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CLIMATE CHANGE IMPACTS ON HUMAN HEALTH DUE TO CHANGES IN AMBIENT OZONE CONCENTRATIONS

Draft Report

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EXECUTIVE SUMMARY

Reports from the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Research Council (NRC) have stated that future climate change has the potential to cause air quality degradation via climate-induced changes in meteorology and atmospheric chemistry, posing challenges to the U.S. air quality management system and the effectiveness of its pollution mitigation strategies.

For the past several years, the Global Change Research Program (GCRP) in EPA's Office of Research and Development (ORD), in partnership with EPA's Office of Air and Radiation (OAR) and the academic research community, has been evaluating the potential consequences of global climate change for air quality in the United States. An overview report of the initial phases of this effort, *Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone*, describing the results from studies using linked climate change and air quality models to simulate the possible range of changes in ozone (O_3) concentrations across the United States associated with future climate change, was released in April, 2009.

A second EPA GCRP report, *Land-Use Scenarios: National-Scale Housing-Density Scenarios Consistent with Climate Change Storylines*, released in June 2009, describes the Integrated Climate and Land-Use Scenarios (ICLUS) project. Under ICLUS, a number of high-resolution, spatially explicit population projections consistent with assumptions in the IPCC Special Report on Emissions Scenarios (SRES) social, economic, and demographic storylines were developed for the United States.

The work described here builds on these two reports. In this current project, we take the next step of examining the potential indirect impacts of climate change on the health of a future U.S. population (c. 2050) via its direct impact on O_3 concentrations. This analysis considers the health impacts associated with O_3 changes induced only by future climate change. To achieve this, modeling scenarios were designed to simulate the response of O_3 to global climate change alone without changes in anthropogenic emissions of ozone precursors (e.g., due to future air quality management efforts and/or future economic growth).

Because of the extreme complexity of the coupled climate-air quality-health system, and the many uncertainties present at each step of analysis, it is most useful to frame this study as a sensitivity analysis. Therefore, we have attempted to assess the sensitivity of modeled human health impacts to assumptions about, and modeling and methodological choices for, the following key inputs:

- Climate-induced changes in future meteorological conditions;
- Corresponding changes in O_3 concentrations in response to these meteorological changes;
- The size, and geographic distribution across the United States, of the affected population;

- The concentration-response (C-R) relationships that link O_3 levels to specific health outcomes;
- The fraction of the year over which O_3 is assumed to affect health (i.e., the "O_3 season").

The Environmental Benefits Mapping and Analysis Program (BenMAP), EPA's premier air pollution benefits analysis model, was the system used to integrate the diverse climate, O_3, and population scenarios to estimate the changes in adverse health effects resulting from climate-induced O_3 concentration changes. BenMAP contains within it a database of C-R functions from the epidemiological literature. Each O_3 C-R function is an estimate of the relationship between ambient O_3 concentrations and a population health effect (e.g., premature mortality or hospital admissions for respiratory illnesses). For several of the health effects that have been associated with exposure to ambient O_3, more than one C-R function has been reported in the epidemiological literature. There is no one "correct" set of C-R functions to use to estimate O_3-related adverse health effects, and EPA has used different sets of functions in different benefits analyses involving O_3, as both methods and available functions have evolved over time. For this analysis we looked to the benefit analysis for the most recent O_3 National Ambient Air Quality Standards (NAAQS) Regulatory Impact Analysis (RIA), completed in 2008.

Using these C-R relationships, along with the scenarios of ambient O_3 concentrations and population around 2050, BenMAP estimates the number of cases in the population of each O_3-related adverse health effect attributable to climate change in each grid cell (30 km x 30 km) of the conterminous United States. National-level impacts, as well as impacts in three broad regions – the Northeast, the Southeast, and the West were delineated for this analysis.

The major conclusions of this report are as follows:

- Looking across all combinations of climate change/air quality models, population projections, O_3 season definitions, and C-R functions for all-cause premature mortality considered in our analysis, estimates of national O_3-related all-cause premature mortality around 2050 attributable to climate change range from -1,092 to 4,240 – that is, from over 1,000 cases of O_3-related premature mortality avoided because of climate change to over 4,200 cases attributable to climate change. Despite this range, the large preponderance of the estimates are positive, suggesting that, all else being equal, climate change would be likely to increase the incidence of O_3-related all-cause premature mortality in 2050.
- The source of the greatest uncertainty at the national level appears to be the particular climate change/air quality models used.
- The choice of population projection also made a significant difference, although only about half that of climate change/air quality scenario at the national level.
- It is important to take into account that the size of the population exposed to O_3 will increase by a future year. Failing to do so will result in estimates that are substantially biased downward. In one case, for example, of the almost 400-case difference in estimates of O_3-related premature mortality produced by the two

population projection extremes (holding climate change/air quality model constant), 67 percent (or 265 deaths) was due to the difference between the result produced by the Census_2000 population "projection" (175 deaths), which assumes no population change from the year 2000, and the next highest result, produced by the Woods & Poole projection (439 deaths).

- Not only is the total population exposed to O_3 in a future year important, but the age (and geographic) distribution of that population can also make a significant difference in the estimated impact of climate change on O_3-related adverse health effects. For example, the number of O_3-related deaths estimated using the population projection with the greatest total population (424.8 million) was less than the number estimated using a different population projection with a smaller total of only 386.7 million. This is because about 26 percent of the latter population is 65 or older compared to only about 21 percent of the former, resulting in more premature deaths.
- The national results can mask important regional differences. The Northeast showed the most consistent level of O_3-related premature mortality across the climate/air quality scenarios used in this study, while in the Southeast the estimated premature mortality impacts varied significantly across the scenarios. The West generally showed the smallest impacts across the scenarios, largely due to the smaller projected populations compared to the Northeast and Southeast.
- A climate-induced extension of the O_3 season later into the fall and earlier into the spring has the potential to significantly increase the incidence of adverse health outcomes.

At this stage in the development of our scientific understanding of climate change and its potential impact on air pollution-related human health, it would be unwise to rely on any one model or any one population projection. This may be the most important "take away" message of our analysis. The different model combinations can produce widely varying results, particularly at the regional level, in some cases leading to fundamentally different conclusions about the overall impact of climate change on O_3-related health effects. This has a number of implications for the development of meaningful analyses to assess the range of benefits associated with responses to climate change. However, while there is a very wide range of results, including some that suggest that climate change would decrease the incidence of O_3-related mortality, the large preponderance of results across the different climate change/air quality models and population projections suggest that, all else being equal, climate change would produce an increase in O_3-related adverse health effects in 2050.

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LIST OF ABBREVIATIONS

AGCM	Atmospheric General Circulation Model
AOGCM	Atmosphere-Ocean General Circulation Model
AQ	air quality
BC	boundary conditions
BEIS	Biogenic Emissions Inventory System
CAA	Clean Air Act
CAM	Community Atmosphere Model
CACM	Caltech Atmospheric Chemistry Mechanism
CICE	The Los Alamos Sea Ice Model
CCM3	Community Climate Model version 3
CCSM	Community Climate System Model
CSIM	Community Sea Ice Model
CLM	Community Land Model
CMAQ	Community Multiscale Air Quality Model
C-R	concentration-response
CMIP	Coupled Model Intercomparison Project
CTM	Chemical Transport Model
EC	elemental carbon
ENSO	El Niño-Southern Oscillation
GCM	General Circulation Model
GCTM	Global Chemical Transport Model
GISS	Goddard Institute for Space Studies
GMAO	Global Modeling and Assimilation Office
HadCM3	Hadley Centre Coupled Model
IC	initial condition
IGSM	Integrated Global System Model
LANL	Los Alamos National Laboratory
LWC	liquid water content
MDA8	Maximum Daily 8-hour Average Ozone Concentration
MM	Mesoscale Model
MM5	Mesoscale Model (Version 5)
MARKAL	MARKet Allocation Model
MOSIS	Meteorology Office Surface Exchange Scheme
MPMPO	Model to Predict the Multiphase Partitioning of Organics
NAAQS	National Ambient Air Quality Standard
NCAR	National Center for Atmospheric Research
NH_4^+	ammonium ion
NO_3^-	nitrate ion
OC	organic carbon
O_3	ozone
OGCM	Oceanic General Circulation Model
PAN	peroxyacetylnitrate
PBL	planetary boundary layer

PCM	Parallel Climate Model
PCTM	PCM/CCSM Transition Model
POP	Parallel Ocean Program
RACT	reasonably available control technology
RCM	Regional Climate Model
RCMS	Regional Climate Modeling System
RCTM	Regional Chemical Transport Model
RH	relative humidity
RRF	relative reduction factor
PM2.5	particulate matter with aerodynamic diameter below 2.5 µm
SIP State	Implementation Plan
SAPRC	statewide air pollution research center
SMOKE	Sparse Matrix Operator Kernel Emissions
SOA	secondary organic aerosols
SO2	sulfur dioxide
SO4=	sulfate ion
SRES	special report on emissions scenarios
SST	sea surface temperature
THC	thermohaline circulation
TKE	turbulent kinetic energy
UKMO	United Kingdom Meteorology Office
VOC	volatile organic compound

CLIMATE CHANGE IMPACTS ON HUMAN HEALTH VIA CHANGES IN AMBIENT OZONE CONCENTRATIONS

1. INTRODUCTION

There is now a substantial and growing literature on the potential impacts of climate change that may occur in the absence of efforts to mitigate the atmospheric accumulation of greenhouse gases due to global emissions and other factors (e.g., deforestation). The recent Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) found that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC, 2007). The IPCC also found that "most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." Furthermore, of particular importance for the U.S. Environmental Protection Agency's (EPA's) mission to protect human health and the environment was the IPCC finding that "future climate change may cause significant air quality degradation by changing the dispersion rate of pollutants, the chemical environment for ozone and aerosol generation and the strength of emissions from the biosphere, fires and dust. The sign and magnitude of these effects are highly uncertain and will vary regionally."

Discussion of the potential sensitivity of air quality to climate change has increased in recent years. In 2001, the National Research Council (NRC) posed the question "To what extent will the United States be in control of its own air quality in the coming decades?" noting that "…changing climatic conditions could significantly affect the air quality in some regions of the United States …" and calling for the expansion of air quality studies to include investigation of how U.S. air quality is affected by long-term climatic changes (NRC, 2001). A subsequent NRC report emphasized that the U.S. air quality management system must be "flexible and vigilant" to ensure the effectiveness of pollution mitigation strategies in the face of climate change (NRC, 2004).

The Global Change Research Program (GCRP) in EPA's Office of Research and Development (ORD) has been evaluating the potential consequences of global climate change and climate variability for air and water quality, aquatic ecosystems, and human health in the United States. In an initial report, *Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone* (U.S. EPA, 2009a), the GCRP provides air quality managers and scientists with timely and useful information about the potential effects of climate change on air quality in the United States. This report, written in partnership with EPA's Office of Air and Radiation (OAR), describes the multidisciplinary research efforts using linked climate change and air quality models to simulate the possible range of changes in ozone

(O_3) concentrations across the United States as a result of the future meteorological changes associated with modeled climate change scenarios.

The GCRP assessment was designed to be carried out in two phases. In the first phase, modeling systems were used to consider the sensitivity of air quality responses to global climate change alone; this includes direct meteorological impacts on atmospheric chemistry and transport, and the effect of these meteorological changes on climate-sensitive natural emissions of pollutant precursors, such as volatile organic compounds (VOCs) and nitrogen oxides (NO_x), but not changes in anthropogenic emissions of these pollutants (e.g., due to future air quality management efforts and/or future economic growth). The second phase, now ongoing, is tackling the additional complexities of integrating the effects of changes in anthropogenic emissions, in the U.S. and worldwide, with the climate-only impacts investigated in the first phase.

In a second report, *Land-Use Scenarios: National-Scale Housing-Density Scenarios Consistent with Climate Change Storylines* (U.S. EPA, 2009b), the GCRP considers the interactions between climate change and changes in land use, observing that land use could exacerbate or alleviate climate-change effects. Noting that it is important to use land-use scenarios that are consistent with the assumptions underlying recognized international climate-change scenarios, this report describes its Integrated Climate and Land-Use Scenarios (ICLUS) project. The ICLUS project developed several population projections based on the IPCC Special Report on Emissions Scenarios (SRES) social, economic, and demographic storylines. The GCRP adapted these storylines to the United States and modified U.S. Census Bureau population and migration projections to be consistent with these storylines.

The work described in this report builds on the work described in these two preceding GCRP reports. In this current project we take the next step, examining the potential indirect impacts of climate change on the health of a future U.S. population via its direct impact on O_3 concentrations that adversely affect human health. Our analysis is based on only the first phase of the GCRP climate and air quality assessment (U.S. EPA, 2009a) – i.e., it considers the health impacts associated with O_3 responses to global climate change alone, not including changes in anthropogenic emissions of ozone precursor pollutants (e.g., due to future air quality management efforts and/or future economic growth). Following the climate change/air quality modeling efforts on which the current effort builds, we focus on future years around 2050.

To achieve its mission to protect human health and the environment, EPA implements a variety of programs under the Clean Air Act that reduce ambient concentrations of air pollutants. Secondary pollutants such as O_3 are not emitted directly into the atmosphere: instead they are created by chemical reactions between NO_x and VOCs in the presence of heat and sunlight. These pollutants are emitted from a variety of sources, including motor vehicles, chemical and power plants, refineries, factories, and consumer and commercial products, as well as natural sources such as vegetation, lightning, and biological processes in the soil. EPA's efforts have been successful: between 1980 and 2007, emissions of VOCs and NO_x decreased by 50 and 39 percent, respectively, even though gross domestic product increased 124 percent, vehicle miles traveled increased 103 percent, and energy consumption increased 30 percent (U.S. EPA, 2008). Air pollution, however, including O_3 pollution, continues to be a widespread public health and environmental problem in the United States, with peak level O_3 concentrations in numerous counties still exceeding the National Ambient Air Quality Standards (NAAQS) for O_3,[1] and with health effects ranging from increased premature mortality to chronic impacts on respiratory and cardiovascular health (e.g., see Jerrett et al., 2009).

Significant regional variability already exists in ground-level O_3 under current climate conditions. A large body of observational and modeling studies have shown that O_3 concentrations tend to be especially high where the emissions of VOCs and NO_x are also large, and that O_3 concentrations increase even more when meteorological conditions most strongly favor net photochemical production – persistent high pressure, stagnant air, lack of convection, clear skies, and warm temperatures (e.g., U.S. EPA, 1989; NRC, 1991; Cox and Chu, 1993; Bloomfield et al., 1995; Morris et al., 1995; Sillman and Samson, 1995; EPA, 1999; Thompson et al., 2001; Camalier et al., 2007; among many others). Consequently, the O_3 NAAQS are most often exceeded during summertime hot spells in places with large natural and/or anthropogenic NO_x and VOC emissions (e.g., cities and suburban areas).

Since climate change may alter weather patterns, and, hence, potentially increase the frequency, duration, and intensity of O_3 episodes in some regions, this has the potential to create additional challenges for air quality managers. However, the links between long-term global climate change and O_3 changes is not necessarily straightforward, reflecting a balance among multiple interacting factors (U.S. EPA, 2009a). For example, the current relationship between temperature and O_3 does not necessarily provide a basis for predicting O_3 concentrations in a warmer future climate, since higher temperatures are often correlated with other important drivers of O_3 such as sunlight and stagnation (NRC, 1991; U.S. EPA, 2009a).

As noted above, this analysis focuses on the time period around 2050, following the climate change/air quality modeling efforts on which the current effort builds. Section 2 of this report gives background information on the literature relevant to the analysis discussed here. Section 3 provides an overview of the methods used in our analysis. The methods used in each component of the analysis are described in more detail in the subsequent sections of the report. In particular, Section 4 describes the climate change/air quality models that were used to simulate changes in O_3 concentrations across the United States resulting from various modeled climate change scenarios. Section 5 describes the five population projections used in the analysis. Section 6 describes how we modeled the human health impacts resulting from the climate-induced changes in O_3 concentrations. Finally, Section 7 presents and discusses the results of our analysis.

[1] Currently set at 75 parts per billion (ppb) for the 8-hour NAAQS.

2. BACKGROUND

There are many papers in the literature that describe the potential relationships between climate change, air quality, and human health in general terms. Several of these studies have outlined steps for estimating the health impacts resulting from climate change. Other studies have used climate change and air quality models of varying formulations and complexities, along with health impact functions, to estimate air pollution-related health impacts expected to result from climate change.

Patz, et al. (2000) summarized research resulting from the National Assessment of the Potential Consequences of Climate Variability and Change (NAPCCVC) under the U.S. Global Climate Change Research Program. They identified five categories of health outcomes that are likely to be affected by climate change: temperature-related morbidity and mortality; health effects of extreme weather events (such as storms, tornadoes, hurricanes, and precipitation extremes); air pollution-related health effects; water- and food-borne diseases; and vector- and rodent-borne diseases. The National Assessment's categorization of potential health effects generally agrees with the categorization described in the IPCC's Fourth Assessment Report (IPCC, 2007).

The analysis described in this report focuses only on air pollution-related – in particular, O_3-related – health effects. Based on the NAPCCVC document, Bernard et al. (2001) outlined the pathways through which climate change may affect exposure to air pollutants that have been associated with adverse health effects. Climate change may affect exposures to air pollution by affecting:

- weather and pollutant transport and transformations;
- anthropogenic emissions (mitigative and/or adaptive actions);
- natural sources of air pollutant emissions (such as biogenic VOCs); and
- the distribution and types of airborne allergens (Bernard, et al., 2001).

Increased temperatures and sunlight due to climate change might impact the development, transport, and dispersion of O_3. Higher temperatures can accelerate photochemical reactions that form O_3 in the troposphere (Bernard, et al., 2001). Forests, shrubs, grasslands and other natural sources of VOCs may emit greater quantities at higher temperatures. Higher temperatures may also increase soil microbial activity which may lead to an increase in NO_x (Bernard, et al., 2001). However, as O_3 is formed by complex secondary reactions dependent upon the amount of sunlight and relative NO_x and VOCs levels, O_3 levels do not always increase with increasing temperature. In addition, changing temperatures can have an impact on the mixing height or wind speed and direction. Therefore, the impact of increased temperatures and other meteorological changes on O_3 must be evaluated using atmospheric models that simulate the photochemistry and physical advection and diffusion processes that influence ambient O_3 levels across regional scales.

The climate change and air quality models used for the analysis of O_3-related health effects due to climate change, described in this report, incorporate weather and pollutant transport and transformation mechanisms as well as mechanisms for potential increases in biogenic VOC emissions, based on the simulated future meteorology. However, the present analysis does not incorporate the other two pathways noted above – anthropogenic emissions and airborne allergens – through which climate change can influence air-pollution-related health outcomes. For completeness, we discuss these briefly below.

Anthropogenic emissions of air pollutants may occur as a result of actions to either mitigate or adapt to climate change. Mitigative actions, such as implementation of strategies to reduce CO_2 emissions, may have the additional benefit of also reducing criteria air pollutant levels, resulting in short- and longer-term human health benefits (Bell, et al., 2008; Cifuentes, et al., 2001). These benefits (also known as co-benefits or ancillary benefits) may be substantial. Including them in the analysis, however, would require additional assumptions about greenhouse gas control policies. Adaptive actions in response to climate change may include, for example, increased fossil fuel burning to satisfy demand for electricity needed for air conditioning purposes.

Climate change may also affect air pollution-related health outcomes by altering the distribution and types of airborne allergens. Higher temperatures and potentially higher CO_2 levels may themselves result in earlier onset of the pollen season and greater pollen production (Kinney, 2008), thereby increasing the prevalence and severity of asthma and related allergic diseases (Shea, 2008). Given that air pollution may facilitate penetration of allergens into the lungs, increases in levels of airborne allergens may magnify the health effects of air pollutants.

Past literature has noted substantial uncertainty surrounding the likely response of future air pollutant concentrations to climate change, because ambient concentrations of these air pollutants are the result of meteorological conditions, natural systems, and human activities (Bernard et al., 2001). In an update to the NAPCCVC, Ebi et al. (2006) continued to report on studies finding both increased and decreased O_3 concentrations, depending upon the locations and scenarios considered. The divergent results reflect differences in model assumptions as well as a number of factors influencing O_3 levels (Ebi et al., 2006).

Exposure to O_3 may result in several minor and severe adverse health outcomes, including decreased lung function, increased airway reactivity, lung inflammation, emergency room visits and hospitalizations for respiratory illnesses, and premature mortality (see, e.g., Bernard, et al., 2001; Bell et al., 2004; Bell et al., 2005; Levy et al., 2005; Burnett et al., 2001; Moolgavkar et al., 1997; Jerrett et al., 2009). Several studies have examined the potential effects of climate change on O_3-related morbidity and mortality by linking climate change and air quality models.

Knowlton et al. (2004) used an integrated modeling framework to assess O_3-related health impacts in future decades. They linked a global climate model (GCM, created by the Goddard Institute for Space Studies) with a regional climate model (the Mesoscale Model 5; MM5). The modeling domain was comprised of 36-km grid cells across the 31 counties in the New York metropolitan region, covering an area of 33,600 km^2 and a population of 21 million. The linked GCM/MM5 models provided inputs to an air quality model (the Community Multi-scale Air Quality model; CMAQ), which was used to estimate daily 1-hour maximum O_3 concentrations for five summers (June - August) in the 1990s and 2050s. Changes in greenhouse gas emissions for the 2050s were adopted from the A2 Standard Reference Emission Scenario described by the IPCC, which predicted a 1.6-3.2°C temperature increase in the 2050s compared with the 1990s. Population and age structure were held constant at year 2000 level and distribution. Considering climate change alone, there was a median 4.5 percent increase in O_3-related premature mortality across the New York metropolitan area. The authors found that incorporating O_3 precursor emissions did not have a significant impact on the results, but incorporating population growth did.

Bell (2007) followed the framework of Knowlton et al. (2004) but expanded the geographic scope of the analysis to 50 U.S. cities. This study again focused specifically on the impact of altered climate on O_3 and human health. Potential changes in anthropogenic emissions (other than greenhouse gas emissions) were not considered. The scenarios employed projected overall increases in O_3 concentration levels in the targeted future year, with larger increases in cities that currently experience high pollution. Across the 50 U.S. cities considered, the simulated summertime daily 1-hour maximum O_3 concentration increased by 4.8 ppb, on average. The average number of days per summer season on which the 8-hour regulatory ozone standard was exceeded increased by a factor of 1.7. Total daily O_3-related premature mortality was estimated to increase by 0.11- 0.27 percent, depending upon the concentration-response function employed.

Ebi and McGregor (2008) describe several other studies, all using different assumptions regarding climate scenarios, models, time intervals, baseline conditions, and population projections. Although it is difficult to compare results across studies with varying assumptions, we briefly summarize three studies described in Ebi and McGregor (2008).

