to those needs.

### About EPA’s Council for Regulatory Environmental Modeling (CREM):

Given the crucial role that models play in informing regulatory decision making, the EPA established the Council for Regulatory Environmental Modeling (CREM) in 2000 in an effort to improve the quality, consistency and transparency of the models for environmental decision making. The CREM is a cross-Agency council of senior managers charged with developing practices to ensure that EPA's use of environmental models is consistent and defensible.

### About the CREM’s Integrated Modeling Program:

The CREM Integrated Modeling Program includes a set of activities that support CREM Strategic Goal 4 (Enhancing Integrated Modeling for Environmental Decision Making: to bridge disciplines and foster a more integrated and joined up thinking approach to modeling in environmental management and advance integrated modeling science and technology). These activities will help to facilitate the development of a strong integrated modeling capacity that supports environmental decision making at EPA.

**Note:** Development of the symposium report was led by SCG, Inc., under contract to the U.S. Environmental Protection Agency. (Some individual EPA experts contributed specific discussions on topic(s) for which he or she has scientific expertise or knowledge of current Agency practice). The views expressed are those of the authors and do not necessarily reflect the views or policies of the EPA and should not be construed as implying EPA consent or endorsement.

DAY 1: FEBRUARY 1, 2011

### ***Workshop Introduction/Welcome***

**Michael Hiscock, EPA, Office of the Science Advisor**

Dr. Michael Hiscock welcomed participants to the meeting and noted the excellent diversity in participants' backgrounds, experience, and geography. He reiterated the goals of the workshop and thanked the planning committee. This workshop is hosted by the EPA CREM, which is a cross-EPA council of senior leaders whose mission is to promote consistency and consensus among environmental model developers and users. This workshop will highlight tools and the process of successfully using integrated modeling to support decision making. The poster session is an integral part of the workshop and will help facilitate networking.

### **SESSION ON TAKING ACTION ON CLIMATE CHANGE FROM A SENIOR DECISION MAKING PERSPECTIVE**

#### **Regional Perspective**

***Regional Perspective on Climate Change Adaptation: Issues and Decision Support Needs***  
**Beverly Banister, EPA, Region 4**

Ms. Beverly Banister thanked the planning committee and Region 4 staff for their efforts in planning the workshop and the participants for attending. The goal is for the workshop and the tools discussed to be useful for agencies, key stakeholders, and the public. The focus of her talk is Region 4's interest in integrated modeling and climate change adaptation to support regional decision making efforts. The southeast is vulnerable to climate change impacts because it has a long and low-lying coastline and a large at-risk population. The region is prone to frequent natural disasters and has significant forestry, agriculture, infrastructure, tourism, cultural, economic, and ecosystem resources at risk. The region contains 33 percent of the United States' coterminous estuaries and nearly 30 percent of all U.S. wetlands. The Gulf Coast and the Atlantic Seaboard have experienced significant sea level rise during the past 50 years, with a rise of more than 8 inches in some areas. The rate of sea level rise is increasing, which will result in loss of drinking water sources and have negative impacts on infrastructure (e.g., ports). Assessments by the U.S. Army Corps of Engineers indicate that Florida possibly could be inundated by water by the end of the century. The potential implications are serious, interrelated, and interdependent. It is necessary to use a system approach to evaluate climate change in the region and develop an adaptive approach that considers all factors. Integrated modeling and holistic approaches are needed by decision makers so that they can make informed decisions.

On October 14, 2010, the Climate Change Adaptation Task Force, co-chaired by the White House Council on Environmental Quality, the Office of Science and Technology Policy, and the National Oceanic and Atmospheric Administration (NOAA), released its interagency report outlining recommendations to the President regarding how federal agency policies and programs can better prepare the United States to respond to the impacts of climate change. The report recommends that the federal government implement actions to expand and strengthen U.S. capacity to better understand, prepare for, and respond to climate change. The report provided a number of policy goals and recommended actions for the federal government to undertake to promote adaptation work in the United States. The task force developed guiding principles for adaptation, which are to adopt integrated approaches, prioritize the most climate-vulnerable people, places and infrastructure, use the best available science, build strong partnerships,

apply risk management methods and tools, apply ecosystem-based approaches, maximize mutual benefits, and continuously evaluate performance.

The Southeast Natural Resource Leaders Group (SENRLG) has established a strong partnership to preserve, protect, and restore lands. SENRLG partners currently are developing a decision-support tool that will help them to support partnerships that are working to conserve, restore, and protect lands important to the long-term sustainability of the region's ecosystem services. This will help SENRLG provide federal leadership and direction on how to best leverage limited federal resources in support of adaptive planning at multiple scales. Integrated modeling will be used by the partner agencies to coordinate multiple datasets that reflect the important mission objectives of the agencies, present a vulnerability assessment of the risk of expected climate stressors in the region, and help target resources from an integrated perspective. The best science and ecosystem approach can examine all local impacts of climate change and allow agencies to collaborate to determine solutions, leverage resources, and prioritize work.

SENRLG is developing graphic representations of the relationships among resources and risks across a specific geographic region. By graphically overlaying ecosystem service datasets and risk indicators, agencies can identify co-benefits for coordinated actions to resolve an identified threat. In addition to SENRLG, there are several other partnership efforts that are underway in the Southeast to address climate change impacts. There is a need to move beyond traditional partnerships and examine a new perspective, using public and private organizations, to develop strategies to meet goals.

In summary, this workshop provides an opportunity to engage participants and help the Agency move the conversation from the previous 2010 workshop forward. It is necessary to take an integrated approach to address the challenge of climate change adaptation. This workshop is expected to take the next step and help advance development of system-based approaches to assist in decision making and build stronger partnerships. It is necessary to continue to identify science tools and policies to address the multiscale, multimedia, and multidisciplinary problems posed by climate change, which have significant future implications. An integrated model is the cornerstone of such an effort.

A participant noted the importance of funding and commented that decision makers often want demonstrations of tools. Ms. Banister responded that decision makers are realizing that the traditional manner of using one model is becoming obsolete, so they are looking for integrated and interrelated solutions. In terms of funding, Requests for Proposals often are released that incorporate information received from technology staff and modelers.

### **Federal Perspective**

#### ***Challenges for Integrated Modeling***

#### **Andy Miller, EPA, National Program Director for Global Climate Change Research**

Dr. Andy Miller noted that he would reemphasize many of Ms. Banister's discussion points and explained that the federal government often has resources and expertise that states do not. Federal agencies have an increased willingness to work with other federal agencies and states; for example, federal agencies are developing partnerships with states to create tools to help decision makers and local governments. Assistant Administrator Paul Anastas has stated that the future of the Office of Research and Development (ORD) includes recognition that the goal of sustainability is the office's "true north." Climate change is fundamentally a sustainability issue. Responses to climate change that are not sustainable are stopgap measures and not solutions. It is necessary to integrate knowledge of different endpoints, which cannot be completed without integrated modeling. Sustainability requires that knowledge is integrated

## **Integrated Modeling To Characterize Climate Change Impacts and Support Decision Making**

---

across media, receptors, time, space, economic systems, and social behavior; without models, researchers lack insight into how these systems behave. To address climate change effectively, it is necessary to develop models that increase understanding of the consequences of choices.

Decision makers must consider a tremendous array of issues (e.g., air quality, economic and public health, water quality, jobs, financial resources, risk perception, public response). Many of these issues can be modeled, but others that are more difficult to model (e.g., public response) can be equally or more important to decision makers than the issues that can be modeled. The challenge is that the Earth and climate systems exhibit complex and chaotic behaviors that can be unpredictable and are difficult to model. It is necessary to move beyond deterministic approaches, which are useful but must now include other concepts to increase understanding. To gain insights into the increasingly complex problems posed by climate and sustainability, it is necessary to move beyond the current physics/biology-only approach to incorporate chaos, connections, complexity, and self-organizing behavior. Dr. Miller noted that a model is being developed in Europe that integrates the best of all relevant knowledge; the model goes beyond the scope of what EPA modeling would do, but it is one illustration of the scope of models that seek to integrate all relevant knowledge.

Though the current science is not advanced enough to create a model of the world that meets all decision makers' needs, scientific models are of increasing quality even as the ability to develop integrated models is limited by numerous factors (e.g., lack of measured data, understanding of complex system behavior, computational capabilities, chaotic behavior). To be useful, modeled trends must behave similarly to actual trends, the range of modeled results must extend beyond what is measurable, modeled results must provide insight into real-world phenomena, the model's behavior must be robust with respect to a wide range of inputs and objectives, and the limits of the model's range of validity must be understood. A model is useful if it is just complex enough to create new insights but not so complex that it creates confusion. It is necessary to ask how much complexity is enough, which depends on whether researchers are able to provide the needed guidance to those who use the information and whether a balance is provided between scientific completeness and decision maker needs. The key is to maintain constant communication with those who apply model results.

Integrated modeling incorporates all of the uncertainties of each of the component models, but in many cases, the uncertainties cannot be quantified. Modelers must recognize the existence and level of uncertainty and most importantly, communicate what is known and not known and provide guidance to decision makers about the limits of the current understanding. There are different uses for models in a regulatory context, and different levels of uncertainty are acceptable for different purposes. The uncertainties and long timeframes regarding climate only can be addressed through adaptive management approaches; models are needed to address issues in an adaptive manner. Challenges include improving the understanding of processes that are not easily modeled and developing better approaches for representing significant uncertainties. The major challenge is to confront the manner in which modelers think about modeling and ensure that the models being developed provide the most critically needed information. Another significant challenge is to expand modelers' communications with other disciplines and end users to focus on the desired result and convey the limitations. Communication is an ongoing effort and requires work on the part of everyone involved. It also is necessary to move beyond communication and build relationships that allow development of tools that provide users with instant feedback and easily understood outputs and integrate them into the process, which can generate tremendous interest and support.

A participant asked Dr. Miller to rate on a five-point scale the progress that has been made in the integrated modeling effort. Dr. Miller responded that he thought the effort was at three and rising.

Tremendous progress has been made in the ability to model processes involved in climate change and what these processes mean at the regional scale, but as modelers deal with more than the physical world and how to mitigate and adapt, there are difficulties because the needed tools regarding how to prioritize adaptation choices have not been developed. It also is necessary to understand public response.

A participant noted that there were two types of challenges in informing decision makers how to use scientific information: model uncertainty and scenario uncertainty. A decision strategy that incorporates uncertainty is needed. The participant asked what EPA is doing to help local agencies strategize. Dr. Miller said that the Agency is attempting to understand the issues, and Dr. Joel Scheraga will present information regarding what work the Agency is performing in this regard. In terms of sea level rise, it is possible to adapt to a certain extent, but at some point, some adaptations (e.g., seawalls) will not work. Current decision making is very different than that of the past as a result of the pushback from the general public; there is no easy strategy to address this.

A participant noted that there must be feedback between decision makers and modelers, who need to consider the consequences of uncertainty so that it does not impact decisions. Dr. Miller responded that uncertainties are treated differently in different contexts (e.g., homeland security vs. the environment).

### Local Perspective

#### *Local Perspective: City of Atlanta*

#### **Mandy Mahoney, City of Atlanta, Director of Sustainability**

Ms. Mandy Mahoney explained that mayors deal with a great deal of chaos, and often times their schedules are so full that they only have a few minutes to meet with those individuals who can help inform their decisions. To obtain decision makers' attention it is necessary to present "wins" and develop relationships to become the main science advisor on which the decision maker relies. It is necessary for the decision maker to know that the scientist and the model(s) are trustworthy. Scientists are translators and need to explain to the decision maker the problems that can be solved through the information from modeling analyses. It is beneficial to provide reports that lead with the critical problem that a decision maker is attempting to solve and then mention climate (i.e., do not lead with climate). Scientists must communicate with decision makers to perform research that will affect the problems on which the local government is focusing on within the next year or finds critical. Researchers need to drive solutions for climate change and not wait for mandates from administration. Adaptive strategies provide hope. Scientists need to increase public engagement to increase interest and tool development. In summary, Ms. Mahoney explained that researchers and modelers should connect and build relationships with people in local governments and work with them to solve problems and develop tools for climate change mitigation and adaptation; the same mistakes that were made in the past on other policy issues must not be repeated when addressing climate change.

A participant noted that economic and population growth is critical for climate change and adaptation; this creates opportunities but also increases risk. He asked about the potential to substantially address climate change with the continuing growth that will occur. Ms. Mahoney responded that the City of Atlanta is making its city offices and entities accountable for their energy use. This is the first step, as it is necessary to understand energy use to change habits. It also is important to show that dealing with climate change makes business sense and communicate these messages to other communities. Another participant noted that politicians need to develop relationships with the citizens who are performing the needed work in this area, and modelers should lend their expertise as far and as wide as possible.

### SESSION ON INTEGRATED MODELING TO FACILITATE DECISION MAKING

#### ***The Importance of Mainstreaming Climate Adaptation into EPA's Programs and Rules***

**Joel Scheraga, EPA, Science Advisor for Climate Adaptation**

Dr. Scheraga thanked the planning committee and recognized the outstanding effort of Region 4. He explained that he would be highlighting an initiative that includes priorities that will affect modelers' efforts. The climate is changing at an increasingly rapid rate and at a rate beyond historic experience; therefore, the past is no longer a good predictor of the future. Sea level rise also is critical, and the rate for sea level rise is increasing as well. EPA is operating in this rapidly changing world, and the outcomes that the Agency is attempting to attain are sensitive to changes in climate. Until now, EPA has been able to assume "stationarity" of climate, but because the past no longer is a good predictor of the future, climate change is posing new challenges that make it more difficult for EPA to attain its goals and develop sustainable communities. EPA Administrator Lisa Jackson has stated that climate change affects EPA's core mission, and an explicit discussion of climate adaptation has been included in EPA's *Strategic Plan* for the first time. Annual Performance Measures have since been developed to measure the Agency's progress regarding climate change adaptation. The strategy includes integration of adaptation into action development, funding mechanisms, and models and decision-support tools. A smart policy portfolio must consist of both mitigation and adaptation strategies; there are opportunities for co-benefits if resources are used wisely.

Dr. Scheraga displayed a number of graphs and data that highlight changing temperature and precipitation trends. Future impacts of these changes need to be understood to make appropriate decisions. Climate change affects human health and the environment and has significant impact on issues that are important to the general public in various sectors (e.g., health, agriculture, forest, water resources, coastal areas, and wildlife and ecosystems). Many Alaskan communities already have been affected.

In the context of the EPA's mission, climate change may affect EPA's ability to protect human health and the environment and fulfill its statutory, regulatory, and programmatic requirements. Opportunities, however, exist to address the anticipated impacts. Potential impacts of climate change include regional air quality, combined sewer overflows, and total maximum daily loads (TMDLs). Dr. Scheraga described combined sewer overflow in the Great Lakes Region to highlight that considering climate change can help manage risks. A July 2008 report concluded that climate change poses real risks to human health and human systems that support the way of life in the United States. Children, the elderly, the infirm, the poor and tribal communities often are among the most vulnerable to climate health impacts. Environmental justice includes development of intervention strategies that consider these populations. Adaptation is critical if EPA and the communities it serves are to attain the desired environmental, human health, and economic outcomes.

EPA staff members are being asked to consider the following climate questions: What are the environmental and human health outcomes EPA is trying to attain? How is the climate changing? How might climate change affect EPA's mission? What should the Agency do? How can EPA "mainstream" climate adaptation into day-to-day operations? What has the Agency learned? Additionally, Executive Order 13514, issued in October 2009, requires agencies to participate actively in the Climate Change Adaptation Task Force and develop approaches compatible with its strategy. The task force produced a report within 1 year of its creation detailing how federal agencies can adapt to build resilient, healthy, and prosperous communities in response to the Executive Order. The task force made five recommendations. The first recommendation was to encourage and mainstream adaptation planning across the federal government (i.e., each federal agency develops its own plan).

The Cross-EPA Work Group on Climate Change Adaptation Planning was established in January 2011 by the Deputy Administrator and charged to develop and implement a climate change adaptation plan for the Agency. The work group has representatives from every EPA program and regional office. The programs and regions will use this plan to develop their own plans and approaches for mainstreaming adaptation into rule-making processes while taking into account environmental justice implications and priority socioeconomic questions. Climate adaptation, smart growth, and sustainability activities will be integrated.

A participant noted that Alaska villages are in danger. Moving cities based on modeling results that indicate changing coastlines is a challenge. He noted that Congress is not always culturally sensitive, as illustrated by the Senator from Montana who demanded to know why his taxpayers should pay for Alaska village climate adaptation. Dr. Scheraga agreed that these types of issues are sensitive. Another area of uncertainty that needs to be understood is barriers to effective adaptation (e.g., socioeconomic, institutional). Modeling is a function of how decisions are made. Other factors besides science influence decisions; therefore, it is necessary to understand how decisions are made "on the ground" and who makes them.

### SESSION ON INTEGRATED MODELING TO ASSESS CLIMATE CHANGE IMPACTS ON THE ENVIRONMENT AND HUMAN HEALTH

***Session Moderator: Ken Mitchell, EPA, Region 4***

Dr. Ken Mitchell urged the modelers to make the short amount of time that they have with decision makers count. He explained that this session would provide examples of accomplishments at various scales.

#### **National Case Study: EPA Cross-Agency Integrated Modeling Effort To Support Air Quality Assessment**

##### ***Overview of Integrated Modeling Effort To Support Air Quality Assessment***

**Bryan Bloomer, EPA, ORD, National Center for Environmental Research (NCER)**

Dr. Bryan Bloomer highlighted data that indicate that the warming of the climate system is unequivocal. The rate of change is increasing and being translated at the local level. The Clean Air Act has successfully decreased air pollution using many approaches (e.g., risk-, technology-, and market-based), all of which are driven by simple metrics. Administrator Jackson signed a proposed endangerment finding in December 2009 that finds that the emissions of greenhouse gases (GHGs) cause or contribute to endangerment of public health and welfare. The evidence concerning adverse air quality impacts provide strong and clear support for this finding. Observational results from the Science to Achieve Results (STAR) grants program provide ground-truthing and useful decision making information.

