EPA/600/R-08/042
MARCH 2008

# SUMMARY REPORT FOR THE WORKSHOP ON INTEGRATING CLIMATE CHANGE ADAPTATION INTO AIR QUALITY DECISION MAKING

by:

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EPA Contract No. EP-C-07-015
Work Assignment Number 0-2

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## List of Abbreviations

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| CCS | Center for Climate Strategies |
| CCSP | Climate Change Science Program |
| CIRAQ | Climate Impact on Regional Air Quality |
| EPA | U.S. Environmental Protection Agency |
| ERG | Eastern Research Group, Inc. |
| GCAQ | Global Change Impact on U.S. Air Quality |
| GCRP | Global Change Research Program |
| GHG | greenhouse gas |
| IPCC | Intergovernmental Panel on Climate Change |
| MARKAL | MARket ALlocation energy systems model |
| NAAQS | National Ambient Air Quality Standard |
| NESCAUM | Northeast States for Coordinated Air Use Management |
| NOAA | National Oceanic and Atmospheric Administration |
| NOx | nitrogen oxides |
| OAQPS | Office of Air Quality Planning and Standards |
| ORD | Office of Research and Development |
| ppb | parts per billion |
| PM | particulate matter |
| PM2.5 | particulate matter with aerodynamic diameter less than or equal to 2.5 microns |
| SIP | state implementation plan |
| STAR | Science to Achieve Results |
| VMT | vehicle miles traveled |
| VOC | volatile organic compound |
| WRAP | Western Regional Air Partnership |

# 1.0 Introduction

Over the past few decades, air quality planners have forecasted future air pollution levels based on information about changing emissions from stationary and mobile sources, population trends, transportation demand, natural sources of emissions, and other pressures on air quality. However, these planning efforts typically have not considered the fact that our future climate will likely differ from present conditions and that climate change can affect both emissions sources and atmospheric fate and transport processes that determine air pollution levels.

To develop an understanding of the highest-priority science questions regarding adaptation and the effects of climate change on air quality, the U.S. Environmental Protection Agency (EPA) held a "Workshop on Integrating Climate Change Adaptation into Air Quality Decision Making." The workshop (referred to in this report as the "ORD Adaptation Workshop") took place on December 4-5, 2007, at the Holiday Inn Brownstone Hotel and Conference Center in Raleigh, North Carolina. EPA's Office of Research and Development (ORD) organized the workshop, with contractor support provided by Eastern Research Group, Inc. (ERG).

EPA invited approximately 65 individuals from various scientific disciplines and affiliations to attend the ORD Adaptation Workshop. The workshop participants included EPA personnel, academics, consultants, and numerous individuals with air quality planning responsibilities at local, state, tribal, regional, or national levels. Appendix A lists the workshop participants and provides their contact information.

This report documents the discussions at the workshop, which was intended to achieve two primary goals: (1) to determine, through dialog with the air quality planning and research communities, ORD stakeholders' highest priority needs with respect to decision support for climate change adaptation; and (2) to identify which ORD research initiatives and products (e.g., analyses, decision support tools) will be most useful in addressing the stakeholders' needs.

The remainder of this report is organized into the following sections:

- **Section 2: Opening Plenary Session.** This section summarizes presentations made in the opening plenary session, when invited speakers presented background information on EPA's Global Change Research Program, previous and ongoing modeling efforts to estimate the impact of climate change on regional air quality, and critical information needs regarding adaptation to the effects of climate change on air quality from both national and regional perspectives.

- **Section 3: Brainstorming Session on Policy Issues.** This section documents the outcome of a brief brainstorming session, during which all workshop participants were asked to identify and discuss priority air quality policy issues that may be informed by ORD research.

- **Section 4: Summary of Breakout Group Discussions.** This section summarizes discussions that occurred in four breakout groups, which were asked to provide ORD additional feedback on specific topic areas identified in the brainstorming session: multi-pollutant control strategies and co-benefits, unregulated emissions sources, translation of

global issues to local scales, and planning now for a future climate. Discussions on these topics addressed issues and questions raised in the "guidance on breakout sessions" included in the workshop Participant's Guide. To stimulate discussions during the breakout groups, all participants were asked to read a "white paper" on the impacts of climate change on air quality. A copy of this paper, which all participants received prior to the workshop, is available upon request. This section also reviews the "report-outs" from the breakout groups, drawing largely from the summary statements that each group prepared.

- **Section 5: Concluding Plenary Session.** This section documents selected concluding remarks made during the final plenary session.

Technical writers from ERG who attended the workshop prepared this report. While the report thoroughly summarizes the workshop discussions, the report should not be considered to be a transcript and may not capture all issues that were raised. Further, because the ORD Adaptation Workshop was not designed to seek consensus on any topic or to prioritize the participants' many suggestions, the ideas presented in this report should be viewed as a collection of ideas from the workshop participants for EPA's further consideration; the ideas and suggestions throughout this report should not necessarily be viewed as formal consensus recommendations.

ORD organized the workshop to provide input to EPA regarding science needs to address the integration of climate change into air quality management. The perspectives discussed during the workshop were not part of EPA's regulatory development process, but emerged from a process of open discussion and therefore add to the understanding of broader issues; they are included here only to capture the full range of workshop discussions. Note that some of the comments in this summary refer to state and local actions, rather than matters dealt with at the federal level.

## 2.0 Opening Plenary Session

The ORD Adaptation Workshop opened with background presentations given by invited speakers. This section summarizes the presentations and documents question-and-answer sessions that followed.

### 2.1 Welcome and Introduction to the Workshop, Tim Johnson, EPA-ORD

Dr. Johnson thanked participants for attending the ORD Adaptation Workshop and reviewed the two main workshop objectives: (1) to determine, through dialog with the air quality planning and research communities, ORD stakeholders' highest priority needs with respect to decision support for climate change adaptation; and (2) to identify which ORD research initiatives and products (e.g., analyses, decision support tools) will be most useful in addressing the stakeholders' needs. Dr. Johnson clarified that for the purpose of this workshop, "stakeholders" include EPA Program and Regional Offices, as well as state, local, and tribal air quality planning agencies with responsibility for making policy decisions. With all of these different groups represented among the participants, Dr. Johnson strongly encouraged stakeholders to participate actively in workshop discussions to ensure that their viewpoints are communicated to EPA.

For the benefit of workshop discussions, Dr. Johnson clarified the difference between adaptation and mitigation in regards to climate change and stressed that the workshop should focus on adaptation. Adaptation, he noted, includes strategic actions that air quality planners can take to achieve and maintain its air quality goals {e.g., attainment of the National Ambient Air Quality Standards [NAAQS]} in the face of climate change. Mitigation includes actions that planners can take to reduce greenhouse gas (GHG) emissions.

Dr. Johnson acknowledged that air quality planners routinely factor several issues into policy decisions, including population growth, economic growth, and technological change. In addition to issues that have conventionally factored into planning efforts, climate change can have direct and indirect impacts on air quality. Direct impacts include changes to meteorology and atmospheric chemistry that may result from changes to temperature and humidity. Indirect impacts include changes to emissions from temperature-dependent sources (e.g., some biogenic emissions, evaporative losses). As an example of these indirect effects, Dr. Johnson noted that future temperature increases will likely lead to increased demand for air conditioning, which in turn will lead to higher demand for electricity and emissions from electricity generating facilities. Quantifying such anticipated future impacts, and how they vary with region, may be of great interest to the air quality planning community.

Dr. Johnson concluded by reviewing workshop logistics, noting that participants will break into smaller groups to discuss climate change adaptation considerations in regards to air quality, such as: What long-term challenges do planners face in regards to reaching and maintaining attainment with NAAQS? What regional differences are important in terms of how climate change will affect air quality? Which emissions source categories are increasing in importance? How might mitigation efforts affect air quality adaptation strategies?

Dr. Johnson concluded by thanking the Workshop Steering Committee and other attendees instrumental in planning the workshop.

## 2.2 Adapting to a Changing Climate to Protect Air Quality, Joel Scheraga, EPA-ORD

Dr. Scheraga's presentation outlined several of EPA's ongoing climate change research activities, particularly those conducted under the Agency's Global Change Research Program (GCRP) (see: http://cfpub.epa.gov/gcrp/). Dr. Scheraga explained that the GCRP is assessing potential consequences of *global change*, which includes climate change along with the larger context of population growth, economic development, technology change, and other factors that will likely impact EPA's ability to fulfill statutory, regulatory, and programmatic requirements. A broad goal of the GCRP is to provide timely and useful scientific information to planners and other stakeholders in order to support decision-making processes. One component of this broader goal is to help environmental managers mainstream climate change considerations into day-to-day decision-making to better attain their air quality goals.

Dr. Scheraga noted that the GCRP's assessment activities are part of the larger U.S. Climate Change Science Program (CCSP), an interagency program responsible for leveraging and coordinating global change and climate change research activities across agencies (see: http://www.climatescience.gov/). After describing the various CCSP goals and strategic planning efforts, Dr. Scheraga identified two key products that EPA is developing:

- An Interim Assessment, scheduled to be released in 2008, to evaluate the effects of *climate change* on air quality, and
- A more comprehensive assessment, scheduled to be released in 2012, to evaluate the effects of *global change* on air quality.

These assessments will help EPA and the broader planning community understand what climate change means for air quality in the U.S. and learn how best to deal with the risks and opportunities posed by climate change. Dr. Scheraga emphasized that ongoing GCRP assessment activities are entirely separate from the periodic reviews of the NAAQS. He explained that the GCRP assessments will help determine how climate change might affect an area's ability to attain the NAAQS, but those assessments will not change the standards themselves. In short, the NAAQS review process is conducted independently of the GCRP assessments.

Dr. Scheraga listed several reasons why the GCRP assessment activities are important. He noted, for instance, that the Intergovernmental Panel on Climate Change (IPCC) has reported that a warming climate will lead to significant changes in regional meteorological patterns, some of which will affect air quality.[1] However, IPCC's findings do not quantify how a changing climate might affect air quality in a given region, and many air quality planners are interested in knowing the extent to which climate change might affect future success in attaining and maintaining the NAAQS. Dr. Scheraga listed several other ways that climate change may be expected to affect air quality (e.g., by affecting chemical reaction rates, atmospheric transport processes, biogenic emission rates, selected anthropogenic sources). Examples of key questions being considered in the GCRP assessments include:

- What is the effect of projected changes in climate, climate variability, and land use patterns on regional U.S. air quality?

[1] See http://www.ipcc.ch/ipccreports/ar4-syr.htm.

- Which areas will experience air quality improvements and which will experience deterioration due to climate change alone? How many areas are at risk of failing to attain standards due to climate change?

- What is the impact of climate change relative to other factors that affect air quality?