Hwang et al. (2004) found an average increase in O_3 peaks of 2.0 – 3.2 ppb in the 2050s (2.1-2.7°C temperature increase), with a corresponding increase in daily mortality ranging from 0.08 to 0.46 percent, depending on the concentration-response function used. Increases were similarly found for hospital admissions. Anderson et al. (2001) found increases in O_3 to result in 20 percent more premature deaths in 2050 in the United Kingdom (corresponding to a 0.89-2.44°C temperature increase). West et al. (2007) examined 10 world regions and found large increases in O_3, with a population-weighted average of 9.4 ppb, in the year 2030 under the IPCC A2 Standard Reference Emission Scenario. Of these three studies, West et al. (2007) was the only study to consider population growth. All results were sensitive to specification of O_3 thresholds in the concentration-response relationships used to estimate O_3 health effects.

Tagaris et al. (2009) used regional CMAQ air pollutant modeling for the years 2001 and 2050, as well as the Goddard Institute for Space Studies global and the MM5 regional climate models for the year 2050 to estimate $PM_{2.5}$ and O_3 concentrations. Health effects were assessed using The Environmental Benefits Mapping and Analysis Program (BenMAP), the air pollution health impact model also used in our analysis. The authors did not estimate population projections for the year 2050; instead, they used 2001 population levels. Their simulations showed that two-thirds of the U.S. were adversely affected by climate change-driven air quality-related health effects. Like other analyses, the authors noted that both positive and negative impacts varied geographically. Nationally, they estimated approximately 4,000 additional premature deaths due to $PM_{2.5}$ and 300 due to O_3. They also found that in almost a dozen states the increased premature mortality due to increased O_3 levels was offset by reduced premature mortality due to decreased $PM_{2.5}$. They also noted large uncertainties, however, including those associated with emissions projections to simulate future climate, meteorological forecasting, downscaling from large scale to small scale models, $PM_{2.5}$ speciation, pollutant-pollutant interactions, temperature-pollutant interactions, and concentration-response functions.

The model-based scenarios of potential impacts of climate change on O_3-related health effects from several studies conducted in the U.S. are summarized below in Table 2-1.

There is a substantial literature focusing on temperature-related health impacts. Moreover, these impacts may include not only the direct effects of temperature on human health, but also an indirect effect via the influence of temperature on air pollutant-related health effects – i.e., there may be synergistic effects of temperature and air pollution on human health. A few studies have reported such synergistic relationships between temperature and O_3-related health outcomes. In their analysis of 60 large eastern U.S. communities during April to October, 1987-2000, Ren et al. (2008a) found that temperature modified O_3-premature mortality associations and that such modification varied across geographic regions. In particular, they found that in the northeast region a 10-ppb increment in ozone was associated with an increase of 2.22 percent, 3.06 percent, and 6.22 percent in mortality at low, moderate, and high temperature levels, respectively. However, such a pattern was not apparent in the southeast region. Ren et al. (2008b) found similar patterns for cardiovascular mortality, O_3, and temperature during the summer in 95 large U.S. communities.

Although the analysis described in this report does not address the climate change-related health impacts of temperature, such a focus, including possible synergies between temperature and O_3 in their impacts on human health, would be a natural sequel to the current analysis.

Table 2-1. Summary of Selected Studies Projecting Impacts of Climate Change-Related Ozone Health Impacts

US Geographic Area	Health effect(s)	C-R Function / Air Quality Model	Climate scenario	Temperature increase and baseline	Population projections and other assumptions	Main results	Reference
New York metropolitan region	Ozone-related deaths by county	C-R function from published epidemiologic literature. Gridded ozone concentrations from CMAQ.	GISS driven by SRES A2, downscaled using MM5. 2050s.	1.6-3.2ºC in 2050s compared with 1990s.	Population and age structure held constant at year 2000. Assumes no change from US EPA 1996 national emissions inventory and A2-consistent increases in NO_x and VOCs by 2050s.	A2 climate only: 4.5 percent increase in ozone-related deaths A2 climate and precursors: 4.4 percent increase in ozone-related deaths	Knowlton et al. 2004
50 cities, eastern states	Ozone-related hospitalizations and deaths	C-R function from published epidemiologic literature. Gridded ozone concentrations from CMAQ.	GISS driven by SRES A2, downscaled using MM5. 2050s.	1.6-3.2ºC in 2050s compared with 1990s.	Population and age structure held constant at year 2000. Assumes no change from US EPA 1996 national emissions inventory and A2-consistent increases in NO_x and VOCs by 2050s.	68 percent increase in average number of days/summer exceeding the 8-hr regulatory standard, resulting in 0.11-0.27 percent increase in nonaccidental mortality and an average 0.31 percent increase in cardiovascular disease mortality	Bell et al. 2007
Los Angeles and San Diego regions, California	Ozone-related hospitalizations and deaths	C-R function from published epidemiologic literature. Gridded ozone concentrations.	HadCM3 driven by SRES A2, downscaled using MM5, then a photochemical model in the 2050s and 2090s.	2.1-2.7ºC in 2050s, and 4.6-5.5ºC in 2090s.	Population and age structure held constant. Assumes no change from US EPA 1997 national emissions inventory and A2- consistent increases in NO_x and VOCs by 2050s and 2090s.	Average increase in ozone peaks of 2.0-3.2 ppb in the 2050s, and 3.1-4.8 ppb in the 2090s. Increases in maximum peak concentrations are 2- to 3-fold higher. Percent increase in daily mortality in the 2050s range from 0.08 to 0.46 percent depending on the exposure-response relationship. Increases in the 2090s are 0.12-0.69 percent. Projected increases in hospital admissions are higher	Hwang et al. 2004
Nationwide	Ozone and PM-related health effects and deaths	BenMAP for health effects. Gridded ozone concentrations from CMAQ for 2001 and 2050	GISS driven by SRES A1B, downscaled using MM5. 2050s.	1.6ºC in 2050s compared with 2001.	Population and age structure held constant. Assumes no change from US EPA 2001 national emissions	Climate change to adversely affect air quality in 2/3 of the US. Additional 300 ozone-mortality deaths in 2050 due to climate change-induced ozone increases. Impacts vary spatially.	Tagaris et al. 2009

Abbreviations: C-R, Concentration-Response; CMAQ, Community Multiscale Air Quality; GISS, Goddard Institute for Space Studies; HadCM3, a climate model from the Hadley Centre; MM5, Fifth generation NCAR/Penn State Mesoscale Model; NOx, nitrogen oxides; SRES, Special Report on Emissions Scenarios (IPCC); VOC, volatile organic compound.
Table modified from Ebi and McGregor (2008).

3. OVERVIEW OF METHODS

The basic structure of the analysis described in this report is illustrated in Figure 3-1. Each research group exploring the potential impacts of climate change on O_3 concentrations in the United States used two linked models: First, a climate change model was used to develop scenarios of meteorological conditions within the United States for the present day and for future change around the year 2050.

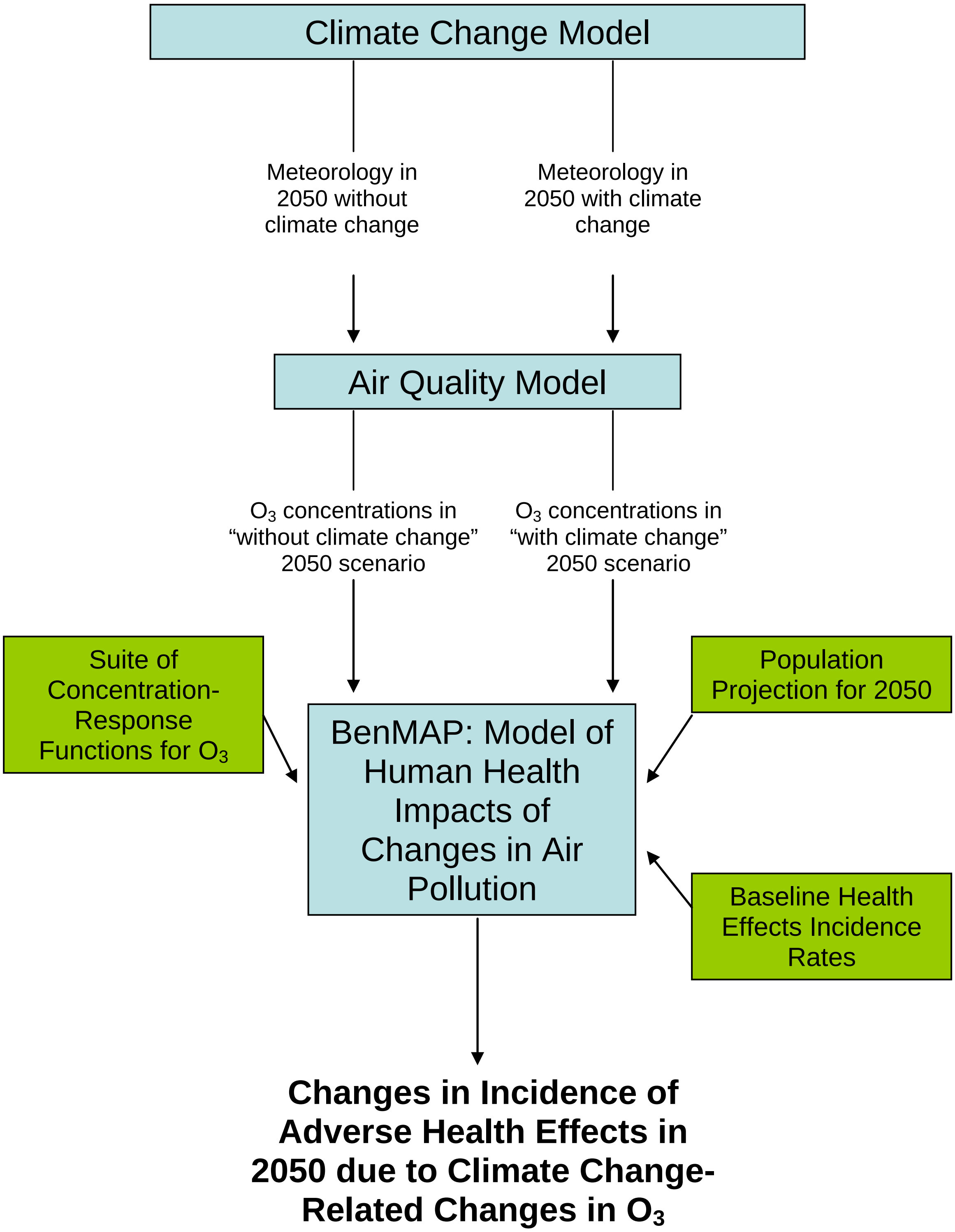
These modeled with- and without-climate change meteorological scenarios were then input to an air quality model to simulate the ambient O_3 concentrations that would result under each scenario. Therefore, each climate change/air quality model produces a pair of (with- and without-climate change) O_3 characterizations in each cell of an air quality grid over the United States. Although different models used different grids, for consistency the air quality grids for all of the models were remapped to a 30 km x 30 km grid for this analysis.

The U.S. population that will be affected by these climate change-induced changes in ambient O_3 concentrations will itself change over time, so the third component of the analysis is a projection of the population – its size, geographic distribution, and composition – to the target year of the analysis, 2050. Population projections were made at the county level and interpolated to the grid cell level, using the same grid that was used by the climate change/air quality models.[2]

Finally, we used BenMAP (Abt Associates Inc., 2008), EPA's premier air pollution benefits analysis model, to estimate the changes in adverse health effects predicted to result from the changes in ambient O_3 concentrations simulated by the climate-air quality modeling systems. BenMAP takes as input two O_3 scenarios: a with-climate-change scenario (produced by a pair of linked climate change and air quality models) and a without-climate-change scenario (produced by the same pair of linked models, but with the climate change model simulating present-day climate). BenMAP contains within it a database of concentration-response (C-R) functions from the epidemiological literature. Each O_3 C-R function is an estimate of the relationship between ambient O_3 concentrations and a population health effect (e.g., premature mortality or hospital admissions for respiratory illnesses). Using this database along with the grid cell-specific with- and without-climate-change scenarios of ambient O_3 concentrations in 2050, and grid cell-specific population projections to 2050,

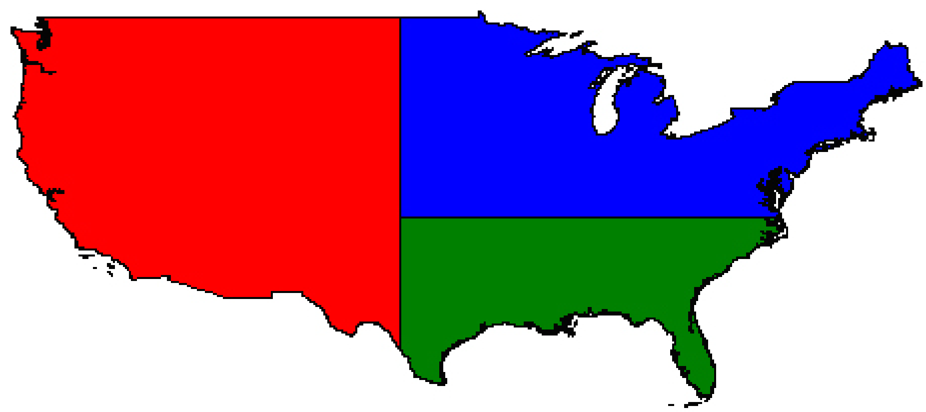
[2] There is something of an internal inconsistency in this. As noted above in Section 1, our analysis is based on only the first phase of the GCRP report (U.S. EPA, 2009a) – i.e., it considers the health impacts associated with O_3 responses to global climate change alone, including direct meteorological impacts on atmospheric chemistry and transport, and the effect of these meteorological changes on climate-sensitive natural emissions of pollutant precursors (such as VOCs and NO_x), but *not* changes in anthropogenic emissions of these pollutants (e.g., due to future air quality management efforts and/or future economic growth). Thus, we allow for an increase by the year 2050 in the population exposed to O_3 in which adverse health effects can occur, but we do not allow for a corresponding increase in anthropogenic emissions of O_3 precursor emissions. That will be part of the second phase of the EPA analysis.

Figure 3-1. The Structure of the Analysis of O_3-Related Impacts on Human Health Attributable to Climate Change



BenMAP estimates the adverse health impacts – i.e., the number of cases in the population in 2050 of each O_3-related adverse health effect – attributable to climate change in each grid cell of the grid covering the United States. National impacts are calculated by summing up the grid cell-specific impacts; regional impacts are similarly calculated by summing up the grid cell-specific impacts for cells within specified regions of the country. Three broad regions were delineated for this analysis, as shown in Figure 3-2 below: the Northeast (defined as east of 100 degrees west and north of 36.5 degrees north latitude (the Missouri compromise)); the Southeast (defined as east of 100 degrees west and south of 36.5 degrees north); and the West (defined as everything west of 100 degrees west longitude).

Figure 3-2. Regions of the United States Defined for this Analysis



For several of the health effects that have been associated with exposure to ambient O_3, more than one C-R function has been reported in the epidemiological literature. There is no one "correct" set of C-R functions to use to estimate O_3-related adverse health effects, and EPA has used different sets of functions in different benefits analyses involving O_3, as both methods and available functions have evolved over time. For this analysis we looked to the benefit analysis for the most recent O_3 NAAQS Regulatory Impact Analysis (RIA), completed in 2008 (U.S. EPA, 2008b).

O_3 is typically measured by air quality monitors on an hourly basis. There are various ways in which O_3 concentrations can be characterized. Among these are the 24-hour average, the daily 1-hour maximum, and the daily 8-hour maximum, which is the basis of the current O_3 NAAQS. All of the air quality models included in this analysis used the daily 8-hour maximum, and the metric input to BenMAP is the daily 8-hour maximum averaged over all days in the O_3 season. This results in a single value for each grid cell for each of the two air quality scenarios (with-climate change and without-climate change) per model.

There is substantial uncertainty surrounding each of the inputs to our analysis, particularly because it focuses so far in the future –

- the meteorological conditions that will result from the accumulation of greenhouse gases in the atmosphere,
- the corresponding changes in O_3 concentrations,
- the size, as well as the age and geographic distribution of the population that will be affected, and
- the relationships between adverse health effects in that population and (future) O_3 concentrations.

Even the definition of "the O_3 season" in 2050 is uncertain,[3] and this definition will affect the results of the analysis, since the longer the season, the greater the period of time over which O_3-related adverse health effects can occur.

There has recently been much emphasis on the uncertainty surrounding several of the inputs to the typical air pollution benefits analysis (see, for example, National Research Council, 2001). The uncertainty surrounding climate change is even greater.[4] The uncertainty in our analysis is thus substantial and comes from multiple sources. Assessing and characterizing this uncertainty is therefore an important part of our analysis. While some of this uncertainty – in particular, the statistical uncertainty surrounding estimated coefficients in C-R functions – can easily be quantified, much of it cannot. Each climate change model simulation is an attempt to approximate a future complex reality, just as each air quality simulation is an attempt to approximate a future complex reality, contingent on the future reality approximated by the linked climate change model. Each population projection is an attempt to approximate the size, geographic distribution, and composition of the U.S. population over forty years into the future.

Because of the extreme complexity involved, and because we are trying to approximate a plausible reality substantially far in the future, we cannot quantitatively assess much of this uncertainty. Even assigning probabilities to the different models (representing our subjective assessments about the relative accuracy with which each approximates a future reality) is premature. Because of this, we have chosen to present our analysis as a series of "sensitivity analyses" or "what if" scenarios designed to assess the impact of the various assumptions and modeling approaches on the results of the analysis. The goal of the analysis, then, is to present a range of predicted human health impact levels, and illustrate how different (uncertain) inputs to the analysis affect the output.[5]

The key features of the analysis for which there is more than one plausible option are:

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[3] Most of the models included in the analysis identified the O_3 season as June, July, and August. The results of at least one of the models, however, suggested that a possible consequence of climate change may be not only an increase in O_3 concentrations during the O_3 season, but an expansion of the O_3 season as well.

[4] This is true, as time goes on, not so much about the reality of climate change, but about the specifics of it.

[5] This approach – using different input models/assumptions/values and showing how the results change is a sensitivity analysis approach, not an uncertainty analysis, because it doesn't assign probabilities to the different input models/assumptions/values. It incorporates uncertainty into the analysis in the sense that it illustrates the uncertainty surrounding the output value resulting from the uncertainty surrounding input values.

- the climate change model (or equivalently, the description of the meteorological conditions in the "state of the world" in 2050 with climate change as opposed to the "state of the world" in 2050 without climate change);
- the air quality model (or equivalently, the grid cell-specific O_3 concentrations in 2050 corresponding to each set of meteorological conditions);
- the size and geographic distribution of the population in 2050[6];
- the span of the O_3 season in 2050; and
- the relationship between each adverse health effect in that future population and O_3 concentrations under each future predicted scenario (i.e., the C-R functions).[7]

Because the climate change and air quality models are linked, we discuss the choice of these models in combination. The seven model combinations included in our analysis are discussed in Section 4. The five different population projections included in the analysis are discussed in Section 5. Because most of the models included in the analysis identified the O_3 season as June, July, and August, we used that definition as one of two alternative choices in our analysis. Because at least one of the models suggested that climate change may result in an expansion of the O_3 season, we considered as an alternative choice an O_3 season extending from May through September.[8]

The C-R functions used in the analysis are discussed in Section 6.3.2. As noted above, we used the suite of C-R functions EPA used for the benefit analysis for the recently completed O_3 NAAQS RIA. For some of the health endpoints that have been associated with O_3 there is only one C-R function available. For some, EPA pooled several C-R functions (as described in Section 6.3.2). For others, however, EPA used two or more C-R functions and presented results separately based on each. This illustrates not only the uncertainty surrounding estimated coefficients in individual C-R functions resulting from statistical error, but also the often-substantial differences between function-specific results for the same health endpoint. In the case of premature mortality, for example, there are four different C-R functions included in the suite of functions used to assess impacts.

For a single O_3-related health effect using a single C-R function, we thus produce 7 (climate change/air quality models) x 5 (population projections) x 2 (O_3 season definitions) = 70 different estimates of O_3-related impacts due to climate change in 2050. For a health effect such as premature mortality, for which we have four separate C-R functions, we produce 70 x 4 = 280 different estimates. The analysis thus allows us to examine the potentially wide range of possible estimates of O_3-related health effects

[6] Like the population size and distribution in 2050, the baseline incidence rates in 2050 for the relevant health effects are also uncertain. However, while we projected mortality rates to 2050, we did not incorporate this uncertainty in our analysis. This is another source of potentially important uncertainty that could be incorporated in a subsequent extension of the analysis described here.
[7] Changes in behavior by 2050 (including, for example, increased use of air conditioning) could affect these C-R relationships. This additional source of uncertainty is not included in the current analysis.
[8] This "expanded O_3 season" is the standard definition of the O_3 season in many EPA analyses and epidemiological studies focusing on O_3.

attributable to climate change and how the different input values/models/approaches affect those estimates.

4. MODELING CLIMATE CHANGE AND CORRESPONDING CHANGES IN AMBIENT OZONE CONCENTRATIONS

Our analysis includes seven modeling efforts of six research groups (the Illinois group carried out two sets of runs). We give a brief description of each of these modeling efforts below, based on the descriptions given in the EPA/ORD report (U.S. EPA, 2009a) on which the current work builds. More detailed descriptions are given in that report.

The modeling efforts included in our analysis can be divided into two major groups: (1) those that have primarily used global climate and chemistry models to focus on the large-scale changes in future U.S. air quality, and (2) those that have used nested, high-resolution, global-to-regional modeling systems to focus on the regional details of the potential future changes. The research teams at Harvard University and Carnegie Mellon University fall into the first category. The second category includes the research teams at EPA's National Exposure Research Laboratory (NERL); the University of Illinois; Washington State University; and a joint effort of Georgia Institute of Technology (GIT), the Northeast States for Coordinated Air Use Management (NESCAUM), and the Massachusetts Institute of Technology (MIT).[9]

As noted in the EPA/ORD report, each approach – the global model simulations and the downscaled regional simulations – has its strengths and weaknesses. The global models simulate the whole world in an internally consistent way across both climate and chemistry, but because of computational demand must use coarse spatial resolution, thereby potentially missing or misrepresenting key processes. Dynamical downscaling with a Regional Climate Model (RCM) dramatically increases the resolution and process realism for the region of interest, but at the expense of introducing lateral boundary conditions into the simulation. The advantages and trade-offs of these two categories of model are discussed in more detail in the EPA/ORD report.

All of the results of these modeling efforts that are used in our analysis are from simulations that held anthropogenic emissions of precursor pollutants constant at present-day levels but allowed climate-sensitive natural emissions of biogenic VOCs to vary in response to the simulated climate changes. As such, these model results provide scenarios of the changes in O_3 concentrations specifically due to climate change.

4.1. The Harvard University Research Effort

In early work for this project, the Harvard research group examined the role of potential changes in atmospheric circulation by carrying out General Circulation Model (GCM) simulations, using the Goddard Institute for Space Studies (GISS) GCM version II′, for the period 1950−2052, with tracers representing carbon monoxide (CO) and black carbon

[9] Two additional research teams, discussed in the EPA/ORD report – at Columbia University and at the University of California, Berkeley – are in this second category but are not included in our study because they modeled O_3 changes over only a portion of the United States rather than the whole country.