Dr. Bloomer described the "Climate Penalty Factor," which can be used as a rule of thumb for local planners to protect air quality. Although air pollution improved following power plant nitrogen oxide emission reductions, it did not improve as much as it would have if temperatures had not increased. This additional cost to society and increase in human health impacts is a penalty that results from rising temperatures. For example, if mid-latitude cyclone frequency had not declined, the northeastern United States would have been largely compliant with the ozone air quality standards by 2001.

Dr. Bloomer described STAR-funded integrated modeling of climate and air quality. Climate change mitigation and adaptation in terms of earth and human systems are complex; therefore, the models focus on human health and air quality. Conceptual models of climate change and air quality were developed. In terms of connecting global climates to regional air quality, the modelers asked how to start with the global climate scenario and calculate regional impacts on air quality. A system was developed with integrated extramural researchers in institutions across the United States working together to each build part of a larger assessment framework to support local air quality decisions. The dynamical downscaling included coarse-scale model output and fine-scale model input. It is necessary to integrate all models effectively to support decision making.

Dr. Bloomer provided several examples of work that uses models to make predictions and presented their results. The many academic institutes that collaborated and ran the models found that ozone degradation is similar across geographic locations and various simulations. The methodology was extended to examine particulate matter (PM) concentration. The preliminary work is not a cause for concern. EPA reported that because climate change exacerbates ozone pollution, and potentially PM pollution, stronger emissions controls will be needed to achieve current air quality standards in the future. An integrated global model has been downscaled into the Community Multiscale Air Quality Model, and this model is being used to examine human health at the state level; results indicate that there is an increased death rate as a result of increases in ozone. Avoiding deaths caused by air pollution requires integrated modeling for policy analysis and adaptation of air quality management systems.

### ***Integrated Climate and Land Use Scenarios (ICLUS) and the Environmental Benefits Mapping and Analysis Program (BenMAP)***

**Philip Morefield, EPA, ORD, National Center for Environmental Assessment**

Mr. Philip Morefield encouraged local decision makers to speak to EPA scientists about beneficial work and/or opportunities to collaborate. The ultimate goal is to create integrated scenarios that are coherent, internally consistent, and provide a plausible description of a possible future state of the world; the scenarios also should provide alternative views of future conditions considered likely to influence a given system or activity. The terms "reality" and "truth" are not in the definition of "scenario." The goals of ICLUS are to create seamless land-use scenarios for the coterminous United States that are consistent with Intergovernmental Panel on Climate Change (IPCC) emission storylines, provide consistent benchmarks for local and regional land-use studies, and identify geographic areas in which climate/land-use interactions may exacerbate impacts or create adaptation opportunities. Mr. Moreland provided examples of ICLUS growth scenarios and IPCC global emissions scenarios. The scenarios classified as "A" are increasingly economic, whereas the "B" scenarios are environmental; the "1" scenarios are more global, whereas the "2" scenarios are regional.

In terms of output, ICLUS uses a spatial allocation model to obtain housing density to determine estimated impervious surface values. This allows an interpretation of IPCC scenarios as applied to the United States. Mr. Morefield described a flow diagram of the ICLUS model highlighting demography. Data sources for this demographic modeling include the U.S. Census Bureau's *City and County Data Book*, U.S. Census Bureau components of change rates, National Center for Health Statistics information on county populations, U.S. Census Bureau data for net international migration, and U.S. Census Bureau Public Use Microdata Sample File data for domestic migration. Mr. Morefield highlighted a graph and animated geographical maps of population projections for ICLUS scenarios. It is important to note the lack of effect from population density. The Spatially Explicit Regional Growth Model (commonly known as SERGoM) extrapolates from the local to the national scale.

A connection between impervious surface and ecosystem services is documented in the literature. Aquatic ecosystems are stressed at five percent impervious surface values, impaired at seven to 10 percent impervious surface values, and impacted at greater than 10 percent values. The modelers converted housing density to impervious surfaces and allocated it to 1-ha resolution. This helps decision makers to determine where to place funding to increase water quality and save watersheds. ICLUS version 1 was created via numerous collaborations internal and external to EPA, and more information can be found at <http://www.epa.gov/ncea/global>; data are available at <http://geogateway.epa.gov>. ICLUS version 2 will update all components and incorporate public transportation; preliminary output is expected by summer 2011.

Mr. Morefield described a case study with human health impacts. This was the start-to-finish climate change impact assessment that shows that the scenario approach is possible and necessary. BenMAP is a tool that can be downloaded and run for estimating health and economic impacts of changes in air pollution. Change in mortality is a function of change in pollutant level, mortality effect, mortality incidents, and exposed population. Linkages were demonstrated between the models and aggregation of data and were found to be applicable to ICLUS populations. ICLUS scenarios include different assumptions regarding international migration change scenarios. Finally, sensitivity is important in analysis.

### **Regional/Local Case Study: Outcomes of the December 2010 Austin Systems Thinking Workshop on Local Climate Change Effects on Human Health and Well-Being**

#### ***Systems Thinking Process***

**Tom Fontaine, EPA, ORD, National Health and Environmental Effects Research Laboratory**

Dr. Tom Fontaine described the 2-day “Systems Thinking Workshop on Local Climate Change Effects on Human Health and Well Being” in Austin, Texas, held in December 2010. The focus of the workshop was to employ systems-thinking techniques to help develop models that predict local and regional human population health, vulnerabilities to stress, and well being in the context of climate change and changes in ecosystem services. A systems-thinking approach was chosen because it helps identify possible unintended consequences of well-intentioned actions. It is a participatory approach that draws on the expertise of many, and it develops a common set of conceptual models together so that all have ownership. Additionally, it can produce models that help test actions before implementing them and helps identify uncertainties and areas on which to place data collection emphasis. It allows thinking about the unexpected ahead of time. Dr. Fontaine provided examples that could have been helped by systems thinking (e.g., drainage and removal of wetlands, introduction of non-indigenous species).

Participants of the workshop attempted to develop a toolbox regarding the local and regional effects on human health and well-being (e.g., bench and field research, monitoring, modeling, benefit cost analysis, risk analysis) for a variety of different uses (e.g., heuristic, forecasting, intervention, policy, regulation, litigation). Selection of participants was driven by local and regional focus on Travis County, Texas, and San Joaquin Valley, California. Participants included federal, state, and local agency staff; consultants; nongovernmental organizations (NGOs); and the ORD's Systems Thinking Advisory Team (STAT). The goals of the workshop were to: formulate problems; visualize products to inform decisions; inventory existing models and tools; use systems thinking to draw a conceptual diagram; develop time, space, and scenario considerations; identify and build models for Travis County and the San Joaquin Valley; identify data sources and gaps; apply the model to a real-life problem and test ideas before implementation; obtain feedback; and develop a presentation for this meeting.

Travis County faces a number of issues that are affected by climate change, including flash flooding, air quality, and the hosting of hurricane evacuees. Issues that the San Joaquin Valley is facing that are

affected by climate change include air quality, water availability, weather, and built environment. The question was whether the participants could develop models that are applicable to both geographic locations. The program participants performed participatory problem formulation, which includes high-level problem formulation while focusing on the following questions: What are the consequences of climate change on human health and well-being in Travis County and the San Joaquin Valley area for the next 50 years? What actions and adaptations can be implemented to minimize adverse effects and maximize positive effects? How can predictive climate change modeling be integrated into a multidisciplinary environmental public health indicators tool to provide local policy makers with a visual analysis of how vulnerable populations and the environment might be impacted by proposed climate change policies? Following the problem formulation, participants "burrowed" down additional levels to further understand the problem. The participants visualized the endpoints that informed decisions and determined what the desired final product would be. It is necessary to determine details that are necessary to develop a useful tool for decision makers. The participatory modeling process is a STAT-facilitated exercise that develops conceptual and mathematical models and identifies data and gaps. It is necessary to conceptualize the system and overlay climate change affects to determine how these affect the system.

***Vulnerability Assessments as Decision-Support Tools for Climate Change Adaptation***  
**George Luber, Centers for Disease Control and Prevention (CDC), National Center for Environmental Health, Associate Director for Climate Change**

Dr. George Luber explained that despite the existing breadth of organizations and sectors with initiatives on climate change and the likelihood of anticipated health effects of climate change, public health effects of climate change remain largely unaddressed. Climate impacts (e.g., more intense and frequent heat waves, air pollution in stagnant air masses, more frequent heavy rainfall events) have direct health effects (e.g., heat stress, cardiovascular disease, asthma, respiratory illness, drowning, direct injury). Other climate impacts (e.g., effects on key ecosystem parameters, more frequent heavy rainfall events, increase in areas affected by drought) have indirect health effects (e.g., impacts on vector-borne and zoonotic disease, waterborne diseases, harmful algal blooms, changes in food sources, malnutrition, forced migration). It is necessary to be prepared for direct effects and understand the indirect effects.

The CDC's Climate Change Program was formally constituted in March 2009 and leads efforts to identify the health impacts of climate change in vulnerable populations, anticipates future trends, shows that systems are in place to detect and respond to emerging health threats, and takes steps to ensure that these health risks can be managed currently and in the future. One key component of the program is the Climate-Ready States and Cities Initiative. Eight states and two cities were funded for adaptation planning via cooperative agreements with their health departments with the objective to enhance the capability of state and local health agencies to deal with the challenges associated with climate change. Another key effort is to develop decision-support tools.

Dr. Luber provided two examples that highlight the various ways that science is unfolding to address climate change impacts. These and other investigations have highlighted some of the most important individual and community risk factors for hyperthermia and heat-related death. The approach for one of the projects (using National Aeronautics and Space Administration data and models to improve heat watch warning systems for decision support) used meteorological, mortality, remotely sensed, and sociodemographic data from 1995 through 2005. It was assumed that increased surface thermal characteristics lead to an increase in risk. Variables were modeled using logistic regression and artificial neural networks to create spatially specific risk maps for the cities in the study area. Land surface temperature was estimated using remote sensing assets, U.S. Census Bureau socioeconomic data were

used at the census tract level, and a retrospective analysis of death certificates was performed for past events. Modeling the events with predictive analysis uses logistic regression to determine the initial risk of each census tract, fees, and variables identified as statistically significant, inputs them into an artificial neural network, and mines all of the variables using the artificial neural network.

The second project, Central Texas Climate Change Environmental Public Health Indicators Tracking Tool, is designed to help individuals "on the ground" respond to specific threats. Travis County, Texas, has several environmental hazards that affect human health including flooding, severe weather, and heat and drought. Health tracking infrastructure was built to track the prevalence of risk factors and integrate this information with policy objectives, which are to target policy-making priorities to vulnerable populations and raise public awareness of the connection between public health and climate change. Dr. Luber displayed maps that highlighted extreme heat and health overlays; additional maps highlighted flooding and health overlays. The tool allows visual comparison of various scenarios with each set of baseline indicators. Each layer of information can be added to compare indicators with each other and identify the success of policies in terms of targeting areas with vulnerable populations.

To successfully build public health adaptation strategies for climate change, it is necessary to: develop data-driven approaches that identify spatially specific vulnerable populations and places; enhance surveillance by integrating environmental, meteorological, and health data; and identify co-benefits for health of mitigation and adaptation strategies. All strategies will need to improve surveillance or enhance the systems that are already in place. It is necessary to assess these needs and retool public health care services so they provide effective responses. Higher level issues (e.g., migration, civil conflict) have challenged or slowed development of the health sector, and as a result, climate change activities must be prioritized in this context in addition to the ongoing development of other non-health sectors.

### ***Systems Thinking Products: Using Integrated Models for Exploring Climate, Ecological, and Economic Impacts in Future Climate Scenarios***

**Roel Boumans, University of Vermont, GUND Institute for Ecological Economics Fellow**

Dr. Roel Boumans explained that the December 2010 workshop used declarative modeling as its modeling approach. He displayed a diagram with stock flow modeling language within several software packages. The Simulistics Simile modeling software was used because it can begin with declarative modeling and move to more complex modeling. The participatory process involves three steps. The first step uses scoping and consensus building to allow participants to build a high-generality, low-resolution conceptual model to represent all interests and make decisions about the functional connections between variables. The second step involves a research model toward more detailed and realistic attempts to replicate dynamics; this includes collecting historical data for calibration and uncertainty analysis. The third step is a management model for exploration of scenarios and management options based on the scoping and research models.

On the morning of the first day of the December workshop, the participants worked on the scoping model, a conceptual model in which parameters were combined to show their various effects on human health. In the afternoon, participants were shown a preview of the research model to highlight its components and allow visualization of the endpoints. During the morning of the second day, a vulnerability index was created. The vulnerability index was integrated into the larger spatial model to predict the effects of changes in land use. Dr. Luber explained that the Multiscale Integrated Model of Ecosystem Services (MIMES) includes information on the biosphere, anthroposphere, hydrosphere, lithosphere, and atmosphere and exchanges between these domains. Decision makers need to be able to work with the research model framework, which includes MIMES and the vulnerability index. The Generalized

Environmental Modeling System for Surfacewaters (GEMSS<sup>®</sup>) is an online geospatial data repository from which data can be organized and formatted to be used by the research model. GEMSS<sup>®</sup> also can be used to overlay the data output of the model. The data can be accessed at the Google Code Hosting Site.

### ***Systems Thinking Process To Support Decision Making in Austin***

**Marc Coudert, Austin (Texas) Climate Protection Program, Environmental Program Coordinator**

Mr. Marc Coudert provided information regarding the City of Austin's landscape and geospatial social issues and population growth. One significant demographic trend is an increasingly sharp edge of affluence; Interstate-35 separates high- and low-income areas, with significant differences in population density on either side of the freeway. The city contains "heat islands," and climate projections for the area include hotter, longer droughts and larger storms. A recent hurricane caused flooding. These issues are being discussed but not in a coordinated manner. Barriers have been identified, including perception, lack of attention, bureaucracy, and finances. The city has coordinated departments to create a Climate Action Team and address key issues. Modeling techniques identified in the workshop are used for decision making in Austin, Texas. All of the tools and models that EPA produces must be understood by citizens. Models are used to set policy and help with interdepartmental communication; assist with short-, medium- and long-term decision making; and set policy discussion. The next steps are to work with departments, collaborate with the group assembled at this workshop, and create models. Technical and financial assistance and regional coordination are needed; regional coordination is important to determine what others are accomplishing and not duplicate efforts.

### **Panel Discussion**

A participant asked Dr. Luber how many lives had been saved by the models in the Austin case study. Dr. Luber responded that the idea is to build tools to assess the benefits (e.g., mortality, cost saving); no policies have been evaluated currently. Dr. Bloomer added that EPA performs accountability assessments regarding human health impacts after policies have real indications of increased public health; the Agency also has model tools that indicate what might have happened if no action was taken. These two components need to be brought together.

A participant noted that a critical component was problem formulation with stakeholder participation so that decision makers obtain the expected answers. He asked how well the process worked in Austin. Dr. Fontaine responded that attempts to involve the most appropriate people were successful so that the outputs, goals, and model were identified correctly. There still is work to be done, however.

A participant noted that bridging the gap between analysis and decision making is important and asked whether there was any information about what has worked in the past to bridge this gap. Dr. Bloomer responded that the project in the San Joaquin Valley analyzed smart growth decisions and applied air quality metrics to outcome scenarios to determine the best plan. The University of Texas at Austin has a similar project that examines congestion pricing; the project helps with development of a strategy for the City of Austin. There also are several additional examples in Atlanta, Georgia, and other cities. Dr. Boumans noted that it is important to collect case studies so that they can be referred to and understand the outcomes that decision makers need to provide feedback. Dr. Fontaine cited the examples of Everglades restoration in South Florida, land use in the Lima Valley in Oregon, and water futures and water tradeoffs in the Pacific Northwest.

A participant noted that the ongoing relationship between researchers and decision makers is critical and asked where this relationship fits in with the federal mandates. How are priorities set? How are individuals selected for these relationships? Mr. Coudert responded that the products from the City of Austin project

hopefully will be a prototype for other cities to emulate. Dr. Luber highlighted the “test-bed” approach and pilot projects with a focus on a national database and its applicability. It would be beneficial to develop a tool that can be modified and applied at any level. The cities in this project were chosen because of their unique opportunities or challenges. Mr. Morefield added that implementation is local, but the national center is charged with national projects so it attempts to partner with umbrella organizations who act as a filter to inject EPA research and input at the local level. Dr. Mitchell said that the morning talk regarding the task force's guiding principles provided hints about the direction that this may be taking.

A participant asked whether infrastructure systems were discussed at the December 2010 workshop. Dr. Luber responded that they had been, and this was the premise behind the approach. Dynamic layers were added to a static model. Mr. Coudert added that at least 35 percent of energy must come from renewables, and there are other programs that will help with climate change adaptation in addition to GHG mitigation.

### SESSION ON INTEGRATED MODELING TO ASSESS CLIMATE CHANGE IMPACTS ON THE ENVIRONMENT AND HUMAN HEALTH

*Session Moderator: John Powers, EPA, Office of Water (OW)*

**Local Case Study: Oyster River Culvert Analysis Using Climate Change Scenarios**  
**Michael Simpson, Antioch University New England**

Mr. Michael Simpson highlighted one method by which New England is addressing climate change and extreme storm events by translating models to the local level. The focus has been on culverts, which can be field checked and measured relatively easily and have a tangible dollar value attached to them that can be used in replacement and mitigation cost analysis. If orifice flow is not working correctly, upstream flooding, erosion, and sediment deposition and transport can occur, which can result in destruction of infrastructure and deaths. Culverts are not dams. The site for the study that Mr. Simpson described is the Oyster River Watershed, which is comprised of 19,000 acres and six towns and has experienced vigorous population growth and a recent unprecedented increase in extreme and record storms. The model nested spatial data, zoning and construction overlays, precipitation data, and field data. GIS spatial analysis was used to examine land-use types that affect runoff. These were layered in the GIS model to develop a runoff coefficient and examine the potential for runoff with the baseline for the whole system.