Dr. Scheraga emphasized that stakeholder input plays an important role in establishing these key questions and directing future research efforts, and such input comes to the agency through various means, such as the ORD Adaptation Workshop. Accordingly, he encouraged workshop participants to provide ORD feedback on decision support needs, future research directions, and potential adaptation strategies. A record of the question-and-answer session following Dr. Scheraga's presentation follows:

- *Question 1: How does one distinguish adaptation to global climate and multi-pollutant planning?* Dr. Scheraga noted that adaptation and multi-pollutant planning are closely related, with no need to consider them separately during the workshop. He added that multi-pollutant planning is gaining increasing attention, both in terms of research and policy.

- *Question 2: Does the interim assessment examine metropolitan and rural areas throughout the entire U.S.?* Dr. Scheraga noted that the 2007 Interim Assessment examines the impact of climate change on air quality in urban and rural areas throughout the 48 contiguous states. Though this assessment does not address Hawaii and Alaska, those states will be included in the 2012 comprehensive assessment.

- *Question 3: How might climate change affect the susceptibility or vulnerability of human health and ecosystems to air quality impacts? Some research has shown an interaction between higher temperatures and adverse health effects due to air quality.* Dr. Scheraga agreed that research should examine and characterize any such climate-related susceptibilities to outdoor air quality, whether for humans or ecosystems. He emphasized that the GCRP is examining a broad spectrum of climate-related impacts to human health and the environment, including any information available on such potential interactive effects (i.e., effects resulting from exposure to increased air pollution *in a* warmer climate, in addition to effects resulting strictly from increased air pollution *due to* a warmer climate).

### 2.3 Using Models to Simulate U.S. Air Quality in 2050, Chris Nolte, NOAA-EPA

Dr. Nolte gave an update on ongoing modeling analyses to estimate how future climate might impact U.S. air quality in the year 2050. The modeling results presented were conducted as part of a multi-agency collaborative effort, known as the Climate Impact on Regional Air Quality (CIRAQ) project. One major goal of CIRAQ, according to Dr. Nolte, is to use models to simulate how future climate conditions may affect regional air quality (in particular, ozone and particulate matter) under future emissions scenarios—an important issue to research because future climate conditions are typically not factored into current air quality decision-making processes. Insights offered from these models can help policymakers determine whether, and to what extent, climate change adaptation considerations should factor into decision-making.

Dr. Nolte then reviewed CIRAQ's general modeling approach, which predicts regional-scale meteorology and air quality based on "downscaled" global climate and chemistry modeling. This modeling is simulating regional air quality for a current (1999-2003) and a future (2048-2052) 5-year time frame. Dr. Nolte emphasized that this modeling is based on IPCC's "A1B" emissions scenario, which includes several important assumptions, such as considerably decreased emissions of nitrogen oxides and volatile organic compounds (VOCs) by the year 2050. Other modeling studies based on different IPCC emissions scenarios should not be expected to yield comparable results. Readers interested in more complete documentation of the CIRAQ modeling studies should refer to original publications (see: http://www.epa.gov/AMD/Climate/index.html).

Dr. Nolte then reviewed several results that have emerged from CIRAQ's modeling efforts; note that regulatory comparisons are with respect to standards in effect at the time of analysis.

- **Change in mean summer 8-hour maximum ozone concentrations.** Dr. Nolte first presented findings for the modeling simulations based on "climate change only" (i.e., precursor emissions fixed at 2001 levels except VOC emissions from biogenic sources were allowed to vary with temperature), which found that future mean summer 8-hour maximum ozone concentrations were predicted to increase (between 2 and 5 ppb) in only a few isolated regions of the country—parts of California and Texas and in the coastal areas of mid-Atlantic states. However, when these models were run allowing nitrogen oxides and VOC emissions to vary according to the IPCC A1B emissions scenario, future mean summer 8-hour maximum ozone concentrations were predicted to decrease throughout virtually the entire United States, including decreases by more than 10 ppb in much of the Midwest. Dr. Nolte acknowledged, however, that the IPCC A1B scenario assumes a considerable decrease in future emissions of ozone precursors: a 48% decrease in emissions of nitrogen oxides and a 21% decrease in emissions of VOCs.

- **Change in 95$^{th}$ percentile summer 8-hour maximum ozone concentrations.** Dr. Nolte then reviewed predicted future ozone concentrations based on a statistic more indicative of peak concentrations—the 95$^{th}$ percentile summer 8-hour maximum concentration. For the "climate change only" simulation, ozone concentrations in the 95$^{th}$ percentile were predicted to increase over a broader region and by a greater magnitude in comparison to the predictions for mean summer 8-hour maximum ozone concentrations. This finding, when compared to that presented in the previous bulleted item, suggests that peak ozone levels in the future are likely much more sensitive to climate change than are summertime mean ozone concentrations.

- **Change in mean September-October 8-hour maximum ozone concentration.** Dr. Nolte next presented simulation results depicting changes in mean 8-hour maximum ozone concentrations computed for the months of September and October. For the "climate change only" simulation, the future concentrations during these months exceeded the current concentrations over much of the United States—a finding that suggests that the future climate may lead to a longer ozone season.

- **Changes in ozone associated with increased methane concentrations.** Dr. Nolte then discussed modeling results in simulations that evaluated how increasing concentrations of atmospheric methane might impact ozone levels. These simulations suggested that

increased methane concentrations over the next 50 years (i.e., from 1.85 ppm to 2.40 ppm) has the potential to increase ozone concentrations throughout much of the United States, and the methane-related increases could be comparable to the increased ozone levels resulting from climate change.

Summarizing, Dr. Nolte noted that the effect of climate change on ozone concentrations is smaller than the effect of planned emission changes, which he acknowledged are highly uncertain. CIRAQ's research suggests that factors other than climate change (e.g., increases in atmospheric methane concentrations) should also be considered when predicting future changes in ambient ozone concentrations. These and other findings have considerable inter-annual variations, underscoring the need for using multi-year assessments in future modeling work. Dr. Nolte also commented on important sources of bias and uncertainty in the linked modeling system. Dr. Nolte concluded by discussing NOAA's ongoing work to improve its climate and air quality modeling capabilities. A record of the question-and-answer session following Dr. Nolte's presentation follows.

- *Question 1: Why do ozone concentrations in the Los Angeles appear to be far more sensitive to climate than ozone concentrations elsewhere in the country?* Dr. Nolte said he has not fully investigated this issue, but suspected that the unique findings for the Los Angeles area might result from this area being highly sensitive to changes in nitrogen oxide concentrations and the fact that regional air quality models have historically not performed well in this area. Dr. Nolte added that these findings warrant further examination.

- *Question 2: Has CIRAQ conducted modeling to evaluate future changes in PM2.5 concentrations?* Dr. Nolte said that CIRAQ has conducted some PM2.5 modeling, but he did not present these results due to time restrictions. Dr. Nolte noted that PM2.5 is difficult to model because it is composed of many constituents (several of which have unique atmospheric chemistries) and because the modeling must evaluate all four seasons, rather than focusing primarily on summertime in the case of ozone. Dr. Nolte briefly discussed some results of PM2.5 modeling, and he referred workshop participants to slides at the end of his presentation for additional preliminary results.

- *Question 3: Did CIRAQ's modeling consider other IPCC emission scenarios? If so, what did these modeling results find?* Dr. Nolte said his group has not conducted extensive research into other IPCC emissions scenarios, but may do so depending on availability of funding.

- *Question 4: Recent increases in carbon dioxide emissions appear to exceed the increases based on the IPCC emissions scenario used in the CIRAQ modeling. Should this modeling be based on a scenario that is less optimistic about future changes in carbon dioxide emissions?* Dr. Nolte noted that his research has been criticized on both sides of this issue: some reviewers have commented that this modeling is based on overly optimistic assumptions (i.e., assumed future emissions being unrealistically low), while others have commented that the modeling is based on overly pessimistic assumptions (i.e., assumed future emissions being higher than what would be expected as a result of future regulations and anticipated technology change).

Two workshop participants commented further on this issue. One participant noted that the IPCC A1B emissions scaling factors predict a very substantial, and possibly unrealistic, decrease in future nitrogen oxides emissions. Another participant noted that researchers from the Northeast States for Coordinated Air Use Management (NESCAUM), Georgia Institute of Technology, and Massachusetts Institute of Technology have conducted extensive research on future emissions and air quality projections under an EPA Science to Achieve Results (STAR) grant. Dr. Nolte added that the CIRAQ results and the STAR grant results are qualitatively similar, but he recommended that future modeling efforts more fully investigate the sensitivity of these findings to alternate emissions scenarios.

### 2.4 Integrating Climate Change into Air Quality Programs, Lydia Wegman, EPA-Office of Air Quality Planning and Standards

Ms. Wegman's presentation provided a national perspective on climate-related impacts on air quality and national policies, research activities, and programs that have already begun to evaluate or inform adaptation strategies. Ms. Wegman first offered a very general review of the state of the science on climate-related air quality impacts:

- **Particulate matter and visibility.** Ms. Wegman noted that climate change is expected to have mixed impacts on airborne particulate matter (PM) and visibility, with increases and decreases projected for different regions. The modeling used to make these projections is highly complex, as many different interrelated factors affect PM concentrations and visibility (e.g., changes in precipitation, wildfire frequency and intensity, air quality feedbacks on climate).

- **Ozone.** Future ozone concentrations throughout much of the United States are generally expected to be higher in a warmer climate, assuming that decreases in precursor emissions do not offset the temperature-related ozone increases. Ms. Wegman cited a recent modeling study[2] that projects that 50 cities in the eastern United States will experience, on average, more than 5 additional days with 8-hour concentrations above the NAAQS by 2050, when assuming a "business-as-usual" climate change scenario (i.e., the IPCC A2 emissions scenario).

- **Research needs.** Ms. Wegman identified several general areas where research is needed to inform adaptation policies. Examples include: What is the magnitude of the so-called "climate penalty" for ozone, and how does that vary regionally and with emissions scenarios? What are the "win-win" scenarios for climate and air quality? Which components of PM are most important for public health in a future climate? How are changes in ozone and PM concentrations expected to contribute to climate change?

Ms. Wegman added that efforts to develop and implement adaptation strategies may also be complicated by recent and anticipated future changes to the NAAQS. For fine particulate matter, the 2006 revisions to the 24-hour average NAAQS, for instance, will lead to new attainment

[2] Bell ML, R Goldberg, C Hogrefe, PL Kinney, K Knowlton, B Lynn, J Rosenthal, C Rosenzweig, JA Patz. 2007. Climate change, ambient ozone, and health in 50 US cities. Climatic Change, 82(1-2): 61-76.

designations in December 2008. Additionally, proposed changes to the ozone standard, if promulgated, will likely result in numerous areas that meet the current standard to be designated as non-attainment, not even considering the added challenges that climate change might pose.