(BC) (Mickley et al., 2004). They based the concentrations of greenhouse gases for the historical past on observations, while future greenhouse gases followed the A1b IPCC SRES scenario. A key result from these simulations is a future 10% decrease in the frequency of summertime mid-latitude surface cyclones moving across southeastern Canada and a 20% decrease in cold surges from Canada into the Midwest. Since these events typically clear air pollution in the Midwest and Northeast, pollution episodes in these regions increase in duration (by 1−2 days) and intensity (by 5−10% in pollutant concentration) in the future. These simulated future circulation changes are consistent with findings from some other groups in the broader climate modeling community; the Harvard model also successfully reproduces the observed 40% decrease in North American cyclones from 1950−2000.

These results are supported, and expanded upon, by more recent work from this group -- e.g., see Leibensperger et al. (2008), who found that the frequency of mid-latitudes cyclones tracking across eastern North America in the southern climatological storm track was a strong predictor of the frequency of summertime pollution episodes in the eastern United States for the period 1980−2006. In addition, they found a decreasing trend over this period in the number of cyclones in this storm track that they attributed to greenhouse warming, consistent with a number of other observational and modeling studies.[10]

Subsequent to the initial modeling effort, the Harvard group applied the GEOS-Chem Global Chemical Transport Model (GCTM), driven by the GISS III GCM (Wu et al., 2007), to simulate 2050s O_3 air quality over the United States (Wu et al., 2008a), as well as global tropospheric O_3 and policy-relevant background O_3 over the United States (Wu et al., 2008b). For one set of simulations with this modeling system designed to isolate the impacts of climate change alone on air quality, anthropogenic emissions of precursor pollutants were held constant at present-day levels, while climate changed in response to greenhouse gas increases under the IPCC A1b scenario (Wu et al., 2008a). Climate-sensitive natural emissions, e.g., of biogenic VOCs, were allowed to vary in response to the change in climate. In these simulations, they found that at global scales, future O_3 averaged throughout the depth of the troposphere increases, primarily due to increases in lightning (leading to additional NO_x production), but near the surface increases in water vapor generally caused O_3 decreases, except over polluted continental regions. Focusing in more detail on the United States, they found that the response of O_3 to climate change varies by region. Their results show increases in mean summertime O_3 concentrations of 2−5 ppb in the Northeast and Midwest, with little change in the Southeast. The Harvard group also found that peak O_3 pollution episodes are far more affected by climate change than mean values, with effects exceeding 10 ppb in the Midwest and Northeast.

[10] Other groups, however, do not necessarily find the same decrease in future mid-latitude cyclones when analyzing similar GCM outputs, or even the same GCM outputs downscaled using an RCM (e.g., see Leung and Gustafson, 2005).

4.2. The Carnegie-Mellon University Research Effort

The Carnegie Mellon group performed global-scale simulations of atmospheric chemistry under present and future (2050s) climate conditions using a "unified model," i.e., the GISS II′ model modified to incorporate tropospheric gas phase chemistry and aerosols. Ten years of both present and future climate were simulated, following the A2 IPCC greenhouse gas emissions scenario, with anthropogenic air pollution emissions held at present-day levels to isolate the effects of climate change. As in the Harvard project, the effects of changes in certain climate-sensitive natural emissions were also included as part of the "climate" changes simulated.

The Carnegie Mellon group found that a majority of the atmosphere near the Earth's surface experiences a decrease in average O_3 concentrations under future climate with air pollution emissions held constant, mainly due to the increase in humidity, which lowers O_3 lifetimes (Racherla and Adams, 2006). Further analysis of these results on a seasonal and regional basis found that, while global near-surface O_3 decreases, a more complex response occurs in polluted regions. Specifically, summertime O_3 increases over Europe and North America, with larger increases for the latter. A second key finding is that the frequency of extreme O_3 events increases in the simulated future climate: over the eastern half of the United States, where the largest simulated future O_3 changes occurred, the greatest increases were at the high end of the O_3 distribution, and there was increased episode frequency that was statistically significant with respect to interannual variability (Racherla and Adams, 2008).

The general results of the Carnegie Mellon effort are broadly consistent with those of the Harvard research effort, although there are some important differences. In contrast to the regional pattern of future U.S. O_3 change found by the Harvard University group, the Carnegie Mellon research group found a relatively smaller response in the Northeast and Midwest but a strong increase in the Southeast, using some similar models and assumptions as the Harvard project (although with a different IPCC greenhouse gas scenario and some key differences in the ocean surface boundary condition). These differences appear to be largely due to (1) differences in how the chemical mechanisms regulating the reactions and transformation of biogenic VOC emissions are represented in the two modeling systems and (2) possible differences in future simulated mid-latitude storm track changes.

4.3. The EPA NERL Research Effort

A research team at EPA's National Exposure Research Lab (NERL) built a coupled global-to-regional climate and chemistry modeling system covering the continental United States. They used the output from a global climate simulation with the GISS II′ model (including a tropospheric O_3 chemistry model) for 1950−2055, following the A1b IPCC SRES greenhouse gas emissions scenario for the future simulation years (i.e., the same simulation described in Mickley et al., 2004) as climate and chemical boundary conditions for the regional climate and air quality simulations. The Penn State/ National

Center for Atmospheric Research (NCAR) Mesoscale Model Version 5 (MM5) was used at the Department of Energy's Pacific Northwest National Laboratory (PNNL) to create downscaled fields from this GCM simulation for the periods 1996−2005 and 2045−2055 (Leung and Gustafson, 2005). The NERL group used this regionally downscaled meteorology to simulate air quality for 5-year-long subsets of these present and future time periods with the CMAQ model. Multiple years were simulated to examine the role of interannual variability in the results.

A key element of this project was extensive evaluations of the simulated meteorological variables, not just for long-term climate statistics (e.g., monthly and seasonal means), but for synoptic-scale patterns that can be linked more directly to air quality episodes (Cooter et al., 2005; Gilliam et al., 2006; Gustafson and Leung, 2007). One important finding was that the subtropical Bermuda High pressure system off the southeastern United States coast, a critical component of eastern United States warm season weather patterns, was not well simulated in the downscaled model runs, a result that is likely attributable to biases in the GCM. Another key finding was that the reduction in cyclones tracking across the northern United States found in Mickley et al. (2004) was not as clearly present when this global model output was downscaled using MM5 (Leung and Gustafson, 2005).

In a set of future simulations with this global-to-regional climate and air quality modeling system, for which anthropogenic emissions of precursor pollutants were held constant while climate changed, the NERL group found increases in future summertime maximum daily 8-hour (MDA8) O_3 concentrations of roughly 2−5 ppb in some areas (e.g., Northeast, Mid-Atlantic, and Gulf Coast) compared to the present-day, though with strong regional variability and even decreases in some regions (Nolte et al., 2008). This regional variability in future O_3 concentration changes was associated primarily with changes in temperature, the amount of solar radiation reaching the surface, and, to a lesser extent, climate-induced changes in biogenic emissions. The increases in peak O_3 concentrations tended to be greater and cover larger areas than those in mean MDA8 O_3. The NERL team also found significant O_3 increases in September and October over large portions of the country, suggesting a possible extension of the O_3 season into the fall in the future.

4.4. The University of Illinois Research Effort

The University of Illinois group focused on exploring and evaluating, as comprehensively as possible, the capabilities and sensitivities of the tools and techniques underlying the full, global-to-regional model-based approach to the problem. They concentrated on building a system that accounts for global chemistry and climate, and regional meteorology and air quality, capable of simulating effects of climate changes, emissions changes, and long-range transport changes on regional air quality for the continental United States (Huang et al., 2007; 2008). To capture a wider range of sensitivities, they built different versions of this system, which combines multiple GCMs (Parallel Climate Model (PCM) and the Hadley Centre Model, HadCM3), SRES scenarios (A1Fi, A2, B1, B2), and convective parameterizations (the Grell and Kain-Fritsch schemes) with the Model for OZone And Related chemical Tracers (MOZART) GCTM, a modified version of the MM5 RCM (referred to as CMM5), and the SARMAP11 Air Quality Model (SAQM). They also made considerable efforts to evaluate both climate and air quality variables with respect to historical observations and to understand the implications of these evaluations for simulations of future changes.

Several important findings emerge from this group's model evaluation efforts. First, they demonstrated that any individual GCM will likely have significant biases in temperature, precipitation, and circulation patterns, as a result of both parameterizations and internal model variability, so multi-model ensemble means will tend to be more accurate than individual models (Kunkel and Liang, 2005). With proper attention, RCM downscaling can improve on these GCM biases in climate variables over different temporal scales (e.g., diurnal, seasonal, interannual), due to higher resolution and more comprehensive physics, and that furthermore the RCM can produce future simulations of temperature and precipitation patterns that differ significantly from those of the driving GCM (e.g., Liang et al., 2006). They found that the improvements in present-day climate simulation generally led directly to improvements in simulated air quality endpoints, though they also found that the performance of their modeling system tended to be better for monthly and seasonal average O_3 concentrations than for multi-day high-O_3 episodes, reflecting the primary use for which the driving climate models have been designed (Huang et al., 2007). In addition, they found a high sensitivity of downscaled climate (and downscaling skill) to the convective scheme chosen, with different parameterizations working better in different regions/regimes (Liang et al., 2007). This sensitivity strongly affects simulated air quality, for example by altering meteorology and hence also biogenic emissions (Tao et al., 2008).

Notably, the Illinois team also found that the different patterns of GCM biases with respect to present-day observations in different simulations, as well as the way the RCM downscaling altered these biases, were consistently reflected in the future GCM and GCM-RCM differences as well. This suggests a strong link between the ability of a GCM or GCM-RCM downscaling system to accurately reproduce present-day climate and the type of future climate it simulates (Liang et al., 2008).

In future simulations with their coupled global-to-regional modeling system completed to date, based on PCM GCM simulations following both the A1Fi and B1 SRES greenhouse gas scenarios, the Illinois group found changes in O_3 due to climate change alone (i.e., with anthropogenic pollutant emissions held constant at present-day levels) that were of comparable magnitude to those seen by the NERL and others,[11] though with differences in regional spatial patterns (Tao et al., 2007). The larger greenhouse gas concentrations, and hence greater simulated climate change, associated with the A1Fi scenario generally resulted in larger future O_3 increases than for the climate change simulation driven by the B1 scenario.

[11] This includes a research group at Columbia University which was not included here because it focused on only a particular region of the U.S. rather than the entire country.

As noted above, the University of Illinois research group produced two simulations, denoted as Illinois 1 and Illinois 2. These simulations are identical except for the greenhouse gas emissions scenario used in the GCM simulation of future global climate, with Illinois 1 using the IPCC SRES A1Fi and Illinois 2 using B1.

4.5. The Washington State University Research Effort

Similar to the NERL and University of Illinois groups, the Washington State team developed a combined global and regional climate and air quality modeling system to investigate changes in O_3 (and PM) (Chen et al., 2009; Avise et al., 2009). They used the PCM, MM5, and CMAQ models, and they focused on the IPCC A2 scenario for future greenhouse gases. With this system, the Washington State group investigated climate and air quality changes for the continental United States as a whole, and in addition focused in more detail on two specific regions: the Pacific Northwest and the northern Midwest. A key distinguishing feature of their effort is the attention to biogenic emissions and the consideration of land cover changes (both vegetation cover and urban distributions), as well as changes in the frequency of wildfires in their simulations. Evaluations of their coupled system against observations indicated reasonable agreement with observed climatology and O_3 concentrations in their two focus regions.

In five years of simulated summertime O_3 under both present-day and future climate conditions (with constant anthropogenic precursor pollutants), the Washington State group found future O_3 increases in certain regions, most notably in the Northeast and Southwest, with smaller increases or slight decreases in other regions (Avise et al., 2009). These climate change effects were most pronounced when considering the extreme high end of the O_3 concentration distribution. The magnitude of the O_3 increases found by the Washington State group (i.e., a few to several ppb) were roughly comparable to those found by the other regional modeling groups already discussed, though again with differences in the specific regional spatial patterns of the future changes, linked to differences in the spatial patterns of key O_3 drivers, discussed in more detail in the EPA/ORD report.

In addition, by accounting for plausible future changes in land-use distribution, they simulated both net decreases and increases in biogenic emission capacity, depending on region. They found that reductions in forested area in the Southeast and West due to increases in development more than offset potential increased biogenic emissions due to climate change, leading to reduction in MDA8 O_3 levels, while enhanced use of poplar plantations for carbon sequestration significantly increased isoprene emissions in the Midwest and eastern United States, leading to O_3 increases.

4.6. The GIT-NESCAUM-MIT Research Effort

Similar to the NERL, Washington State, and Illinois groups discussed above, the GIT-NESCAUM-MIT group constructed a linked global-to-regional climate and air quality modeling system to investigate the impacts of global change on regional U.S. O_3 and PM concentrations (Tagaris et al., 2007; Liao et al., 2007). Specifically, they used CMAQ, driven by present-day and future climate simulations with the GISS II′ GCM downscaled using MM5 (the same MM5-downscaled GISS II′ GCM simulations developed for the NERL project described above). However, compared to these other groups, they had a unique focus on understanding the climate sensitivity of regional air quality in the context of expected future pollutant emissions under the implementation of current and future control strategies.

Their work to date attempts to determine if climate change will have significant impacts on the efficacy of O_3 and PM emissions control strategies currently being considered in the United States by focusing on (1) comparing the sensitivity of future regional U.S. air quality to changes in emissions around present-day and projected future climate and emissions baselines and (2) accounting for the effects of uncertainties in future climate on simulated future air quality to evaluate the robustness of these results (see Liao et al., 2009).

To address these issues, the GIT-NESCAUM-MIT team developed a detailed, spatially resolved U.S. future air pollutant emissions inventory to understand the relative impacts of climate change on future air quality in different emissions and control strategy regimes. They used the latest projection data available for the near future (to about 2020), such as the EPA CAIR Inventory, and they extended point source emissions to 2050 using the IMAGE12 model combined with the IPCC A1b emissions scenario (the same scenario used in the GISS II′ future climate simulations) and mobile source emissions from Mobile Source Emission Factor Model version 6 (MOBILE6), projecting reductions of more than 50% in NO_x and SO_2 emissions (Woo et al., 2007).

A key finding from the GIT-NESCAUM-MIT work is that, overall, existing control strategies should continue to be effective in an altered future climate, though with regional variations in relative benefit (Tagaris et al., 2007). The magnitude of the "climate change penalty" for controlling O_3 (as defined by the Harvard group) is found to be consistent with the work of Wu et al. (2008a). The spatial distribution and annual variation in the contribution of precursors to O_3 and PM formation under the combined future scenario of climate change and emission controls remain similar to the baseline case, implying the continued effectiveness of current control strategies. The findings further suggest, however, that compliance with air quality standards in areas at or near the NAAQS in the future would be sensitive to the amount of future climate change.

4.7. A Summary of Climate Change/Air Quality Research Efforts

Table 4-1 (taken from Table 3-1 in the EPA/ORD report (U.S. EPA, 2009a)) summarizes key features of the regional climate and O_3 modeling efforts discussed above. These simulations were carried out with linked systems consisting of a GCM/GCTM, dynamical downscaling with an RCM, and regional-scale air quality calculations with an RAQM. In aggregate, they cover a range of models, IPCC SRES scenarios of future greenhouse gas emissions, climate and meteorological model physical parameterizations, and chemical mechanisms. Figure 4-1 shows an overview of the different regional modeling results.

Table 4-1. Summary of Regional Climate and O_3 Modeling Systems*

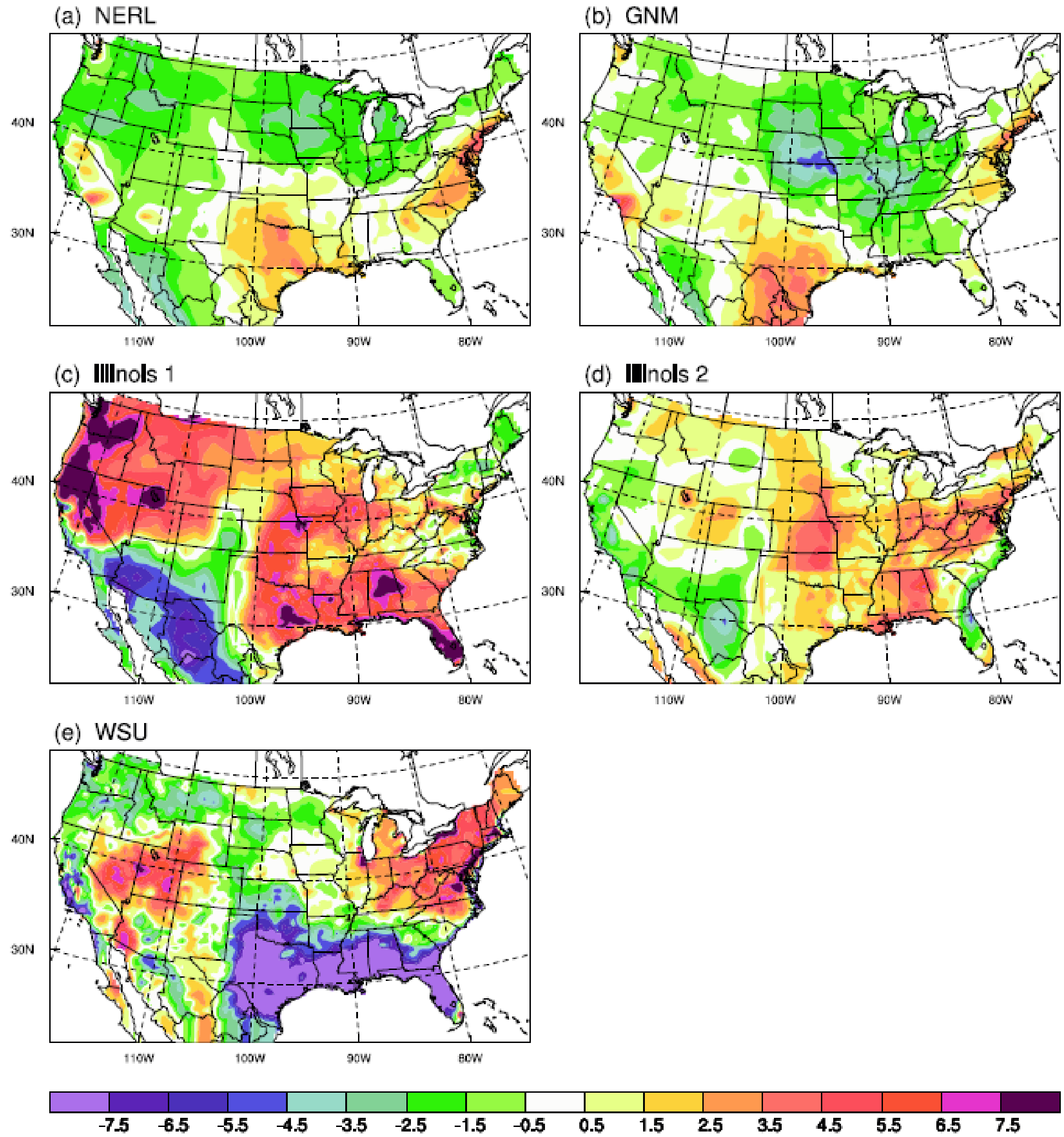
	NERL	Illinois 1	Illinois 2	WSU	GNM
Simulation Period	5 JJAs	4 JJAs	4 JJAs	5 Julys	3 JJAs
GCM	GISS III	PCM	PCM	PCM	GISS III
Global Resolution	4º × 5º	2.8º × 2.8º	2.8º × 2.8º	2.8º × 2.8º	4º × 5º
GHG Scenario	A1b	A1Fi	B1	A2	A1b
RCM	MM5	CMM5	CMM5	MM5	MM5
Regional Resolution	36 km	90/30 km	90/30 km	36 km	36 km
Convection Scheme	Grell	Grell	Grell	Kain-Fritsch	Grell
RAQM	CMAQ	AQM	AQM	CMAQ	CMAQ
Chemical Mechanism	SAPRC99	RADM2l	RADM2	SAPRC99	SAPRC99
Climate Sensitive Emissions	BVOCs; Evaporative	BVOCs; Evaporative	BVOCs; Evaporative	BVOCs; Evaporative	BVOCs; Evaporative

*More details are given in the EPA/ORD report from which this table was taken (U.S. EPA, 2009a).

There are several key similarities between the results from the different groups:

- For all the present/future simulation pairs, some substantial regions of the country show future increases in O_3 concentrations of roughly 2−8 ppb under a future climate.
- Other regions show little change in O_3 concentrations, or even decreases, though the decreases tend to be less pronounced than the increases.
- These patterns of O_3 differences are accentuated in the 95th percentile MDA8 O_3. The basic result of larger climate sensitivity of O_3 concentrations for high- O_3 conditions (e.g., 95th percentile MDA8 O_3) is one of the most robust findings of this synthesis—it holds across all the modeling groups and appears in many different analyses carried out by these groups.

Figure 4-1. 2050s-Minus-Present Differences in Simulated Summer Mean MDA8 O_3 Concentrations (in ppb) for the (a) NERL; (b) GNM; (c) Illinois 1; (d) Illinois 2; and (e) WSU experiments



Some pronounced differences in the broad spatial patterns of change across these research groups emerge as well. For example, the NERL and GNM simulations show increases in O_3 concentration in the Mid-Atlantic and parts of the Northeast, Gulf Coast, and parts of the West. They also show decreases in the upper Midwest and Northwest and little change elsewhere, including the Southeast. By contrast, the Illinois 1 experiment shows the strongest increases in the Southeast, the Northwest, and the Mississippi Valley (as well as the Gulf Coast, in agreement with NERL), with weaker increases in the upper Midwest. In addition, these changes tend to be larger than those from the NERL experiment. The WSU experiment shows the largest increases in the Northeast, parts of the Midwest, and desert Southwest, with decreases in some parts of the West, the Southeast, the Northwest, the Plains states, and the Gulf Coast. As is to be expected, the NERL and GNM patterns are quite similar, with differences primarily reflecting the averaging over five vs. three summers, respectively. This highlights the potential importance of interannual variability in driving differences between modeling groups.

There are important differences in the simulated future regional climate changes across the research groups that seem to drive the differences in the regional patterns of O_3 increases (and decreases). The differences in modeling systems among the groups, as documented in Table 4-1, provide some indication of a number of possible contributing factors that might be responsible for these differences in simulated future regional climate patterns, including

- Differences in the driving GCM
- Differences in the SRES greenhouse gas scenario
- Differences in the RCM (and/or model physical parameterizations) used to simulate regional meteorology
- Differences in the RAQM (and/or chemical mechanisms)
- Differences in the amount of interannual variability captured

Table 4-2 (taken from Table 3-2 in the EPA/ORD report (U.S. EPA, 2009a)) summarizes key features of the global models used in this analysis.