The adequacy of culverts and bridges to convey peak flows was determined by "back-engineering" built culvert capacity to pass peak flow for different scenarios. For this analysis, culvert failure is considered to occur when culverts are in orifice flow for a 25-year, 24-hour storm event. The system is being reverse-engineered to determine which culverts could pass weir flow. The build-out analysis was framed by examining city plans and obtaining input regarding what a future city should look like. Satellite mapping was used to determine specific lot characteristics to develop a new runoff coefficient for each zone district in each town. Impervious surfaces are increasing over time, so modeling predicted what percentage of impervious surface could be expected in the future. A nested analysis was performed for each modeled catchment. Under current land-use conditions, five percent of total culverts are undersized; however, under full conventional build-out, 11 percent of total culverts are undersized.

The study projected future climate change for the Northeast United States using GHG emissions scenarios. The NOAA Geophysical Fluid Dynamics Laboratory Climate Model 2.1 was statistically downscaled and validated via historical data. The 28 percent increase in extreme storm events in the area means that the 100-year storm event becomes a 25-year storm event; since 2005, there have been

four 100-year events in the area. Mr. Simpson showed maps that highlight current land use with recent climate conditions, current land use with climate change, and build-out with climate change. Results indicated that climate change contributes more significantly to undersized culverts, and build-out-related changes more significantly contribute to watershed hydrology. Culverts that were undersized tended to be higher in the watershed, under roads that were not major thoroughfares, and in the 12- to 24-inch range. Mr. Simpson provided information about cost analysis in Durham, New England, and displayed a graph showing cost impact with increasing precipitation. The study examined issues that would allow designs for subdivisions that would not increase the cost of each building more than five percent (i.e., low-impact development design [LID]). LID can mitigate the impact of the number of undersized culverts and decrease average upgrade costs by 33 percent.

Mr. Simpson highlighted other NOAA projects, which found that the majority of watersheds become undersized as a result of climate change. Just after the analysis was finished, a 100-year storm event occurred, so the data were able to be compared and a cost analysis performed. The engineer's estimate to repair a road damaged by the storm event was \$93,000, but the Federal Emergency Management Agency only would provide \$28,000. The Sunapee drainage system also was found to be vulnerable. Mr. Simpson concluded that it is necessary to develop tools and communicate them so that they are readily understood at the local level.

***Regional Case Study: Key Issues for Using Integrated Modeling in Multiscale Climate Change Vulnerability Assessments With Watershed and Estuary Examples***  
**Amanda Babson, EPA, Global Change Research Program (GCRP)**

Dr. Amanda Babson explained that, in terms of science supporting decision making, there are two strategic framings of climate change impacts assessment. Paradigm 1 is to predict then act; and Paradigm 2 is to assess system vulnerabilities and policy risks. Paradigm 1 is the typical approach of current impact assessments, but the state of knowledge about future climate does not currently, and may never, provide a sufficiently accurate prediction to support this paradigm. Dr. Babson displayed a schematic of the traditional approach, which is a top-down prediction of impacts, but its limitation is that the model does not necessarily answer the particular questions of planners. Paradigm 2 is a bottom-up type approach in which uncertainty is dealt with by improving understanding of the impacted systems and the range of climates to which they are sensitive. Dr. Babson displayed a schematic of this approach, which identifies the most important vulnerabilities and uncertainties.

There are three major categories of issues that collectively constrain how impact assessments are performed: (1) challenges of climate prediction; (2) issues and downscaling; and (3) credibility, salience, and legitimacy. Long-term climate prediction is very difficult, and there are limitations, including deficiencies in simulating clouds, precipitation, wind, the diurnal cycle, and major weather patterns; competition for computing resources; and the impracticality of directly assessing the skill of multiple decades of climate coupled with the inability to assess this indirectly. Current models capture only a subset of scientific uncertainty about the climate system, and impact models are less mature than climate models. It is difficult to predict how human behavior affects climate. In terms of downscaling, it is necessary to ensure that the model is suitable, credible, salient, and legitimate. In terms of the realities of effective decision support, there is a need to use the existing literature better.

The EPA Climate Ready Estuaries Program's Vulnerability Assessment Approach was used in collaboration with the San Francisco Estuary Partnership and Massachusetts Bays Program to perform a vulnerability assessment. Key goals from the Comprehensive Conservation and Management Plan were selected, and conceptual models were created for key ecosystem processes. The approach assesses the

sensitivities of processes across a range of climate change scenarios and assesses the vulnerabilities of management goals to inform adaptation planning. These assessments elicit: (1) qualitative judgments on relative influences of physical and ecological variables that regulate key climate-sensitive processes, (2) sensitivities of influences under current conditions and future climate change scenarios, and (3) the degree of confidence in judgments about these relationships.

Two mid-century climate scenarios for San Francisco Bay were used: a lower-range scenario (warm climate) and a higher-range scenario (warmer, somewhat drier climate). A mix of qualitative and quantitative variables was used as drivers. Dr. Babson highlighted workshop results that were relevant to scenario development. Variation between participants was greater than between scenarios, and variability in the current system spans the range of future change, so most influence types do not change. Existing models were not available to bridge relevant variables, and participants were relied on to integrate physical drivers to the specifics of the system. For a complex ecosystem with high natural variability and a mid-century management horizon, it is necessary to look at the broadest possible range of climate scenarios.

The ORD GCRP 20 Watershed Study originally supported OW in meeting its *National Water Program Strategy: Response to Climate Change* goals and since has been broadened. The study sites are regional-scale watersheds, and regionally downscaled climate change scenarios from the National Center for Atmospheric Research's North American Regional Climate Change Assessment Program (NARCCAP) were used. The modeling approach for this study will focus on stream flow, nitrogen, phosphorus, and sediment using 30-year historical and 30-year future periods. Five pilot watersheds will use two watershed models to determine the effects of climate change, land-use change, and coupled climate and land-use change; sensitivity studies will be included to assess the influence of different methods of downscaling. In 15 non-pilot watersheds, one watershed model will be used to determine the effects of climate change, land-use change, and coupled climate and land-use change.

Dr. Babson recommended that Paradigm 2 be adopted for multi-scale modeling to support decision making. It is necessary to begin by identifying vulnerabilities of current management goals and ensure that many model and data options are available. Multiple models should be used to develop scenarios that span a broad range of plausible futures, and adaptation should be integrated into planning.

### ***National Case Study: Hydrologic and Water Quality System (HAWQS): A National Watershed and Water Quality Assessment Tool***

**Raghavan Srinivasan, Texas A&M University**

Dr. Raghavan Srinivasan explained that HAWQS is a national watershed and water quality assessment system that is capable of supporting a wide variety of national-, regional-, and local-scale economic, policy, and impact analyses. It is a server/client modeling system that uses Web-based and desktop interfaces to access datasets for modeling and uses the latest nationally available federal government database at three spatial resolutions. Additionally, HAWQS uses the latest Soil Water Assessment Tool (SWAT) and the National Hydrology Database Plus stream network. This schematic design includes three-tier architecture, including front-end Web and desktop interfaces for users, middle-tier servers for handling user requests and responses, and a back-end database that contains all SWAT-related datasets for a 50-year period. SWAT, a landscape watershed model, can simulate the potential for hydrology and water quality issues. SWAT is a product of more than 40 years of U.S. Department of Agriculture model development and is widely used for water quality, water supply, and climate change models around the world. The study has identified more than 2,100 watersheds across the continental United States at different spatial scales.

HAWQS can evaluate the impacts of management alternatives, pollution control scenarios, climate change scenarios on the quantity and quality of water, and environmental benefits of conservation practices at the national scale. HAWQS has many benefits. It uses mostly public domain databases, tools, and technology, and no GIS software or expert knowledge is required. It has the flexibility to perform simple assessments with client/server architecture, and complex scenarios and analyses can be performed effectively using additional desktop tools. A powerful desktop visualization tool is available to analyze the complex outputs. It can be used by policy makers and economists conducting benefit assessments of water programs and help inform regulations and policies at the regional and national scales. It can help recommend new policies by providing scientifically defensible assessments and allows targeting of high-impact pollution cases for enforcement assessment and its benefits. Finally, HAWQS can perform national, regional, and local watershed assessments at three spatial scales over 42 years of historical weather data using nationally consistent federal databases and well-established models.

The NARRCAP simulation strategy used in the 20 Watershed Study was to obtain data from IPCC emissions scenarios and global climate models and downscale them to the watershed level. An example application is the Apalachicola-Chattahoochee-Flint (ACF) Watershed near Atlanta. The ACF Watershed is 19,600 square miles and contains Atlanta and its water supply; the watershed has been subject to long-running legal disputes over fair management of the system and has good flow gauging and precipitation records. The ACF project included 14 different climate change scenarios. The downscaled models agreed on a consistent increase in temperature; however, rainfall changes are much less clear and increase or decrease depending on the model used. Rainfall intensity changes are expected. Resulting flow volumes display a broad array of possible futures, as do future pollutant loads. Land-use change does not have a significant effect on the whole-basin scale but will have local impacts.

The next step is to link models of different processes, different spatial representations, different temporal resolutions, models using different units, models based on different concepts, and models based on different variables. An open model standard interface (OpenMI) is used to link models because no one model can accomplish everything. The OpenMI standard interface has a common memory stream that other models can access simultaneously and allows integration of SWAT and SOBEK-RE. The integrated model result is highly determined by the model that has a coarser time step (SWAT) than a finer time step (SOBEK-RE). The SWAT OpenMI compliant model can be linked to other hydroinformatics tools to address integrated water resource and water quality management problems. OpenMI was found to be a promising tool for integrated modeling, making the best use of the strengths of each individual modeling software.

### Panel Discussion

A participant asked Mr. Simpson whether LID was encouraged in the Oyster River Watershed scenario. Mr. Simpson responded that it had not been because the modeling was robust. Sunapee is going to develop a model that will answer local policy questions.

A participant asked Dr. Babson the best way to average climate models. Dr. Babson responded that modelers are encouraged to average models instead of attempting to determine which models perform best at which extremes.

A participant asked how to ensure modelers provide actionable science to decision makers. Mr. Simpson responded that it is difficult to judge how margin of error affects models. He recommended that modelers do not provide the worst-case scenario to local government but instead provide a reasonable deduction. Dr. Babson added that it is necessary to include uncertainty in discussions with decision makers. Dr. Srinivasan stated that decision makers must determine the risk that they are willing

to take. They need to make decisions regardless, and modelers are providing them with more knowledge to make the decision. Models increase decision makers' knowledge base. Mr. Simpson thought that this is scale-dependent; ground truthing becomes more difficult as the scale increases. It is necessary to perform sensitivity analyses to determine which parameters are most appropriate.

A recent survey of U.S. Forest Service (USFS) staff indicated that only 50 percent believe that climate change is a reality. Land managers are not comfortable with the lack of knowledge and model competence. Scientists must be careful with the data and information that they share and must minimize uncertainty. Dr. Babson said that the key is to consider users' acceptance of uncertainty and ensure that the model is appropriate. Dr. John Powers noted that it is important to develop a framework that allows decision makers to see how scientific information can be integrated and partnerships with modelers can occur. Mr. Simpson said that a significant challenge is speaking with the engineers, because if the engineers do not believe what the modeler is telling them, then they will not sign off. Engineers currently are using data from the 1920s through 1959.

A participant asked about the status of the 20 Watershed Survey, whether the results were incorporated into the Chesapeake Bay TMDLs, and whether the Susquehanna results could be used by the Susquehanna River Basin Commission to examine regulatory programs and assist with decision making. Dr. Srinivasan responded that the project will be finalized within the next 3 to 4 months, and the results will be available after the report is written and peer reviewed. It will not be incorporated within the Chesapeake Bay endeavor, which has a different model. Regarding the Susquehanna River Basin, urban land use changes the scope of that particular study, but baseline models can be used to ask questions and obtain answers.

A participant asked about the scale of the ACF and Flint River Basin projects and how the models were calibrated. Dr. Srinivasan replied that 14 locations were used for validation and calibration of hydrology and water quality.

Dr. Powers asked how HAWQS could be applied on a national scale. Dr. Srinivasan answered that the researchers are working on a national-scale project with SWAT and are applying the same approach to HAWQS. Several papers have been published on this, and he could share these with the participants. Dr. Babson noted that she likes the term "decision scale." Determining whether the model is transferable to other locations with similar scales is a challenge. Dr. Srinivasan added that, in terms of scale, it is necessary to consider that decisions made in one location can affect another location, and it is necessary to provide the appropriate links. Scale must include cause and effect.

### **BREAKOUT SESSIONS: DECISION MAKING NEEDS AND THE ROLE OF INTEGRATED MODELING**

The purpose of this breakout session was to identify the information needs related to climate change impacts to support decision making on a national, regional, and local scale. The participants were charged with the following questions:

- What decision making needs related to climate change impacts are you interested in?
- What is the scope of the decision making need (e.g., planning, guidance, policy, regulation)?
- What are the climate change impacts related to the decision making need?
- What is the spatial scale of the decision making need (e.g., national, regional, local)?
- What is the temporal scale of the decision making need?
- Given the decision making needs identified in Part 1, select and define a specific decision making need that can be analyzed using a systems thinking or integrated modeling approach. This specific decision making need also will be considered in the Day 2 breakout session.

- What information is required from the data or models (model output) to inform the specific decision?
- At what stages in the decision making process is this information needed?
- What are the tolerances for uncertainty to inform this decision?

### ***Introduction and Charge for Day 1 Breakout Session: Modeling for Action: Creating Integrated Models That Get Used***

#### **Drew Jones, Climate Interactive**

Mr. Drew Jones was struck by the abundance of possibilities when bringing modelers and decision makers together; he is learning a good deal about bridging gaps. It is appropriate to use simulations because they have the power to change real behavior, and he provided an example of inspiring 120 people to carry their trash on campus for 1 week when he was in college. This simulation led to actionable changes. The question is how to touch people deeper, and simulations help people to experience long-term consequences of their actions in ways that create new possibilities. He noted that there has been confusion regarding the United Nations Framework Convention on Climate Change (UNFCCC). Science-grounded simulation models are available, but policy makers do not use them because scientists were not "crossing the bridge" to encourage decision makers to use them.

Climate Interactive's simulation model, Climate Rapid Overview and Decision Support (C-ROADS), is a simulation oriented to decision makers that helps users understand the long-term climate impacts of scenarios to reduce GHG emissions. The goal is to provide custom feedback to decision makers regarding the implications of a range of different scenarios. C-ROADS has been broadly disseminated and used. The U.S. Department of State, President Barack Obama, and the Chinese government have used C-ROADS; Climate Interactive developed a Chinese interface specifically for the Chinese government.

Three themes emerged during the development of the software: rapid iteration to meet user needs, multiple forms of simulation, and the ability to correct specific scientific misunderstandings (e.g., leveling emissions does not level temperature). A common version is available to the public, and additional software is not needed; data are available as well. The software is open source to increase distribution and creativity. Finally, Mr. Jones described a role-playing game that is very similar to the actual UNFCCC.

A participant asked how carbon intensity could be incorporated and what occurs per capita when carbon intensity is changed by country. Mr. Jones responded that feedback is provided to decision makers regarding the implications of their assumptions, and per capita graphs can be used to accomplish this. It is necessary to empower everyone with as much science as possible. The software can change carbon intensity, and the model output can be displayed per capita.

A participant asked whether the model incorporates the fact that China's emissions are a direct result of U.S. consumption. Mr. Jones responded that this is an aspect of fairness. The model does not allocate differences, but this is a very good point.

A participant asked whether human health could be incorporated into C-ROADS. Mr. Jones responded that he has been unable to add global indicators of human health, and he was unsure whether this was possible as this issue often is a downscaled regional or local issue.

A participant asked whether decision makers and negotiators realize the rough impacts of their decisions. Mr. Jones responded that he did not think they did. The participant asked how this could be addressed.

Mr. Jones responded that this was a great transition to the breakout group sessions, because the participants are attempting to create simulations and analyses that are powerful and action generated.

### Red Group Breakout Session

Mr. Jones and Ms. Mahri Monson, EPA, Office of Enforcement and Compliance Assurance, co-facilitated the session; Mr. Robert Howard, EPA, Region 4, served as rapporteur. The breakout group was composed of modelers, advocates, educators, and program managers. The overall goal of the breakout sessions was to use integrated modeling to support necessary decisions. The specific purpose of the first session was to identify the real information needs related to climate change to support decision makers.

Following introductions, the participants each identified a critical decision making need:

- Prioritizing soft marsh restoration.
- Information to use in environment advocacy.
- Probability distribution function.
- Incorporation of economic factors into models.
- The difference between doing something and doing nothing during the long term.
- Examples of model success and failure.
- Land-based impact modeling.
- Development of a sound economic framework for different cultural groups to analyze and communicate tradeoffs to decision makers.
- Adaptation strategies for local and state governments that go beyond incremental changes to true impacts.
- Tradeoffs between adaptation and mitigation.
- Human disease incidence associated with climate change.
- Merging air quality issues with climate issues.
- More specifics on time scale and various metrics to make conversations with politicians more productive.
- Small business decisions that will impact climate change.
- Adaptation plans for local governments.
- Hydrological modeling to determine how climate change will affect water resources.
- Development of state conservation plans.
- Stakeholder participation.
- Provision of necessary tools and resources so that state governments can make the best decisions.