Given these challenges, EPA and air quality planning authorities may need to start developing new approaches for maintaining air quality. Some approaches, Ms. Wegman noted, have already been recommended by the National Academy of Sciences and the Clean Air Act Advisory Committee, such as: comprehensive multi-pollutant air quality planning; integrating air quality planning with other regional planning goals (e.g., land use, transportation, renewable energy and energy efficiency); and implementing multi-pollutant sector-specific approaches.

Finally, Ms. Wegman highlighted ongoing EPA activities related to the links between climate and air quality. These included regulatory activities, research into the links between climate change and effects on human health and welfare, voluntary emissions reduction programs, and multi-pollutant sector-based approaches. Ms. Wegman concluded by stating that: (1) significant additional investment in research and analysis, both internal and external to EPA, will be necessary to understand and take advantage of linkages between climate change and air quality programs and (2) multi-pollutant approaches are needed to simultaneously address criteria pollutants, air toxic pollutants, and greenhouse gases (climate change).

### 2.5 Air Quality Issues with Changing Climate in the West, Tom Moore, Western Regional Air Partnership (WRAP)

Dr. Moore's presentation addressed climate change adaptation strategies potentially applicable to air quality issues in the western United States. He began by describing several ways that climate change has already impacted (or may be expected to impact) air quality in the West. For instance, in some areas of the West, climate change may result in decreased amount and duration of snow-pack, increased temperature, and magnified drought—all of which are expected to increase the risk for large wildfires and lead to higher emissions from this source. Further, changes in precipitation patterns and drought will likely affect emissions of fugitive dust, an important component of the primary PM emissions inventory in the western United States. Dr. Moore noted that these and various other climate-related factors have a strong bearing on air quality issues in the West.

Focusing on wind-blown dust, Dr. Moore presented data from a 2002 primary $PM_{10}$ emissions inventory. The inventory showed considerable spatial variations in total primary emissions throughout the western United States, as well as differences in the factors contributing to the wind-blown dust (e.g., agriculture, land cover). He also displayed photographs and satellite images to illustrate the significance of major dust storms in Phoenix and northwest Texas. Dr. Moore advocated greater use of satellite imagery and remote sensing to evaluate the frequency and severity of dust storms and to assess other emissions and air quality issues, as appropriate. Dr. Moore advocated careful evaluation of all types of dust emissions, whether the emissions originate from sources that are clearly anthropogenic (e.g., construction, mining), sources that are clearly natural (e.g. volcanoes), or sources that are influenced by both anthropogenic and natural forces (e.g., wind erosion from bare areas or dry reservoirs and lake beds). Dust emissions will likely continue to be important when addressing air quality concerns and potential climate change mitigation efforts.

With respect to air emissions from fires, Dr. Moore addressed several topics. For instance, he noted that the annual amount of wildfire acres burned in the United States increased between 1991 and 2006—a trend that he argued cannot be attributed solely to climate change, because it also results from fire management policies implemented over the years. He added that changes in land management practices are expected to result in increased prescribed burning activity in the next decade. Given that fires account for a considerable portion of criteria pollutant air emissions in the West, Dr. Moore emphasized the need to integrate land management practices (e.g., fire management policies) into air quality planning and adaptation efforts.

Dr. Moore presented additional findings from other studies to introduce concepts for further discussion during the workshop. First, he presented an analysis of airborne sulfate data for the Grand Canyon National Park to emphasize that, in some areas, a considerable portion of air pollution originates from locations outside the area. Second, based on the same inventory, Dr. Moore noted that an emissions source of growing interest on the West coast is from "Pacific offshore" sources (i.e., emissions from shipping vessels along the coastline of California, Oregon, and Washington)—a category that is not explicitly included in EPA's National Emissions Inventory. He added that emissions from the "Pacific offshore" sources might increase in a future climate of reduced productivity in agriculture in the western United States. Based on these and other observations, Dr. Moore strongly advocated that ORD more explicitly consider emissions sources and source categories of interest in the western United States, including dust, fires, agriculture, offshore vessels, and contributions from other countries.

Dr. Moore closed his presentation by introducing two existing programs that may become focal points for managing GHG emissions in the West, and perhaps eventually on a national scale. First, he introduced The Climate Registry (see http://www.theclimateregistry.org for more details)—a collaborative effort among states, regions, provinces, and tribes to develop and manage a GHG emissions reporting system and to examine potential mitigation policies. Second, he introduced the Western Climate Initiative (see http://www.westernclimateinitiative.org for more details), which is a collaborative effort among several western states and Canadian provinces to address regional challenges posed by climate change. Dr. Moore recommended that EPA consider coordinating with these groups when identifying and evaluating potential adaptation strategies.

### 2.6 Integrating Climate Adaptation into Air Quality Decision Making, Kenneth Colburn, Center for Climate Strategies

Dr. Colburn's presentation addressed various policy implications of climate change and its impacts on air quality. He began by commending ORD for its ongoing research efforts under the GCRP, which have been designed to help inform policy decisions. Dr. Colburn emphasized the importance of continuing to seek stakeholder input to ensure that the GCRP products adequately meet decision-makers needs. He also strongly advocated the need for GCRP products to be "place-based" in order to be most useful for state, local, and tribal decision makers. Dr. Colburn noted that decision makers will continue to seek information from ORD, particularly in the form of assessments and various types of modeling analyses (e.g., economic modeling, adaptation options modeling). A particularly vital tool, he noted, is an integrated modeling framework for air quality, which will effectively downscale global models and incorporate inputs from various scientific disciplines. Developing and refining this modeling framework is a challenging task,

due to the underlying scientific and technical complexities, but is a worthwhile endeavor, given the extent of policy needs for adaptation strategies.

To illustrate an area requiring further research, Dr. Colburn reviewed some findings from a recent presentation delivered by Praveen Amar (NESCAUM) at a Symposium on Climate Change held in August, 2007. That presentation addressed the significance of the so-called "climate penalty" for regional ozone and PM2.5 concentrations in the United States. While modeling results suggest that this climate penalty in 2050 may be relatively "small" for some regions (assuming no changes to anthropogenic emissions), Dr. Colburn emphasized that "small" increases in ozone and PM2.5 concentrations can be very important for regions with air quality currently at or near the NAAQS. These initial modeling efforts, Dr. Colburn noted, raise many issues that future research can examine, such as apparent regional differences in the climate penalty, future patterns in extreme stagnation events, seasonal effects for precursors and other pollutants, feedback loops, and the changing nature and composition of PM.

Recognizing that emissions data are critical inputs to modeling how climate may affect air quality, Dr. Colburn recommended that future research examine a broader range of emissions scenarios, considering estimates of actual emissions. Dr. Colburn noted that some researchers' models are based on fairly optimistic projections of future GHG emissions; however, some analyses suggest that "observed" GHG emissions between 2000 and 2006 (3.3%) are increasing at a faster rate than predicted by multiple IPCC emissions scenarios (1.1-2.4%). This observation, Dr. Colburn noted, is consistent with other recent findings, such as: carbon dioxide emissions from fossil fuel combustion have been increasing faster than expected, the "carbon intensity" of the global economy has stopped decreasing, and the carbon dioxide removal efficiencies of some natural sinks are decreasing. These observations collectively suggest that the carbon cycle is generating stronger climate forcing and sooner than expected. As a result, current and ongoing modeling efforts, by relying on overly optimistic future GHG emissions scenarios, may not adequately represent the future climate and therefore understate climate-related air quality impacts.

Dr. Colburn then reviewed different ways that air quality planning agencies can contribute to ongoing efforts to implement effective mitigation and adaptation strategies. He noted, for instance, that the Center for Climate Strategies has already worked cooperatively with states to develop baseline GHG emissions inventories, identify action options (e.g., mitigation strategies), and investigate the implications of those options. Through these and other efforts, 37 states now have or are developing climate action plans, most with a goal of reducing 80% of GHG emissions by 2050.

While many states have launched mitigation actions to reduce GHG emissions, Dr. Colburn acknowledged that very few states have developed and implemented adaptation strategies, especially in the area of air quality. Given this situation, ORD has an excellent opportunity to provide the necessary tools and guidance to help state, tribal, and regional planning agencies integrate climate change adaptation into air quality decision making.

Dr. Colburn emphasized that air quality planners are ideal candidates to develop effective mitigation and adaptation strategies. While climate change undoubtedly affects many resources beyond air quality, air quality planners have a well-established history of providing consistent

leadership on environmental issues that bridge gaps across multiple disciplines. For example, the air quality community was instrumental in promulgating national energy policies, even though this issue influences a number of different sectors of the environment and economy. A record of the question-and-answer session following Dr. Colburn's presentation follows.

- *Question 1: Alaska has recently experienced significant air quality problems due to massive wildfires and wind-blown dust. Thus, the impacts of climate change on air quality are already being observed in Alaska. Might some consider Alaska a "testing ground" for adaptation?* Satellite imagery does confirm the existence of tundra fires, a new and unique problem facing air quality managers in Alaska that they never anticipated. In that sense, Alaska is indeed already facing climate-related air quality impacts that other states are not encountering.

- *Question 2: In Minnesota, mitigation efforts started to move forward, but some factions resisted these efforts unless adaptation was officially "taken off the table." Why might this be happening?* Some states view mitigation as a more tangible concern that can be addressed through multiple sectors: energy supply and demand, transportation, agriculture, waste management, and others; and a state's growing interest in mitigation should not be interpreted as a lack of interest in adaptation.

- *Question 3: What is ORD's focus with regards to monitoring of carbon dioxide? Does ORD plan to do any monitoring from satellites?* Dr. Joel Scheraga (EPA-ORD) answered this question, noting that the CCSP has a tremendous focus on monitoring atmospheric concentrations of GHGs, including carbon dioxide. While EPA does not conduct this monitoring, the agency works closely with the other federal agencies (e.g., the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration) who are responsible for the monitoring.

- *Question 4: Scientists predict that temperatures will continue to rise and climate will continue to change for several decades, even if major mitigation efforts are immediately launched nationwide. Therefore, adaptation strategies will be necessary, regardless of the extent of mitigation that takes place.* Dr. Colburn agreed, noting that the planning community should not consider launching mitigation *or* adaptation strategies, but rather must start developing and implementing mitigation *and* adaptation strategies.

## 3.0 Brainstorming Session on Policy Issues

After the opening plenary session, workshop participants were asked to break into small groups (5-10 people) to identify priority air quality policy issues and questions that ORD research can help inform. After this 30-minute brainstorming session ended, an individual from each group communicated a list of priority air quality policy issues to the larger group. A composite list of policy issues and questions was generated based on these report-outs, and ORD representatives at the workshop then organized this list into four categories for purposes of subsequent discussion. Later in the workshop, four breakout groups further discussed the policy issues and questions for these categories and identified research questions and products associated with each listed item. Section 4 of this report documents the discussions during those breakout groups.