Table 4-2. Summary of Global Climate and O_3 Modeling Systems Used in This Analysis*

	Harvard	**CMU**
Simulation Period	5 summer/falls	10 summers/falls
GCM	GISS III	GISS II′
Resolution	4º × 5º	4º × 5º
GHG Scenario	A1b	A2
GCTM	GEOS-Chem	GISS II′
Climate Sensitive Emissions	BVOCs; Lightning and soil NO_x	BVOCs; Lightning and soil NO_x

*More details are given in the EPA/ORD report from which this table was taken (U.S. EPA, 2009a).

In the Harvard experiment, the largest O_3 increases are mostly in a sweeping pattern from the central United States, across the Plains states and the Midwest, and extending into the Northeast. In contrast to the regional model results discussed above, there is not as obvious a spatial correlation between the changes in O_3 and those of any one of the driver variables. In the CMU experiment, a different regional pattern of change emerges. Here, the major increases in future O_3 concentrations are instead centered on the Gulf Coast and eastern seaboard, with minimal O_3 changes in the upper Midwest and northern Plains states.

It is important to reiterate that the differences in IPCC SRES scenarios for the simulations listed in Tables 4-1 and 4-2 refer only to greenhouse gas concentrations, and not precursor pollutants. As emphasized above, all of the results used in this analysis are from simulations that held anthropogenic emissions of precursor pollutants, as well as other relevant chemical species (e.g., CH_4) constant at present-day levels. Climate-sensitive natural emissions, such as biogenic VOCs, evaporative emissions, and lightning NO_x (depending on the modeling system used), were allowed to change in response to the simulated climate change, with the biogenic VOCs being the dominant impact. Land use and land cover also remained constant. Finally, potential impacts of changes in O_3 concentrations on plant productivity and carbon uptake were not included (e.g., see Sitch et al., 2007).

5. POPULATION PROJECTIONS

The size and geographic distribution of the U.S. population in 2050 are key inputs to the estimation of the O_3-related human health impacts of climate change in the U.S. in that year. The greater the proportion of the population living in areas of significant change in O_3 concentrations, the greater the population health impacts will be. Because population size and distribution in 2050, a year that is well in the future, depend on a number of factors that are difficult to predict, there is substantial uncertainty about these population inputs to our analysis. We have therefore selected five population projections for our analysis to illustrate how the estimated O_3-related human health impact of climate change in 2050 is affected by our estimate of population size and geographic distribution in that year.

One of our "projected" populations is just the 2000 Census population (i.e., we assumed no change from the 2000 Census population by 2050). For another of our population projections we extrapolated from the Woods and Poole population projections for the year 2030 already in BenMAP. The remaining three population projections included in our analysis come from the ICLUS project (USEPA 2009b). We describe the Woods and Poole projection and the ICLUS population projections below.

5.1. Extrapolation of Woods and Poole Population Projections to 2050

BenMAP uses Woods and Poole population growth projections to model populations in a future year. Woods and Poole population growth projections incorporate the assumptions from the U.S. Census Bureau population growth model into a comprehensive model of economic and demographic changes over time. These projections are available at the county level for several population sub-groups, defined by age, gender, race, and ethnicity. BenMAP contains a series of population growth projections, based on Woods and Poole data, for each population sub-group in each county. There are 3,109 counties and 304 different population sub-groups per county.[12]

Woods and Poole population growth projections are available only through 2030, however, whereas our analysis year is 2050. Therefore, it was necessary to extrapolate Woods and Poole population growth projections to 2050. Given the large number of population growth series, we used automatic forecasting algorithms that have been implemented in the forecast package for R (Hyndman (2009), R Development Core Team (2009)).

In order to generate our forecasts, we used a set of models that belong to the class of exponential smoothing (ES) forecasting methods. (See Gardner (2006) and Hyndman

[12] For detailed information about subgroup definitions, see the BenMAP User Manual (Abt Associates Inc., 2008), available at: http://www.epa.gov/air/benmap/docs.html,.

(2009) for the theoretical background of exponential smoothing models.) We evaluated the following three ES models: simple exponential smoothing, linear exponential smoothing, and damped-trend exponential smoothing. These models are categorized by their trend component: none, additive, and damped, respectively. We estimated all three models for each population growth series and then chose the best-fitting model based on the Bayesian Information Criterion (BIC), a standard measure of goodness of fit of a model to the underlying data. The best model was used to forecast each series out to 2050.

These ES forecasting methods try to extrapolate trends seen in a given set of years beyond the final year of the dataset. Thus the set of years on which the extrapolation is based could affect the resulting extrapolation. We applied the method described above to each of the following three series of years: 2000 – 2030; 2010 – 2030; and 2020 – 2030. We then averaged the results. This gives somewhat more weight to the latter years, which is appropriate, since time trends may change over the longer course of years beginning in 2000 or 2010.

The resulting 2050 population forecast was adjusted to match the Census national population projection for 2050.[13] For each of the 304 population sub-groups we calculated the 2050 national total, as implied by the extrapolated Woods and Poole growth projections. We then calculated percent differences between these population totals and the population totals projected by the Census Bureau. Finally, we adjusted each county- and population subgroup-specific extrapolated Woods and Poole projection using corresponding percent differences. This method allowed us to match the Census Bureau national population projection as well as preserve some of the county-specific demographic patterns and trends.

5.2. ICLUS Population Projections to 2050

As noted above, the ICLUS project developed land-use outputs based on the social, economic, and demographic storylines in the IPCC SRES, and adapted these to the United States. ICLUS outputs are derived from a pair of models: a demographic model that generates population projections and a spatial allocation model that distributes projected population into housing units across the landscape. The models were run for the conterminous United States and output is available for each scenario by decade to 2100. A detailed description of the methods used can be found in the second GCRP report on which the current project builds (U.S. EPA, 2009b).

Population projections were developed for the four main SRES storylines and a base case. The base case population projection uses the standard Census projection method; we refer to this as the Census projection.

[13] The Census national population projections for 2050 can be obtained from http://www.census.gov/population/www/projections/downloadablefiles.html .

The ICLUS project uses the SRES storylines because these storylines are direct inputs into general circulation models developed by the climate change science community. These storylines were selected to facilitate future, more integrated assessments of climate and land use at national or regional scales, because the broad underlying assumptions are the same.

The SRES describes storylines along two major axes: economic versus environmentally-driven development (A-B) and global versus regional development (1-2); the four quadrants defined by these axes comprise the four storylines, A1, A2, B1, and B2. GCRP adapted these storylines to the United States. Table 5-1 below (Table 3-1 in the GCRP report (U.S. EPA, 2009b)) provides a qualitative description of the global storylines modified for the United States.

Table 5-1. ICLUS Population Projection: Demographic Characteristics*

Storyline	Demographic Model		
	Fertility	Domestic Migration	Net International Migration
A1	Low	High	High
B1	Low	Low	High
A2	High	High	Medium
B2	Medium	Low	Medium
Baseline ("Census")	Medium	Medium	Medium

*Source: U.S. EPA, 2009b

The SRES storylines do not provide a clear blueprint for downscaling to the local or even the national level. In incorporating the SRES storylines into county-level projections for the United States, an effort was made to be consistent in qualitative terms with the global SRES storylines. Given the wide range of potential interpretations, this consistency was understood to imply that the qualitative trends do not contradict established theory, historical precedent, or current thinking. It was also a goal to model a wide a range of assumptions, while remaining consistent with the SRES and U.S. demographic patterns.

For each of the storylines adapted to the United States, the fertility assumptions are exactly consistent with the global assumptions, while domestic and international migration patterns leave more room for interpretation and are more specifically adapted to the United States. The low U.S. Census scenario for mortality was chosen for all storylines used in the modeling. These model inputs were varied to develop the different scenarios rather than to investigate the relative importance of each of the inputs.

Considering the projected trajectory of the total U.S. population under each of the five ICLUS scenarios, scenarios A1 and B1 have the same relatively low population trajectories, while A2 has a relatively high population trajectory; scenario B2 and the base case have the same medium population trajectory (see Figure 3-3 in U.S. EPA, 2009b).

For the current project, we selected three of the ICLUS population projections – A1, A2, and the base case, BC (referred to as the baseline in Table 5-1) – to provide the lower and upper bound ICLUS total population projections as well as a “middle” case. Rationales connected to the selected SRES storylines are discussed briefly below for scenarios A1 and A2.

5.2.1. ICLUS population projection A1

A1 represents a world of fast economic development, low population growth, and high global integration. In this storyline fertility is assumed to decline and remain low in a manner similar to recent and current experience in many European countries (Sardon, 2004). A plausible rationale would be that the rapid economic growth in this storyline leads to continuing high participation of women in the workforce, but it becomes increasingly difficult to combine work with childbearing due to inflexibilities in labor markets. At the same time, social changes in family structures lead to increasing individuation, a rise in divorce rates, a further shift toward cohabitation rather than marriage, later marriages and delayed childbearing, all of which contribute to low fertility. Substantial aging resulting from the combination of low birth rates and continued low death rates raises the demand for immigration. Meanwhile, economic growth throughout the world and an increasingly unified global economy encourage the free movement of people across borders. Domestic migration is anticipated to be relatively high as well, as economic development encourages a flexible and mobile workforce.

5.2.2. ICLUS population projection A2

The A2 storyline represents a world of continued economic development, yet with a more regional focus and slower economic convergence between regions. Fertility is assumed to be higher than in A1 and B1 due to slower economic growth, and with it, a slower decline in fertility rates. International migration is assumed to be low because a regionally-oriented world would result in more restricted movements across borders. Domestic migration is high because, like in A1, the continued focus on economic development is likely to encourage movement within the United States.

6. MODELING HUMAN HEALTH IMPACTS OF PREDICTED CHANGES IN AMBIENT OZONE CONCENTRATIONS

The meteorology under each of two different scenarios (with and without climate change) predicted by a climate change model to occur by a future year are input to an air quality model, as described above. The air quality model in turn predicts the corresponding ambient O_3 concentrations, under each of the two scenarios, in each 30 km x 30 km cell of a grid covering the contiguous United States (see Section 3). Both the size and demography of the U.S. population by 2050 are similarly predicted within each of these grid cells. These scenario-specific O_3 concentrations and projected 2050 populations at the grid cell level are key inputs to BenMAP, which contains within it the remaining components of the analysis necessary to estimate the human health impacts in the U.S. population in 2050 due to climate change under different scenarios. The flow of modeling inputs to the analysis is illustrated in Figure 3-1 above. A brief description of BenMAP is given below in Section 6.1.

Once the O_3 concentrations in the "with climate change" and "without climate change" scenarios have been modeled, and the grid cell-specific populations have been projected to 2050, the estimation of the human health impacts of predicted changes in ambient O_3 concentrations due to climate change follows a structure that is identical to the structure of a typical air pollutant benefit analysis. We describe that structure below in Section 6.2. The specific methods we used to estimate the O_3-related human health impacts of climate change in 2050 are described in Section 6.3.

6.1. An Overview of BenMAP [14]

BenMAP is a powerful, yet easy-to-use tool that helps analysts estimate human health benefits resulting from changes in air quality. BenMAP was originally developed to analyze national-scale air quality regulations, including, for example, the National Ambient Air Quality Standards for Particulate Matter (2006) and Ozone (2008) as well as the Locomotive Marine Engine Rule (2008).

BenMAP is primarily intended as a tool for estimating the human health effects and economic benefits associated with changes in ambient air pollution. The improvements in human health as a result of air pollution control regulations are typically referred to as the benefits of the regulations. As part of the process of developing new regulations, government agencies are typically required to assess the benefits and the costs of that regulation. Essentially, benefit analysis develops monetary values to inform the policy making process and allows decision makers to directly compare costs and benefits using the same measure (i.e., dollars). BenMAP is a tool that was developed to support these types of benefit analyses.

[14] This section is adapted from Chapter 1 ("Welcome to BenMAP") of the BenMAP User Manual (Abt Associates Inc., 2008).

BenMAP estimates benefits from improvements in human health, such as reductions in premature mortality, heart attacks, chronic respiratory illnesses, and other adverse health effects. Other benefits of reducing air pollution (i.e., visibility and ecosystem effects) are not quantified in the current version of BenMAP. After estimating the reductions in adverse health effects, BenMAP calculates the monetary benefits associated with those reductions, although this final step may be omitted.

First BenMAP determines the change in the ambient air pollutant from a baseline scenario to a control scenario within each grid cell of an air quality model grid.[15] Because BenMAP does not include an air quality model, this data must be input into BenMAP as modeling data or generated from air pollution monitoring and/or modeling data pre-loaded into BenMAP. BenMAP has several options for generating grid cell-specific changes in ambient air pollutant concentrations. A more detailed description of a commonly-used method is given below in Section 6.3.1.

Next, BenMAP applies health impact functions to the exposed population. Health impact functions are derived from concentration-response (C-R) functions estimated in epidemiology studies. A C-R function describes the relationship between ambient concentrations of a pollutant and the corresponding population levels of an adverse health effect. A health impact function describes the relationship between *changes in* air pollutant concentrations and the corresponding *changes in* the health effect. The basic structure of a typical air pollutant benefit analysis that BenMAP is used to carry out is described in Section 6.2 below.

6.2. The Structure of an Air Pollutant Benefit Analysis

The analysis of the impacts of climate change on O_3-related health effects is structured like most air pollution benefits analyses carried out by EPA using BenMAP. The key components of a BenMAP benefits analysis are:

- Ambient concentrations (at the air quality model grid cell level) of a criteria air pollutant in a specified year under two scenarios:
    - a baseline scenario, and
    - a control scenario;
- Concentration-response functions relating ambient concentrations of the pollutant to the incidences of adverse health effects in the population;
- Baseline incidence rates (numbers of cases per unit population per year) for the adverse health effects included; and
- Population (at the air quality model grid cell level) in the specified year.

[15] The baseline scenario is the scenario for which we have baseline incidence rates, usually obtained from vital statistics sources. It is therefore the scenario that either represents current air pollutant levels or is the closer of the two scenarios to current levels. In the typical air pollutant benefits analysis, the control scenario is a scenario in which an air pollutant rule or regulation has been implemented in a future year. Air pollutant levels are therefore lower than baseline levels in the typical air pollutant benefits analysis.

As we show below, to calculate the change in incidence of a health effect attributable to implementation of an air pollutant rule or regulation in a typical benefits analysis we need the baseline incidence rate for the health effect – i.e., the number of cases of the health effect per unit population (e.g., per 100,000 population) per year. Because such incidence rates are typically obtained from vital statistics sources or state or local health departments, they reflect current (baseline) conditions. The baseline scenario is thus the scenario reflecting current conditions, and the "control" scenario is the scenario reflecting conditions when controls have been put in place to implement a proposed rule or regulation.

The C-R functions used in an O_3 benefits analysis are empirically estimated relationships, reported by epidemiological studies, between ambient concentrations of O_3 and the incidence of specified health effects in a population. Below we describe the basic method used to estimate the changes in the incidence of a health endpoint associated with specified changes in O_3, using a "generic" C-R function of the most common functional form.

Although some epidemiological studies have estimated linear C-R functions and some have estimated logistic functions, most of the studies in the air pollution epidemiological literature have used a method referred to as "Poisson regression" to estimate exponential (or log-linear) C-R functions in which the natural logarithm of the health endpoint is a linear function of the air pollutant (e.g., O_3):

$$y = Be^{\beta x} \qquad (1)$$

where x is the ambient O_3 level, y is the incidence of the health endpoint of interest at O_3 level x, β is the coefficient of ambient O_3 concentration, and B is the incidence at x=0, i.e., when there is no ambient O_3. The relationship between a specified ambient O_3 level, x_0, for example, and the incidence of a given health endpoint associated with that level (denoted as y_0) is then

$$y_0 = Be^{\beta x_0} \ . \qquad (2)$$

Because the log-linear form of C-R function (equation (1)) is by far the most common form, we use this form to illustrate the "health impact function" – the relationship between a change in the pollutant concentration and the corresponding change in incidence of the health effect in the population.

If we let x_0 denote the baseline O_3 level, and x_1 denote the control scenario O_3 level, and y_0 and y_1 denote the corresponding incidences of the health effect, we can derive the following relationship between the change in x, $\Delta x = (x_0 - x_1)$, and the corresponding change in y, Δy, from equation (1):[16]

[16] In a typical benefits analysis, in which the baseline represents air pollutant concentrations before implementation of a proposed rule or regulation and the control scenario represents air pollutant concentrations after implementation, the baseline concentration is higher than the corresponding control

$$\Delta y = (y_0 - y_1) = y_0[1 - e^{-\beta \Delta x}]. \qquad (3)$$

Alternatively, the difference in health effects incidence can be calculated indirectly using relative risk. Relative risk (RR) is a measure commonly used by epidemiologists to characterize the comparative health effects associated with a particular air quality comparison. The risk of mortality at ambient O_3 level x_0 relative to the risk of mortality at ambient O_3 level x_1, for example, may be characterized by the ratio of the two mortality rates: the mortality rate among individuals when the ambient O_3 level is x_0 and the mortality rate among (otherwise identical) individuals when the ambient O_3 level is x_1. This is the RR for mortality associated with the difference between the two ambient O_3 levels, x_0 and x_1. Given a C-R function of the form shown in equation (1) and a particular difference in ambient O_3 levels, Δx, the RR associated with that difference in ambient O_3, denoted as $RR_{\Delta x}$, is equal to $e^{\beta \Delta x}$. The difference in health effects incidence, Δy, corresponding to a given difference in ambient O_3 levels, Δx, can then be calculated based on this $RR_{\Delta x}$ as

$$\Delta y = (y_0 - y_1) = y_0[1 - (1/RR_{\Delta x})]. \qquad (4)$$

Equations (3) and (4) are simply alternative ways of expressing the relationship between a given difference in ambient O_3 levels, Δx, and the corresponding difference in health effects incidence, Δy. These health impact equations are the key equations that combine air quality information, C-R function information, and baseline health effects incidence information to estimate ambient O_3 health risk.[17]

Changes in adverse health effects are calculated in BenMAP within each grid cell of the air quality grid by applying each health impact function, described in equations (3) and (4), to the exposed population in the grid cell. While BenMAP applies the same "national" health impact function to all grid cells, population estimates and baseline incidence rates are as location-specific as possible. The grid cell-specific changes in health effects are then summed across grid cells to produce county-level, state-level, and/or national estimates of health impacts.

6.3. Estimation of the O_3-Related Human Health Impacts of Climate Change

This project is analogous to a typical air pollutant benefits analysis. However, instead of asking about the human health benefits of a proposed rule or regulation that will affect

scenario concentration. This does not have to be the case, however. If the baseline concentration is lower than the corresponding control scenario concentration, Δx will be negative.

[17] Note that y0 in equations (3) and (4) is the baseline incidence, not the baseline incidence rate. We typically can obtain baseline incidence rates. To derive the baseline incidence, we multiply the incidence rate by the appropriate population.

ambient O_3 concentrations, we are asking about the human health effects of climate change that will affect ambient O_3 concentrations. The pollutant of interest is O_3 and the specified year is 2050. Each linked pair of climate change and air quality models produces two O_3 scenarios, with O_3 concentrations at the air quality model grid cell level: a "with climate change" scenario and a "without climate change" scenario, both in the future year 2050.

Because both the with- and without-climate-change scenarios are in 2050, neither scenario is really a "baseline" scenario – that is, we cannot obtain baseline incidence rates from vital statistics sources for either scenario. Instead, we projected current baseline incidence rates to the year 2050, as described in Section 6.3.3 below. The names "baseline" and "control" scenario, used in a typical air pollution benefits analysis, thus don't really fit here. What matters, however, is that we are comparing two different scenarios. We refer to these as the "without climate change" scenario and the "with climate change" scenario. Both scenarios are hypothesized "states of the world" in 2050.

The analysis allows population to change from the present to 2050 in both scenarios. In the "with climate change" scenario, it also allows climate change-related meteorology, as well as the corresponding concentrations of ambient O_3 to change from the present to 2050, but keeps everything else (e.g., economic activity and anthropogenic emissions) constant. Thus any change in O_3 concentrations, and corresponding changes in human health effects, between the with- and without-climate change scenarios can be attributed to climate change.

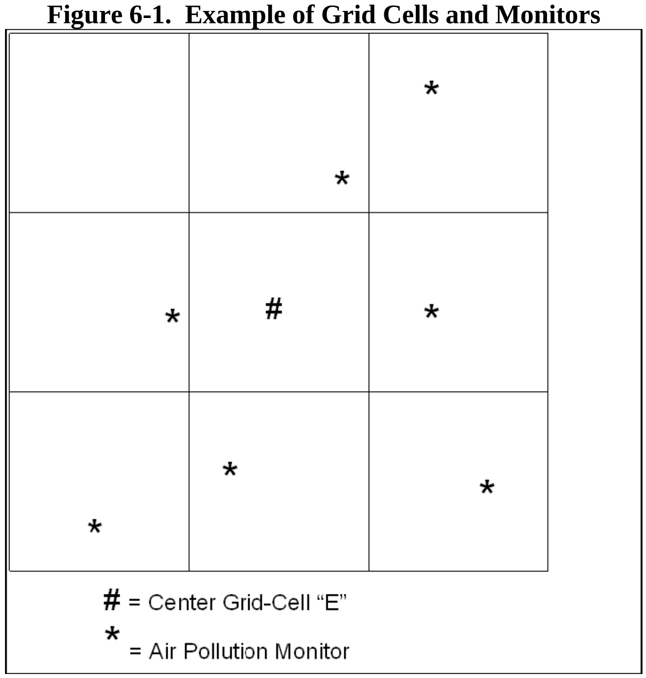
6.3.1. Ambient O_3 concentrations: Adjustment of modeled with- and without-climate-change O_3 concentrations in 2050

Each climate change/air quality model combination described above in Section 4 produced a pair of modeled summer average of daily 8-hour maximum O_3 concentrations in each 30 km by 30 km grid cell: the estimated "with climate change" and "without climate change" concentrations. Air pollution benefits analysts generally acknowledge, however, that they have more confidence in monitored air pollutant concentrations than modeled concentrations, since monitor values are actual measurements. However, unlike modeled values, monitors do not exist in all grid cells of an air quality model grid. In a typical BenMAP analysis, then, both modeled and monitor values are used to produce grid cell-specific air pollutant estimates in the baseline and control scenarios that are considered superior to either the monitor values or the modeled values alone.