The next step was to select a need, or a combination of needs, to discuss further. Several areas of overlap were identified: (1) rising sea level, (2) financial/economic aspects, (3) health, and (4) communication tools. The group decided to focus on how to integrate financial/economic aspects into models; no decision maker will make a cost-incurring decision in the absence of a thorough cost analysis.

Several cost analysis notions were considered. EPA should not limit analysis to up-front human health costs but also should calculate the costs to the environment. In the past, ecosystems performed their functions for free, but as resources become scarce, ecosystem components have suddenly acquired value and should be included as inputs into the economy. Ecological services need to be entered into national accounting equations. Another consideration is a model that can be used within the current budget. Short-term costs often overshadow long-term benefits; flexibility should be integrated to account for differences in decision makers' management of various issues.

Equally important to the determination of costs associated with policy change is the cost of doing nothing (the currently followed plan); there is no incentive to move forward without a comparison. Identifying the costs associated with immediate initiation of adaptation strategies compared to delays in implementation of 5 years or longer would be useful for decision makers. A good environmental model should be used to illustrate the probable effects of several scenarios on a specific piece of land; data are needed across a range of time scales.

A common language that ecologists and economists can use to communicate often is lacking; therefore, a method is needed to communicate across fields. Particularly relevant to decision making is gaining an understanding of who the “winners” and “losers” are in a particular situation (e.g., key parties, industries, commoners) and determining the approach that will most likely lead to successful decision making. For example, the services produced by forests for communities can lead to conflict between stakeholders trying to make decisions on the same issue.

Economic predictions are made with some degree of uncertainty. How much is acceptable for these climate models? Economists tend to be more tolerant of risk and uncertainty, whereas scientists are challenged by this concept and will need to adapt. A decision framework should incorporate differences in uncertainty and risk, which are dependent on investment and other relevant factors. In terms of non-regulatory-based decisions, the degree of uncertainty is small because a choice is being made (e.g., decision to clean up one site rather than another requires explanation, including risk and uncertainty). Essentially, no decision is irrelevant; the sooner information reaches decision makers, the more beneficial.

In terms of economic and financial information, model outputs need to include:

- The value of ecosystem service.
- Who accrues the costs/savings.
- Opportunity costs.
- The cost of doing nothing.
- The cost/benefit of delaying action.
- Assessment of tradeoffs.
- Common language (economic/environmental).

### **Green Group Breakout Session**

Dr. Noha Gaber, EPA, OSA and Dr. Winona Victory, EPA, Region 9 facilitated the session, and Mr. Rick Gillam, EPA, Region 4, served as rapporteur.

The group members spent time individually brainstorming about: (1) the scope of decision making needs, (2) climate change impacts related to the decision making need, (3) the spatial scale of the evaluation, and (4) the temporal scale of the evaluation.

The group discussed what “actionable” climate information is and the uncertainty surrounding it. This information often includes an objective element and a more normative or subjective component. Models can help regional decisions related to state implementation plans (SIPs) for air pollutants, TMDL standards for water quality, and Superfund clean-up targets at ports affected by sea level rise.

A consultant standing in for an EPA water office manager described work on “climate-ready water utilities” and how incorporating climate-driven changes fits into the budget cycles for water infrastructure investments from the time span of years to decades. Denitrification, nitrification, and watershed transfers are key issues for planning and TMDL development and evaluation. In addition, policy changes under the

## Integrated Modeling To Characterize Climate Change Impacts and Support Decision Making

---

Clean Air Act affect the delivery of nitrogen from a monthly to yearly time span. An EPA atmospheric modeler and analyst discussed air quality and climate interactions related to GHGs, aerosols, and ozone on regional planning efforts.

In terms of integrated modeling on the research side, with a particular focus on landscapes, receiving waters, and decision-support tools, exploring options that touch on state variables, forcing functions, and decision outputs and formats is key. The sensitivity and uncertainty of models are important aspects to track in addition to how they are presented to decision makers. Climate also impacts in-stream temperature; fish offer many commercial and recreational services. Additionally, it is a challenge to balance competing needs for short- versus long-term time horizons in providing modeling support for decisions.

The group members discussed their work and needs:

- A participant from the Inter-American Development spoke of the need for policy, plans, and guidance for Latin American countries on adapting to climate change, particularly in the water security arena including both quality and quantity.
- An environmental expert with the Seminole Tribe of Florida is seeking resources on what tools may be available to the tribe on tracking and assessing climate change impacts, particularly in the area of wetlands, mitigation monitoring, and habitat preservation during the short-term.
- An EPA air quality modeler investigates climate impacts on the impact of the expected range of temperatures and how population growth and land use may optimally affect the design parameters for local infrastructure.
- Another EPA environmental specialist focuses on the impact of climate change on environmental justice issues in communities, particularly as they relate to emissions and aesthetic considerations like scent.
- A National Environmental Policy Act (NEPA) expert reviews environmental impact statements and looks for good cumulative effects analyses that integrate GHG emissions, ecosystem impacts, water availability, and runoff.
- Another NEPA expert reviews SIP plans and models and is interested in the impact of climate change on regional and local planning.
- An EPA modeling researcher focuses on energy system models with inputs on population growth, and criteria pollutant emission estimates to support the Office of Air & Radiation's scoping and scenario efforts.
- An EPA specialist in the GHG impacts of biofuels supports decision makers in the Office of Transportation and Air Quality.
- An extension agent in North Carolina works on land-use planning, water quality and natural resource management and is interested on factors that might shape the design and siting of a new wastewater treatment plant (WWTP) near a coastal river in the state.
- A Susquehanna River Basin Commissioner is interested in models that predict stream-flow, water quality and quantity, flooding, and drought as the commission refines its comprehensive plan and makes decisions related to allowable water withdrawals. Traditionally, the commission has used a 7-day, 10-year low-flow value to guide withdrawal decisions but they are working on developing an ecologically-based flow criteria value with The Nature Conservancy.

For the second phase of the breakout session, the group elected to adopt a systems point of view and focus on key issues affecting the design and siting of a new WWTP along the Roanoke River in North Carolina that may experience sea level rise as a test case to identify key environmental and social decision factors and modeling issues.

Rainfall is considered a key factor, but current climate models are not good at predicting it. Moreover, it is possible to experience reduced rainfall but greater extremes, which complicates how to account for this climate change impact. The group brainstormed a number of factors that influence the siting and design decision, including:

- Service area population and character.
- Geography.
- Land use.
- Available treatment technology and water usage.
- Energy source use.
- Hydrology (and precipitation affecting) of the receiving stream and its water quality.
- Available locations.
- Emergency access.
- Condition of the collection system.
- Regulatory requirements.
- Environmental justice issues that may impact the surrounding community.
- Methane emissions.
- Scent/aesthetics.
- Operator and local community risk perception.
- Cost.
- Endangered species/conservation issues.

Additionally, the current set of design criteria may have to be altered to account for the impacts of climate change, and the design parameter approach, whether based on historic or traditional methods, may have to be reconsidered, as highlighted by the Susquehanna River Basin example. How to communicate how the design parameters are changing is a key challenge that warrants careful thought. A “participatory modeling” approach to design and siting may be optimal in this type of scenario that examines land, air, and water deposition, emissions, and discharges.

The decision making focus of the community leaders may be short-term, but the modelers’ responsibility may be to include questions and information about anticipating long-term environmental dynamics. More sophisticated questions often emerge once community leaders get beyond the initial stages of exploring what environmental and social factors influencing plant siting and design.

### **Yellow Group Breakout Session**

Dr. Jim Fox, University of North Carolina at Asheville, and Dr. Linda Rimer, EPA, Region 4, co-facilitated the session. The participants brainstormed answers to the charge questions and discussed how to bridge the gap between modelers and decision makers.

In response to the charge question regarding the scope of the decision making need, the participants developed the following list:

- Planning for forest ecosystems.
- Planning for imperiled species.
- Guidance for impacts of climate change on estuaries.
- Understanding and interpretation of model outputs.
- Program integration.
- Planning for land managers.
- Research gaps.
- Planning for private landowners.

- Planning for sage desert.
- Investment decisions for landscape conservation and infrastructure.
- Identification and removal of barriers.
- Future energy needs.
- Resource planning and regulation.
- Policies for development.
- Planning for infrastructure.
- Ecosystem management including emergency management and monitoring design.

In response to the charge question regarding climate change impacts related to the decision making need, the participants developed the following list:

- Change in sea ice.
- Water quality, quantity, and habitat.
- Extreme weather events.
- Economic, environmental, and social impacts.
- Sea level rise.
- Flood control.
- Water supply.
- Lack of stationarity.
- Unintended consequences (e.g., health, property, services).
- Change in temperature related to population and societal impacts.
- Snow pack.
- Crop yields.
- Ecosystem function.
- In-stream flow.

In response to the question regarding the spatial scale of the decision making need, the group members noted that the scales are resource- and issue-dependent. Potential scales are global, national, regional, local, watershed, estuary, and micro-scale (backyard, field). The majority thought that the regional and local scales were the most critical. In response to the question regarding the temporal scale of the decision making need, the participants noted that it could be short- to long-term or immediate (for comprehension of model concepts). Most local government decision making is on a scale of 1 to 5 years, and ecosystem services management is on a scale of 3 to 5 years. The majority of participants thought that the scale of more than 20 years was the most beneficial.

Using the decision making needs that they had identified, the group members selected and defined a specific decision making need that could be analyzed using a systems thinking or integrated modeling approach. The participants discussed what information is required from the data or models to inform the specific decision, which they determined to be planning for water quality and quantity during a 20-year time period in the Western United States, taking snowmelt into consideration. Critical information includes the timing and volume of the snow melt, precipitation, global cyclic weather, planning for population and economic growth, water demand, historical records, and land use.

In terms of what stages in the decision making process this information is needed, the group thought that education of decision makers and planners should be undertaken immediately, and lead time for infrastructure projects must be considered. Participants discussed the tolerance for uncertainty to inform this decision. Model and economic uncertainty and the economic viability of the community must be considered. Additionally, risk tradeoff, reversibility, resilience, risk aversion, and population growth need to be considered.

The participants noted that no climate change adaptation model will be "one size fits all." It is necessary to include decision makers in the discussion from the beginning, identify opportunities, and take advantage of whatever is possible. Consistency among climate change models also is critical.

### Blue Group Breakout Session

Mr. Bob Horn, Stanford University, and Dr. Gabriel Olchin, EPA, Office of the Science Advisor (OSA), co-facilitated the session; Mr. Daniel Garver, EPA, Region 4, served as rapporteur. The breakout group was composed of data users, modelers, and managers. The discussion began with several decision makers identifying issues that are important for decisions.

The most germane decisions about climate change adaptation are made at the local or regional levels. One participant pointed out that in Georgia, most of the elected officials at the county level do not believe in climate change. In general, rural areas are less likely to understand the implications of climate change in their region and take action. When information is produced, it needs to be framed in terms that will be received and appreciated by the average decision maker. Local, real-world consequences must be explained to get buy-in from the community. It also may be more effective to avoid the word "climate" and discuss "weather extremes" instead, because "climate change" is politically charged, and people find it easy to relate to weather extremes.

States have a responsibility to ensure local decision makers take climate change into account. If local ordinances are not put into place by county governments, states can issue mandates or regulations; however, it may be more effective to use incentives (tools, information, cost-avoidance, financial support) to encourage local governments to consider climate change in their decisions. At the federal level, it is important to provide states with support for resiliency, preparedness, and other climate change issues. Federal funding is a very strong motivator; one option is to require climate change to be considered at the local level before state revolving funds are approved.

Economic considerations, in contrast to climate change, are usually a high priority and strong drivers of decisions. For example, Minnesota adopted a renewable energy policy because it was economically beneficial. Any co-benefits in terms of climate change were of secondary importance. Decision makers may be more likely to consider climate adaptation if it is integrated into high-priority regional problems. Furthermore, the climate change problem cannot be solved without addressing other problems as well, such as economics.

Scale is another important consideration. Local decisions require state-, regional-, or community-level information and models. Taking a top-down approach, global models need to be re-scaled to a regional level and then tailored specifically to the local level. Coordination is essential. Otherwise, each continent/country/region/community develops their own tool, and it becomes impossible to integrate all of the different models.

EPA Region 4 has the largest population and the highest projected degree of growth in the United States. As such, managing water for the burgeoning population, fish, and wildlife is a top priority. Water shortages already are being faced, and climate change is anticipated to stress the system further. The breakout group decided to focus on regional water quantity decisions and identified the following considerations:

- State-level water resource planning is based on current water records, but this will no longer be relevant with climate change.

## **Integrated Modeling To Characterize Climate Change Impacts and Support Decision Making**

---

- Models must provide information about the weather, hydrology, and precipitation at the appropriate time and spatial scales; there is a discrepancy between the scales of the models and the scales of the decisions.
- Tools should be scalable.
- Information at a local (catchment) level will help decision makers pinpoint where climate changes are likely to occur and prioritize their actions.
- Hydrology and water models need to be linked to atmospheric models.
- There is a data gap between what is known about the natural landscape and incremental changes in the populated landscape; information is needed about impervious surfaces and density of structures.
- The effects of socioeconomics on land-use changes and how this affects water quantity and quality should be considered.
- Communication must occur laterally (across agencies) and vertically (national to local and vice versa).
- Information does not always have to be precise; incorporating a rough estimate into a decision is better than not incorporating it at all.

Participants agreed that the most important considerations for water resource planning decisions in the context of climate change were economics, consistent communication, scale-relevant information, and precision and uncertainty.

DAY 2: FEBRUARY 2, 2011

### DAY 1 BREAKOUT SESSION REPORTING AND DISCUSSION

**Session Moderator: Gabriel Olchin, EPA, OSA**

Ms. Monson provided the report out for the Red Breakout Group. She explained that her group had identified decision-support needs, such as the importance of including health impacts, the probability distribution of sea level rise, and the need to better incorporate economic and financial information into the models. The value of ecosystem services, the costs and benefits of delaying action, the cost of the "business as usual" scenario, and assessment of tradeoffs are important in terms of model output needs. Regarding the question of when information is needed in the decision making process, information is needed at the beginning of the process and in the planning stages so that information is provided to citizens early, which will allow them to influence decision makers; information must be strategically timed within the decision making process. In terms of uncertainty, there is a need to address the distinction and relationship between risk and uncertainty and to understand and communicate uncertainty.

Drs. Victory and Gaber provided the report out for the Green Breakout Group. Guidance on incorporating climate change information should be added to NEPA reviews, air quality SIPs, water management, Superfund cleanup, investment decisions, management of specific sectors and land use, ecosystem protection and management, environmental justice concerns, assessment of energy needs, and assessment of cumulative impacts. The breakout group discussed whether climate information is actionable. Models are learning tools that can facilitate discussion among stakeholders. It is necessary to take advantage of climate models, despite limitations and uncertainties. Additionally, it is important to understand local decision makers' tolerance for uncertainty. Specific climate consequences relative to specific political action areas should be identified. There is a long-term challenge in integrating climate into budget planning, and it is necessary to understand how climate change factors are different than other factors already considered by decision makers. Climate change is not yet covered by a defined regulatory process that is accepted and respected without question by decision makers, and models are tools that are one component of the entire scenario that decision makers consider. The breakout group chose as its focus the designing and citing of a WWTP and the factors that need to be considered (e.g., land use, air quality impacts, precipitation, operation, energy source and cost, treatment technologies, water and energy usage, regulatory requirements). The various connections among these issues were identified; the process is iterative and should include the perspective of local stakeholders, who may be able to identify relevant issues and the factors needed to address them.

Dr. Rimer provided the report out for the Yellow Breakout Group. The group discussed the scope of the decision making need and focused on planning (e.g., forest ecosystems, sage desert, imperiled species, private managers, infrastructure). The breakout group also considered guidance for impacted water quality, understanding of climate change modeling in translation, research gaps, and investment decisions. Water quality was identified as a significant concern. Climate change impacts related to the decision making need are changes in sea ice, transportation, sea level rise, lack of stationarity, temperature, population growth, ecosystem functions and health, human health, snowpack, and in-stream flow. Other impacts include water quantity, quality, and habitat; extreme water events; economical, environmental, and social impacts; flood control; and crop yields. The spatial scale is issue-, resource-, and value-dependent and can be global, national, regional, or local. Other scales include watershed, estuary, and/or microscale. The specific scenario on which the group chose to focus was planning for water quality and quantity during a 20-year time period in the Western United States, taking snowmelt into

consideration. The information required for the scenario is the timing of the snowmelt, precipitation, global cyclic weather, population and economic growth, water demand, historical records, and changes in land use. This information is needed immediately within the process for education, decision making, and planning. There are several uncertainties to consider, including the model, economic considerations, societal responses, and population growth. How issues are framed influences public discussions. No climate change adaptation model will fit all situations. It is necessary to include decision makers in the discussion at the beginning of the process, look for opportunities, and take advantage of whatever is possible. Consistency among climate change models also is critical.

Dr. Olchin provided the report out for the Blue Breakout Group. This group identified areas of expertise among the group members before discussing decision making needs. The group determined that the scope of the decision making requires planning, the climate change impacts related to the decision making need are water resources, and the spatial scale is local and regional. The group examined water resources planning in terms of systems thinking and identified the following critical information needs: weather, wildlife, economics, cost avoidance, ecosystem services, energy, land-use change and planning, watershed vulnerability, hydrologic processes, and water quality and quantity. There is a need for water balance within water and air models, scalable tools, lateral communication and coordination, and identification of problem-specific precision and uncertainty. Additional needs include incorporation of downscaled regional models and identification of the decision makers at the local level. Economics and land use must be linked to climate impact problems. The group thought that it was important to avoid discussing climate change when talking with decision makers and instead focus on impacts. Cost avoidance also was discussed by the breakout group. The following list of “C” needs were identified: culverts, cost avoidance, critters (wildlife management and climate change), criteria, critical decisions, and consistent communication; not needed are climate or carbon.