Following is the composite list of air quality policy issues and questions developed by the small groups. Except for minor editorial revisions, this composite list is identical to the one displayed at the workshop:

**Topic #1: Multi-Pollutant Control Strategies and Co-Benefits**

- How can we better understand co-benefits and dis-benefits for traditional pollutants and GHGs?
- How do we balance concerns across pollutants (i.e., air toxics, criteria pollutants, GHGs)?
- What range of pollutants (e.g., coarse PM) have climate-related sensitivity?
- What models or policies should be developed for multi-pollutant issues?

**Topic #2: Un-regulated sources**

- How do we deal with sources that have not been regulated or not as extensively studied (e.g., agriculture, buildings, aviation, shipping, etc.)?
- How sensitive are individual sectors to the effects of climate change?
- What is the most appropriate regulatory approach for agriculture?
- How do fires affect air quality and carbon sinks? How does climate change affect the frequency and severity of fires? What fire management policies should be developed in light of climate change?
- Should the natural events policy be reevaluated?
- How do we address increased residential and commercial cooling, taking into account regional differences?

**Topic #3: Translation of Global Issues to Local Scales**

- How do you make local policy to address regional issues? How do local decisions affect regional air quality?
- How should uncertainty be factored into policy?
- What impacts can air quality assessments have on future air quality planning actions?
- How do we factor global "stressors" into regional air quality planning efforts?
- Modeling issues: How can planners interface with modelers to ensure their questions are answered? Do we have consensus on models to use? Can models offer the type of predictions that planners may ideally want?

**Topic #4: Planning now for future climate**

- How do you plan in the face of potential extreme and episodic events?
- How do we plan for future air quality in the context of climate change?
- Should we consider "proactive maintenance plans" and how would they be implemented?
- How do we take a system-wide approach for air pollution control?
- How do we improve our monitoring of rural areas and other under-monitored regions?
- How do we bridge gaps between climate science and air quality planning, considering differences in temporal scales?
- How do we include tribal communities in policy decisions?

**Miscellaneous: Policy issues and questions identified by workshop participants, but not classified into any of the categories during the workshop[3]**

- How will climate change policies impact air quality?
- How do you build a successful program at state or municipal level?
- How uniform should federal policies be?
- Will we need to apply "significance levels" to GHGs?
- What ambient or source monitoring strategy is needed for GHGs? Is a strategy needed for "ambient" GHGs? How can we measure the impacts of climate change on air quality?

[3] The grouping of policy issues and questions occurred during a short break at the workshop. However, not enough time was available to assign every policy issue or question into one of the four categories listed in the section. The policy issues and questions listed in this "miscellaneous" category were not classified into the four categories strictly due to timing constraints.

- How are modeling results best communicated and by whom? How do we communicate to various audiences (e.g., children)?
- What motivates people to change behavior?
- What indicators can be developed to track climate-related impacts on air quality?
- What level of detail regarding technology portfolios do policy planners need for their decision-making?
- What adaptation strategies can be implemented at the local level to reduce temperatures?
- What are the air quality impacts of changes in precipitation patterns, and how do these vary regionally?
- What incentive structures (e.g., subsidies) can be put in place to encourage design and retrofit of communities to reduce GHG emissions and meet air quality objectives?
- What do technology choices for GHGs mean for air quality at different time horizons? What are the win-win scenarios?
- What are the air quality impacts of mitigation strategies?
- How can the state implementation plan development and review process motivate planners to incorporate climate change into their planning?
- How do we coordinate research and planning efforts across universities, states, etc.?

In summary, the previous list documents priority air quality policy issues and questions that workshop participants identified during the brainstorming session. Section 4 of this report documents discussions during four breakout groups, which were asked to further discuss the issues and questions listed above.

## 4.0 Summary of Breakout Group Discussions

Following the opening plenary session (Section 2) and the small group brainstorming session (Section 3), the workshop participants split into four self-selected groups to discuss how ORD research can help inform four categories of policy issues and questions. Each breakout group had two sessions that were framed around guiding questions and suggested processes listed in the Workshop Participant's Guide, though some groups did not adhere strictly to this framework:

- During the first breakout group session, the groups were asked to identify research questions that ORD can and should address to inform the highest priority policy issues and questions regarding adaptation to the impacts of climate change on air quality.

- During the second breakout group session, the groups were asked to identify short-term and long-term research products for the individual research questions and to provide specific recommendations as to how EPA can most effectively deliver its products and decision support tools to the planning community.

This section summarizes the discussions that occurred in each breakout group and during the groups' "report-outs" in the final plenary session. ERG technical writers who attended the various breakout group discussions prepared the following summaries, all of which were reviewed by at least one EPA representative who also attended the respective groups. As noted elsewhere in this report, all content in this section should be viewed as a collection of individual opinions, as the breakout group format was not designed to reach consensus or assign priorities to specific suggestions or recommendations.

### 4.1 Breakout Group 1: Multi-Pollutant Control Strategies and Co-Benefits

Marcus Sarofim and Gary Kleiman facilitated discussions in this breakout group. Other participants attending this breakout group were:

| | | | |
|---|---|---|---|
| Bob Bielawa | Joe DeCarolis | Dale Evarts | Alice Gilliland |
| Doug Grano | Carey Jang | Rhea Jones | David Kryak |
| Meredith Kurpius | Tonalee Key | Dan Loughlin | Douglas McKinney |
| Paulette Middleton | Sharon Phillips | Samudra Vijay | Darrell Winner |

During the "report out" at the plenary session, Gary Kleiman summarized this group's discussions. The following text provides a general overview of the discussions.

#### 4.1.1 Day One Discussions

During the first session, the breakout group initiated conversation reviewing the four questions assigned to this breakout from the brainstorming session (see Section 3). The breakout group participants conducted another brainstorming activity to further develop specific research and policy questions. Every participant in the breakout group was asked to write additional ideas on note cards, which were then posted on flipcharts for all participants to review. The facilitator then worked with the participants to re-categorize the ideas and identify several common themes. Following are the major discussion points that emerged:

- *Characterizing technologies and actions for multi-pollutant air quality planning:* Participants noted a need to characterize the co-benefits and dis-benefits (or trade-offs) of technologies or policy actions with respect to air quality, climate, economy, human health, and the environment. The characterization should consider both temporal and spatial issues and should also address behavioral changes. Although the group noted the importance of evaluating technologies and actions among a variety of sectors, the group highlighted a near-term focus on characterizing bio-fuels technology and policy.

- *Developing decision support information and tools.* Participants discussed the need for decision support tools to facilitate a state-local-federal partnership on climate and air quality. The tools should be flexible, given that the users will have different baseline capabilities and available data (e.g., regional meteorological data, emissions inventory data). The tools should also assist states and regions in calibrating energy models to current inventory data.

- *Creating robust policy to address both air quality and GHG emissions.* Participants defined robust policies that offer "win-win" scenarios for improving air quality and reducing emissions of GHGs. Discussion touched on regulatory approaches, market-based approaches, and other incentives for improving air quality in a "climate-friendly" way. Participants were also interested in the interactions of policies at the local, state, regional, and federal levels. Specifically, how a local policy might best prepare for more stringent federal policies expected to apply in the future.

- *Balancing air quality and climate strategies.* While a robust policy helps improve air quality and reduces GHG emissions, participants also identified several niche areas that require planners to focus on a balance of air quality and climate, taking into account human health, the environment, and other factors. Participants listed several specific research areas when discussing this topic, such as better quantifying how atmospheric concentrations of methane and nitrogen oxides contribute to climate change and air quality, evaluating how climate change may lead to changes in aerosol composition, and identifying situations in which well-intentioned GHG mitigation strategies may actually worsen air quality.

During their discussions, the breakout group participants noted that several common themes (or cross-cutting issues) emerged that may warrant further consideration by ORD. Following is a brief summary of those themes:

- *Uncertainty.* Participants recognized that the complex modeling systems used to predict the impact of climate change on air quality have considerable uncertainty. They added that ORD should attempt to quantify and discuss uncertainties inherent in any tools, databases, and other products prepared for the air quality planning community. The implications of uncertainties for policy development should also be addressed.

- *Behavior.* ORD should consider providing more emphasis on understanding how to change human behaviors with respect to perceptions and actions on air quality and climate. Participants provided an example of using technology-specific discount rates to represent a balance between short-term air quality benefits and longer-term and inter-

generational climate benefits. Participants encouraged EPA to tackle the difficult challenge of promoting behavior change on a local level for a problem that is of global scale.

- *Communication.* Recognizing the complexity of research on the impacts of climate change on air quality, participants emphasized the need for ORD to communicate findings effectively. Part of these communications includes acknowledging and characterizing uncertainties for decision makers. Participants recommended that ORD document uncertainties in a manner that still encourages action and implementation of technologies and policy actions, while not providing decision makers an excuse for inaction.

- *Planning horizons.* Participants also noted an inherent conflict in the planning horizons for air quality policies and climate change policies. Effective air quality policies may result in reduced ambient concentrations over a short time frame (years), while effects of climate change policies likely will not be realized for a much longer time frame (several decades). Similarly, air quality planners must meet looming deadlines for air quality policies, whereas GHG policies are focused on 2020 and beyond. Assessments and the related models and data must consider the different planning horizons and realities that planning authorities face. Participants asked for an appropriate planning horizon (in years) for assessing how GHG policy impacts on air quality.

- *Collaborations.* Participants emphasized the need for ORD to collaborate with other research, assessment, and stakeholder groups during all stages of its assessment processes. As one example, participants noted that many stakeholders—some from the international community—have substantial experience in implementing GHG policies and assessing their effectiveness. Participants encouraged ORD to engage these stakeholders and the global community in their research efforts. Another suggestion for collaborating and maintaining stakeholder input was for EPA to hold a follow-up meeting with the planning community and to use a new round of research grants (e.g., Science to Achieve Results) to help focus research questions.

### 4.1.2 Day Two Discussions

During the second session, the breakout group brainstormed a list of potential products and delivery mechanisms for the research and policy questions. A record of these discussions follows:

- *How can EPA characterize technologies or actions for multi-pollutant air quality planning?* Some participants compared these characterizations to a Best Available Control Technology/Reasonably Available Control Technology/Lowest Achievable Emission Rate listing equivalent for GHG technologies and policies. Participants agreed that for a characterization exercise to be useful for air quality planners, the listing should enable analysis of benefits and trade-offs from a perspective of environmental attributes, economic attributes, and public health attributes. Participants also discussed important content and features of a characterization product. The content should eventually span all sectors, although the group prioritized the following topics for characterization: bio-fuels,

land use and forestry policies (including albedo effects), energy efficiency and renewable energy opportunities, and control technologies for GHG, criteria pollutants, and air toxics. The tool's format should remain simple and be widely accessible, with individual records containing information on cost-effectiveness, marginal abatement curves, spatial and temporal variability, and impacts on radiative forcing.