There are several options in BenMAP for estimating baseline and control scenario grid cell-specific air pollutant concentrations using monitor and modeled values. The option that EPA typically uses for a future-year analysis first applies a spatial interpolation of monitor values to grid cell centers and then applies a temporal adjustment using the ratios of modeled values. These spatial and temporal adjustment procedures are described in detail in Appendix C ("Air Pollution Exposure Estimation Algorithms") of the BenMAP User Manual (Abt Associates Inc., 2008). We describe them briefly here.[18]

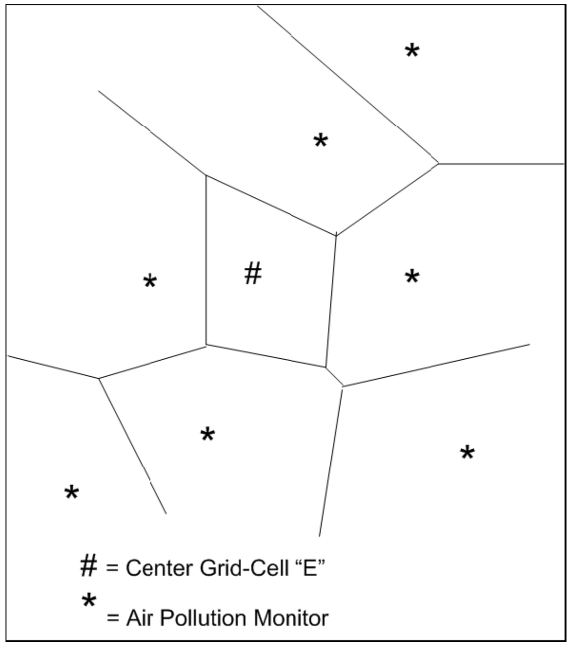
Although there are several ways to spatially interpolate monitor values to grid cell centers, EPA benefits analyses typically use a method called Voronoi Neighbor Averaging (VNA). The VNA algorithm interpolates air quality at every grid cell by first identifying the set of monitors that best "surround" the center of the grid-cell. In particular, BenMAP identifies the nearest monitors, or "neighbors," by drawing a polygon, or "Voronoi" cell, around the center of each BenMAP grid cell. The polygons have the special property that the boundaries are the same distance from the two closest points. An example of a grid cell and "neighboring" monitors is shown in Figure 6-1; the corresponding Voronoi cells are shown in Figure 6-2.

Figure 6-1. Example of Grid Cells and Monitors



[18] The brief description given here is a condensed version of the more detailed description given in Section C.3 of Appendix C of the BenMAP User Manual.

Figure 6-2. Illustration of Voronoi Cells Around the Same Grid Cell Center



To estimate the air pollutant level in each grid cell, BenMAP calculates the metric (e.g., the summer average of daily 8-hour maxima) for each of the neighboring monitors, and then calculates an inverse-distance weighted average of the metrics. The further the monitor is from the BenMAP grid-cell, the smaller the weight.

However, monitors are more likely to be located in areas with higher population than in rural areas. If a grid cell is in a rural area, a weighted average of "neighboring" monitor values may still not give a good approximation to the pollutant concentration in the grid cell. Because of this, EPA typically also uses a spatial scaling technique in which, for each of the neighboring monitors, BenMAP multiplies the monitoring data by the ratio of the baseline modeling data for the destination grid cell to the baseline modeling data for the grid cell containing the monitor. For example, suppose the destination grid cell (without a monitor) is in a rural area, and the modeled baseline pollutant value is half the modeled baseline pollutant value in the grid cell containing a neighbor monitor. That monitor value would be multiplied by one half (and similarly the other neighboring monitors would be multiplied by the appropriate ratios) before the inverse-distance weighted average of monitor-specific metrics is calculated.

This first step of spatial interpolation of monitor values and spatial scaling using "without climate change" modeling values produced "without climate change" scenario estimates of summer average daily 8-hour maxima for each grid cell. Year 2007 monitor values were used.

Grid cell-specific "with climate change" scenario O_3 concentrations were estimated by combining both spatial and temporal scaling. After the first step of spatial scaling described above, BenMAP applied the ratio of the modeled future-year value to the modeled baseline value in the destination cell.[19] The future-year ("with climate change") O_3 concentration in a grid cell is thus estimated by (1) spatially interpolating a present-year value, using both interpolation of (year 2007) monitor values and spatial scaling using present-year modeled values, and then (2) temporally scaling the resulting value by the ratio of future-year to present-year modeled values. This produces future-year ("with climate change") estimates that take advantage of both the ratios of future to recent-year modeled values and information we have from actual recent-year monitor measurements.

6.3.2. Concentration-response functions

There are often several epidemiological studies reporting multiple concentration-response (C-R) functions for the same pollutant/health endpoint combination, and substantial thought goes into the selection of appropriate health endpoints, studies, and C-R functions. For this project, we followed the selection of health endpoints, studies, and C-R functions EPA used in the benefits analysis for the O_3 National Ambient Air Quality Standards (NAAQS) Regulatory Impact Analysis (RIA) completed in 2008.[20] The O_3-related health endpoints and studies EPA used in the O_3 NAAQS RIA are listed in Table 6-2 of the RIA.[21] A more detailed summary of health endpoints, epidemiological studies, and C-R functions used – including the estimated coefficient ("beta") of O_3 in the function and the standard error of the estimate, the location(s) and age range covered, and the O_3 metric used – is given in Table 6-1 below. As can be seen in Table 6-1, we included the following adverse health effects in our analysis: mortality from all causes; non-accidental mortality;[22] hospital admissions for respiratory illnesses; hospital admissions for chronic obstructive pulmonary disease (COPD), with and without asthma; hospital admissions for pneumonia; emergency room (ER) visits for asthma; school loss days from all causes; and minor restricted activity days.

In all cases, the metric used was the daily 8-hour maximum.[23] In several cases, however, the original C-R function used a different metric (e.g., the 24-hour mean), and these coefficients were converted to coefficients for the daily 8-hour maximum.[24]

For several health endpoints, two or more C-R functions were pooled. In particular, for respiratory hospital admissions we undertook the following pooling procedure:

1. Moolgavkar et al. (1997) estimated C-R functions in Minneapolis for hospital admissions (HA), pneumonia (ICD-9 codes 480-487) and HA, COPD (ICD 490-496). We summed the results from these two non-overlapping subcategories.

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[19] BenMAP actually combined the two steps into one by multiplying the monitor value by the ratio of the future-year value in the destination cell to the baseline value in the cell containing the monitor.

[20] The O_3 NAAQS RIA is available online at: http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_cr.html .

[21] Available online at: http://www.epa.gov/ttn/ecas/regdata/RIAs/6a-ozoneriachapter6appendixa.pdf .

[22] This typically excludes accidents, homicides, and suicides.

[23] The measure of O_3 concentration input to BenMAP from the climate change/air quality models is the O_3 season average of the daily 8-hour maxima. The C-R functions are daily functions, so this O_3 season average of daily 8-hour maxima would be applied to each day.

[24] The process of converting C-R function coefficients is described in Appendix G ("Ozone Health Impact Functions in U.S. Setup") of the BenMAP User Manual. See, in particular, Section G.5 ("Converting Functions to 8-Hour Daily Maximum Metric").

Table 6-1. Summary of Concentration-Response Functions Used to Estimate Climate Change-Related Impacts of O_3 on Human Health

Health Endpoint	Study	Location	Age Range	Metric	Beta	Std. Err.	Notes
Mortality, All Cause	Bell et al. (2005)	US & non-US cities	All ages	Daily 8-hour max. [1]	0.000795	0.000212	Warm season
Mortality, All Cause	Levy et al. (2005)	US & non-US cities	All ages	Daily 8-hour max. [2]	0.001119	0.000179	Warm season
Mortality, Non-Accidental	Bell et al. (2004)	95 US cities	All ages	Daily 8-hour max. [1]	0.000261	0.000089	Warm season
Mortality, Non-Accidental	Ito et al. (2005)	Meta-analysis [7]	All ages	Daily 8-hour max. [1]	0.001173	0.000239	Warm season
		Meta-analysis	All ages	Daily 8-hour max. [2]	0.000532	0.000088	
Hospital admission (HA), All Respiratory	Burnett et al. (2001)	Toronto, CAN	0-1	Daily 8-hour max. [2]	0.008177	0.002377	Warm season
HA , COPD [4]	Moolgavkar et al. (1997)	Minneapolis, MN	65+	Daily 8-hour max. [1]	0.00196	0.001238	All year
HA , Pneumonia [4]	Moolgavkar et al. (1997)	Minneapolis, MN	65+	Daily 8-hour max. [1]	0.00266	0.000762	All year
HA , Pneumonia [4]	Schwartz (1994a)	Minneapolis, MN	65+	Daily 8-hour max. [1]	0.002784	0.001305	All year
HA , COPD (less asthma) [4]	Schwartz (1994b)	Detroit, MI	65+	Daily 8-hour max. [1]	0.003424	0.001293	All year
HA , Pneumonia [4]	Schwartz (1994b)	Detroit, MI	65+	Daily 8-hour max. [1]	0.003230	0.000806	All year
HA , All respiratory [4]	Schwartz (1995)	New Haven, CT	65+	Daily 8-hour max. [1]	0.001777	0.000936	Warm season
HA , All Respiratory [4]	Schwartz (1995)	Tacoma, WA	65+	Daily 8-hour max. [1]	0.004931	0.001770	Warm season
ER, Asthma[5]	Peel et al. (2005)	Atlanta, GA	All ages	Daily 8-hour max.	0.000870	0.000529	
ER, Asthma[5]	Wilson et al. (2005)	Portland, ME	All ages	Daily 8-hour max.	0.003000	0.001000	
ER, Asthma[5]	Wilson et al. (2005)	Manchester, NH	All ages	Daily 8-hour max.	-0.001000	0.002000	
School Loss Days, All Cause[6]	Chen et al. (2000)	Wachoe Co, NV	5-17	Daily 8-hour max. [2]	0.015763	0.004985	All year
School Loss Days, All Cause[6]	Gilliland et al. (2001)	Southern California	5-17	Daily 8-hour max.[3]	0.007824	0.004445	All year
Minor Restricted Activity Days	Ostro and Rothschild (1989)	Nationwide	18-64	Daily 8-hour max. [2]	0.002596	0.000776	

[1] Converted from 24-hour mean.
[2] Converted from daily 1-hour maximum
[3] Converted from 8-hour mean
[4] These studies were pooled in BenMAP to generate pooled incidence estimates for respiratory hospital admissions.
[5] These studies were pooled in BenMAP to generate pooled incidence estimates for asthma-related ER visits. Note: Jaffe et al. (2003) is listed in Table 6-2 of EPA's O_3 NAAQS RIA as being among those studies included in the pooled analysis for asthma-related ER visits. However, we were informed via personal communication with Neal Fann (EPA/OAQPS) that this study was ultimately not included because it covered a substantially different age range (ages 5 – 34) from the other studies.
[6] These studies were pooled in BenMAP to generate pooled incidence estimates for school loss days.
[7] This was a meta-analysis of 43 U.S. and non-U.S. studies.

2. Schwartz (1994a) also estimated C-R functions in Minneapolis for the same two subcategories. However, this study found a significant effect only for HA, pneumonia. So the estimate of "PM-related HA for respiratory illness" in Minneapolis based on Schwartz (1994a) was taken to be just PM-related HA, pneumonia.
3. The estimates of "PM-related HA for respiratory illness" in Minneapolis from (1) and (2) above were pooled using a fixed effects pooling method.[25]
4. Schwartz (1994b) estimated C-R functions for the same two non-overlapping subcategories in Detroit. We similarly summed these results.
5. Finally, Schwartz (1995) estimated C-R functions for "HA, all respiratory" in New Haven, CT and Tacoma, WA. We pooled the HA, All respiratory results from these C-R functions with the results from steps (3) and (4).[26]

To obtain the asthma ER visits results, we pooled Peel et al. (2005) and Wilson et al. (2005) using the random/fixed effects method. To obtain the results for school absence days, we pooled Gilliland et al. (2001) and Chen et al. (2000) also using the random/fixed effects method.

6.3.3. Baseline incidence rates

This section describes the development of baseline incidence rates for mortality and morbidity health endpoints examined in our analyses. First, we describe the source of 2004-2006 individual-level mortality data and the calculation of county-level mortality rates. Second, we describe how we use national-level Census mortality rate projections to develop 2050 county-level mortality rate projections, which are used as baseline mortality incidence rates. We then describe the baseline morbidity incidence rates, including hospitalization rates and emergency room (ER) visit rates.

Mortality

We obtained individual-level mortality data, including residence county FIPS, age at death, month of death, and underlying causes (ICD-10 codes), for years 2004-2006 for the entire United States from the Centers for Disease Control (CDC), National Center for Health Statistics (NCHS). The detailed mortality data allowed us to generate cause-specific death counts at the county level for selected age groups. The county-level death counts are then divided by the corresponding county-level population to obtain the mortality rates. To provide more stable estimates, we used three years (2004-2006) of mortality and population data,[27] i.e.,

[25] When choosing fixed effects as the pooling method, pooling weights are generated automatically based on the inverse variance of each input result, with the weights normalized to sum to one. Results with a larger absolute variance get smaller weights. (For more details, see Section J.2.1.3 in the BenMAP User Manual, Appendix J).
[26] For more details on the pooling method, see Section J.2.1.4 in BenMAP User Manual Appendix J.
[27] The population data for 2004-2006 were Woods and Poole estimates based on the 2000 Census.

$$Mortality\ Rate(2004-2006)_{ijk} = \frac{\sum_{2004}^{2006} death_{ijk}}{\sum_{2004}^{2006} population_{ijk}},$$

where *i* represents the specific cause of mortality (e.g., non-accidental mortality), *j* represents a specific county, and *k* represents a specific age group.

Mortality rates based on 20 or fewer deaths were considered unreliable.[28] If the rate for a given cause of death was unreliable in certain counties in a state, we summed up the deaths attributed to that cause in those counties, as well as the populations in those counties and created an aggregate rate for that cause of death in those counties. If that aggregate "state-level" rate was unreliable, we aggregated to the region level,[29] and if the region-level rate was still unreliable, we aggregated to the national level.[30]

To estimate age- and county-specific mortality rates in the year 2050, we calculated adjustment factors, based on a series of Census Bureau projected national mortality rates, to adjust the above age- and county-specific mortality rates in 2004-2006 to corresponding rates for 2050. The procedure we used was as follows:

- For each age group, we calculated the ratio of the Census Bureau national mortality rate projection in year 2050 to the national mortality rate in 2005. Note that the Census Bureau projected mortality rates were derived from crude death rates.[31]

- To estimate mortality rates in 2050 that are both age-group-specific and county-specific, we multiplied the county- and age-group-specific mortality rates for 2004-2006 by the appropriate ratio calculated in the previous step. For example, to estimate the projected mortality rate in 2050 among ages 18-24 in Wayne County, MI, we multiplied the mortality rate for ages 18-24 in Wayne County in 2004-2006 by the ratio of Census Bureau projected national mortality rate in 2050 for ages 18-24 to Census Bureau national mortality rate in 2005 for ages 18-24.

[28] Refer to http://www.health.state.ny.us/diseases/chronic/ratesmall.htm for an explanation of why rates based on fewer than 20 cases are marked as unreliable.

[29] We used the four regions defined by the U.S. Bureau of the Census. See the definitions on the next page.

[30] At each level of aggregation, only those counties with unreliable rates for the specified cause of death were included. So, for example, if 5 counties in a given state had unreliable rates for a specific cause of death, a "state-level" rate was created by summing the deaths from that cause across those counties and dividing by the sum of the populations in those counties. If this "state-level" rate was still unreliable, we repeated the process at the region level.

[31] The following formula, given by Chiang (1967, p.2 equation 7), was used: M = Q/(1-(1-A)*Q), where M denotes the projected mortality rate, Q denotes the crude death rate, and A denotes the fraction of the interval (one year) lived by individuals who die in the interval. A=0.1 if age < 1, and A=0.5 otherwise.

Hospitalizations

Regional hospitalization counts were obtained from the National Center for Health Statistics' (NCHS) National Hospital Discharge Survey (NHDS). NHDS is a sample-based survey of non-Federal, short-stay hospitals (<30 days), and is the principal source of nationwide hospitalization data.[32] The survey collects data on patient characteristics, diagnoses, and medical procedures. Public use data files for the year 1999 survey were downloaded (from ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHDS/) and processed to estimate hospitalization counts by region. NCHS groups states into four regions using the following groupings defined by the U.S. Bureau of the Census:

- **Northeast** - Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania
- **Midwest** - Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas
- **South** - Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas
- **West** - Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California, Alaska, Hawaii

We used the 2000 Census to obtain more age specificity, and then corrected the 2000 Census figures so that the total population equaled the total for 1999 forecasted by NHDS. In particular, for each type of hospital admission (ICD code or codes) we: (1) calculated the count of hospital admissions by region in 1999 for the age groups of interest, (2) calculated the 2000 regional populations corresponding to these age groups, (3) calculated regional correction factors that equal the regional total population in 1999 divided by the regional total population in 2000, (4) multiplied the 2000 population estimates by these correction factors, (5) divided the 1999 regional count of hospital admissions by the estimated 1999 population, and (6) applied the regional rates to every county in that region.

Similar to mortality rates, the hospitalization rates are also cause-specific and the hospital admissions endpoints are defined by different combinations of ICD codes that are used in the selected epidemiological studies.

Emergency Room Visits for Asthma

Regional asthma emergency room visit counts were obtained from the National Hospital Ambulatory Medical Care Survey (NHAMCS). NHAMCS is a sample-based survey, conducted by NCHS. The target universe of the NHAMCS is in-person visits made in the United States to emergency and outpatient departments of non-Federal, short-stay hospitals (hospitals with an average stay of less than 30 days) or those whose specialty is

[32] Note that the following hospital types are excluded from the survey: hospitals with an average patient length of stay of greater than 30 days, federal, military, Department of Veterans Affairs hospitals, institutional hospitals (e.g. prisons), and hospitals with fewer than six beds.

general (medical or surgical) or children's general. Public use data files for the year 2000 survey were downloaded (from: ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHAMCS/) and processed to estimate hospitalization counts by region. We obtained population estimates from the 2000 U.S. Census. The NCHS regional groupings described above were used to estimate regional emergency room visit rates.

6.3.4. Populations

The extent of the impacts of climate change-related changes in ambient O_3 concentrations will depend in part on the extent to which areas of large O_3 changes coincide with areas of high population density. Because the target year for this analysis is 2050, we must rely on population projections. We have used four different population projections in our analysis; these are described in detail in Section 5 above. Regardless of the population projection being used, BenMAP derives grid cell-specific population estimates.

6.3.5. Summary of key features of the analysis

In summary, for a given climate change/air quality model combination and a given population projection, we used BenMAP to estimate the changes in incidence of O_3-related health effects that are estimated to occur in a future year as a result of climate change-induced changes in O_3 concentrations. The basic features of the analysis are as follows:

- The target year for the analysis: 2050;
- The O_3 metric: the average of daily 8-hour maxima over the O_3 season;
- Air quality model grid (for all air quality models used): 30 km x 30 km grid cell of an air quality grid over the coterminous U.S.
- Adjustment of modeled without-climate-change and with-climate-change scenario O_3 metrics:
  - Without climate change scenario: spatial adjustment in BenMAP, using both monitor and modeled values (described in Section 6.3.1);
  - With-climate-change scenario: spatial and temporal adjustment in BenMAP, using both monitor and modeled values (described in Section 6.3.1);
- Selection of health endpoints, epidemiological studies, and C-R functions: chosen to match the suite used in EPA's recently completed benefits analysis for the O_3 NAAQS RIA.
- Results calculated at the grid cell level and then aggregated to
  - The regional level[33]; and
  - The national level.

[33] The country was divided into three broad regions: The Northeast, the Southeast, and the West. The definitions of these regions are given in Section 3.

6.3.6. Assessing and characterizing uncertainty

As noted above in Section 3, there is substantial uncertainty surrounding each of the inputs to our analysis. While some of this uncertainty – in particular, the statistical uncertainty surrounding estimated coefficients in C-R functions – can easily be quantified, much of it cannot. Each climate change model is an attempt to approximate a future reality, just as each air quality model is an attempt to approximate a future reality, contingent on the future reality approximated by the linked climate change model. Each population projection is an attempt to approximate the size, geographic distribution, and composition of the U.S. population over forty years into the future.

We do not have ways to quantitatively assess much of this uncertainty. Even assigning probabilities to the different models (representing our subjective assessments about the relative accuracy with which each approximates a future reality) is premature. Because of this, we have chosen to present our analysis as a series of "sensitivity analyses" or "what if" scenarios designed to assess the impact of the various assumptions and modeling approaches on the results of the analysis. The goal of the analysis, then, is to present a range of predicted O_3-related human health impact levels, and illustrate how different (uncertain) inputs to the analysis affect the output.

We carried out the analysis using all combinations of the seven climate change/air quality models described in Section 4, the five different population projections described in Section 5, and the two definitions of "O_3 season" – June, July, and August, used in most of the climate change models, as well as an expanded O_3 season from May through September. We also used more than one C-R function for a given O_3-related health endpoint if more than one was used in EPA's O_3 NAAQS RIA benefits analysis. No one set of input characterizations was given any more weight than any other set when we interpreted the results.

The entire set of analyses, using all different combinations of input characterizations, thus creates a potentially wide range of results that serves to illustrate

- the breadth of uncertainty surrounding estimates of O_3-related health impacts that may be attributable to climate change in a future year (2050), and
- which uncertain inputs "matter most."

An uncertain input to an analysis can be important in different ways:

- It can be important because the value of the outcome of the analysis is sensitive to the value of the (uncertain) input – i.e., a relatively small change in the input value results in a relatively large change in the outcome of the analysis.
- It can be important because it contributes a relatively large share of the uncertainty about the outcome of the analysis, so that if we could reduce the uncertainty about the input we would disproportionately reduce the uncertainty about the outcome.

- It can be important because it has the potential to affect the decision that a decision-maker would make based on the analysis.[34]

[34] These types of uncertainty importance are not mutually exclusive. An uncertain input can be important in all three ways, or in one or two ways. It is possible, for example, that several uncertain inputs could be important in the first two ways but not in the third way, if the decision-maker would make the same decision regardless of the values of the uncertain inputs used in the analysis – e.g., that the outcome of the analysis depends on the values of the uncertain inputs but that, given any of the possible values, the decision-maker would make the same decision.

7. RESULTS AND DISCUSSION

We produced 7 (climate change/air quality models) x 5 (population projections) x 2 (O_3 season definitions) = 70 potential “answers” to the question: How many O_3-related cases of a given health effect (e.g., premature mortality) may be attributable to climate change in the conterminous United States in the year 2050? For some health effects for which we have more than one C-R function, we have produced some multiple of 70 results. In the case of all-cause mortality, for example, for which we have two different C-R functions, we produced twice this number, or 140 potential “answers.” In addition, we’ve considered several different health endpoints – all the health endpoints included in the 2008 O_3 NAAQS RIA benefits analysis. This includes all-cause mortality, non-accidental mortality, hospital admissions for respiratory illnesses, emergency room visits for asthma, school loss days, and minor restricted activity days. Results for all combinations of these health endpoints, C-R functions, climate change/air quality models, population projections, and O_3 season definitions were aggregated to the national level as well as to each of the three regions considered in this analysis. We present all of these results in tables in Appendix A. Below we summarize and discuss the most salient features of these results.