### Discussion

A participant noted that, in terms of cost avoidance, much of the future focus is on mitigation and adaptation; cost avoidance could be connected to this. To increase attention, it is necessary to communicate with citizens prior to communicating with decision makers.

Another participant thought that there was a need for actionable information. There may be a great deal of uncertainty in modeling, but the path of short-term, least regret can be identified until uncertainties can be resolved at a later date. Dr. Rimer agreed that this could be accomplished immediately as data become available, especially in terms of the ecosystem services research that is in progress. A participant noted that decision makers frequently deal with uncertainty and make economic decisions in spite of it. A participant noted the need to discuss stakeholders’ needs; communication must be mutual. Stakeholder input should be obtained early in the process, and stakeholders should be engaged from the beginning before any decision is made to increase their acceptance of the final product. Another participant thought that there was a need to provide decision makers with decision strategies, matrices, and explanations of how adaptive management can be incorporated.

### SESSION ON INTEGRATED MODELING FOR TAKING ACTION ON CLIMATE CHANGE

**Session Moderator: Cindy Bohn, U.S. Fish and Wildlife Service**

Before introducing the session panelists, Ms. Cynthia Bohn noted the importance of another “C” (in keeping with the list introduced by the Blue Breakout Group): collaboration.

**Comparative Risk Assessment Framework and Tools (CRAFT) Model Regional Partnership  
Jim Fox, University of North Carolina at Asheville, Director of the National Environmental  
Modeling and Analysis Center**

Dr. Fox highlighted some of the recommendations from the “EPA Southeast Climate Change Adaptation Planning Workshop” that took place in February 2010; participants at the workshop discussed how to approach the climate adaptation issue. The recommendations were to develop an education and outreach role on climate change that is clear and understandable, create a climate change information clearinghouse for the Southeast, conduct coordinated vulnerability assessments, define priorities, and develop adaptation policies. Participants at the workshop discussed the importance of enabling local decision making. To move from assessment action, it is necessary to think globally, assess regionally, and act locally. This effort must begin with education and outreach to ensure that everyone receives a consistent message. An educational and outreach opportunity is at the Summer Institute on Climate Change in Asheville, North Carolina, from June 15 to July 1, 2011, which is being hosted by NOAA’s Cooperative Institute for Climate and Satellites.

The regional assessment phase is dominated by the technical community, a group that can populate a framework that will support decision making at a variety of scales; decision makers and stakeholders depend on modelers to provide these types of tools. NOAA regional climate assessments take a bottom-up approach. Climate is one issue, but other issues also affect decisions; people want to know how climate impacts the issues that are important to them. To take local action, decision makers require tools that are at the proper scale. In addition to spatial scales, temporal skills also are important. A 20-year planning horizon is the most common temporal scale, but most climate models are longer term.

Dr. Fox highlighted three real-world examples. The Interstate-40 landslide in 2010 had a \$200 million impact on the economy of Asheville, North Carolina. There are several “pinch points” in the area that are similar to the location at which the landslide occurred; these points are very vulnerable to the disruption of transportation. The scale of decisions regarding this issue is local. Another real-world example is the gasoline supply disruption of 2008 that resulted from Hurricane Ike; the Asheville market had severe disruptions for nearly 2 weeks. This example highlights a similar vulnerability as the first example, but the scale is very different. The third example is the water shortages during the droughts of 2002 and 2007. The similarity in all three examples is that decision makers had to deal with climate variability rather than long-term increases or decreases in temperature or precipitation.

SENRLG uses in a process called CRAFT to examine a Landscape Conservation Highlight Project in the Southeast. CRAFT is a four-stage process that starts with problem definition, a clear structuring of action alternatives, and identification of risks for each of the alternatives, and then effective communication of the findings; decision makers can use CRAFT to assist with decisions. The first step is to start with an understanding of the problem by addressing the values of risk. Values are linked to goals and objectives, and linked objectives are color coded in the same manner, which allows the team to better communicate common values. Another tool included in the first stage is a conceptual model that allows the team to understand the relationship and influences among potential activities and alternatives and lays the

groundwork for understanding what possible tradeoffs could be; in the example that Dr. Fox highlighted, very few of the factors were related to climate. In Stage 2, alternatives are devised based on the problem and likely tradeoffs rather than what might satisfy a single objective. Dr. Fox displayed a map that shows the spatial relationship among the various items that the different agencies value. The third stage predicts future conditions or management actions using models that use probabilities and scenarios. Bayesian Belief Networks are used to highlight different scenarios.

SENRLG is learning important lessons as it works with groups are creating decision-support tools. It is important to move from assessment to action and create tools that are not just for the educational or technical communities. It is important to focus on customer needs (i.e., decision makers) as well as on vulnerability and resilience. Finally, it is important to use decision-support process such as CRAFT.

### ***Climate Resilience Evaluation and Awareness Tool***

**Steve Fries, Computer Sciences Corporation for Curt Baranowski, EPA, Office of Water**

Dr. Steve Fries explained that EPA's Climate Ready Water Utilities (CRWU) Program is focusing on achieving a state of readiness by striking the proper balance when adding climate uncertainty to other challenges in utility priorities and leveraging existing programs as the most efficient and effective means to pursue "Climate Ready" status. CRWU's priorities are to: (1) support utilities with practical tools and information to utilize adaptive response frameworks to deal with uncertainty and capacity issues; (2) examine climate change impacts on water resources and infrastructure, and the adaptation options prepare for them, beyond typical regulatory "silos" in utility boundaries; and (3) bring together partners at the federal, state, local and association levels to create integration and coordination opportunities. CRWU's current activities include the Climate Resilience Evaluation and Awareness Tool (CREAT), CRWU toolbox, and Tabletop Exercise Tool for Water Systems.

CREAT helps drinking water and wastewater utilities to assess the climate-related risks, evaluate adaptation options to reduce risk, and conduct assessments as part of long-term planning and decision making processes, and complements existing tools used to make projections and assessments regarding utility management. The tool is designed to evolve over time and accommodate a wide range of uncertainty in climate information. Following CREAT's steps in sequence allows users to inventory their utility's assets and identify climate change concerns, then conduct baseline and resilience analyses and generate reports. Any step throughout the assessment process may be revisited and refined. Once a user has entered utility information, the next step is to identify climate-related threats. Climate information stored within the model is conservative and includes regional assessments based on the most recent GCRP assessment (currently 2009) and a range of temperature and precipitation projections for various U.S. locations. CREAT also supplies a library of adaptation measures being used by water and wastewater utilities to respond to climate change that users can reference during their assessments. Following analysis, the final steps are implementation planning, and generating reports in Microsoft Word and Excel that contain details of the inventories entered throughout the process and assessments conducted. Ultimately, these reports can be used to support a utility's planning decisions.

CREAT is a very comprehensive tool with a user-friendly interface and embedded resources. There are several benefits of CREAT, including the fact that it provides awareness information for utilities and conducts risks assessments using qualitative and quantitative information taking into account the uncertainty that surrounds climate science. The tool produces reports that can be integrated into adaptation decision making and planning processes. In summary, CREAT provides regional assessments and is built to accept new climate data modules as information becomes available. CREAT is an example

of how to bridge the gap between modelers and target groups to develop tools for climate change decisions.

### ***Modeling Scenarios of the Future Using the EPA Nine-Region MARKAL: Energy, Climate, and Emissions***

**Dan Loughlin, EPA, ORD, National Risk Management Research Laboratory**

Dr. Dan Loughlin explained that global change air quality assessment is the motivation for the ORD Energy and Climate Assessment Team's work. The team is performing evaluations of regional U.S. air quality under changing climate and emissions in phases. Phase 1, which is complete, evaluated climate change-only impacts on future air quality; Phase 2, which is ongoing, evaluates climate change and emissions change impacts on future air quality. Phase 1 results indicate that climate change has the potential to produce significant increases in ground-level ozone for much of the United States and lengthen the ozone season. Air quality managers should begin to consider the potential effects of climate change and adjust their monitoring to account for the lengthening ozone season. In terms of the Phase 2 emissions scenarios, the team is examining alternative emissions scenarios to 2050; however, there is no one accurate projection of future air pollutant emissions. Factors impacting future emissions include population growth and migration, economic growth and transformation, land-use and land-cover change, climate change, technology change, individual and corporate decisions, and public policies. Additionally, there is considerable uncertainty in each of these factors. The team is developing and evaluating a set of scenarios that are plausible to capture a meaningful range of possible futures to provide insight about the combined and relative effects of the major factors driving changes in future air quality. The team is using integrated modeling framework for analyzing future emissions scenarios.

The group models the energy system with MARKAL, considering all processes together as an energy system. The group focuses on the energy system because of its contributions to U.S. anthropogenic emissions; 89 percent of U.S. electricity production uses water for steam or cooling. Also, there are water quality concerns related to new hydraulic fracturing approaches for extracting shale gas. The MARKAL framework is an energy modeling framework that has been applied to a variety of applications and scales. EPA MARKAL national and regional databases allow optimization from 2000 to 2050 in 5-year steps; the national database was released to the public in 2006. Results are aggregated on a national level but can be run on a regional level.

Dr. Loughlin provided graphic examples of an energy system future run with and without a hypothetical GHG policy; these examples highlight the impact of a hypothetical GHG policy on emissions. Another graph highlighted regional admission changes under each scenario. The group has developed a methodology for converting MARKAL emission projections into the inputs needed for the Sparse Matrix Operator Kernel Emissions (commonly known as SMOKE) Model.

It is beneficial to use MARKAL to examine regional issues and support decision making because it is relatively inexpensive and may be useful in helping to develop scenarios for use in other analyses (e.g., energy security and clean energy strategies in the context of different goals and resource allocations). Modeling expertise is required, however, which takes time to develop.

### ***Water Supply Stress Modeling and Technology Transfer Mechanisms: Discovering and Applying Climate Change Science***

**Steve McNulty, USFS, Southern Research Station, and David Meriwether, USFS, Southern Region Planning**

Dr. Steve McNulty provided information about the Water Supply Stress Index–Carbon and Biodiversity (WaSSI-CB) Model. Forest water use is related to forest productivity, which is related to ecosystem carbon sequestration. All of the information needed to predict carbon sequestration is available from the water supply model. Biodiversity is related to ecosystem water use and productivity; therefore, a modification of the water supply model equation could be used to predict carbon sequestration, changes in biodiversity, and tradeoffs between water supply and carbon gain. Several models that the group developed with others are incorporated into the WaSSI-CB.

The Western and Eastern United States have different demands on water resources. WaSS-CB takes into account all demands and uses of water as well as supply and demand to create the stress Index. WaSSI is the total water supply from all sectors divided by the total water demand from all sectors. Dr. McNulty displayed a diagram of the pieces of the model that highlights how water, carbon, and biodiversity are interrelated. The participants were shown spatial resolution maps that highlight the model output. Scenarios also were developed that could be compared to baseline. Climate change is not the only consideration; groundwater supplies also need to be considered. The model can show the impacts of precipitation, population, and climate change and predict wildlife and tree biodiversity.

Ecological relationships between water, productivity, and biodiversity allow for the assessment of alternative future conditions on ecosystem services. WaSSI uses these relationships to determine how land use, population, climate change, and management decisions will impact ecosystem function. This simple model is being incorporated in the online Template for Assessing Climate Change Impacts and Management Options (TACCIMO) tool to assist land managers in their decision making processes.

Mr. David Meriwether explained that the science-management relationship is very important for science and management to be effective together. The relationship requires a common focus, commitment of resources, hard work, adaptation, and endurance. Agency actions have several levels and include strategic plans, national forest plans, annual programs of work, and site-specific management. Strategic plans generally are fairly broad, but the other three types of plans increase focus on regional and local action.

To address climate change, the Uwharrie and Mississippi Forest Plans include initiatives to maintain and restore native ecosystems, manage the potential for soil erosion, reduce vulnerability to drought and windthrow, and reduce vulnerability to insects and diseases. New perspectives have been gained as climate science has been examined. A current planning project in the George Washington National Forest has been used to determine how to use information from TACCIMO in planning and management. TACCIMO provides localized estimates of precipitation and temperature and filters and reports science synthesis and literature. Mr. Meriwether provided example data regarding local projections for the George Washington National Forest, which have resulted in a much more robust response in the draft plan for the George Washington National Forest Climate Change Strategies. Also, carbon management is a direct focus. The strategies are to: reduce vulnerability by maintaining and restoring resilient native ecosystems, provide watershed health, provide carbon sinks for sequestration, reduce existing stresses, respond to demands for cleaner energy, and provide sustainable operations and partnerships across landscapes and ownerships.

One specific focus is to protect and restore beaver meadows, wetlands, and floodplains to improve natural water storage, reduce flood hazards, and prolong seasonal flows. Additionally, beaver meadows, wetlands, and floodplains improve habitat for Northeastern bulrush and American woodcock. Another example is swamp pink, an endangered plant species that requires a very specific hydrology; climate change has the potential to either increase or decrease water levels at established swamp pink sites. The survival of the species will depend on monitoring and protection of hydrology. These examples epitomize how building climate science into management practices from an adaptation perspective is comprised of three key components: assessment, monitoring, and management.

### ***Tools and Resources for Estimating the Multiple Benefits of Clean Energy***

**Robyn Kenney, EPA, Office of Air and Radiation**

Ms. Robyn Kenney explained that EPA's State and Local Climate and Energy Program helps state, local, and tribal governments identify, analyze, implement, and track clean energy policies and programs that achieve multiple benefits and synergies. The program offers identification and documentation of cost-effective policies and initiatives; tools, guidance, and outreach support; measurement and evaluation of the environmental, economic, energy, and public health benefits of various initiatives; peer exchange opportunities; and a collection of tools and resources on its Web site

(<http://www.epa.gov/statelocalclimate/index.html>).

The program hosts a regular climate and energy Webinar series on relevant topics related to state and/or local government climate change and clean energy efforts. A three-part series on climate adaptation was held in November and December of 2010 and January 2011. The materials are available at <http://www.epa.gov/statelocalclimate/web-podcasts/index.html>. Another priority focus area is the environmental, health, energy system, and economic benefits of clean energy. This is important because many analyses focus heavily on the costs of policies and include less quantification of the benefits, resulting in overstated costs. By estimating and considering the numerous benefits of clean energy during the decision making process, states can obtain a more comprehensive assessment of the value of clean energy, demonstrate where clean energy can cost-effectively achieve state goals and support planning strategies, and identify and design options that maximize benefits. The EPA *Assessing the Multiple Benefits: A Resource for States* report is intended for nonspecialists and is available for download at <http://www.epa.gov/statelocalclimate/resources/benefits.html>). Chapter 4 focuses on the air and health benefits of clean energy, and Chapter 5 focuses on the economic benefits of clean energy.

Ms. Kenney provided information on two tools to assess and communicate the multiple benefits of clean energy, the Co-Benefits Risk Assessment (COBRA) Screening Model and the GHG Equivalencies Calculator. COBRA is a free screening tool that quickly estimates the air quality, human health, and associated economic impacts of various state- and county-level emission reduction scenarios and enables users to obtain a first-order approximation of costs and benefits of different emission scenarios. COBRA can estimate the monetary value of health effects avoided and produce a visual map that shows the impacts by county. COBRA contains a variety of human health effects (e.g., mortality, infant mortality chronic bronchitis, respiratory hospital admissions, work-loss days) and their economic values. COBRA enriches discussion of co-benefits for states, is a flexible and easy-to-use free screening tool, generates results quickly, and provides mapping of results that facilitates visualization of impacts. It is important to remember, however, that assumptions are somewhat inflexible and simplified and should not be used for regulatory compliance.

The GHG Equivalencies Calculator, which can be found at (<http://www.epa.gov/cleanenergy/energy-resources/calculator.html>), is a simple, Web-based tool that translates GHG reductions in it easily

understood metrics and help stakeholders and citizens process actions taken by governments and the private sector. It can be used to communicate the magnitude of GHG emission reductions and includes peer-reviewed calculations and references.

### Panel Discussion

A participant was troubled that the tools described contain absolute projections of parameters in future scenarios; temperature predictions are reasonable, but precipitation predictions are not. Inclusion of absolute predictions of precipitation may provide the wrong impression to end users. Dr. Fries responded that much of the feedback that was received during the pilot test of CREAT indicated that more confidence was needed in the description of how projections were generated, so EPA adopted a range of possible futures. This provides a false sense of uncertainty but not a false sense of precision. This is a challenge regardless. Values need to be transparent.

A participant asked about the range of expected changes in TACCIMO. Dr. McNulty replied that the range must be shown and provide an idea of trending in models. Mr. Meriwether said that managers rely on their experience. Managers tend to think in terms of averages, so connecting uncertainty and variation is a challenge; modelers must think differently to address this.

A participant asked, in terms of evaluating decision-support tools, how to demonstrate, measure, quantify, and/or assess the extent to which they are being used in decision making, to decrease vulnerabilities, and/or in policies that increase adaptation. Mr. Meriwether stated that this is a challenge and that applications of models and science have been isolated to some degree. Some agencies have developed a "scorecard" to attempt to measure this; USFS has added adaptation to its scorecard to assess how well vulnerability assessments are performed and the success of direct actions, and these are being built into its programs. Dr. Fox stated that a multi-hazard risk tool was created in response to requests from emergency managers expected to use it. He provided examples of its use, including local fire departments that allocated resources based on the tool. Dr. McNulty said that he knows when a tool or model is effective because managers begin contacting him frequently.