- *What decision support information or tools are needed to facilitate state-local actions and state-local-federal interactions?* Participants noted that one product of potential interest is regional level multi-pollutant emissions inventories, which ORD may be able to develop from existing inventories and emission factors, filling data gaps where possible. More generally, participants noted that ORD tools and other products should be user-friendly, publicly available, capable of running on desktop computers, and have "plug-and-play" functionality. Participants noted that multiple tools may need to be developed to address various issues, such as co-benefits and trade-offs for multi-pollutant control strategies, impacts on multiple environmental media, and relationships between pollutant emissions and estimated climate forcings (or radiative forcings).

- *How do planners balance air quality and climate strategies?* Participants noted several areas where ORD research or guidance can better prepare air quality planners for implementing policy with the greatest benefit for both air quality and climate. Some participants wondered if planners should place equal focus on climate and air quality. Others sought guidance on how to determine whether (and to what extent) a GHG mitigation policy might affect air quality. Examples of additional specific research questions identified for this topic include: Under what circumstances do albedo changes have positive effects on both climate and air quality? What control measures for black carbon are expected to have a positive effect on both climate and air quality? What factors (e.g., temperature) or co-exposures (e.g., to pollen, dust) might exacerbate ozone-related health effects? What are the light reflective and absorbing properties of key components of PM2.5 and is it possible to rank these components in terms of adverse health effects and radiative forcing? To what extent do reductions in PM emissions affect precipitation trends?

At the end of the second session, the participants in this breakout group reflected on their earlier discussions and developed a short list of "prioritized research products" and other action items, which included the following items:

- Ongoing summaries on current technologies and policy actions with respect to climate and air quality linkages. The 2007 assessment will provide useful information, but participants envision the need for ORD to publish a broader literature review.

- A catalog of measures and strategies for air quality and climate planning that is easily tailored for location-specific applications.

- Regional multi-pollutant inventories.

- User-friendly decision support tools that can be run with default values or user-specific inputs for certain applications.[4]

- Continued research on balancing air quality concerns with climate concerns.

- Training opportunities for using and communicating research products.

- Follow-up workshops, teleconferences, or peer reviews to allow for stakeholder input and collaboration.

The participants also briefly discussed means by which EPA can most effectively deliver its research products and decision support tools. Some suggestions for delivery included preparing additional white papers, developing Web sites, hosting workshops, preparing research agendas, and distributing various "tools" (which may include inventories, decision support tools, and emissions verification tools).

## 4.2 Breakout Group 2: Un-Regulated Sources

Cynthia Gage and Brian Morton facilitated discussions in this breakout group, which was attended by the following participants:

| | | |
|---|---|---|
| Rebecca Dodder | Heather Hawkins | Vinson Hellwig |
| Robert Noland | Jim Southerland | Sara Terry |
| Richard Valentinetti | Shelley Whitworth | |

During the "report out" at the plenary session, Cynthia Gage summarized this group's discussions. The text below (in Sections 4.2.1 and 4.2.2) provides a record of discussion for this breakout group.

### 4.2.1 Day One Discussions

During the first session, the breakout group brainstormed about various emissions sources that are currently un-regulated or under-regulated by state, tribal, regional, or federal authorities. Topics and categories discussed included energy efficiency, agriculture, some categories of mobile sources (including shipping, trucking and ports), biogenic emissions, land use, and current barriers to regulation. Breakout group participants offered several observations and listed research questions on each of these topics, though they did not engage in highly detailed discussions given the large number of topics to consider and the limited time available. A brief summary of the breakout group members' main points and questions raised on the individual topic areas follows:

[4] When discussing this topic, some participants commented at length about the need for professional software development support. ORD representatives noted that their role is usually limited to developing prototypes, because significant investment is required to design and code user-friendly interfaces and to conduct necessary product testing and user training. Participants suggested that prior to making large investments for usability, ORD should poll the actual population of potential users on the need for these enhanced software design features, given that some modeling tools may only need source code, scripts, and limited user-interfaces. Most participants agreed that maintaining a collaborative approach among stakeholders will help identify how to prioritize the content, features, and usability of any research product.

Energy Efficiency

- Improving energy efficiency of buildings has both climate change and air quality benefits.

- While electricity generating facilities generally are becoming more efficient, less efficient facilities occasionally come on-line to generate power during peak demand periods. This issue may be of concern in a warmer climate, as peak demand periods may become more frequent to support a greater demand for cooling.

- Can state implementation plans (SIPs) or emission inventories account for increased use of appliances at off-peak times or improved energy efficiency of appliances? Should consumer products with high energy efficiency be taxed at a lower rate?

- The U.S. should consider researching relevant regulations and policies that other countries have implemented. In the United Kingdom, for example, energy efficiency evaluations may soon be required as part of most residential real estate transactions, which should allow prospective buyers to factor this information into their purchasing decisions.

Agriculture

- As agriculture output changes regionally and worldwide, transportation patterns will also change in order to ship agricultural products to their destinations. Such shifts in agricultural resources and transportation demand should be considered in research on impacts of climate change on emissions sources.

- Further research can help inform other topics related to agriculture, such as (1) the extent to which climate change will affect species migration and the implications on agriculture and (2) whether climate change is expected affect emissions of ammonia from agricultural sources.

- Animal feeding operations emit large amounts of methane. Mitigation strategies (e.g., supplementing the diets of livestock) can reduce methane emissions from these operations. Further, EPA's AgSTAR program (http://www.epa.gov/agstar) has promoted technologies (e.g., anaerobic digestion of manure to capture biogas) to harness energy from methane that would otherwise be released by these operations.

Mobile sources

- State and local planning agencies develop policies to address air emissions from mobile sources, which account for a large portion of emissions of certain criteria pollutants, precursors, and GHGs. However, these agencies generally cannot regulate air emissions from international shipping and trucking, which can also account for a considerable portion of these emissions in certain jurisdictions.

- Breakout group members offered different perspectives on whether mobile sources should be considered as "un-regulated" or "under-regulated" sources. On the one hand,

many regulations (e.g., emissions standards, inspection and maintenance programs) apply to mobile sources. On the other hand, regulations typically have not addressed travel demand and traffic congestion. Even though emissions standards have been developed to limit the amount of emissions per mile traveled, the number of miles driven (or vehicle miles traveled) is largely unregulated.

Biogenic Emissions

- What are the biogenic sources of isoprene? How sensitive are biogenic emissions to changes in temperature? How will species migration patterns driven by climate change affect biogenic emissions in different regions? How well do models characterize the atmospheric chemistry of isoprene and what key uncertainties might research inform?

- How will changes in land use and land cover alter future anthropogenic and biogenic emissions of isoprene, VOCs, and carbon dioxide? Projections made by existing models differ based on assumptions used.

Land use

- What impact might sea level rise have on land use and associated air emissions from residential, transportation, and industrial sources? How will these impacts be quantified and over what time frame might they be observed? Can new communities be more "sustainable"?

- What insights can be gleaned from Hurricane Katrina regarding air quality impacts from extreme weather events that may be more frequent in a future climate? How did air emissions change as a result of population displacement, construction and demolition activities in damaged neighborhoods, and other adaptation outcomes?

- How might population migration patterns change due to perception of extreme weather events that may be more frequent or severe in a warmer climate? How might these perceptions affect corporate decisions for locating businesses?

Ports

- To what extent can or should ports implement standards to reduce emissions from vessels? How would these standards affect shipping patterns? In California, for instance, all major ports are in non-attainment areas; therefore, vessels that ship products to or from the state have no choice but to comply with any statewide port policies that apply to non-attainment areas. In Texas, however, Houston is the only major port in a non-attainment area. As a result, if Texas has statewide policies or standards that address ports in non-attainment areas, vessels that ship products to or from Texas have a choice of complying with these policies or standards or using other nearby ports in attainment areas (e.g., Corpus Christi). Developing standards for ports poses other challenges, such as the potential need for federal and international agreements.

- Ship idling could be reduced through use of generators or shore-to-ship power (also referred to as "cold ironing"), similar to truck-stop electrification.

- One breakout group member likened massive container ships to unregulated electricity generating facilities and recommended that standards be considered to use cleaner burning fuels, which would help reduce emissions from this source.

Barriers

- Breakout group members identified possible regulatory approaches to address emissions from selected transportation sources, but also identified barriers preventing their application to the United States. For example, one participant noted that trucks entering London now must demonstrate that they meet applicable emissions standards or pay fees to operate the trucks in the city. While some breakout group members agreed that this could be an effective incentive to reduce emissions from trucking sources, others noted that such policies might be difficult to implement in the United States due to existing interstate commerce clauses. More generally, participants noted that interstate and international commerce clauses must be considered prior to proposing regulations to limit emissions from the trucking and shipping industry.

- Breakout group members voiced concern about the fact that certain sources, particularly international shipping and aviation, remain largely un-regulated in comparison to other air emissions sources. Some breakout group members feared that efforts to regulate these sources will continue to be unsuccessful, until a consensus is reached that the sources are major emissions problems for attaining air quality standards. However, some participants suspected that political barriers largely prevent regulatory development efforts for some of these un-regulated or under-regulated sources.

### 4.2.2 Day Two Discussions

At the beginning of the second session, the group returned to the original questions developed during the first day's larger group brainstorming session on policy issues. Those questions follow, exactly as they were presented (except for minor editorial revisions for clarity). Observations made by breakout group members are documented in brackets.

- How do we deal with sources that have not been regulated or as extensively studied? What is the magnitude of those unregulated sources? Worldwide, what regulatory and economic incentive-based approaches are in use? Are the existing statues and treaties obstacles to regulation?

- How sensitive are individual sectors to the effects of climate change?

- What is the most appropriate regulatory approach to agriculture? How does climate change affect ammonia emissions and PM formation?

- How do fires affect air quality and carbon sinks? How do higher temperatures and drought affect wildfires and the frequency of prescribed burns? Do we need to change the way we count exceedances related to fires (prescribed burns vs. wildfires)? [One breakout group member wondered if wildfires may no longer be considered "exceptional events" if they become increasingly frequent occurrences.]

- How do we address increased residential and commercial cooling, taking regional differences into account? Quantification of emissions and emission reductions (criteria pollutants, air toxics, and GHGs) associated with heating and cooling needs and building retrofits is needed. Could this type of quantification be included in SIPs? Is there a way to get credit for emission control strategies used outside of a specific jurisdiction that affect that jurisdiction? [One breakout group member noted that the Renewable Energy Certificate program in the Northeast is an example of such credits.] Are there any barriers to inclusion?