7.1. National Results

There is a wide range of possible “answers” to the question posed above – i.e., there is, not surprisingly, a large amount of uncertainty about the impact of climate change on future (2050) O_3-related human health effects. This is evident both for O_3-related mortality, discussed in Section 7.1.1, and morbidity, discussed in Section 7.1.2.

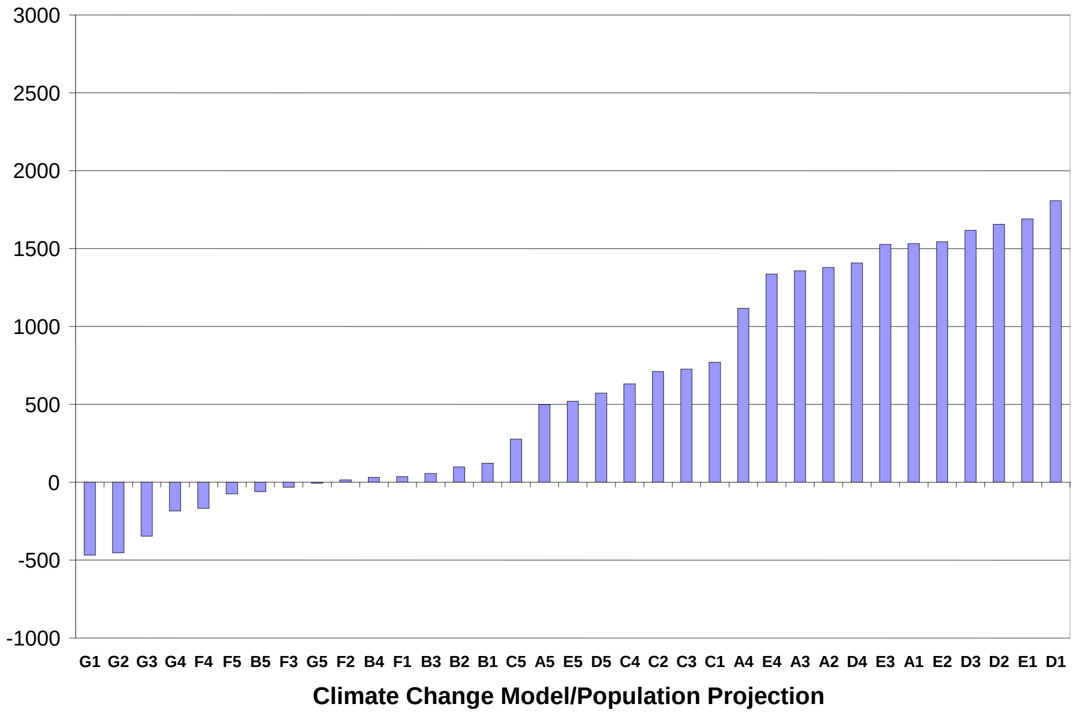
7.1.1. Mortality

Figure 7-1 shows the impact of climate change/air quality model, population projection, and C-R function on estimates of the national incidence of O_3-related all-cause premature mortality attributable to climate change, when the O_3 season is defined as June, July, and August (as it was in most of the climate change/air quality modeling efforts). The top panel of Figure 7-1 shows estimates based on Bell et al. (2005); the bottom panel shows estimates based on Levy et al. (2005). The indicators for the climate change models and population projections on the x-axis of Figure 7-1, as well as the abbreviations for the models and population projections used in subsequent figures and tables, are given in Figure 7-2.

Looking across all combinations of climate change/air quality models, population projections and C-R functions for all-cause mortality considered in our analysis, based on the O_3 season defined as June, July, and August (shown in Figure 7-1), estimates of national O_3-related all-cause premature mortality in 2050 attributable to climate change range from -657 to 2,550 – that is, from over 600 cases of O_3-related premature mortality *avoided because of* climate change to over 2,500 cases *attributable to* climate change.

Figure 7-1. Estimated National O_3-Related Cases of All-Cause Mortality in 2050 O_3 Season (Defined as June, July, and August) Due to Climate Change: Impact of Climate Change/Air Quality Model, Population Projection, and C-R Function

Bell et al. (2005)



Levy et al. (2005)

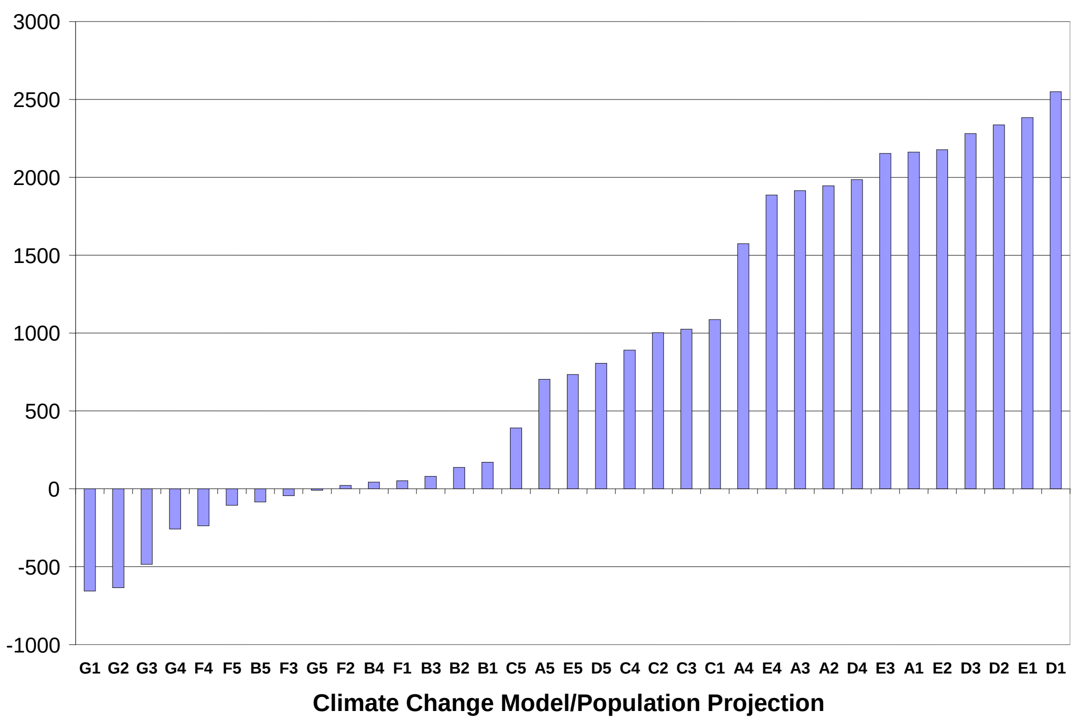


Figure 7-2. Indicators and Abbreviations for Climate Change/Air Quality Models and Population Projections in Figures

Indicator in Figures	Climate Change/Air Quality Model	Abbreviation Used in Figures
A	Carnegie-Mellon University	CMU
B	GIT-NESCAUM-MIT	GNM
C	Harvard University	Harvard
D	University of Illinois - using A1Fi GHG scenario	Illinois-1
E	University of Illinois - using B1 GHG scenario	Illinois-2
F	EPA's National Exposure Research Lab	NERL
G	Washington State University	WSU
Indicator in Figures	**Population Projection**	**Abbreviation Used in Figures**
1	Integrated Climate and Land-Use Scenarios project - A1 scenario	ICLUS_A1
2	Integrated Climate and Land-Use Scenarios project - A2 scenario	ICLUS_A2
3	Integrated Climate and Land-Use Scenarios project - base case	ICLUS_BC
4	Exponential smoothing projections of Woods & Poole 2030 populations in BenMAP To 2050	Woods & Poole
5	Year 2000 Census Population	Census_2000

If we use the expanded definition of the O_3 season, from May through September, the range of results expands accordingly – from -1,092 to 4,241. Moreover, this range does not reflect the full extent of uncertainty, because it does not incorporate the uncertainty surrounding each individual input to the analysis.[35] However, while the wide ranges of estimates for both definitions of the O_3 season include some that are negative, the preponderance of estimates are positive, suggesting that, all else being equal, we would expect climate change to increase the incidence of O_3-related all-cause premature mortality in 2050.

The results for non-accidental mortality follow a similar pattern to what is shown in Figure 7-1 for all-cause mortality. Because the coefficient of O_3 in the C-R function reported in Bell et al. (2004) is smaller than the coefficients in Bell et al. (2005) and Levy et al. (2005), however, the magnitudes of the estimates based on Bell et al. (2004) are substantially smaller. Looking across all combinations of climate change/air quality models and population projections, for an O_3 season defined as June, July, and August, estimates of O_3-related non-accidental premature mortality due to climate change based on Bell et al. (2004) range from -147 to 570. Once again, the great preponderance of the estimates is positive. This is broadly consistent with what other researchers have reported on the O_3-related human health impacts of climate change (see, e.g., Knowlton et al., 2004; Bell 2007; Hwang et al., 2004; Tagaris et al.; 2009).

[35] For example, the figures shown in this section are based on the point estimates of the C-R functions from Bell et al. (2005) and from Levy et al. (2005), but there is statistical uncertainty surrounding each of these point estimates. Another set of inputs to the analysis for which we did not incorporate uncertainty are the baseline incidence rates. While current rates are relatively uncertain, we used rates projected to the year 2050. Like the population projections, these projected baseline incidence rates similarly have substantial uncertainty surrounding them.

7.1.2. Morbidity

Matrices of point estimates of O_3-related morbidity in 2050 attributable to climate change, for the different combinations of climate change/air quality model and population projection are shown for each of the morbidity endpoints in Table 7-1. For more complete estimates, including 95 percent confidence or credible intervals, see Appendix A.

While the general magnitudes of the estimates of O_3-related morbidity in 2050 attributable to climate change will differ from those for mortality – and will vary from one morbidity endpoint to another – the broad pattern of results seen for mortality across the different climate change/air quality models, for each population projection, is largely mirrored for the morbidity endpoints we included in our analysis. In particular, the order of the models in terms of predicted results for mortality (for any given population projection) – Illinois-1, Illinois-2, CMU, Harvard, GNM, NERL, and WSU – is followed for the morbidity endpoints as well.

However, because several of the morbidity endpoints focus on specific age subgroups of the population, and the population projections differ to some extent in their predicted age distributions, there are some notable differences in patterns across the population projections, given a climate change/air quality model – both between mortality and some of the morbidity endpoints, and between different morbidity endpoints. The influence of age distribution in the projected population is discussed in more detail in Section 7.2.2 below.

Like the results for O_3-related mortality, the preponderance of results for O_3-related morbidity is positive – i.e., overall, the models predict that climate change will increase the incidence of O_3-related morbidity. This is broadly consistent with the few morbidity results reported by other researchers (see, e.g., Hwang et al., 2004; Tagaris et al.; 2009).

Table 7-1. Estimated National O_3-Related Incidence of Morbidity Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August, Based on Different Combinations of Climate Change/Air Quality Model and Population Projection*

Climate Change/Air Quality Model	Population Projection				
	ICLUS_A1	ICLUS_A2	ICLUS_BC	Woods & Poole	Census_2000
Hospital Admissions for Respiratory Illness (Ages <1)					
Illinois-1	1570	2650	1990	2350	1600
Illinois-2	1610	2740	2060	2350	1610
CMU	1250	2060	1550	1830	1290
Harvard	710	1230	940	1100	820
GNM	190	310	200	170	10
NERL	-40	-100	-100	-100	-160
WSU	-430	-770	-540	-510	-190
Hospital Admissions for Respiratory Illness (Ages 65+)					
Illinois-1	6050	5500	5410	4850	1940
Illinois-2	5650	5120	5110	4630	1780
CMU	5190	4630	4580	3880	1670
Harvard	2530	2320	2410	2130	940
GNM	300	220	80	10	-250
NERL	70	10	-140	-620	-310
WSU	-1480	-1420	-1050	-650	30
Emergency Room Visits for Asthma (All Ages)					
Illinois-1	1370	1710	1490	1760	1290
Illinois-2	1330	1670	1460	1720	1240
CMU	1230	1500	1300	1490	1130
Harvard	700	870	770	900	730
GNM	-80	-130	-130	-180	-220
NERL	-90	-130	-130	-170	-200
WSU	0	-60	0	-60	190
School Loss Days (Ages 5 - 17)					
Illinois-1	633000	925000	743000	880000	659000
Illinois-2	638000	937000	755000	893000	650000
CMU	522000	745000	599000	679000	545000
Harvard	299000	445000	362000	422000	347000
GNM	50000	67000	44000	35000	-29000
NERL	-25000	-50000	-50000	-67000	-84000
WSU	-134000	-212000	-153000	-197000	-27000
Minor Restricted Activity Days (Ages 18 - 64)					
Illinois-1	1959000	2063000	1934000	2333000	1681000
Illinois-2	1941000	2049000	1927000	2362000	1612000
CMU	1637000	1688000	1582000	1818000	1436000
Harvard	926000	990000	941000	1131000	872000
GNM	120000	108000	73000	58000	-78000
NERL	-76000	-109000	-130000	-202000	-213000
WSU	-333000	-375000	-301000	-460000	2000

*Respiratory hospital admissions and emergency room visits for asthma are rounded to the nearest 10; school loss days and minor restricted activity days are rounded to the nearest 1000.

7.2. Uncertainty

As noted above, there is substantial uncertainty surrounding each of the inputs to our analysis, particularly because the analysis focuses so far in the future. In particular, there is uncertainty surrounding

- the meteorological conditions that will result from the accumulation of greenhouse gases in the atmosphere (as predicted by the different climate change models);
- the corresponding changes in O_3 concentrations (as simulated by the different air quality models);
- the size, as well as the age and geographic distributions of the population that will be affected (as represented in the different population projections); and
- the relationships between adverse health effects in that population and (future) O_3 concentrations (as embodied in the different C-R functions).

We do not have ways to quantitatively assess much of this uncertainty. Even assigning probabilities to the different models (representing our subjective assessments about the relative accuracy with which each approximates a future reality) is premature. Instead, we present our analysis as a series of “sensitivity analyses” or “what if” scenarios designed to assess the impact of the various assumptions and modeling approaches on the results of the analysis.

We discuss two of the most important sources of uncertainty below. Uncertainty due to different C-R functions for the same health endpoint, as well as the standard uncertainty surrounding individual C-R functions due to the statistical estimation of their coefficients, can be seen in the tables of results in Appendix A.

7.2.1. Influence of O_3 Changes from the Climate Change/Air Quality Models

The source of the greatest uncertainty appears to be the climate change/air quality models. Figure 7-3 illustrates the influence of climate change/air quality model on estimated non-accidental deaths attributable to climate change in 2050, using the C-R function for non-accidental mortality from Bell et al. (2004). Figure 7-4 provides the legend for Figure 7-3.

The range of results across climate change/air quality models is the largest when combined with the ICLUS_A1 population projection. Using the C-R function from Bell et al. (2004) for non-accidental deaths and the June, July, August O_3 season definition, the combination of the Illinois-1 modeling system and the ICLUS_A1 population projection predicted 570 O_3-related non-accidental deaths attributable to climate change in 2050; at the other extreme, the combination of WSU and ICLUS_A1 predicted almost 150 O_3-related deaths avoided because of climate change in 2050. The difference between the two estimates is over 700 deaths.

Figure 7-3. Estimated National O_3-Related Non-Accidental Mortality (Based on Bell et al., 2004) in 2050 O_3 Season (Defined as June, July, and August) Due to Climate Change: Impact of Climate Change/Air Quality Model, for Each Population Projection

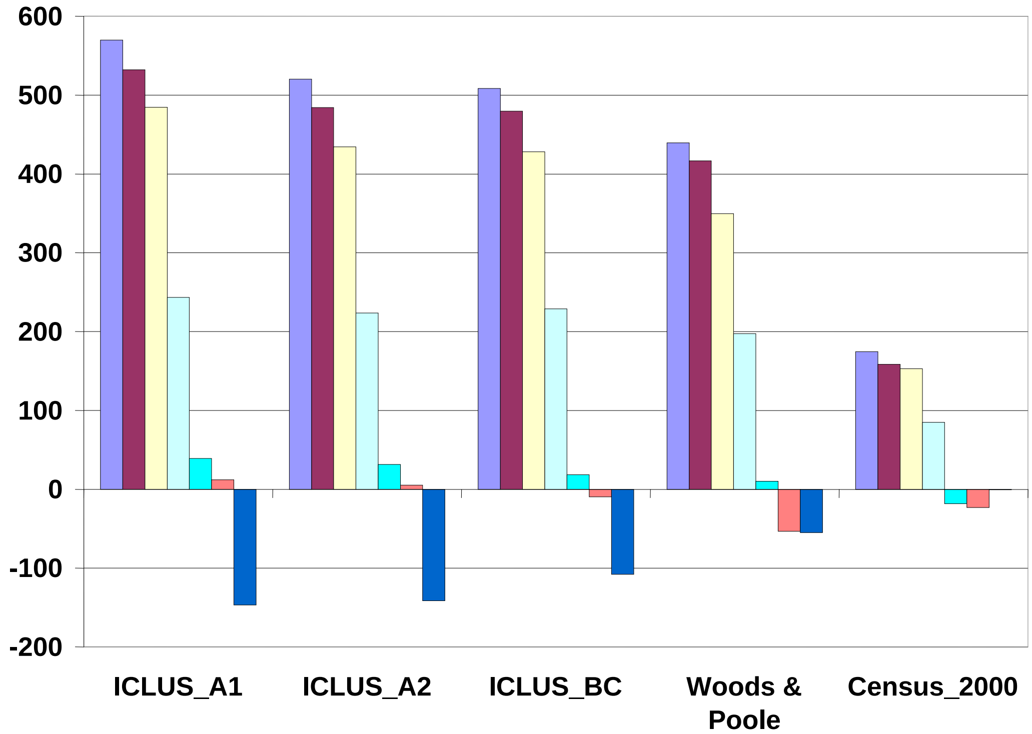
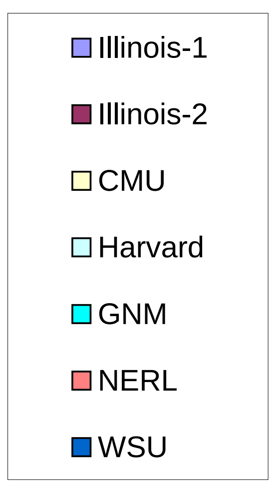


Figure 7-4. Legend for Climate Change/Air Quality Models in Figures



Similarly, using the C-R function for all-cause mortality from Levy et al. (2005) and the June, July, August O_3 season definition, the combination of the Illinois-1 modeling system and ICLUS_A1 population projection predicted over 2,500 O_3-related deaths attributable to climate change in 2050 nationally; at the other extreme, the combination of the WSU modeling system and ICLUS_A1 predicted over 650 O_3-related deaths avoided because of climate change in 2050. The difference between these two estimates is over 3,200 deaths.

The results from the individual climate-O_3 simulations input to BenMAP are in agreement on a number of fundamental points (U.S. EPA, 2009a). For example, they all found that climate change caused increases in summertime O_3 concentrations over substantial regions of the country, with these increases in the range of 2-8 ppb. They also found a greater sensitivity of peak O_3 events to climate change than mean summer O_3. However, there are also clear differences across the simulations in the spatial distributions of O_3 changes across the country, with areas of little O_3, or even decreases, interspersed throughout the areas of increases with different patterns from simulation to simulation (see Figure 4-1 above). There seems to be (very generally) more agreement on uniform climate-induced O_3 increases for the eastern half of the country than for the West, though parts of the Southeast also show some of the strongest disagreements across the modeling groups. These differences across simulations will be discussed in more detail in Section 7.3 below.

The wide range of predicted O_3-related mortality incidence attributable to climate change – including a fundamental difference in the message about whether climate change will increase or decrease O_3-related mortality – highlights the need to use an ensemble approach, rather than relying on any one modeling system to predict the O_3-related human health effects attributable to climate change in a future year. This is perhaps the most important “take away” message of our analysis.

However, while there is a very wide range of results, including those that suggest that climate change would decrease the incidence of O_3-related mortality, the large preponderance of the results across the different climate change/air quality simulations show positive values, thereby suggesting that, all else being equal, climate change would lead to an increase in O_3-related non-accidental deaths in 2050.

7.2.2. Influence of Projected Population Changes

The population projection also made a significant difference, although a smaller difference than the climate change/air quality model. Figure 7-5 illustrates the influence of population projection on estimated non-accidental deaths attributable to climate change in 2050, using the C-R function for non-accidental mortality from Bell et al. (2004). Figure 7-6 provides the legend for Figure 7-5.

Figure 7-5. Estimated National O_3-Related Non-Accidental Mortality (Based on Bell et al., 2004) in 2050 O_3 Season (Defined as June, July, and August) Due to Climate Change: Impact of Population Projection, for Each Climate Change/Air Quality Model

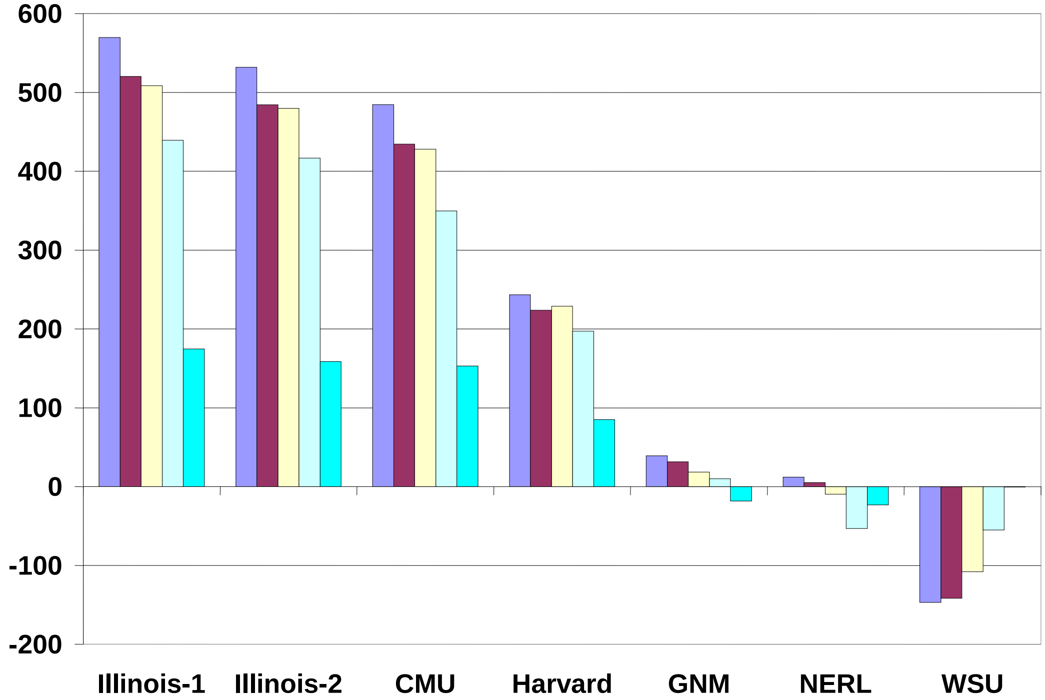
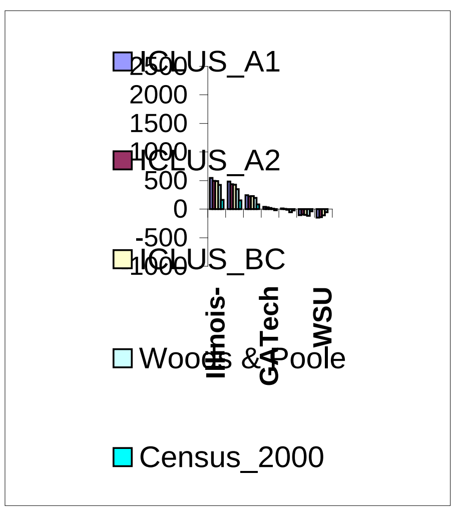


Figure 7-6. Legend for Population Projections in Figures



The spread in results across population projections is the largest when combined with the Illinois-1 climate change/air quality model. Using the C-R function from Bell et al. (2004) and the June, July, August O_3 season definition, the combination of the ICLUS_A1 population projection and the Illinois-1 resulted in about 570 O_3-related deaths attributable to climate change in 2050, as noted above; at the other extreme, the combination of Census_2000 and Illinois-1 resulted in only 175 O_3-related deaths due to climate change in 2050. The difference between the two estimates is almost 400 deaths (as compared to a difference of over 700 deaths across climate change/air quality models).