A participant has noticed that very simple and very complicated models and tools are not used. The challenge is to simplify these models and tools without "dumbing them down." For example, COBRA is excellent for the public, but many decision makers think that COBRA data are acceptable for strategic planning, even though this is not the case. He asked how to balance the simple and the complex. Dr. Loughlin replied that it is a challenge to develop a mid-level model. Simple models cannot be used for SIPs but can be informative. An ongoing difficulty is describing exactly what a model or a tool can provide. Dr. Fox thought that tools should be connected to EPA modelers, who can explain the limitations to decision makers; modelers must be communicators as well as be responsible for technology transfer. Dr. Loughlin agreed that modelers should work with decision makers to ensure that the models and tools are used and applied correctly. Ms. Kenney stressed the need to be careful about how the tools are characterized, particularly the simplified ones. For example, those users who request COBRA are asked to provide information and given a guide to ensure that the model is used correctly. BenMAP can be used if COBRA is too simple. Dr. McNulty added that the key is scale; it is necessary to develop the appropriate tool for the scale to help users.

A participant thought that there was a problem with communication. It appears as though tools are developed and modelers then convince the users to adopt them. It might be beneficial to reverse the process and ask managers about the specific vulnerabilities that are of greatest concern (e.g., sea level rise vs. climate change) and then either determine which tools are most appropriate or build appropriate tools. Adaptation strategies may be embraced by communities if scientists communicate with them. Dr.

Fries explained that this was how CREAT was developed for the water community; modelers asked the water community for their concerns, and this community considered climate change its most significant concern. Dr. Fox provided three examples of how a similar strategy had been used in North Carolina.

A participant asked whether there were any techniques that translated across a broad spectrum of interrelated issues. Mr. Meriwether stated that this is a dilemma of planning. An effort was made to gather input and science; current goals and objectives are driven by ecosystem resilience with human and environmental health being taken into consideration. There is an attempt to evaluate climate change and its effect on other issues.

A participant reiterated that communication is important, and language must not be a barrier. It is necessary for people to understand that climate change is a real issue. Current funding is provided for mitigation rather than adaptation. Dr. McNulty agreed that education should be a critical component of all efforts, from how to use the models correctly to the fact that climate change is a problem. TACCIMO was developed to communicate about climate change in a consistent manner.

### **BREAKOUT SESSIONS: IDENTIFYING THE CURRENT MODELING CAPABILITIES, GAPS, AND NEEDS TO BRIDGE THOSE GAPS**

The purpose of this breakout session was to revisit the specific decision making needs selected on Day 1. Participants will determine current modeling capabilities to address the decision-support needs, identify the gaps in current capabilities, and described what needs to be developed to bridge these gaps. The participants were provided charge questions based on the decision support need defined in the first breakout session:

- What are our current capabilities to address the modeling and decision support needs?
- What models are available?
- What data are available? What is the temporal and spatial scale of the data?
- What inputs to the models require (considering temporal and spatial scales)?
- What are the gaps for supporting our decision making needs?
- What needs to be developed to bridge these gaps?

#### ***Introduction and Charge for Day 2 Breakout Session: Information Murals, Context, and Detail for Decision Makers***

**Robert Horn, Stanford University**

Dr. Robert Horn explained that dynamic murals are will become an integral component of the 21st century. He described the World Business Council for Sustainable Development, a CEO-membership group of 200 of the largest corporations in the world. The Vision 2050 Project Task Force consisted of 29 of the top strategists of these companies and was chaired by four CEOs. The task force goal was to create a vision of a sustainable 2050. The task force used an extensive backcasting exercise that produced 350 milestones that must be accomplished during the next 4 decades along 10 pathways (e.g. energy, transportation, buildings, food, forest, governance). Dr. Horn used a dynamic information mural to highlight the outcomes and products of the task force; the mural contains 40 milestones that must be achieved by 2020 to achieve the goal of a sustainable 2050. These 40 milestones are not radically dependent on technological breakthroughs, and no "science fiction" assumptions were made. These milestones are as approximately challenging as the moon mission. The significant challenge is that no single leadership exists for the globe.

Contradictions, paradoxes, taboos, and topics that are too emotionally disturbing to discuss become the “elephants in the room,” obvious truths that are ignored. Behind these topics lie significant, interrelated problems, which can be mapped and are further confused by data inundation and multiple viewpoints. This concept can be included in the information murals, and Dr. Horn included an illustration of what chaos and catastrophes may look like in 2040 and beyond. The mural also includes special to potential tipping points and their interactions. Ultimately, it is important that the climate change message is clear and understood.

A participant noted that there is a good deal that needs to be considered, including how to communicate the message to children and accomplish important tasks during the next 10 years. Dr. Horn responded that the messages need to be tailored and framed regarding risk, and communicators must have a personal understanding of the pathways.

A participant noted that a commitment from President John F. Kennedy allowed the successful moon landing; a similar commitment may be necessary to address the challenges of climate change mitigation and adaptation.

A participant was encouraged to hear the number of businesses and involved in this effort, which can help to address the stagnation present in the rest of the business community. Dr. Horn responded that several companies are addressing this and have made significant changes within their organizations.

A participant noted that complex understanding often can allow one to see simple solutions and asked whether Dr. Horn saw any. Dr. Horn responded that 40 such solutions had been identified, and 40 workgroups of government and NGOs with high-level leadership are needed to take responsibility for these during the next 10 years.

A participant asked how much would a capitalistic system satisfy. Dr. Horn responded that capitalism is called for to transform industry.

### **Red Group Breakout Session**

Mr. Jones and Ms. Monson co-facilitated the session; Mr. Howard served as rapporteur. The specific goals for Day 2 were to identify a specific decision making need based on Day 1 discussions, describe the need’s capability gaps, and determine how to bridge those gaps.

The facilitators provided four potential concrete decision scenarios that could each relate to economics/financial analysis and asked the group to decide which should be moved forward in the session. The four scenarios are as follows:

- A mayor’s strategy regarding heat-related deaths in Austin, Texas, and how to incorporate economics into the decision. (Note: Most heat-related deaths occur in Chicago, Illinois, and other places not used to heat.)
- A county board decision on future culvert upgrades.
- A municipality must decide on sewer improvement.
- A North Carolina plan for coastal adaptation to sea level heights.
- Drinking water supplies.
- Chemical treatment plants.
- Population displacement.

The group initially selected Scenario 4 but decided to further specify the issue and ultimately chose drinking water supplies in relation to the scenario. In addressing current capabilities to address modeling and decision needs related to drinking water supplies, the group first considered adaptation strategy options:

- Desalinization (expensive).
- Alternative sources (upstream, reservoir).
- More efficient water use.
- Acceptance of lower quality water.
- Separation of sewage water from drinking water.
- Population adjustment (retreat).
- Modification of systems (e.g., use of cisterns).

An early step in cost analysis should include a high-quality engineering study to examine necessary costs and identify gaps in existing infrastructures. Population surveys also need to be conducted to determine the acceptable level of brackishness. Economic analyses have not accounted for quality of drinking water (e.g., individuals in Florida accept lower standards than those in North Carolina). How much is the community willing to pay for water quality? What impact will water quality have on permanent and tourist populations? Another major issue to investigate is groundwater ecology and how sea water impacts groundwater. The data available on the impact of seawater intrusion on groundwater and drinking water supplies are a reflection of sea level and must be incorporated into these models.

Next, the group examined other sides of the issue. A design should be proposed that conveys the worst-case scenario, and decision makers should know the basis of that design. To effectively convince decision makers, capabilities need to be described to demonstrate the potential for success. An integrated analytical tool can be created based in part on data already available (e.g., salt erosion and per-gallon desalinization costs) that will aid understanding of phased solutions. The key is to incorporate all of the calculated costs into the tool, including infrastructure, indirect costs, and energy requirements. Community involvement and discussions with constituents are necessary before actual planning commences. Community economics must be considered.

The group identified the following gaps:

- Conservation.
- Usage rates fluctuate depending on the season; how does this impact future projections?
- Specific environmental costs.
- What are the energy costs of running desalinization?
- Undiscovered water treatment technologies.
- Alternatives to desalinization.
- Precipitation changes.
- How the cost of water impacts those who can afford high quality water.
- Competing regional needs/downstream effects (e.g., drinking water vs. fishing waters).
- Long-term solutions for barrier island systems.

Finally, the group discussed several potential means to bridge the gaps:

- Climate utilities monitoring.
- Comb the literature to determine tradeoffs and thoroughly examine some of the decisions.
- Find knowledge on salinity levels and factor this into decisions.
- Mapping work and physical modeling.
- Linking of sea level, demand, and energy cost projections.
- Understand the relationships.

- End user education and outreach to help in the overall decision making process.

Ultimately, the group decided that the primary solution is a customizable tool that supports many inputs for weighing and incorporating economic uncertainties that visually demonstrates impact. Economists and modelers will need to: (1) discuss how uncertainties are dealt with and communicated across disciplines; and (2) develop a common language that will be understood by all stakeholders so that uncertainty can be successfully communicated.

### Yellow Group Breakout Session

Drs. Fox and Rimer co-facilitated the session. The participants discussed computational power and noted that remote sensing data increase in quality each year, but the ability to explain values and management objectives so that they can be applied to models has not changed substantially. Turning values into objectives and performance measures is a significant challenge.

The health of valuable resources over time is weather dependent. It is beneficial to identify weather-dependent issues and focus on these in terms of climate change. A better use of a model might be to determine which parameters will cause the most problems. It might be beneficial to find commonalities and determine which climate change variables are of interest to many decision makers, stakeholders, and agencies.

Decision makers should include modelers early in the process and constantly interact with them because, generally, scientists are not comfortable asking what decision makers need. The opening dialogue is critical to learn how to approach stakeholders, decision makers, modelers and so forth, and the information dialogue must be an iterative process. Modelers should:

- frequently communicate with stakeholders to obtain any new information and ensure that their work meets the stakeholder needs
- not consider decision makers as end users but as partners
- investigate examples of how decisions makers presently make decisions with current uncertainty levels. It is important to communicate model output analyses to decision makers (i.e., translation). It also is necessary for decision makers to understand the data and information well enough to determine where to place resources. What decision makers want and need must be reconciled with the capabilities of the model and linked to data.

Decision makers are tackling a nebulous issue while working to perform meaningful interventions. Models are not used to make decisions; decision makers incorporate data that the model produces and analyze them with other information. A participant used the saying, "Fair to me, fair to you, fair to the mountains," to illustrate the point that fairness needs to be considered in modeling, which is a challenging concept.

Engineers want numbers that they can use for design; modelers must engage engineers and convince them that their ranges are reasonable. It is necessary to build relationships of trust between modelers and engineers.

There is a significant amount of literature available on how to collaborate well. Early "wins" are important in collaborations. Learning to communicate and developing a common vocabulary and definitions are critical.

Modelers must be careful about how they use static and dynamic downscaling, particularly in terms of extreme events, because they generally are not available to translate the results to decision makers. There also is a concern regarding downscaling and the simplification of results; the current level of

uncertainty may be discouraging. How can the level of uncertainty be communicated to keep people engaged? It is necessary for decision makers, stakeholders, and the public to understand that there is a significant amount of uncertainty in regard to climate change when modeling the resources and values that need to be managed. It also is necessary for decision makers to understand what claims are being made regarding downscaled models. Finally, downscaling is not appropriate for all situations.

Participants concluded that it is necessary to identify "showstoppers" (e.g., legal and human health constraints), help agencies understand how to engage decision makers, understand the drivers of impacts on the resources that are being managed, and include human behavior into models.

### Blue and Green Group Breakout Session

During Day 2, the green and blue breakout groups were combined but maintained their focus on the siting and design of a WWTP. Dr. Gaber co-facilitated the combined group. The group blended the Blue Group's expertise on water resource planning with the Green Group's scenario on the design and location of a WWTP. The breakout session began by identifying further considerations for the scenario and then identified existing models/data, data gaps, and methods to bridge the gap between data and decision makers.

During Day 1, the Green Group identified a number of decision factors for the WWTP scenario: population, sewer system infrastructure, availability and usage of water, precipitation, water treatment technologies, water and energy use, energy source and costs, anaerobic processes (methane), and flooding. During Day 2, the following additional factors were added to the scenario: drought/evaporation, migration/population changes, effects of nearby septic systems, physical access to the facility, current and future regulations (e.g., pharmaceuticals), water treatment processes (e.g., pretreatment, tertiary treatment), geology, topography, environmental justice, sea level rise, storm surge, total daily maximum load of discharge and downstream, and sludge waste.

Next, the group identified current modeling and data capabilities.

- Precipitation and Temperature Models.
- Downscaled global models, PDF of precipitation.
- Weather Research and Forecasting Model, Regional Climate Model Versions 3 and 4, and Mesoscale Model (commonly known as MM5).
- Scenarios of mean projections and extremes.
- Timescale of 30 to 50 years.
- Historical observational data.
- Watershed Models
- Catchment hydrology, stream flow, physical and chemical water quality parameters, nutrient load, sediments.
- Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis, HAWQS, Variable Infiltration Capacity Model, Hydrological Simulation Program–Fortran.
- Air Quality Models.
- Effects of WWTP (e.g., methane emissions).
- Population Models.
- Land-Use Change Models.
- ICLUS (includes demographics).
- Risk Assessment Models.
- Human and ecological health, security.
- Stream Models.

## Integrated Modeling To Characterize Climate Change Impacts and Support Decision Making

---

- Absorption, clean-up capacity under different flow scenarios.
- Plant Operation Models.
- Energy usage, treatment efficiency.
- ENERGY STAR Model, network models.
- Flood Risk Models.
- Storm surge, sea level rise.
- Hazus, Simulator of Climate Change Risks and Adaptation Initiatives (commonly known as SimCLIM), Sea, Lake and Overland Surges from Hurricanes Model (commonly known as SLOSH).

The group identified gaps in modeling/data capabilities:

- Modeling the Human Dimension (Behavior).
- Costs/incentives.
- Technology.
- Models to Optimize Costs and Pricing.

Consistent analyses are key when factoring climate change into decisions. State or federal regulations or voluntary guidance are methods that can be used to address this issue. Many small communities may not have the resources to hire an expert to perform the analyses. In other cases, the resources may exist, but the consultants may not be able to obtain the information they need. In some instances, the data may not be accessible or affordable. Case studies or best practices may be inexpensive options to assist decision makers with analyses. The group identified actions that could be taken to bridge the gap between models/data and decision makers:

- National Climate Service (NOAA).
- Data and Model Clearing House and Case Studies (<http://www.climatechangeclearinghouse.org>).
- Federal Assistance.
- Best practice manuals.
- Data from global modeling, downscaling.
- State Assistance.
- State revolving funds.
- Hydrological and water quality data.

### DAY 2 BREAKOUT SESSION REPORTING AND DISCUSSION

#### ***Session Moderator: Noha Gaber, EPA, OSA***

Dr. Olchin provided the report out for the Green and Blue Breakout Groups. The groups re-evaluated the conceptual map that had been created on Day 1 to include site determination, risk assessment, other climate change impacts, and nonpoint sources that should be considered downstream. Modeling and data capabilities include temperature and precipitation, catchment hydrology, water and air quality, stream models, WWTP engineering models, flood risk, land-use and population change, and risk assessment. Modeling and data gaps include human behavior; economic considerations (e.g., costs, incentives, technology advances); and optimization of cost and use. To bridge the gaps, establishment of a “model clearinghouse” would be beneficial. Other methods by which to bridge the gaps include best practices manuals and analytical approaches and State Revolving Funds. Federal agencies can bridge the gaps via global scenarios and downscaled climate data, and state agencies can focus on permitting.

Dr. Babson provided the report out for the Red Breakout Group. The group discussed the example of a North Carolina implementation plan for sea level rise, but this was not specific enough so the group

focused on municipal water supply that is threatened by saltwater intrusion from sea level rise. The participants examined management issues, and the goal was to determine how to incorporate economic information into decision making. The group determined that tools are available; for example, engineering firms can be hired to determine cost. Other costs, however, are more challenging (e.g., acceptance of decreased water quality). There is a set of needs related to cost; the group was not aware of current tools that would be acceptable to explore various tradeoffs. There is a need for simpler interfaces and screening-type tools for decision makers, but these need to be balanced with complex site-specific information and modeling regarding building infrastructure. Communication tools need to be developed to communicate uncertainty.

Mr. Kevin Moody, Federal Highway Administration, provided the report out for the Yellow Breakout Group. The breakout group discussed how to take societal or communal values that are meaningful and build  $f(x)=y$  using goals and performance measures to increase understanding and determine which variables are common to all of these values and sensitive to weather changes. There is concern about how existing models are blended to provide a range of values to characterize the uncertainty. Although computational power and remote sensing data increase in quality each year, the ability to explain values and management objectives so that they can be applied to models remains difficult. The initial question that must be asked is how to understand how to determine management objectives and underlying assumptions and uncertainty to influence decisions. Ultimately, modelers should be honest brokers. It is important to recognize that alternative fuel sources have significant costs, which must be communicated to decision makers. Models require a sound foundation in resource management objectives and weather-sensitive independent variables of performance measures. A suite of approaches is necessary for downscaling. Current gaps include scaling, agreement on the meaning and definition of language, and information that defines the resource attribute. It is necessary to know the limitation scales of data and be logically coherent and transparent. To bridge these gaps, communication and interaction among modelers, scientists, and decision makers is necessary. Drivers of impacts on managed resources must be understood, and information dialogue is important to obtain relevant information. Model output is not the endpoint, and decision makers must be treated as partners rather than end users. Fairness is important to the equation.

### WRAP-UP DISCUSSION

Dr. Gaber stated that the next step is to develop a white paper based on the discussions at the workshop. She noted the various themes that have been discussed throughout the workshop and allowed the participants to discuss them and adjust them as necessary:

- Often times, climate is the elephant in the room. Stakeholders may not want to discuss climate change, so modelers need to wait until they understand stakeholder needs and frame climate change in a manner that addresses these needs.
- Cross-sector impacts are important. Climate impacts are interdependent and inter-connected, so a systems thinking approach is necessary.
- There are scientific, economic, and institutional barriers to effective adaptation.
- Federal agencies can provide perspective, resources, and guidance.
- It is necessary to move beyond communication to form partnerships between modelers, scientists, and analysts and decision makers early in the problem formulation stage.
- Local knowledge must be leveraged to understand how the system works, identify the vulnerabilities of current management goals, and then use models to help assess the situation and develop adaptation solutions.
- Successful case studies related to best practices should be collected.