- How and who does scientific research into behavior change? What is working in the European Union in regards to behavior change?

In addition, the facilitator listed several topics on flipcharts that were posted around the meeting rooms. Breakout group members were asked to write underlying research and policy questions they had regarding these topics. The following text lists the questions that breakout group members posted on the flipcharts (which have been revised only for editorial purposes), organized by topic. Some breakout group members made comments when the facilitator read the following questions. Those comments are presented below in brackets.

<u>Land Use/Sustainable Communities</u>

- Better tools for evaluating alternative land use designs are needed.

- What hardware would be required to continually monitor or track carbon dioxide emissions from a house or car, which could provide feedback to the consumer?

- Do land use policies have co-benefits for air quality?

- How do we account for changes in major urban areas and how do we quantify the impact or mitigation of these changes (examining the inter-relationship of climate change and non-attainment areas)?

- What are the measurement criteria for validating “smart growth” policies? What are the metrics for success?

- Better guidelines to calculate benefits/disincentives for developing town centers or sustainable communities are needed.

<u>Non-criteria pollutants</u>

- Quantification and evaluation of GHG reductions, by way of technological advances or reduction techniques (such as no-till farming), are needed. Incentives to help induce new technologies are needed. If a benefit can be quantified, economic incentives may follow.

- Do state emission reduction estimates and emission inventories match? Are we starting from a common inventory? Do bottom-up and top-down approaches match?

- A way to keep track of voluntary GHG reduction programs and emission reductions is needed. Are state efforts being synthesized? Is there a way to perform an objective evaluation of these programs? Has the Government Accountability Office done this?

- Where is the verification of GHG reduction measures? The climate registry users want certainty on the protocols. Does the science back it up?

- There are differences in the impacts of hydrofluorocarbons and perfluorocarbons.

- A review of chlorine's role in tropospheric ozone formation and formaldehyde as an ozone precursor is needed.

- How can we factor in water vapor and other GHGs that have not been addressed in a satisfying manner? Can a state receive credit for ozone and black carbon reductions, which both act as "warmers"?

- Methane should be added back to the list of ozone precursors. It impacts background ozone.

- How will carbon dioxide reductions reduce other pollutants? Can regulation of carbon dioxide reduce other pollutants enough to offset climate impacts on air quality? How can this be quantified?

<u>Shipping, Ports, and Freights</u>

- Where are the new ports going to be as sea level rises?

- As new regulations are promulgated, as driven by new technologies, how can a ramp-up of old technology use be prevented prior to the new technology requirement?

<u>On-road Transportation and Non-Road Sources</u>

- How do we address growth in vehicle miles traveled (VMT) in SIP planning? What are the barriers? Is conformity a better way to address VMT growth? How could conformity be changed to include carbon dioxide?

- Identification of institutional barriers to federal funding program guidelines and the development of recommended changes is needed.

- What policies work for areas where transportation is the main contributor to non-attainment?

- Can states quantify impacts on biofuel penetration? What are the health effects? Models do not reflect these newer forms of fuels.

- Requiring that the air conditioning flag in MOBILE6 to be turned on would improve modeling.

- How often is transportation the main contributor to non-attainment? How do new fuel standards impact this? What kind of standard might help solve related nonattainment problems?

- Are evaporative emissions going to be impacted by climate change? Do models reflect this?

- If fossil fueled electricity generation and gasoline- or diesel-fueled transportation are greatly reduced, what is the largest possible impact on GHG reductions? Other GHG categories are at or near the "worst" level until these are controlled.

- What is technically feasible in regards to transportation to get an 80% carbon dioxide reduction?

Shipping, Freight, and Aviation

- What can be achieved by regulating carbon dioxide and nitrogen oxides from shipping and aviation (including international trucking)? What are the costs and benefits? Is this a federal issue? What are the economic benefits? These are sources of fine PM and ozone but states have no authority beyond regulating ground equipment.

- What are the freight transport consequences of climate-induced shifting of agricultural processes?

- Is there a global warming metric for contrails?

Agriculture

- Are there under-documented health effects from consolidated animal feeding operations (such as from hydrogen sulfide) that may be expected to increase under future climate? How can we implement technological options such as methane from consolidated animal feeding operations for power? Would there be any benefits in regards to water quality? [A breakout group member indicated that Vermont power companies are currently attempting to improve their public image by funding alternative energy sources, such as methane recovery from animal feeding operations. Other members added that public image and perceptions have a history of helping to shape public policy. Finally, another participant noted that many mitigation efforts, while motivated by concerns of climate change, ultimately require behavioral change, and the underlying factors that drive behavioral change should be investigated.]

- Will economics act as a hindrance? What are the economics of large-scale manure conversion (considering stench, water quality)?

- How will climate affect emissions from agriculture, including consolidated animal feeding operations, and how will that affect air quality?

- We need to evaluate agriculture in a "systems approach" to determine lifecycle cost, benefits and dis-benefits, including biofuels, changes in practices, and regional differences in practices. Does the structure of subsidies need to change?

- How can agriculture be regulated to reduce emissions? What are the options with land use approaches to reduce transportation emissions? What are the climate change and air quality tradeoffs of urban sprawl versus agriculture?

- In regards to agriculture and forestry, research is needed on ways to increase carbon sinks and minimize agricultural and forestry losses due to poor air quality in conjunction with rising temperature, decreasing water availability, and shifts to different industries.

- How are forest species changing due to climate change? Are climate-stressed ecosystems more susceptible to the impacts of climate change? Emissions from some species are regionally influenced by climate.

- Agriculture is an important sink and a source of non-fossil fuel. How do we transport biofuels to demand sites? [One breakout group member emphasized that the viability of bio-fuels as an alternative fuel source depends, in part, on proximity of fuel production facilities to demand sites.]

<u>Parking Lot (used for comments that do not fit under the previous topics)</u>

- How effective are voluntary emission reduction programs?

- ORD should provide technical assistance with downscaling global circulation models to facilitate integrations of climate change and SIP air quality modeling.

- Are the emission inventories used in global circulation models prepared with sufficient spatial, temporal, and sector-specific resolution to allow a meaningful comparison with the inventories used for regional air quality monitoring?

- Local and state actions, no matter how stringent, will be most effective locally. How can we motivate local actions?

- If federal law does not require action, states are somewhat limited to those mitigation actions that generate jobs and result in short- and long-term economic gains (based on public perspective). Can we document the advantage of green technologies?

- How can GHG and air pollution impacts be considered as part of regional energy regulation (energy generation and distribution regulation)? Regional dispatch is part of the Federal Energy Regulatory Commission, which does not include air quality issues, just costs.

- We need a strategy to communicate modeling results to state and local agencies. Many believe that existing emission reduction programs are more important, but climate programs will be more relevant to those areas on the cusp of attainment.

- Are there under-utilized technologies to get reductions in currently unregulated sectors? Can we quantify potential reductions?

- How sensitive are current models to extreme weather events and what impact would these have on air quality? What does this mean in regards to attainment? Can models predict extremes and can probabilities be assigned? Can this be done at the local level?

- How do we integrate climate change adaptation into non-attainment SIPs?

- We need better modeling tools to show how climate change impacts NAAQS attainment.

- How accurate are regional and local climate forecasts? If they are not that accurate, how should a local planning area use this information in planning?

The facilitator summarized the various issues placed in the "parking lot," noting that they fall under the following topics: Successes of regulatory programs need to be measured and verified; uncertainties in climate modeling and predictions need to be communicated; extreme weather events and their impacts need to be modeled, and the probability of their occurrence should be estimated; and current emissions from un-regulated and under-regulated sectors needs to be quantified and their potential climate-related sensitivities assessed.

### 4.3 Breakout Group 3: Translation of Global Issues to Local Scales

Susan Wierman facilitated this group. Other participants attending this breakout group were:

| | | |
|---|---|---|
| Edith Chang | Rich Damburg | Brooke Hemming |
| Robert Hodanbosi | Tom Moore | Chris Nolte |
| Roman Orona | Carol Shay | |

During the "report out" at the plenary session, Susan Wierman summarized this group's discussions. The following text presents a record of the discussion that led up to the group's main findings.

#### 4.3.1 Day One Discussions

During the first session, the breakout group focused on identifying the highest priority research questions to inform policy questions pertaining to "translation of global issues to local scales." The initial discussion addressed the following issues:

- *What is a decision support system?* Breakout group members first discussed the essential and most helpful elements of an effective decision support system. Models and other software tools to run analyses, a pre-built framework that can be filled in with local data, and other software-based tools that can be tailored to use in air quality planning were all identified as tools that be most beneficial to air quality planners.

- *What challenges might ORD face in creating a decision support system?* Participants discussed several challenges to developing a decision support system, with most of the comments addressing two general topics.

    - *Complexity.* The linked modeling systems used to assess impacts of climate change on air quality bring together individual models or analytical tools from multiple different fields (science, economics, etc.). Further, the number and variety of models available may create more questions than answers, especially when they generate different results. Examples of questions that need to be considered include: what are the underlying differences between the available models, which model is best for a given application, and what assumptions should be used for a particular analysis.

    - *Different time horizons.* Climate models are typically run to simulate conditions over several decades or even centuries into the future, and air quality models tend to be used to characterize regional air quality scenarios for much shorter time frames. With the 5- or 10-year time horizon of most SIPs, air quality planners may not be familiar with characterizing inputs (e.g., emissions scenarios) for many decades into the future. Some participants noted that member states of the Regional Greenhouse Gas Initiative have set timelines for meeting air quality and mitigation goals, and that experience may serve as a model for how to help air quality planners recognize and understand the complications presented by evaluating issues that have inherently different time scales.

- *In "global to local", what does local mean?* The breakout group members also discussed which parties are expected to lead efforts to incorporate climate change into air quality planning, with discussions centering on the following topics:

    - *State versus federal lead.* Workshop group members acknowledged an intrinsic conflict between states' flexibility and their need for federal guidance or pressure to address an issue such as climate-related impacts on air quality. States frequently have better knowledge and data to support decisions of a local nature, but they may lack the broader climate change expertise necessary for developing adaptation strategies. Furthermore, states have various in-house capabilities and tendencies when taking on new issues: some have limited resources and tend to be reactive to federal pressure or requirements, others with greater internal resources might still need direction and the necessary clout to persuade political entities to act on climate change, and still have a track record for tackling emerging issues without federal pressure. In short, many states likely will not develop and implement adaptation strategies without at least some direction from EPA or a federal requirement to do so.