Our analysis is one of the first to try to project population growth increases as well as changes in age and geographic distributions by a future year, and we find that this affects the estimates of health impacts substantially. The impact of projecting the size of a future population is clearly illustrated by comparing the results based on the Census_2000 population projection to those based on any of the other population projections. The Census_2000 population "projection" isn't really a projection – i.e., it assumes that the population in 2050 will be exactly what it was in the year 2000. This is unrealistic in a way that will produce a known (downward) bias in results. In fact, of the almost 400-case difference in results produced by the two population projection extremes, noted above, 67 percent (or 265 deaths) is due to the difference between the result produced by the Census_2000 population "projection" (175 deaths) and the next highest result, produced by the Woods & Poole projection (439 deaths).[36]

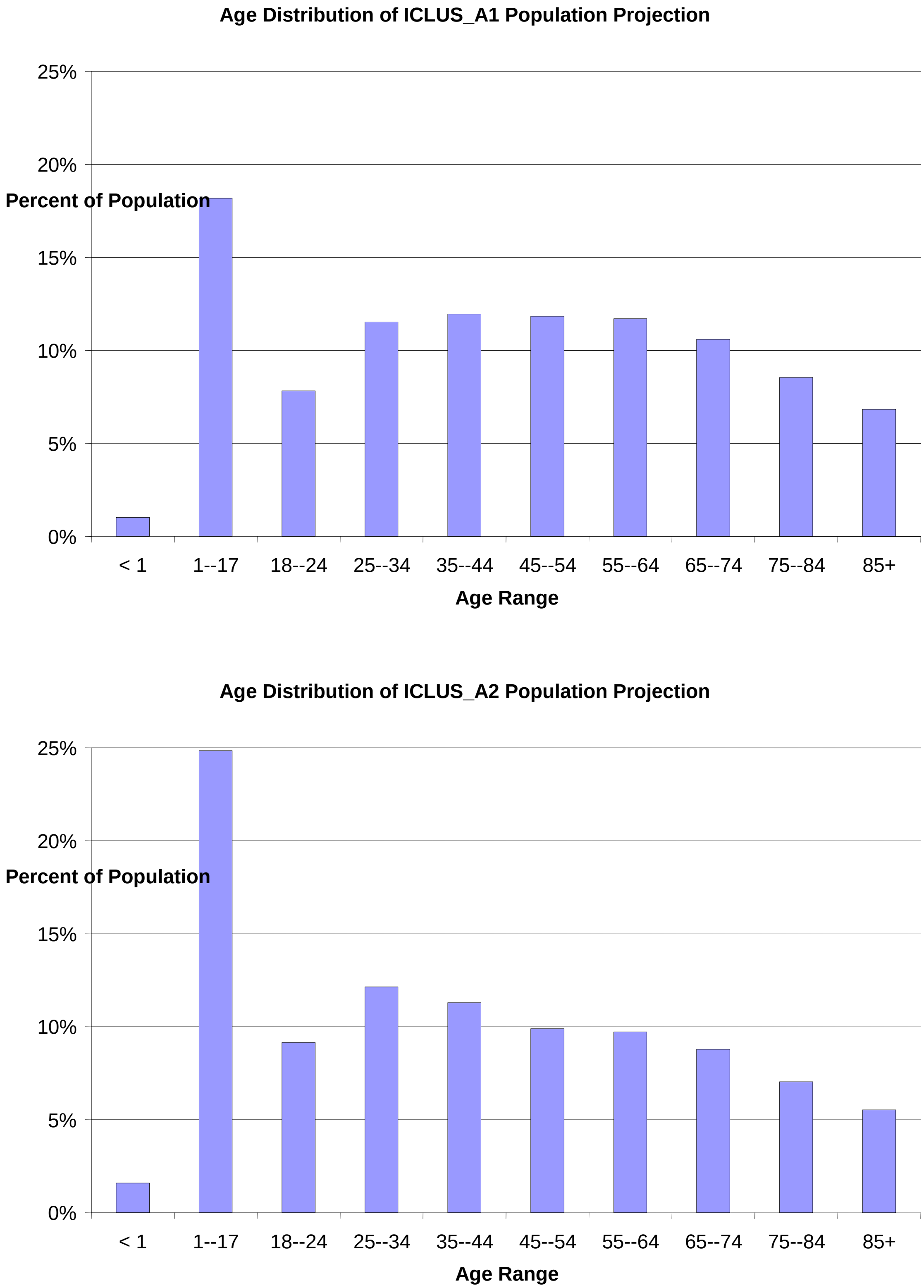
Our results illustrate, then, how important it is to take into account that the population is likely to have grown between the present and a year as far in the future as 2050. Public health strategies to reduce adverse health consequences will need to account for both the changes in risks from climate change and population changes.

Not only is the total population exposed to O_3 in a future year important, but the age and geographic distributions of that population can also make a substantial difference in the impact of climate change on O_3-related adverse health effects. The ICLUS_A2 population projection, for example, is, in total, greater than the ICLUS_A1 population projection (424.8 million vs. 386.7 million). However, the ICLUS_A1 population projection is skewed more towards the older ages than the ICLUS_A2 population projection, as shown below in Figure 7-7. In particular, about 26 percent of the ICLUS_A1 population projection is 65 or older, versus only about 21 percent of the ICLUS_A2 population projection.[37] Since older people have substantially higher baseline incidence rates for mortality (and other adverse health effects) than younger people, the same increase in O_3 concentration will result in more deaths among an older population than a younger one. This is reflected in the slightly higher numbers of O_3-related deaths attributable to climate change in 2050 when the ICLUS_A1 population projection is used (as compared with the ICLUS_A2 population projection) despite the overall smaller population.

[36] These numbers are still based on Bell et al. (2004) and the June, July, and August definition of the O_3 season.

[37] This results in a greater number of people ages 65 and up in the ICLUS_A1 population projection (over 100 million) than in the ICLUS_A2 population projection (under 91 million), even though the latter total population is somewhat larger.

Figure 7-7. Age Distributions of ICLUS_A1 and ICLUS_A2 Population Projections to the Year 2050



The importance of the age distribution of the affected population is particularly apparent when we consider the impact of climate change on O_3-related morbidity endpoints, because several of these health endpoints focus on specific age subgroups in the population. The impact of age distribution can be seen, for example, if we compare the mortality results to the results for hospital admissions for respiratory illness among infants. For every climate change/air quality model, the ICLUS_A1 population projection predicts a greater magnitude of O_3-related non-accidental mortality than does the ICLUS_A2 population projection (as shown above in Figure 7-5). In contrast, estimates of O_3-related respiratory hospital admissions among infants attributable to climate change in 2050 based on the ICLUS_A1 population projection are uniformly smaller in magnitude than the corresponding estimates based on the ICLUS_A2 population projection, regardless of the climate change/air quality model (as shown in Table 7-1 above). This is because the ICLUS_A2 population projection has a greater percentage of the population (and a larger total population) under 1 year of age relative to the ICLUS_A1 population projection, and a smaller percentage of the population in the 65 and older categories relative to ICLUS_A1. Thus the ICLUS_A1 population projection predicts fewer infant respiratory hospitalizations but more deaths (the preponderance of which occur among those 65 and older).

7.3. Regional Results

The three broad regions into which we divided the country for this analysis are shown in Figure 3-2 above. The particular regional divisions used were chosen to roughly match the major divisions in the climate-O_3 results (see U.S. EPA, 2009a; also Figure 4-1 above for the regional modeling results): i.e., a relatively more uniformly positive O_3 sensitivity to climate in the Northeast across the simulations; large amplitudes of climate-induced O_3 changes in the Southeast but with large disagreements across the simulations; and a fairly mixed picture west of the Mississippi. Clearly the regions chosen are very broad, thereby limiting the spatial specificity of the discussion. The high degree of variability across the simulations, and the generally high level of uncertainty in regional climate modeling, suggest that it is probably not particularly useful to look in detail at smaller-scale areas (e.g., an individual state). Note, however, that the basic regional results shown here are not particularly sensitive to the choice of averaging domains – for example, averaging over only the state of California as opposed to the entire West.

As discussed above in Section 7.2.1, there are significant differences across the seven climate-O_3 simulations in the spatial patterns of O_3 changes they simulate, resulting in particular in relatively large differences in the Southeast, and to a certain extent the West. Nationally, these inter-simulation differences in O_3 response to global climate change are due largely to differences in how the modeling systems simulate the following key factors (in roughly the following order of importance; U.S. EPA, 2009a):

- Regional patterns of incoming solar radiation at the surface (which strongly affects O_3 photochemistry) driven primarily by differences in regional cloud cover patterns across the simulations;
- Regional patterns of simulated temperature change;

- How the different models respond to changes in climate-induced VOC emissions from natural sources (e.g., vegetation).

These differences, in turn, stem from differences in how the models represent the following:

- Large-scale circulation patterns that strongly affect regional meteorology, such as the extra-tropical storm tracks and the subtropical high pressure systems over the adjacent oceans;
- Small-scale physical processes that must be parameterized in the models, in particular those related to the production of clouds and precipitation;
- Key chemical pathways that control the control the interaction between NOx, VOCs, and O_3 in regions of large increases in biogenic VOC emissions.

The national estimates of O_3-related human health effects attributable to climate change are the sums of the regional estimates, and they can mask very different regional scenarios, as illustrated below in Figures 7-8 and 7-9. (The legends for these figures are given in Figures 7-4 and 7-6, respectively.) The WSU climate change/air quality model offers a particularly striking example of this. At the national level, the WSU model predicts modest overall decreases in O_3-related premature mortality as a result of climate change. These modest national decreases are the sums of much more substantial decreases in the Southeast, small decreases in the West, and substantial increases in the Northeast. Using the ICLUS_A1 population projection, the June, July, August definition of the O_3 season, and Bell et al. (2004), for example, the WSU model predicts about 280 O_3-related deaths in the Northeast attributable to climate change and about 370 O_3-related deaths in the Southeast and 50 O_3-related deaths in the West avoided as a result of climate change. The national total, then, is 280 + (–370) + (–50) = -150. The modest national result obscures the more substantial impacts of climate change on O_3-related deaths in opposite directions in the Northeast and Southeast.

As discussed above, and more extensively in U.S. EPA (2009a), the climate change/air quality models differ substantially in the regional patterns of climate-induced O_3 changes they simulate. With the exception of Illinios-1 and Illinios-2, none of the models shows regional impacts uniformly in one direction – i.e., increases in O_3 concentrations attributable to climate change in some regions are accompanied by decreases in other regions. While the WSU model shows large decreases in O_3-related deaths in the Southeast and large increases in the Northeast, two of the other models – GNM and NERL – show just the opposite regional effects, although neither of these models show effects of the same magnitude as the WSU model.

Figure 7-8. Estimated National and Regional O_3-Related Non-Accidental Mortality (Based on Bell et al., 2004) in 2050 O_3 Season (Defined as June, July, and August) Due to Climate Change: Impact of Climate Change/Air Quality Model, for Each Population Projection

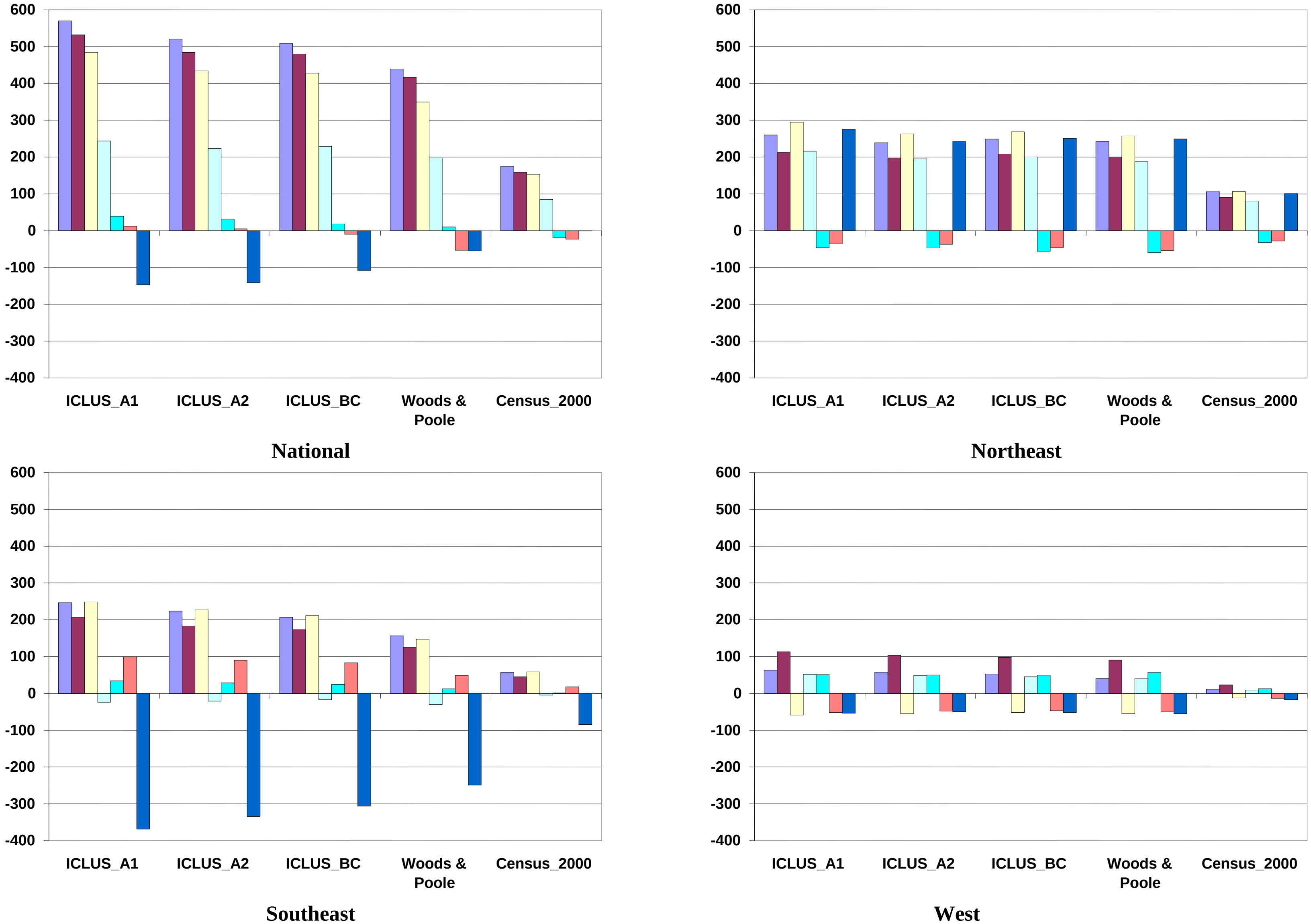
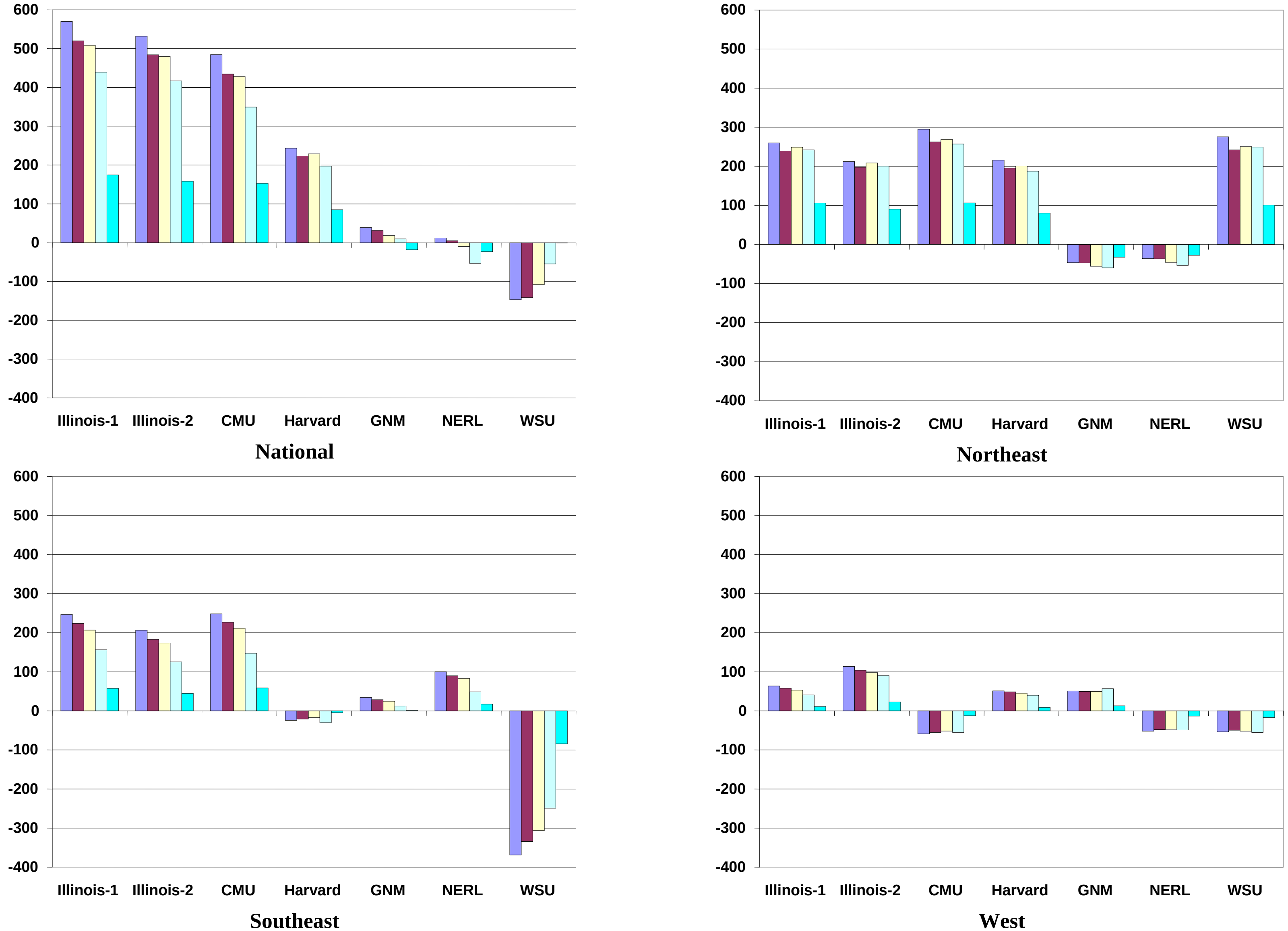


Figure 7-9. Estimated National and Regional O_3-Related Non-Accidental Mortality (Based on Bell et al., 2004) in 2050 O_3 Season (Defined as June, July, and August) Due to Climate Change: Impact of Population Projection, for Each Climate Change/Air Quality Model



All of the models show relatively small effects in the West. This is, in part, because the population in the West is smaller than the populations in the Northeast and Southeast. Using the ICLUS_A1 population projection, for example, the population in the West is only 58 percent of the population in the Northeast in 2050 and only 75 percent of the population in the Southeast. For some of the climate change/air quality models, the smaller magnitude of effects in the West is also due to smaller magnitude O_3 changes in the West. The CMU model, for example, simulated average increases in O_3 concentration in the Northeast and Southeast of about 2.3 and 2.2 ppb, respectively, whereas it simulated an average decrease in the West of about 0.8 ppb. In contrast, however, the GNM model simulates greater O_3-related adverse health effects in the West than in the Southeast, even given the smaller population – using the Woods & Poole population projection, Bell et al. (2004), and an O_3 season of June, July, and August, for example, the GNM model simulates 57 O_3-related deaths in the west due to climate change and only 13 in the southeast.