- Tools should allow modeling results to be communicated in a simple manner to inform the public and decision makers about risks in terms that are relevant to them.
- The limitations of simplified tools should be communicated clearly.
- There is uncertainty related to modeling and decision making contexts.
- It is necessary to understand decision makers' tolerance to uncertainty and provide a decision strategy to address uncertainty and frame it in terms of risk.
- Decision scale is as important as temporal and spatial scale.
- Rapid iteration is needed to meet user needs.

Dr. Horn thought that systems thinking is a necessary but insufficient approach. In terms of understanding decision makers' tolerance for uncertainty, in many cases, decision makers are accustomed to dealing with risk. Uncertainty needs to be framed in terms of risk. Dr. Fontaine thought that although systems thinking may not be sufficient, it is not insufficient. There may be different ways of examining problems that may not be captured by current thinking.

A participant noted that in-stream flow will become an issue because it has relationships to many issues related to climate change. The international "FLOW 2011: Instream Flow Valuation in Public Decision-Making" conference will be held in Nashville, Tennessee, from May 2–4, 2011.

Ms. Brenda Johnson noted that when addressing problems in terms of climate impacts and adaptation, the scope of the problem should be expanded to include geographic and temporal bounds. A definition of "system" should be included in the white paper.

A participant noted that discussions have been vague regarding decision support. There is a huge diversity of end users, and it is necessary to identify the different types of decision makers to help understand which tools are appropriate for each context. Often, a governance network is in place; therefore, multiple decision makers and different scales are involved in one issue. This must be considered because often there is not one discrete agent. Dr. Horn added that one included unit might be a model of decision makers and how they make decisions. He agreed that often a decision making network or cluster is in place; there are many definitions of decision makers.

A participant thought that the rhetoric regarding interagency cooperation and collaboration was more generous than warranted. EPA, NOAA, the U.S. Geological Survey, and other agencies all are holding workshops on climate change decision support, which indicates that their efforts are overlapping and not coordinated. There are many good collaborations, but some relationships are impeding research. Interagency barriers and the potential for significant inefficiencies exist. Dr. Horn responded that he is encouraged by this fact because it indicates that the climate change topic no longer is being deflected among agencies. The participant replied that the topic of climate change still is being deflected, but because federal agencies have been mandated to address it, each of them is working in its individual silo. Another participant pointed out that Region 1 held an interagency climate change workshop 1.5 years ago.

Dr. Loughlin noted the current budget constraints and how these affect collaboration between agencies and interaction with decision makers. He wondered how funds could best be used to develop the most creative and useful tools to address various issues and create resource efficiency.

Dr. Gaber asked for input regarding who the audience would need to be to make the white paper effective. Participants thought that the audience for the white paper should include EPA senior managers, other agencies (e.g., USGCRP, NOAA National Climate Service), modelers, and state managers. It is

necessary to reach those who can collaborate (decision makers, planners) to examine the issue with consistency across the country; creation of a network of collaborators would be beneficial. Because it takes resources to build networks, including EPA managers and other agencies in the audience for the paper may help obtain these resources. Additionally, senior EPA leaders need to know what issues need to be addressed.

The participants thought that the white paper should articulate what is needed at different scales, identify gaps and barriers, propose best practices in working with stakeholders, identify what issues need to be addressed in using scientific information in formulating adaptation decisions, and publicize available tools and resources to build on existing strengths. The white paper could be framed as SWOT analysis for integrated modeling to help highlight the broad array of useful tools and models that have been cultivated over a long period of time. A resource directory (i.e., model and tool clearinghouse) with case studies to summarize and highlight available tools should be included in the white paper.

Dr. Gaber thanked the attendees for their participation and noted that she had learned a great deal; she asked that participants continue to work with the Agency on this important topic. She adjourned the meeting at 5:03 p.m.

**Integrated Modeling to Characterize Climate Change Impacts and Support Decision Making**

**February 1 – 2, 2011**

**POST-PARTICIPANTS LIST**

---

**Kiran Alapaty**

U.S. Environmental Protection Agency  
Atmospheric Modeling and Analysis Division  
Applied Modeling Branch (E243-02)  
109 TW Alexander Drive, Room E-231-I  
Research Triangle Park, NC 27711  
Telephone: (919) 541-3130  
E-mail: alapaty.kiran@epa.gov

**Kedesch Altidor**

U.S. Environmental Protection Agency  
Region 4  
61 Forsyth Street, SW (9T25)  
Atlanta, GA 30303-8960  
Telephone: (404) 562-8110  
E-mail: kedesch.altidor@epa.gov

**Shirley Arvey**

Booz Allen Hamilton  
Department of Public Health Practice  
230 Peachtree Street NW, Suite 2100  
Atlanta, GA 30303  
Telephone: (770) 714-5719  
E-mail: arvey\_shirley@bah.com

**Amanda Babson**

U.S. Environmental Protection Agency  
Office of Research and Development  
1200 Pennsylvania Avenue, NW, 8601P  
Washington, DC 20460  
Telephone: (703) 347-8612  
E-mail: babson.amanda@epa.gov

**Sam Baker**

Georgia Department of Transportation  
Planning Division  
600 W Peachtree Street, NW  
Atlanta, GA 30308  
Telephone: (404) 631-1742  
E-mail: sbaker@dot.ga.gov

**Beverly Banister**

U.S. Environmental Protection Agency Region 4  
Air, Pesticides, and Toxics Management  
Division  
61 Forsyth Street, SW  
Atlanta, GA 30303-8960  
Telephone: (404) 562-9326  
E-mail: banister.beverly@epa.gov

**Robert Beach**

RTI International  
Environmental, Technology, and Energy  
Economics  
PO Box 12194  
3040 Cornwallis Road  
Research Triangle Park, NC 27709-2194  
Telephone: (919) 485-5579  
E-mail: rbeach@rti.org

**Glen Behrend**

Georgia Department of Natural Resources  
Georgia Environmental Protection  
Division of Water Protection  
Suite 1152, East Floyd Towers  
2 Martin Luther King Jr. Drive, SE  
Atlanta, GA 30318  
Telephone: (404) 567-0474  
E-mail: glen.behrend@dnr.state.ga.us

**Cyrus Bhedwar**

ICLEI USA  
Southeast Regional Office  
150 Garnett Avenue, SW  
Atlanta, GA 30303  
Telephone: (404) 588-5954  
E-mail: cyrus.bhedwar@iclei.org

**Bryan Bloomer**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Center for Environmental Research  
1200 Pennsylvania Avenue, NW, 8726P  
Washington, DC 20460  
Telephone: (703) 347-8040  
E-mail: bloommer.bryan@epa.gov

**Cynthia Bohn**

U.S. Fish and Wildlife Service  
1875 Century Boulevard, Room 200  
Atlanta, GA 30345  
Telephone: (404) 679-7122  
E-mail: cynthia\_bohn@fws.gov

**Roel Boumans**

U.S. Environmental Protection Agency  
AFORDable Futures  
4685 Greenbush Road  
Charlotte, VT 05445  
Telephone: (202) 564-8344  
E-mail: roel\_boumans@gmavt.net

**Cheryl Brown**

U.S. Environmental Protection Agency  
Western Ecology Division  
Pacific Coastal Ecology Branch, (1805T)  
2111 SE Marine Science Center Drive  
Newport, OR 97366  
Telephone: (541) 867-4042  
E-mail: brown.cheryl@epa.gov

**Roger Buerki**

Sierra Club  
Centennial Group  
499 Lyle Drive  
Marietta, GA 30067  
Telephone: (678) 429-0226  
E-mail: buerki@juno.com

**Raul Munoz Castillo**

Interamerican Development Bank  
Water and Sanitation Area  
1300 New York Avenue, NW  
Washington, DC 20577  
Telephone: (202) 623-3404  
E-mail: raulmu@iadb.org

**Linda Chappel**

U.S. Environmental Protection Agency  
Air Economics Group  
109 TW Alexander Drive (C439-02)  
Research Triangle Park, NC 27711  
Telephone: (919) 541-2864  
E-mail: chappell.linda@epa.gov

**John Clayton**

Hazen and Sawyer, PC  
5775 Peachtree-Dunwoody Road  
Atlanta, GA 30342  
Telephone: (813) 486-1398  
E-mail: jclayton@hazenandsawyer.com

**Barry Clinton**

U.S. Forest Service  
Coweeta Laboratory  
3160 Coweeta Laboratory Road  
Otto, NC 28763  
Telephone: (828) 524-2128  
E-mail: bclinton@fs.fed.us

**Carol Couch**

The University of Georgia  
College of Environment and Design  
609 Caldwell Hall  
Athens, GA 30606  
Telephone: (678) 227-1267  
E-mail: cacouch@uga.edu

**Marc Coudert**

City of Austin  
Austin Climate Protection Program  
721 Barton Springs Road  
Austin, TX 78704  
Telephone: (512) 322-6105  
E-mail: marc.coudert@austinenergy.com

**Teresa Crisp**

Dewberry  
2835 Brandywine Road, Suite 100  
Atlanta, GA 30341  
Telephone: (678) 537-8623  
E-mail: tcrisp@dewberry.com

**Lauren Davis**

RTI International  
Department of Energy, Technology, and  
Environmental Economics  
PO Box 12194  
3040 Cornwallis Road  
Research Triangle Park, NC 27513  
Telephone: (919) 316-3464  
E-mail: laurendavis@rti.org

**Kathie Dello**

Oregon State University  
Oregon Climate Change Research  
Institute/Climate Decision Support Consortium  
326 Strand Ag Hall  
Corvallis, OR 97331  
Telephone: (541) 737-8927  
E-mail: kdello@coas.oregonstate.edu

**Duane Dippon**

Bureau of Land Management  
PO Box 2965  
333 SW First Avenue  
Portland, OR 97208  
Telephone: (503) 808-6014  
E-mail: duane\_dippon@blm.gov

**Robert Dykes**

RTI International  
Office of Water and Ecosystems Management  
PO Box 12194  
3040 Cornwallis Road  
Research Triangle Park, NC 27709  
Telephone: (919) 541-8705  
E-mail: rdykes@rti.org

**Robert Elleman**

U.S. Environmental Protection Agency  
Region 10  
Office of Environmental Assessment  
1200 6th Avenue, Suite 900, (OEA-095)  
Seattle, WA 98101  
Telephone: (206) 553-1531  
E-mail: elleman.robert@epa.gov

**John Faustini**

U.S. Fish and Wildlife Service  
SE Region Office  
1875 Century Drive, NE, Suite 200  
Atlanta, GA 30345  
Telephone: (404) 679-7301  
E-mail: john\_faustini@fws.gov

**Gary Foley**

U.S. Environmental Protection Agency  
Office of the Science Advisor  
1200 Pennsylvania Avenue, NW  
Washington, DC 20460  
Telephone: (919) 541-0711  
E-mail: foley.gary@epa.gov

**Thomas Fontaine**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Health and Environmental Effects  
Research Laboratory  
Western Ecology Division  
200 SW 35th Street  
Corvallis, OR 97333  
Telephone: (541) 754-4601  
E-mail: fontaine.thomas@epa.gov

**James Fox**

University of North Carolina at Asheville  
National Environmental Modeling and Analysis  
Center  
Robinson 246, CPO 2345  
One University Heights  
Asheville, NC 28804-8511  
Telephone: (828) 301-2075  
E-mail: jfox@unca.edu

**Steve Fries**

Computer Science Corporation  
6101 Stevenson Avenue  
Alexandria, VA 22304  
Telephone: (703) 461-2015  
E-mail: jfries3@csc.com

**Noha Gaber**

U.S. Environmental Protection Agency  
Office of the Science Advisor  
Council for Regulatory Environmental Modeling  
1200 Pennsylvania Avenue, NW, 8105R  
Washington, DC 20460  
Telephone: (202) 564-2179  
E-mail: gaber.noha@epa.gov

**Mark Gabriel**

U.S. Environmental Protection Agency National  
Exposure Research Laboratory  
Ecosystems Research Division  
960 College Station Road  
Athens, GA 30605  
Telephone: (706) 355-8349  
E-mail: gabriel.mark@epa.gov

**Daniel Garver**

U.S. Environmental Protection Agency  
Region 4  
Air, Pesticides, and Toxics Management  
Division  
61 Forsyth Street, SW  
Atlanta, GA 30303  
Telephone: (404) 562-9839  
E-mail: garver.daniel@epa.gov

**Rick Gillam**

U.S. Environmental Protection Agency  
Region 4  
Air, Pesticides, and Toxics Management  
Division  
61 Forsyth Street, SW  
Atlanta, GA 30303  
Telephone: (404) 562-9049  
E-mail: gillam.rick@epa.gov

**Heather Golden**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Exposure Research Laboratory  
Ecological Exposure Research Division  
26 W Martin Luther King Drive, MS-511  
Cincinnati, OH 45268  
Telephone: (513) 569-7773  
E-mail: golden.heather@epa.gov

**Megan Goold**

U.S. Environmental Protection Agency  
Region 3  
Air Protection Division  
1650 Arch Street, 3AP50  
Philadelphia, PA 19103  
Telephone: (215) 814-2027  
E-mail: goold.megan@epa.gov

**Sara Gottlieb**

The Nature Conservancy  
Georgia Chapter  
1330 W Peachtree Street, NW, Suite 410  
Atlanta, GA 30309-2948  
Telephone: (404) 253-7250  
E-mail: sgottlieb@tnc.org

**Margaret Griep**

U.S. Forest Service  
Biology and Physics Resources  
325 John Knox Road, Suite F-100  
Tallahassee, FL 32303  
Telephone: (850) 523-8567  
E-mail: mgriep@fs.fed.us

**Stacy Harder**

U.S. Environmental Protection Agency  
Region 4  
Division of Air  
61 Forsyth Street  
Atlanta, GA 30303  
Telephone: (404) 562-9042  
E-mail: harder.stacy@epa.gov

**Selena Harper**

Georgia Institute of Technology  
School of Public Policy  
5071 Oak Nut Court  
Stone Mountain, GA 30087  
Telephone: (404) 428-9691  
E-mail: selena.harper@gmail.com

**David Heicher**

Susquehanna River Basin Commission  
Department of Technical Programs  
1721 N Front Street  
Harrisburg, PA 17102  
Telephone: (717) 238-0423, ext. 110  
E-mail: dheicher@srbc.net

**Jeremy Hess**

Emory University  
Department of Emergency Medicine  
49 Jesse Hill Jr. Drive  
Atlanta, GA 30314  
Telephone: (404) 386-7585  
E-mail: [jhess@emory.edu](mailto:jhess@emory.edu)

**Michael Hiscock**

U.S. Environmental Protection Agency  
Office of the Science Advisor  
1200 Pennsylvania Avenue, NW, 8105R  
Washington, DC 20460  
Telephone: (202) 564-8344  
E-mail: [hiscock.michael@epa.gov](mailto:hiscock.michael@epa.gov)

**Robert Horn**

Stanford University  
Human Science and Technology Advanced  
Research Institute (H-STAR)  
2819 Jackson Street, Room 101  
San Francisco, CA 94115  
Telephone: (415) 775-7377  
E-mail: [hornbob@earthlink.net](mailto:hornbob@earthlink.net)

**Robert Howard**

U.S. Environmental Protection Agency  
Region 4  
Water Protection Division  
61 Forsyth Street, SW  
Atlanta, GA 30303  
Telephone: (404) 562-9370  
E-mail: [howard.bob@epa.gov](mailto:howard.bob@epa.gov)

**Brian Hughes**

U.S. Geological Survey  
Department of Water Resources  
3039 Amwiler Road, Suite 130  
Atlanta, GA 30360  
Telephone: (770) 903-9162  
E-mail: [wbhuges@usgs.gov](mailto:wbhuges@usgs.gov)

**Keith Ingram**

Southeast Climate Consortium/University of  
Florida  
Agricultural and Biological Engineering  
PO Box 110570  
Gainesville, FL 32611  
Telephone: (352) 392-1864  
E-mail: [ktingram@ufl.edu](mailto:ktingram@ufl.edu)

**Feng Jiang**

Georgia Department of Natural Resources  
Environmental Protection Division Hydrology  
Unit  
2 Martin Luther King Jr. Drive, SE, Suite 1058  
Atlanta, GA 30334  
Telephone: (404) 463-6198  
E-mail: [feng.jiang@dnr.state.ga.us](mailto:feng.jiang@dnr.state.ga.us)

**Alan Johnson**

Clemson University  
Forestry and Natural Resources  
Lehotsky Hall  
Clemson, SC 29634-0317  
Telephone: (864) 656-4390  
E-mail: [alanj@clemson.edu](mailto:alanj@clemson.edu)

**Brenda Johnson**

U.S. Environmental Protection Agency  
Region 4  
Air Division  
Atlanta Federal Center  
61 Forsyth Street  
Atlanta, GA 30303  
Telephone: (404) 562-9037  
E-mail: [johnson.brenda@epa.gov](mailto:johnson.brenda@epa.gov)

**John Johnston**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Exposure Research Laboratory  
Ecosystems Research Division  
960 College Station Road  
Athens, GA 30605  
Telephone: (706) 355-8300  
E-mail: [johnston.johnm@epa.gov](mailto:johnston.johnm@epa.gov)

**Andrew Jones**

Climate Interactive  
8 Lynmar Avenue  
Asheville, NC 28804-3562  
Telephone: (828) 236-0884  
E-mail: apjones@climateinteractive.org