    - *Local variability.* Citing remarks from the plenary presentations and text in the "white paper," several breakout group members indicated that climate-related impacts on air quality are expected to vary throughout the United States. Accordingly, participants noted that ORD faces a challenge of developing products that are useful to planning agencies nationwide, while being capable of

addressing the considerable spatial variations in regional air quality and their differing pressures. Because the impact of climate change on air quality varies throughout the United States, the most effective adaptation strategies will also vary from one location to the next.

- *What can ORD do to help air quality planners incorporate adaptation into decision making?* With some state, regional, tribal, and national air quality planning agencies having limited resources and time to address emerging issues, breakout group members urged ORD to leverage existing research findings and results from ongoing research products to the greatest extent possible. By compiling and reviewing this information (e.g., as is being done in the pending 2007 assessment of climate change and regional air quality), ORD can have a better sense of what has been done and what needs to be done. This information should also be communicated to other planning agencies so that they do not have to conduct independent reviews of the scientific literature. ORD could assist air quality planners by aiding in decision support tool development and possibly by building a consortium for better communication of available tools, data, and modeling results.

After this discussion, the breakout group compiled suggestions and recommendations for the report-out, based on the guidance in the Participant's Guide. The notes that follow document the remaining discussions that occurred during the first session, which this group later revisited during the second session (see Section 4.3.2 for a summary of those discussions). Therefore, the following summary does not represent the final recommendations from this breakout group.

- *Item 5a: "The policy question/issue you want ORD to inform and why."* What is the scientific justification for regional differences in control programs both in air quality and climate, and how will policy incorporate this regional variability?

- *Item 5b: "The highest-priority science questions that ORD can and should pursue to inform that policy issue."*

  - What are the most likely scenarios that state, local, and tribal air quality managers should be using in their planning? A range of best and worse case scenarios would be helpful.

  - Has the scientific community reached a consensus on the preferred global models to use (including their inputs, assumptions, boundary constraints, and so on)? Which inputs are most uncertain? What sensitivity analyses are available? What pressures on air quality (e.g., fires, off-shore shipping) are specifically factored into these models, and which pressures are excluded?

  - Which sectors (e.g., electricity, water resources, and transportation) are expected to be most affected by climate change?

- *Item 5c: "The most important near-term and long-term research products and decision support tools that ORD should provide, including those that are available now."*

- Few air quality planners are qualified to run and interpret global climate models, due to the models' complexity. ORD should therefore develop a collaborative means for establishing consensus model inputs to be used for air quality management decisions, such as meteorology, climate conditions, reaction rates, and emission rates. ORD should also identify input parameters that are expected to vary depending upon region-specific factors.

- ORD should develop or identify the most accurate global emission inventories and enhance national biogenic and anthropogenic VOC emissions inventories for use in a modeling framework to support air quality planning. Further, ORD should provide guidance on scenarios and projections that models use to forecast future climate and emissions.

- ORD should consider developing a transparent, reproducible, Web-based model for evaluating climate-related impacts on regional air quality, while allowing users to incorporate local data (e.g., emissions inventory, meteorology) as necessary. Any such modeling framework should be well-documented and include sufficient user training and guidance, as well as various scenarios for future emissions and land use.

- ORD should identify or develop simple, common metrics to help state, tribal, and regional planning agencies quantify the impacts of adaptation strategies.

- *Item 5d: "Recommendations as to how EPA can most effectively deliver its products and decision support tools to the air-quality planning community and obtain continuing feedback on the usefulness of its research products."*

    - EPA should develop a clearinghouse of relevant information (e.g., peer-reviewed publications, models, assessments) and work in progress to address the current lack of communication between stakeholders. A consortium of air quality planners and researchers could help better disseminate existing data, tools, and model results, increasing the effectiveness and coordination of research efforts and policy development.

    - Breakout group members noted that increasing communication and cooperation with tribal agencies may require a different approach than with other state and local agencies. Because some initiatives are perceived as "the outside community attacking sovereignty of tribal lands," EPA should, as appropriate, involve tribes in consultative roles in the beginning of major initiatives, training them in analytical tools and assisting in characterizing issues of cultural or other significance to the individual tribes.

### 4.3.2 Day Two Discussions

During the second session, the breakout group continued discussing issues raised on the first day, with the goal of expanding their previously-identified primary needs and formulating concise research recommendations for EPA.

Breakout group members initially discussed the feasibility of translating global climate models and complex linked modeling systems into simplified models that air quality planners can more easily use. Some breakout group members cautioned that efforts to simplify models to make them more accessible to planners might cause them to lose some of their predictive capability. The inherent complexity in the models results from their need to evaluate multiple spatial scales and pollutants and complex atmospheric chemistry. However, other breakout group members expressed interest in creative ways to characterize potential climate change impacts without relying on complex climate models, perhaps through use of reduced-form models.

Breakout group members also revisited the concept of a "users' community" for developing ORD research products. One workgroup member discussed her recent efforts with the "Networked Environmental Information Systems for Global Emissions Inventories" system, for which she evaluated all available information on bottom-up emission inventories developed by different parties with different goals. Her project resulted in a Web-based, distributed database that provides users with tools, data access, and means for identifying the most current inventory data available. Noting the success of that project, some breakout group members suggested that ORD consider launching a similar collaborative effort to ensure that air quality planners remain informed of the latest science regarding climate-related impacts and adaptation strategies.

To prepare for the "report out" in the final plenary session, the breakout group members then identified analytical needs that air quality planners will likely experience when incorporating climate change into their decision making. The following three main needs were identified on page 15 of the "Integrating Climate Change Adaptation into Air Quality Decision Making" white paper and served as the guiding outline for the second session's discussion:

- Need for primary scientific or technical support
- Need for guidance on using linked modeling systems
- Need for inter-agency coordination

For each type of need, the breakout group posted written comments on flipcharts that identified research questions, research products, and delivery methods. The facilitator further organized this feedback into a table, which she presented and summarized during the final plenary session.

### 4.4 Breakout Group 4: Planning Now for a Future Climate

Julia Gamas facilitated discussions in this breakout group, which was attended by the following participants:

| | | |
|---|---|---|
| Ashlea Anderson | Bryan Bloomer | Ira Domsky |
| Laura Draucker | Robert Elleman | Bryan Hubbell |
| Tim Johnson | Ozge Kaplan | Gail Lacy |
| Andy Miller | Natividad Urquizo | |

During the "report out" at the plenary session, Ira Domsky and Robert Elleman summarized this group's discussions. The text below (in Sections 4.4.1 and 4.4.2) provides a record of the discussion for this breakout group.

### 4.4.1 Day One Discussions

To initiate discussion, the facilitator first listed several topics on multiple flipcharts and posted those around the breakout meeting room. The facilitator then asked breakout group members to write down research and policy questions relevant to the topics and to post those written comments on the corresponding flipcharts. After completing this exercise and reading through the posted comments, the facilitator moderated a brief discussion on overarching topics, which addressed the following issues:

- *Consider resource limitations.* Some breakout group members emphasized that air quality planning agencies have limited resources (e.g., funding, staffing, computational power) necessary for modeling air quality impacts due to climate change. Accordingly, they recommended that ORD be mindful of these significant resource limitations when developing products to be used by the various agencies. Overly complicated products, whether they are assessments, guidance, case studies, or decision support tools, might prove to be of limited utility for the agencies with the most limited resources.

- *Make better use of existing information.* Some breakout group members noted that ORD may be able to provide some insights on potential climate-related impacts on air quality through review of existing data, particularly the extremely large volume of ambient air monitoring data for ozone. With approximately 30 years of measurement results available for stations nationwide, ORD can characterize associations between ozone levels and certain meteorological conditions, as well as document how these associations vary regionally.

- *Characterize the impact of climate on meteorology.* Noting that workshop discussions focused on how climate change might affect air quality, one breakout group member emphasized that climate change has an intermediate but equally important affect on regional meteorological patterns. This breakout group member encouraged ORD to prepare information on how climate change is expected to affect key meteorological parameters and to document regional variations in these effects.

- *Consider other research and policy suggestions.* At the end of the first session, some breakout group members offered specific suggestions for ORD to consider, though the suggestions were not discussed in detail. Examples of the suggested research activities follow:

    - Modeling studies that predict future climate-related air quality impacts have conflicting findings, many of which can be explained by underlying assumptions in the modeling protocols (e.g., use of different IPCC emissions scenarios). Air quality planning agencies might benefit from some guidance on how to evaluate seemingly contradictory findings. Alternatively, rather than leaving interpretation up to the planning agencies, ORD may consider developing a preferred set of

models and model inputs and publish the associated predictions of how the "climate penalty" is expected to vary by region and decade.

- The "events" that trigger significant air quality concerns vary from region to region. For example, wind-blown dust and wildfires are of particular significance in parts of the West, while heat waves and stagnation episodes may play a greater role in other parts of the country. One breakout group member recommended that ORD consider listing the various "events" that are most highly associated with regional air quality concerns and then evaluate whether climate change is expected to affect the frequency and severity of these events.

- One breakout group member recommended that ORD consider focusing initial efforts on some near-term goals. As one example, for areas believed to be "at risk" for non-attainment due to climate change, ORD can help identify market-based approaches, non-regulatory incentives, and other strategies to help offset the anticipated climate-related impacts on air quality.

- A breakout group member emphasized that ORD should not limit its research to climate change's impacts on ambient concentrations of ozone and PM2.5. Impacts on deposition and re-emission of pollutants like mercury should be considered, as well.

### 4.4.2 Day Two Discussions

During the second session, breakout group members revisited several discussion topics covered during the first day (see Section 4.4.1) and organized their ideas into two main themes. The two themes, along with a summary of the main discussion points, are listed below. After the discussion ended, the breakout group facilitator further organized the main points into a presentation, which was displayed during the final plenary session.

**How do we begin planning in the context of climate change?**

The breakout groups focused on two topics: science issues (data and models) and planning issues. Regarding the *science issues*, breakout group members raised numerous points. For instance, some encouraged ORD to collect data and run models that will help examine best-case and worst-case scenarios. However, breakout group members had differing opinions on how ORD should proceed with modeling efforts. Some recommended that ORD develop a preferred complex, integrated modeling framework that planners may eventually use to examine climate-related air quality impacts under a wide range of scenarios. Other breakout group members advocated development of reduced-form models that can provide information much more quickly to state, regional, and tribal planners, but without compromising precision and predictive capabilities. Regardless of model complexity, breakout group members noted that stakeholders will ultimately require guidance on the use of the models, such as the appropriate temporal and spatial scales to consider, which time horizons to evaluate, ranges of acceptable inputs, which emissions sources have climate dependencies, and so on.

More generally, some breakout group members encouraged ORD to examine existing modeling frameworks and evaluate the climate-sensitivities among individual elements (e.g., emissions, meteorology, land use change). This evaluation can help identify which climate-related sensitivities are well characterized, and which require further research. Breakout group members then listed several specific areas that may be informed by research: the influence of climate change on the frequency and severity of drought in arid areas and the resulting changes in $PM_{10}$ emissions and ambient concentrations; the impact of climate change on biogenic emissions, including region-specific effects; and climate-related effects on atmospheric deposition processes.