**Tiffini Jones**

E. L. Sustainability Consulting  
4279 Roswell Road, NE, 102-145  
Atlanta, GA 30342  
Telephone: (404) 210-4494  
E-mail: ecolovely@hotmail.com

**Robyn Kenney**

U.S. Environmental Protection Agency  
Climate Protection Partnership Division  
Ariel Rios Building (6202J)  
1200 Pennsylvania Avenue, NW  
Washington, DC 20460  
Telephone: (202) 343-9080  
E-mail: kenney.robyn@epa.gov

**David Knight**

North Carolina Department of Environment and  
Natural Resources  
1601 Mail Service Center  
Raleigh, NC 27699  
Telephone: (919) 715-4152  
E-mail: david.knight@ncdenr.gov

**Chris Knightes**

U.S. Environmental Protection Agency  
Office of Research and Development  
960 College Station Road  
Athens, GA 30605  
Telephone: (706) 355-8326  
E-mail: knightes.chris@epa.gov

**Liz Kramer**

The University of Georgia  
The College of Agricultural and Environmental  
Sciences  
312 Conner Hall  
Athens, GA 30602  
Telephone: (706) 542-3577  
E-mail: lkramer@uga.edu

**Dawn Lemke**

Alabama A&M University  
Department of Natural Resources and  
Environmental Science  
4107 Meridian Street  
Normal, AL 35762  
Telephone: (256) 372-4562  
E-mail: dawn.lemke@aamu.edu

**Elizabeth Letts**

Seminole Tribe of Florida  
Department of Environmental Resource  
Management  
6300 Stirling Road  
Hollywood, FL 33024  
Telephone: (954) 605-7581  
E-mail: elizabethletts@semtribe.com

**Sharyn Lie**

U.S. Environmental Protection Agency  
Transportation and Climate Division  
Office of Transportation and Air Quality  
Office of Air and Radiation  
Ariel Rios Building  
1200 Pennsylvania Avenue, NW  
Washington, DC 20460  
Telephone: (202) 564-1092  
E-mail: lie.sharyn@epa.gov

**Dan Loughlin**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Risk Management Research  
Laboratory (E305-02)  
109 TW Alexander Drive  
Research Triangle Park, NC 27711  
Telephone: (919) 541-3928  
E-mail: loughlin.dan@epa.gov

**Qingchang Lu**

University of Florida  
Urban and Regional Planning Department  
1001 SW 16th Avenue, Apt. 122  
Gainesville, FL 32601  
Telephone: (352) 672-1633  
E-mail: qingchanglu@ufl.edu

**George Luber**

Centers for Disease Control and Prevention  
Climate Change Program  
National Center for Environmental Health (F-52)  
1600 Clifton Road  
Atlanta, GA 30333  
Telephone: (770) 488-3429  
E-mail: gluber@cdc.gov

**Mandy Mahoney**

Atlanta Mayor's Office  
55 Trinity Avenue, Suite 2500  
Atlanta, GA 30303  
Telephone: (404) 954-8488  
E-mail: mmahoney@atlantaga.gov

**Joydeb Majumder**

U.S. Environmental Protection Agency  
Region 4  
Office of the Regional Administrator  
61 Forsyth Street, SW  
Atlanta, GA 30303  
Telephone: (404) 562-9121  
E-mail: majumder.joydeb@epa.gov

**Rohit Mathur**

U.S. Environmental Protection Agency  
Office of Research and Development  
Atmospheric Modeling and Analysis Division  
National Exposure Research Laboratory (E243-03)  
109 TW Alexander Drive  
Research Triangle Park, NC 27711  
Telephone: (919) 541-1483  
E-mail: mathur.rohit@epa.gov

**Michael McGeehin**

RTI International  
1511 Annapolis Way  
Grayson, GA 30017  
Telephone: (770) 825-3935  
E-mail: mmcgeehin@rti.org

**Steve McNulty**

U.S. Forest Service  
Southern Research Station  
920 Main Campus Drive  
Venture Center 2, Suite 300  
Raleigh, NC 27606  
Telephone: (919) 515-9489  
E-mail: smcnulty@fs.fed.us

**David Meriwether**

U.S. Forest Service  
Region 8  
Southern Region Planning  
Venture Center 2  
920 Main Campus Drive  
Raleigh, NC 27606  
Telephone: (404) 347-4663  
E-mail: dmeriwether@fs.fed.us

**Andy Miller**

U.S. Environmental Protection Agency  
Office of Research and Development  
(E305-02)  
109 TW Alexander Drive  
Research Triangle Park, NC 27711  
Telephone: (919) 541-2920  
E-mail: miller.andy@epa.gov

**Kenneth Mitchell**

U.S. Environmental Protection Agency  
Region 4  
Office of the Regional Administrator  
61 Forsyth Street, SW  
Atlanta, GA 30303  
Telephone: (404) 562-9065  
E-mail: mitchell.ken@epa.gov

**John Mlade**

Perkins+Will  
Department of Architecture  
1315 Peachtree Street  
Atlanta, GA 30309  
Telephone: (404) 443-7540  
E-mail: john.mlade@perkinswill.com

**Mahri Monson**

U.S. Environmental Protection Agency  
Office of Enforcement and Compliance  
Assurance  
1200 Pennsylvania Avenue, NW, 2243A  
Washington, DC 20460  
Telephone: (202) 564-2657  
E-mail: monson.mahri@epa.gov

**Kevin Moody**

Federal Highway Administration  
Office of Technical Services  
61 Forsyth Street, SW, Suite 17T26  
Atlanta, GA 30303  
Telephone: (404) 562-3618  
E-mail: kevin.moody@dot.gov

**Philip Morefield**

U.S. Environmental Protection Agency  
Office of Research and Development  
Global Change Research Program  
1200 Pennsylvania Avenue, NW, 8601P  
Washington, DC 20460  
Telephone: (703) 308-8135  
E-mail: morefield.philip@epa.gov

**Amy Morsch**

Duke University  
Nicholas Institute for Environmental Policy  
Solutions  
2101 Campus Drive  
Durham, NC 27708  
Telephone: (919) 613-3772  
E-mail: amy.morsch@duke.edu

**Janine Nicholson**

North Carolina Department of Environment and  
Natural Resources  
Office of Conservation, Planning, and  
Community Affairs  
1601 Mail Service Center  
Raleigh, NC 27699  
Telephone: (919) 715-2700  
E-mail: janine.nicholson@ncdenr.gov

**Jayantha Obeysekera**

South Florida Water Management District  
Department of Hydraulic and Environmental  
Systems Modeling  
3301 Gun Club Road  
West Palm Beach, FL 33406  
Telephone: (561) 682-6503  
E-mail: jobey@sfwmd.gov

**Gabriel Olchin**

U.S. Environmental Protection Agency  
Office of the Science Advisor  
Council for Regulatory Environmental Modeling  
1200 Pennsylvania Avenue, NW, 8105R  
Washington, DC 20460  
Telephone: (202) 564-3312  
E-mail: olchin.gabriel@epa.gov

**Priscilla Oliver**

U.S. Environmental Protection Agency  
Office of Policy and Management  
Atlanta Federal Center, 14th Floor  
61 Forsyth Street, SW  
Atlanta, GA 30303  
Phone: (404) 562-8292  
E-mail: oliver.priscilla@epa.gov

**Tanya Otte**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Exposure Research Laboratory  
Atmospheric Modeling and Analysis  
Division (E243-01)  
109 TW Alexander Drive  
Research Triangle Park, NC 27711  
Telephone: (919) 541-7533  
E-mail: otte.tanya@epa.gov

**Rajbir Parmar**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Exposure Research Laboratory  
Emergency Response Division  
960 College Station Road  
Athens, GA 30605  
Telephone: (706) 355-8306  
E-mail: parmar.rajbir@epa.gov

**James Partain**

National Oceanic and Atmospheric  
Administration  
National Climatic Data Center  
Climate Services Division  
222 W 7th Avenue, Room 23  
Anchorage, AK 99513  
Telephone: (907) 271-3312  
E-mail: james.partain@noaa.gov

**Zhong-Ren Peng**

University of Florida  
Department of Urban and Regional Planning  
PO Box 115706  
Gainesville, FL 32611-5706  
Telephone: (352) 392-0997  
E-mail: zpeng@ufl.edu

**John Powers**

U.S. Environmental Protection Agency  
Office of Water  
1200 Pennsylvania Avenue, NW, 4102M  
Washington, DC 20460  
Telephone: (202) 564-5776  
E-mail: powers.john@epa.gov

**Benjamin Preston**

Oak Ridge National Laboratory  
Climate Change Science Institute  
One Bethel Valley Road (MS-6301)  
Oak Ridge, TN 37831  
Telephone: (865) 574-6496  
E-mail: prestonbl@ornl.gov

**Linda Prokopy**

Purdue University  
Forestry and Natural Resources  
195 Marsteller Street  
West Lafayette, IN 47907  
Telephone: (765) 496-2221  
E-mail: lprokopy@purdue.edu

**Natasha Prudent**

Centers for Disease Control and Prevention  
National Center for Environmental Health  
Climate Change  
4770 Bufford Highway, NE  
Atlanta, GA 30341  
Telephone: (770) 488-7715  
E-mail: ibz0@cdc.gov

**Gloria Putnam**

North Carolina State University  
North Carolina Sea Grant  
Varsity Research Building, Module I  
1575 Varsity Drive  
Raleigh, NC 27695-8605  
Telephone: (919) 513-0117  
E-mail: gloria\_putnam@ncsu.edu

**Brenda Rashleigh**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Exposure Research Laboratory  
960 College Station Road  
Athens, GA 30605  
Telephone: (706) 355-8148  
E-mail: rashleigh.brenda@epa.gov

**Bill Reeves**

Tennessee Wildlife Resources Agency  
Department of Biodiversity  
PO Box 40747  
Nashville, TN 37204  
Telephone: (615) 781-6570  
E-mail: bill.reeves@tn.gov

**Jeffrey Regan**

Georgia Department of Natural Resources  
Environmental Protection Division  
Hydrology Unit  
2 Martin Luther King Jr. Drive, SE,  
Suite 1058  
Atlanta, GA 30334  
Telephone: (404) 463-1958  
E-mail: jeffrey.regan@dnr.state.ga.us

**Linda Rimer**

U.S. Environmental Protection Agency  
Region 4  
Office of the Regional Administrator  
519 Hooper Lane  
Chapel Hill, NC 27514  
Telephone: (919) 541-0785  
E-mail: rimer.linda@epa.gov

**Erin Rivenbark**

U.S. Fish and Wildlife Service  
Department of Ecological Services  
1875 Century Boulevard, Suite 200  
Atlanta, GA 30345  
Telephone: (404) 679-7379  
E-mail: erin\_rivenbark@fws.gov

**Kathleen Roberts**

Alabama A&M University  
Department of Natural Resources and  
Environmental Sciences  
PO Box 1927  
Normal, AL 35762  
Telephone: (251) 599-8805  
E-mail: kokopelliclay@gmail.com

**Chuck Sams**

U.S. Forest Service  
National Forest System  
1720 Peachtree Avenue  
Atlanta, GA 30309  
Telephone: (404) 347-4083  
E-mail: csams@fs.fed.us

**Joel Scheraga**

U.S. Environmental Protection Agency  
Office of the Administrator  
Office of Policy, Economics, and Innovation  
1200 Pennsylvania Avenue, NW, 1804A  
Washington, DC 20460  
Telephone: (202) 564-3385  
E-mail: scheraga.joel@epa.gov

**Katherine Sciera**

U.S. Environmental Protection Agency  
Region 4  
Air, Pesticides, and Toxics Management  
Division  
61 Forsyth Street  
Atlanta, GA 30303  
Telephone: (404) 562-9840  
E-mail: sciera.katherine@epa.gov

**John Seaman**

University of Georgia  
Savannah River Ecology Laboratory  
PO Drawer E  
Aiken, SC 29803  
Telephone: (803) 725-0977  
E-mail: seaman@srel.edu

**Feng Shi**

Delaware River Basin Commission  
Modeling and Assessment Branch  
25 State Police Drive  
West Trenton, NJ 08648  
Telephone: (609) 883-9500  
E-mail: feng.shi@drbc.state.nj.us

**Michael Simpson**

Antioch University New England  
Environmental Studies Department  
40 Avon Street  
Keene, NH 03431  
Telephone: (603) 283-2331  
E-mail: msimpson@antioch.edu

**Kathleen Sloan**

Yurok Tribe  
Environmental Program  
15900 Highway 101 N  
Klamath, CA 95548  
Telephone: (707) 482-1822  
E-mail: ksloan@yuroktribe.nsn.us

**Raghavan Srinivasan**

Texas A&M University  
Department of Biological and Agricultural  
Engineering  
1500 Research Plaza, Office 221E  
College Station, TX 77845  
Telephone: (979) 845-5069  
E-mail: r-srinivasan@tamu.edu

**Joyce Stanley**

U.S. Department of the Interior  
Office of Environmental Policy and Compliance  
75 Spring Street, SW, Suite 1144  
Atlanta, GA 30303  
Telephone: (404) 334-4524  
E-mail: joyce\_stanley@ios.doi.gov

**Jerome Thomas**

U.S. Forest Service  
1720 Peachtree Street  
Atlanta, GA 30309  
Telephone: (404) 347-4177  
E-mail: rartis@fs.fed.us

**Ed Thomas**

National Rural Water Association  
101 Constitution Avenue, NW, 9th floor  
Washington, DC 20001  
Telephone: (443) 739-1358  
E-mail: thomas@ruralwater.org

**Sarah Trainor**

University of Alaska Fairbanks  
Department of Geography  
3352 College Road  
Fairbanks, AK 99709  
Telephone: (907) 474-7878  
E-mail: sarah.trainor@alaska.edu

**Emrys Treasure**

U.S. Forest Service  
Southern Research Station  
920 Main Campus Drive, Suite 300  
Raleigh, NC 27606  
Telephone: (919) 621-9591  
E-mail: etreasure@fs.fed.us

**Daniel Tufford**

University of South Carolina  
Department of Biological Sciences  
715 Sumter Street  
Columbia, SC 29208  
Telephone: (803) 777-3292  
E-mail: tufford@sc.edu

**John Turner**

Southern Highlands Reserve  
558 Summit Ridge Road  
Lake Toxaway, NC 28747  
Telephone: (828) 226-0312  
E-mail: jturner@southernhighlandsreserve.org

**Karen Utt**

Tennessee Valley Authority  
Department of Strategy and External Relations  
1101 Market Street, SP 5D-C  
Chattanooga, TN 37402  
Telephone: (423) 751-3298  
E-mail: krutt@tva.gov

**Winona Victory**

U.S. Environmental Protection Agency  
Region 9/Air  
75 Hawthorne Street  
San Francisco, CA 94105  
Telephone: (415) 972-3736  
E-mail: victory.winona@epa.gov

**Beth Walls**

U.S. Environmental Protection Agency  
Region 4  
National Environmental Policy Act  
61 Forsyth Street  
Atlanta, GA 30303  
Telephone: (404) 562-8309  
E-mail: walls.beth@epa.gov

**Dingbao Wang**

University of Central Florida  
Department of Civil, Environmental, and  
Construction Engineering  
4000 Central Florida Boulevard  
Orlando, FL 32816-2450  
Telephone: (407) 823-1449  
E-mail: diwang@mail.ucf.edu

**Anne Wein**

U.S. Geological Survey  
Department of Geography  
345 Middlefield Road  
Menlo Park, CA 94025  
Telephone: (650) 329-4263  
E-mail: awein@usgs.gov

**Gene Whelan**

U.S. Environmental Protection Agency  
Office of Research and Development  
National Exposure Research Laboratory  
Emergency Response Division  
960 College Station Road  
Athens, GA 30605  
Telephone: (706) 355-8305  
E-mail: whelan.gene@epa.gov

**Marshall Williams**

Army Regional Environmental and Energy Office  
101 Marietta Street, NW, Suite 3120  
Atlanta, GA 30303  
Telephone: (404) 545-6599  
E-mail: marshall.williams@us.army.mil

**Joseph Wisby**

The Nature Conservancy  
Tennessee Chapter  
2021 21st Avenue S, Suite 400  
Nashville, TN 37212  
Telephone: (615) 383-9909  
E-mail: jwisby@tnc.org

**Christina Wright**

National Park Service  
Department of Inventory and Monitoring  
100 Alabama Street, SW  
Atlanta, GA 30303  
Telephone: (404) 507-5821  
E-mail: christina\_wright@nps.gov

**Ben Wright**

Hazen and Sawyer  
Water Resources Management  
1 South Street, Suite 1150  
Baltimore, MD 21202  
Telephone: (410) 539-7681  
E-mail: bwright@hazenandsawyer.com

**Jeremy Wyss**

Tetra Tech  
Department of Water Resources  
2110 Powers Ferry Road, Suite 202  
Atlanta, GA 30339  
Telephone: (770) 850-0949, ext. 113  
E-mail: jeremy.wyss@tetrattech.com

**Yi Zhang**

Georgia Department of Natural Resources  
Environmental Protection Division  
Hydrology Unit  
Two Martin Luther King Jr. Drive, SE,  
Suite 1058  
Atlanta, GA 30334  
Telephone: (404) 657-8807  
E-mail: yi.zhang@dnr.state.ga.us

**Contractor Support**

**The Scientific Consulting Group, Inc.**

656 Quince Orchard Road, Suite 210  
Gaithersburg, MD 20878  
Telephone: (301) 670-4990

**Elsa Desautels**

E-mail: edesautels@scgcorp.com

**Steve Gibb**

E-mail: sgibb@scgcorp.com

**Audrey Glynn**

E-mail: aglynn@scgcorp.com

**Kristen LeBaron**

E-mail: klebaron@scgcorp.com

**Meghan Radtke**

E-mail: mradtke@scgcorp.com

**Michelle Watson**

E-mail: mwatson@scgcorp.com