During this discussion, breakout group members raised several additional questions that ORD may consider evaluating further. Examples of the questions include: How does climate change affect the vulnerability of human health and ecosystems? Are our existing standards sufficiently protective? Are we using the appropriate metrics in our standards? What are the appropriate time scales for planning, implementation, and impacts? Do we have sufficient data to characterize how climate change might affect interactions between environmental media (e.g., deposition)? What motivating factors are most effective for imparting behavior change?

Regarding the *planning issues*, breakout group members raised numerous points. Most generally, some asked how EPA would help ensure that evolving science is communicated to the planning community and integrated into policies. These breakout group members suggested that EPA consider issuing periodic updates to key products (e.g., assessments, white papers) to reflect the latest science; and others recommended that planning agencies consider implementing, as warranted by major scientific advances, "mid-course corrections" in their climate or air quality planning efforts. Overall, these comments noted that planning authorities may need to develop a flexible planning structure to accommodate the emerging science in climate change and its impacts on air quality.

The workshop group members offered several additional recommendations for how climate change impacts could be integrated into air quality planning. Some breakout group members, for instance, suggested that some formal mechanism be established to ensure that climate change is included in maintenance plans. ORD could develop case studies or other guidance to help planning agencies explicitly factor adaptation into their planning efforts. Other breakout group members emphasized that all air quality planning agencies should be aware of potential impacts of climate change, even though some states, regions, and tribes may have limited or no experience preparing SIPs. As for policy implications, two breakout group members commented on the need for "system-wide" adaptation strategies that incorporate planning activities from various disciplines, such as climate action planning, air quality planning, and land use planning (e.g., sustainable development, smart growth, "cool cities"). One added that other forms of planning—such as fire management and agriculture—have links to air quality and climate, and should be considered in "system-wide" approaches. Finally, one breakout group member suggested that OAQPS consider, possibly through input from ORD, the need for probabilistic approaches in SIPs for reaching attainment with air quality standards.

**What elements of planning might ORD research and products inform?**

After discussing general approaches for incorporating climate change into air quality planning, the breakout group considered four specific elements of planning where further research might be warranted:

- *Research into emissions inventories.* Recognizing the importance of emissions inventories in air quality modeling studies, several breakout group members recommended that ORD conduct further research into the existing inventories. Examples of potential research areas follow: Conduct studies to reconcile discrepancies between modeling results (based on emission inventory inputs) and ambient air monitoring data; harmonize top-down inventories (which are commonly used for future climate scenarios) and bottom-up inventories (which are typically used for air quality applications); consider lifecycles and economics when assessing emission reduction strategies; and review existing emission factors to identify those that should be updated with more current information (some $PM_{10}$ emission factors were noted as being based on decades-old studies of questionable quality).

- *Exceptional and episodic events.* The breakout group discussed at length how climate change might affect the frequency and severity of air quality "events." During this discussion, breakout group members used multiple terms—extreme, exceptional, episodic—to describe these events, and some terms were used interchangeably. Ultimately, they recommended that EPA not only better define "exceptional" events (e.g., hurricanes, dust storms) and "episodic" events (e.g., stagnation periods), but also evaluate how these events will differ in our future climate. These evaluations should consider regional differences in exceptional and episodic events, including impacts in rural areas. One breakout group member noted that future climate change can have direct bearing on important policies pertaining to air quality "events," such as possible changes to the exceptional event rule (i.e., if these events become more commonplace, should they still be considered "exceptional"?) and to significant harm levels (i.e., if health effects due to exposure to outdoor air pollution are exacerbated by high temperatures). Further, planning agencies may need to develop and implement adaptation strategies specific to these events, such as outreach to sensitive populations to prevent harmful exposures and temporary emissions reduction strategies to mitigate air quality "events."

- *Monitoring strategies.* The breakout group also discussed whether and how monitoring strategies should be enhanced to assess impacts of climate change on air quality. Most generally, breakout group members recommended that EPA consider developing a new monitoring network optimized for detecting the "climate penalty" signal among ambient air monitoring data, rather than relying on an existing monitoring network established for an entirely different purpose.

  The breakout group members then offered several specific considerations for improving ambient air monitoring strategies. Regarding ground-level monitoring, several questions were asked: What enhancements to the existing monitoring network are necessary to assess and quantify climate-related impacts in rural areas? What other changes should be made to the existing network (e.g., develop new monitoring methods, measure air quality

at different elevations, change monitoring frequencies, monitor for additional pollutants, identify surrogates for climate "signals") to inform planners of the potential "climate penalty"? How can modeling be used to inform decisions, without the need for designing and implementing monitoring networks? Finally, breakout group members also encouraged ORD to ensure it makes best use of existing remote sensing data, which may provide insights on spatial variations in air quality, biogenic emissions, and other issues.

- *Tribal governments.* The breakout group concluded their second session by discussing how EPA can best coordinate with tribal governments on adaptation strategies for climate change, and these discussions addressed numerous topics. One breakout group member, for instance, felt EPA should try to build more capacity with tribal planning agencies, perhaps through additional workshops or conferences. Others recommended that assessments of climate-related impacts should consider resources of cultural significance to tribes. Finally, multiple breakout group members said ORD should not only consider what products to develop for tribes, but seriously consider what insights it can learn from tribes. For instance, oral histories from tribes may offer insights into the impacts of climate change on various environmental media that cannot be gleaned from existing measurements. Such insights might be particularly valuable in areas where monitoring has not been conducted. Additionally, one breakout group member recommended that ORD consult directly with tribes to understand their perspectives of environmental impacts.

After these discussions ended, the facilitator organized key points into a brief presentation for the closing plenary session.

## 5.0 Concluding Plenary Session

The concluding plenary session involved three activities. First, facilitators from the four breakout groups presented key discussion points from their respective groups. Limited discussion occurred during these presentations. However, a meeting facilitator wrote the following overarching questions on flipcharts during the report-out presentations:

**Adapting to Climate Effects**

- How does climate impact areas just in or just out of attainment?
- How do we address increased residential cooling, taking into account regional differences?
- What do increasing fires and changes in fire policy mean for protection of public health? Should the natural events policy be re-evaluated?
- How should climate change be considered in air quality maintenance plans and in SIPs (possibly in a weight-of-evidence section)?
- Are there local measures (e.g., "cool cities") to reduce regional temperatures to avoid ozone increases due to global change?
- More than temperature will change in the future climate. How might precipitation changes affect air quality?

**Interplay of Adaptation and Mitigation**

- How can we encourage the design and retrofit of communities to both reduce GHG emissions and meet air quality objectives?
- What do the technology choices made for GHG reductions mean for local air quality for the next 20 years? For the next 50 years? How can we make the best choices (e.g., "win-win" strategies)?
- What multi-pollutant strategies best protect human health and climate (e.g., sulfate, black carbon, organic carbon, methane)?
- What are the air quality impacts of mitigation technologies (e.g., bio-fuels)?

Second, workshop participants were asked to identify common themes that emerged during the four report-out presentations, and the participants' feedback was typed into a computer and projected on a screen for everyone's review. The following common themes were identified:

- Inventories: reconciliation of global and regional inventories, comparisons across pollutants and sources, etc.

- Characterization and communication of uncertainty throughout the modeling framework (e.g., from emissions to climate modeling to air quality modeling).
- Understanding different temporal and spatial scales of climate and air quality issues.
- Evaluate co-benefits and trade-offs.
- Modeling of different scenarios, with consideration of "extremes" (both range of weather patterns and range of other inputs).
- Impacts of regulatory approaches for different issues, such as multiple pollutants and un-regulated sources.
- Metrics and quantification: How do we measure the impact of the full range of policies?
- Impact metric for climate change and air quality planning.
- Need for effective communications to all audiences.
- Need to engage the public about their role in climate change and air quality.
- Take advantage of social sciences: What is the full range of influences that can be used to promote GHG and multiple pollutant reductions? Who can do this research?
- Forming a community with: academia; the international community; state, tribal, and local planners; and other stakeholders.
- Better characterization of uncertainties in the linked modeling systems.

Third, the workshop concluded with a brief brainstorming session on immediate needs and next steps for identifying adaptation strategies for climate-related air quality impacts. Workshop participants listed recently completed and ongoing research projects that might inform ORD's research on adaptation strategies. One participant noted that EPA's Office of Air Quality Planning and Standards is already conducting air quality management pilot projects with multiple states and "Sustainable Skylines" projects with Dallas and Kansas City, and the results from these projects (when completed) might be of interest to ORD. Multiple participants identified existing modeling results that may help inform research into adaptation. Specific results mentioned included MARKAL energy systems modeling conducted by EPA and NESCAUM, climate and air quality modeling conducted by CIRAQ, and publications submitted through STAR grants.

Workshop participants also listed several immediate needs for air quality planning agencies. Examples of these included: information on the sensitivity of the "climate penalty" to different emissions scenarios, examples of adaptation strategies that can be implemented to address extreme air pollution episodes (e.g., outreach to the public on how to minimize exposures), and reconciliation of different emission inventories (e.g., global versus regional, bottom-up versus top-down). Additionally, several participants encouraged ORD to evaluate and address not only how to adapt to the effects of climate change, but also how to adapt to the mitigation strategies

being implemented to address climate change. Some of these participants emphasized the need to factor economics into mitigation and adaptation strategies and also to consider the potential "penalties" of not taking actions now (particularly for mitigation).

Representatives from some state agencies noted that SIP updates present a good opportunity for integrating climate change into air quality planning. Some feared, however, that adaptation would not become part of SIPs unless EPA develops case studies, detailed guidance, or specific requirements on exactly how this should be done. As one example, a participant noted that her planning efforts would benefit from knowing how many additional tons of VOC reductions over a certain time frame is needed to offset the so-called climate penalty. Without some direction from EPA on such issues, different states and regions may approach adaptation in entirely different ways, and some areas may not consider adaptation at all. This was of particular concern for planning agencies with limited resources and that are focusing on meeting other statutory requirements. In addition, some participants were concerned that adaptation and mitigation efforts may be difficult to launch locally, given a perception that such local efforts have limited benefit on worldwide GHG concentrations and climate change.

The participants also discussed means by which ORD can communicate adaptation issues to stakeholders. Specific options included: holding additional workshops to present key research products, posting results from STAR research grants on the Web, presenting findings at upcoming conferences, holding internal EPA meetings with representation from many programs and offices, and developing a centralized Web site that can serve as a clearinghouse for relevant information (e.g., white papers, STAR grant research products, links).

# Appendix A: List of Participants


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