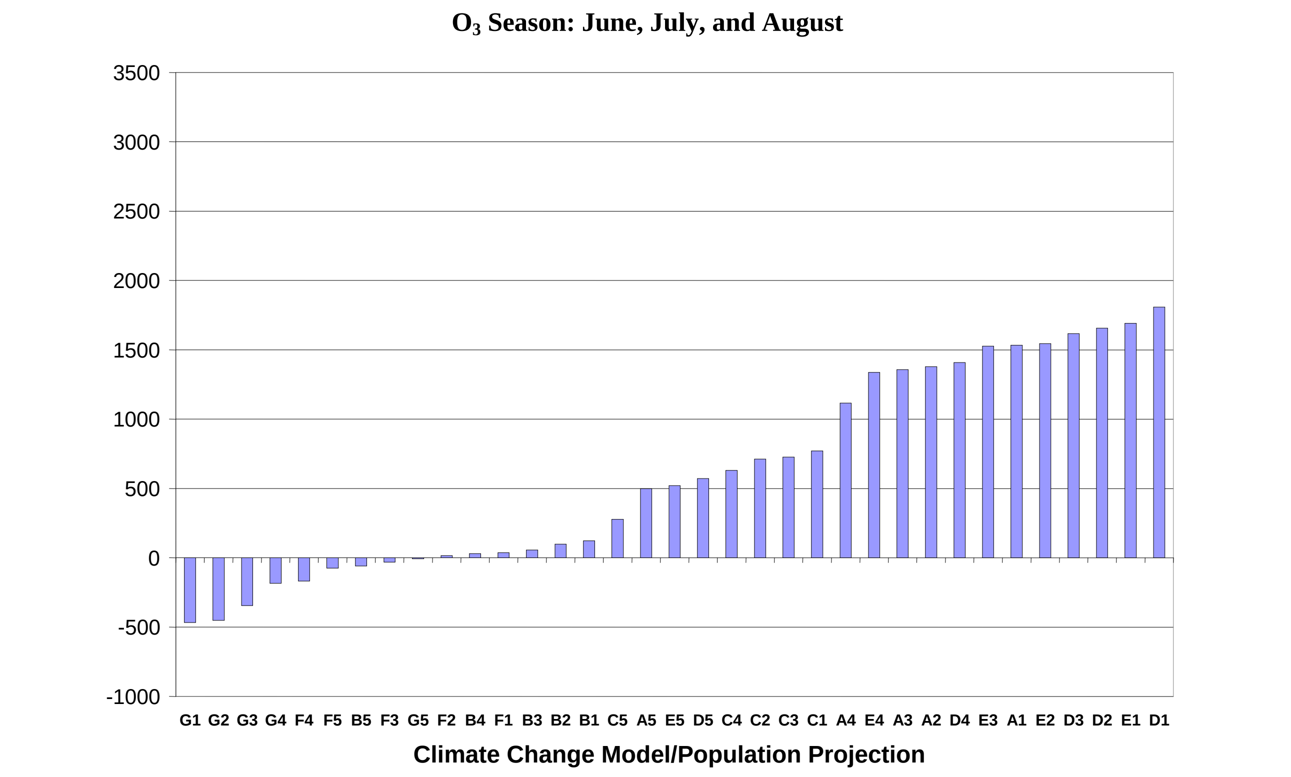
7.4. Extension of the O_3 Season

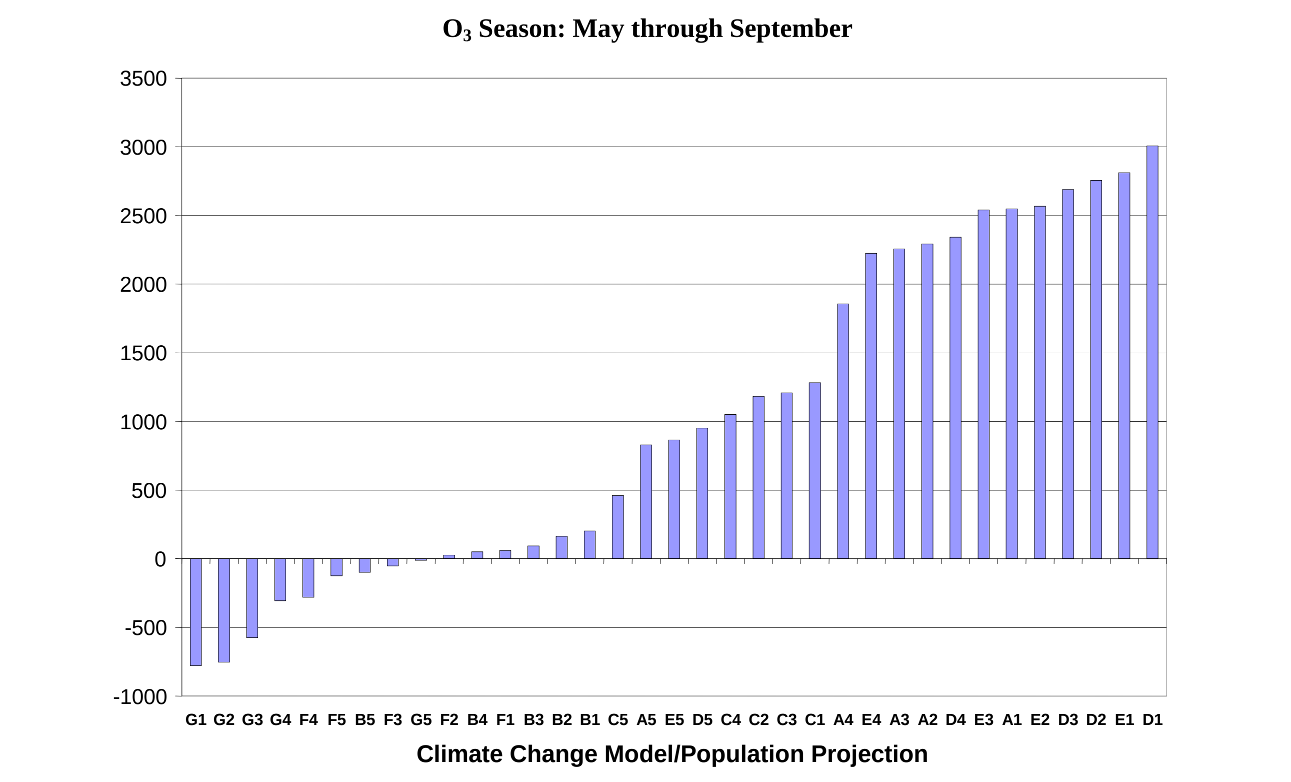
While the climate change/air quality models used in this analysis generally defined the O_3 season as June, July, and August, i.e., climatological summer in the Northern Hemisphere, most air pollution epidemiology studies focusing on O_3 have defined the season more broadly. The "expanded" O_3 season of May through September is actually more consistent with the current understanding of the O_3 season in most locations in the United States.[38] By including only the three summer months in their modeling of climate change-induced O_3 changes, the climate change/air quality modeling efforts considered here may thus have understated the potential O_3-related human health impacts of climate change. A few of the modeling groups have also investigated climate-induced changes in the spring and fall and found a response similar to that in the summer (e.g., see Nolte et al., 2008; Chen et al., 2009; Racherla and Adams, 2008). Therefore, here we estimate the sensitivity of the results to an alternate O_3 season definition.

We expand the O_3 season from June, July, and August to May through September simply by increasing all results by 66 percent, reflecting the facts that there are 92 days in June, July, and August and 153 days in May through September and that we applied a seasonal average (based on June, July, and August) of daily 8-hour maxima to each day in the O_3 season. The contrast in estimated O_3-related human health impacts is illustrated for all-cause mortality in Figure 7-10. This result shows that a longer O_3 season has the potential to significantly increase the incidence of adverse health outcomes associated with climate change. Whether climate change, in general, has the potential to increase the O_3 season beyond is an area that warrants further research.

[38] The O_3 season actually varies somewhat geographically. In some locations – e.g., Los Angeles and Houston – it is considered to be all year.

Figure 7-10. Estimated National O_3-Related Cases of All-Cause Mortality in 2050 O_3 Season (Bell et al., 2005) Due to Climate Change: Impact of O_3 Season Definition





7.5. Conclusions

How important are the projected O_3-related adverse health effects of climate change? Are more O_3-related premature deaths likely to be caused by climate change than would be avoided as a result of implementing more stringent O_3 NAAQS? A comparison of our results to the results obtained in the benefit analysis for the most recent O_3 NAAQS RIA (U.S. EPA, 2008b) may help put our results in perspective.[39] Because we used the suite of C-R functions used in the O_3 NAAQS RIA benefit analysis, such a comparison is relatively straightforward, although there are two notable differences between our analysis and that analysis to keep in mind. First, our analysis defined the O_3 season as either June, July, and August or May through September, whereas the benefit analysis for the O_3 NAAQS RIA defined the O_3 season as May through September.[40] Second, the change in O_3 concentrations in our analysis is from a baseline of O_3 concentrations in the absence of climate change, making no assumption about whether or not the current O_3 NAAQS have been attained. In the benefit analysis for the most recent O_3 NAAQS RIA, the results that are reported if alternative standards are just met are *incremental* to the current standard – i.e., the baseline is a scenario in which the current standard is just met.

With those differences in mind, we used Bell et al. (2004) to compare our results to those in the O_3 NAAQS RIA benefit analysis. Because that analysis defined the O_3 season as May through September, we used our results based on the “expanded” O_3 season rather than the shorter season of June, July, and August for the comparison. Using Bell et al. (2004), the O_3 NAAQS RIA benefit analysis estimated that national full attainment of standards set at 0.079, 0.075, 0.070, and 0.065 ppm would result in 24, 71, 250, and 450 premature non-accidental deaths avoided, respectively (see U.S. EPA, 2008b, Tables 6-18, 6-14, 6-10, and 6-6). All of these estimates are contained within the broader range of results, based on the same study, produced in our analysis. Three of the models (Illinois-1, Illinois-2, and CMU) produced results (using Bell et al., 2004) all of which were greater in magnitude than the estimates of premature deaths avoided if each of the alternative O_3 NAAQS were just met – results from these models range from about 950 to about 580 premature deaths attributable to climate change.[41] Other models (NERL) produced results under 10 in absolute value. It is not surprising that the results produced in our analysis encompass and extend beyond those produced in the O_3 NAAQS RIA benefit analysis, since there is substantial additional uncertainty introduced into our analysis by the climate change models.

What does all of this mean? Recalling the purpose of this report, we have attempted to assess the sensitivity of modeled human health impacts to assumptions about the following key inputs:

- Climate-induced changes in meteorological conditions;

[39] In the O_3 NAAQS RIA benefit analysis O_3 concentrations are largely decreasing as a result of alternative (more stringent) standards being met, so the estimated changes in health effects are numbers of cases *avoided* as a result of these alternative standards being just met. In our analysis, in contrast, O_3 concentrations are increasing in most (but not all) of the scenarios considered as a result of climate change, so the estimated changes in health effects are largely numbers of cases *attributable to* climate change. However, it is reasonable to compare the magnitudes of estimates – i.e., we can compare the absolute values of our estimates to those of the O_3 NAAQS RIA benefit analysis.
[40] Personal communication with Neal Fann, EPA/OAQPS, on September 24, 2009.
[41] Estimates based on Census_2000 were included in our analysis largely to illustrate the importance of projecting the population to a future year. These estimates thus have a substantial downward bias, and are therefore omitted from the comparisons discussed here.

- Corresponding changes in O_3 concentrations;
- The size and geographic distribution of the affected population;
- The relationships that link O_3 levels to specific health outcomes;
- The fraction of the year over which O_3 is assumed to affect health.

Given this context, we can draw the following conclusions:

- Looking across all combinations of climate change/air quality models, population projections, O_3 season definitions, and C-R functions for all-cause mortality considered in our analysis, estimates of national O_3-related all-cause mortality around 2050 attributable to climate change span a range of over 5000, i.e., from roughly -1000 to +4200. Despite this range, the large preponderance of the estimates are positive, suggesting that, all else being equal, climate change would be likely to increase the incidence of O_3-related all-cause premature mortality in 2050.
- The source of the greatest uncertainty at the national level appears to be the particular climate change/air quality scenario used.
- The choice of population projection also made a significant difference, although only about half that of climate change/air quality scenario at the national level.
- It is important to take into account that the size of the population exposed to O_3 will increase by a future year. Failing to do so may result in substantially downward biased estimates of future O_3-related adverse health impacts of climate change.
- Not only is the total population exposed to O_3 in a future year important, but the age (and geographic) distribution of that population can also make a significant difference in the estimated impact of climate change on O_3-related adverse health effects (e.g., the difference in ICLUS_A1 and ICLUS_A2 results discussed above).
- The national results can mask important regional differences. The Northeast showed the greatest agreement (of generally adverse health impacts associated with climate-induced O_3 increases) across the seven climate/air quality scenarios used in this study, while the Southeast showed large disagreements in health impacts across the different scenarios. The West generally showed the smallest impacts, largely due to the smaller projected populations compared to the Northeast and Southeast.
- A climate-induced extension of the O_3 season later into the fall and earlier into the spring has the potential to significantly increase the incidence of negative health outcomes.

At this stage in the development of our scientific understanding of climate change and its potential impact on air pollution-related human health, it would be unwise to rely on any one model or any one population projection. This may be the most important "take away" message of our analysis. The different model combinations can produce widely varying results, particularly at the regional level, in some cases leading to fundamentally different conclusions about the overall impact of climate change on O3-related health effects. This has a number of implications for the development of meaningful analyses to assess the range of benefits associated with responses to climate change.

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APPENDIX A:
TABLES OF RESULTS

Table A-1. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al.(2005)	CMU	ICLUS_A1	1530 (530 - 2540)	930 (440 - 1420)	790 (380 - 1200)	-190 (-290 - -80)
Bell et al.(2005)	CMU	ICLUS_A2	1380 (470 - 2290)	830 (400 - 1270)	720 (340 - 1100)	-180 (-270 - -80)
Bell et al.(2005)	CMU	ICLUS_BC	1360 (470 - 2250)	850 (400 - 1300)	670 (320 - 1030)	-170 (-260 - -70)
Bell et al.(2005)	CMU	Woods & Poole	1120 (340 - 1890)	820 (390 - 1250)	480 (230 - 730)	-180 (-270 - -80)
Bell et al.(2005)	CMU	Census_2000	500 (190 - 800)	340 (160 - 530)	190 (90 - 300)	-40 (-60 - -20)
Bell et al.(2005)	GNM	ICLUS_A1	120 (-380 - 630)	-150 (-380 - 80)	110 (-40 - 260)	160 (40 - 280)
Bell et al.(2005)	GNM	ICLUS_A2	100 (-370 - 570)	-150 (-370 - 60)	90 (-50 - 230)	160 (40 - 270)
Bell et al.(2005)	GNM	ICLUS_BC	60 (-410 - 520)	-180 (-400 - 40)	80 (-50 - 210)	160 (40 - 270)
Bell et al.(2005)	GNM	Woods & Poole	30 (-410 - 470)	-190 (-410 - 30)	40 (-60 - 140)	180 (50 - 310)
Bell et al.(2005)	GNM	Census_2000	-60 (-220 - 100)	-110 (-200 - -10)	0 (-30 - 40)	40 (10 - 80)
Bell et al.(2005)	Harvard	ICLUS_A1	770 (110 - 1440)	680 (320 - 1050)	-80 (-250 - 100)	160 (40 - 280)
Bell et al.(2005)	Harvard	ICLUS_A2	710 (110 - 1320)	620 (290 - 950)	-70 (-230 - 90)	160 (40 - 270)
Bell et al.(2005)	Harvard	ICLUS_BC	730 (130 - 1320)	640 (290 - 980)	-50 (-200 - 90)	140 (40 - 250)
Bell et al.(2005)	Harvard	Woods & Poole	630 (70 - 1190)	600 (270 - 920)	-100 (-230 - 40)	130 (20 - 240)
Bell et al.(2005)	Harvard	Census_2000	280 (60 - 490)	260 (120 - 400)	-10 (-60 - 30)	30 (0 - 60)

Table A-1 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al.(2005)	Illinois-1	ICLUS_A1	1810 (800 - 2820)	820 (390 - 1250)	780 (370 - 1200)	200 (30 - 370)
Bell et al.(2005)	Illinois-1	ICLUS_A2	1660 (730 - 2590)	760 (360 - 1160)	710 (340 - 1090)	180 (30 - 340)
Bell et al.(2005)	Illinois-1	ICLUS_BC	1620 (710 - 2520)	790 (380 - 1200)	660 (310 - 1010)	170 (20 - 320)
Bell et al.(2005)	Illinois-1	Woods & Poole	1410 (600 - 2220)	770 (370 - 1180)	500 (240 - 770)	130 (-10 - 270)
Bell et al.(2005)	Illinois-1	Census_2000	570 (250 - 890)	340 (160 - 530)	190 (90 - 290)	40 (0 - 70)
Bell et al.(2005)	Illinois-2	ICLUS_A1	1690 (770 - 2610)	670 (310 - 1030)	660 (300 - 1010)	360 (160 - 560)
Bell et al.(2005)	Illinois-2	ICLUS_A2	1540 (710 - 2380)	630 (290 - 960)	580 (270 - 900)	330 (150 - 520)
Bell et al.(2005)	Illinois-2	ICLUS_BC	1530 (700 - 2360)	660 (310 - 1010)	550 (250 - 850)	310 (140 - 490)
Bell et al.(2005)	Illinois-2	Woods & Poole	1340 (610 - 2070)	640 (300 - 980)	410 (180 - 630)	290 (120 - 460)
Bell et al.(2005)	Illinois-2	Census_2000	520 (240 - 800)	290 (140 - 450)	150 (70 - 230)	80 (30 - 120)
Bell et al.(2005)	NERL	ICLUS_A1	40 (-510 - 580)	-120 (-330 - 100)	320 (110 - 530)	-160 (-290 - -40)
Bell et al.(2005)	NERL	ICLUS_A2	20 (-480 - 510)	-120 (-310 - 80)	290 (100 - 470)	-150 (-270 - -40)
Bell et al.(2005)	NERL	ICLUS_BC	-30 (-520 - 460)	-150 (-350 - 50)	260 (90 - 440)	-150 (-260 - -40)
Bell et al.(2005)	NERL	Woods & Poole	-170 (-610 - 270)	-170 (-370 - 30)	160 (40 - 280)	-160 (-280 - -40)
Bell et al.(2005)	NERL	Census_2000	-80 (-230 - 80)	-90 (-180 - -10)	60 (20 - 100)	-40 (-80 - -10)

Table A-1 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al.(2005)	WSU	ICLUS_A1	-470 (-1990 - 1060)	870 (350 - 1390)	-1170 (-1930 - -410)	-170 (-410 - 80)
Bell et al.(2005)	WSU	ICLUS_A2	-450 (-1830 - 930)	770 (300 - 1230)	-1060 (-1750 - -370)	-160 (-380 - 70)
Bell et al.(2005)	WSU	ICLUS_BC	-350 (-1680 - 990)	790 (320 - 1260)	-970 (-1610 - -340)	-160 (-390 - 60)
Bell et al.(2005)	WSU	Woods & Poole	-180 (-1400 - 1030)	790 (320 - 1260)	-800 (-1310 - -290)	-170 (-410 - 60)
Bell et al.(2005)	WSU	Census_2000	-10 (-440 - 430)	330 (130 - 520)	-280 (-460 - -100)	-50 (-120 - 10)
Levy et al.(2005)	CMU	ICLUS_A1	2160 (1310 - 3010)	1310 (900 - 1730)	1110 (760 - 1460)	-260 (-350 - -180)
Levy et al.(2005)	CMU	ICLUS_A2	1940 (1170 - 2720)	1170 (800 - 1540)	1020 (700 - 1340)	-250 (-330 - -170)
Levy et al.(2005)	CMU	ICLUS_BC	1910 (1160 - 2670)	1200 (820 - 1580)	950 (650 - 1250)	-230 (-310 - -160)
Levy et al.(2005)	CMU	Woods & Poole	1570 (920 - 2230)	1150 (790 - 1520)	670 (460 - 880)	-250 (-330 - -170)
Levy et al.(2005)	CMU	Census_2000	700 (440 - 960)	490 (330 - 640)	270 (190 - 360)	-60 (-80 - -40)
Levy et al.(2005)	GNM	ICLUS_A1	170 (-260 - 600)	-210 (-410 - -10)	150 (20 - 280)	230 (130 - 330)
Levy et al.(2005)	GNM	ICLUS_A2	140 (-260 - 530)	-210 (-390 - -30)	130 (10 - 240)	220 (130 - 320)
Levy et al.(2005)	GNM	ICLUS_BC	80 (-310 - 470)	-250 (-440 - -60)	110 (0 - 220)	220 (130 - 320)
Levy et al.(2005)	GNM	Woods & Poole	40 (-330 - 420)	-270 (-450 - -90)	60 (-30 - 140)	260 (150 - 360)
Levy et al.(2005)	GNM	Census_2000	-80 (-220 - 50)	-150 (-230 - -70)	10 (-30 - 40)	60 (30 - 90)

Table A-1 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Levy et al.(2005)	Harvard	ICLUS_A1	1090 (530 - 1650)	960 (650 - 1270)	-110 (-260 - 40)	230 (130 - 330)
Levy et al.(2005)	Harvard	ICLUS_A2	1000 (490 - 1520)	880 (590 - 1160)	-90 (-230 - 40)	220 (130 - 320)
Levy et al.(2005)	Harvard	ICLUS_BC	1020 (520 - 1530)	900 (610 - 1190)	-80 (-200 - 50)	200 (110 - 290)
Levy et al.(2005)	Harvard	Woods & Poole	890 (410 - 1370)	840 (570 - 1110)	-130 (-240 - -20)	180 (90 - 270)
Levy et al.(2005)	Harvard	Census_2000	390 (210 - 570)	370 (250 - 490)	-20 (-60 - 20)	40 (20 - 70)
Levy et al.(2005)	Illinois-1	ICLUS_A1	2550 (1690 - 3410)	1160 (800 - 1530)	1100 (750 - 1450)	290 (140 - 430)
Levy et al.(2005)	Illinois-1	ICLUS_A2	2340 (1550 - 3120)	1070 (730 - 1410)	1010 (690 - 1320)	260 (130 - 390)
Levy et al.(2005)	Illinois-1	ICLUS_BC	2280 (1510 - 3050)	1110 (760 - 1460)	930 (640 - 1220)	240 (110 - 360)
Levy et al.(2005)	Illinois-1	Woods & Poole	1990 (1300 - 2670)	1090 (750 - 1430)	710 (490 - 940)	190 (70 - 300)
Levy et al.(2005)	Illinois-1	Census_2000	810 (540 - 1080)	490 (330 - 640)	270 (180 - 350)	50 (20 - 80)
Levy et al.(2005)	Illinois-2	ICLUS_A1	2380 (1610 - 3160)	950 (650 - 1250)	920 (620 - 1230)	510 (340 - 680)
Levy et al.(2005)	Illinois-2	ICLUS_A2	2180 (1470 - 2890)	890 (600 - 1170)	820 (550 - 1090)	470 (310 - 630)
Levy et al.(2005)	Illinois-2	ICLUS_BC	2150 (1450 - 2860)	930 (640 - 1230)	780 (520 - 1030)	440 (290 - 590)
Levy et al.(2005)	Illinois-2	Woods & Poole	1890 (1270 - 2500)	900 (610 - 1190)	570 (380 - 760)	410 (270 - 560)
Levy et al.(2005)	Illinois-2	Census_2000	730 (500 - 970)	410 (280 - 550)	210 (140 - 280)	110 (70 - 150)

Table A-1 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Levy et al.(2005)	NERL	ICLUS_A1	50 (-410 - 510)	-160 (-340 - 20)	450 (270 - 620)	-230 (-340 - -130)
Levy et al.(2005)	NERL	ICLUS_A2	20 (-400 - 440)	-170 (-330 - 0)	400 (250 - 560)	-220 (-310 - -120)
Levy et al.(2005)	NERL	ICLUS_BC	-40 (-460 - 370)	-210 (-380 - -40)	370 (230 - 520)	-210 (-310 - -110)
Levy et al.(2005)	NERL	Woods & Poole	-240 (-610 - 130)	-240 (-410 - -70)	220 (120 - 320)	-220 (-320 - -120)
Levy et al.(2005)	NERL	Census_2000	-110 (-240 - 30)	-130 (-200 - -60)	80 (50 - 120)	-60 (-90 - -30)
Levy et al.(2005)	WSU	ICLUS_A1	-660 (-1950 - 630)	1220 (780 - 1670)	-1640 (-2290 - -1000)	-240 (-440 - -30)
Levy et al.(2005)	WSU	ICLUS_A2	-640 (-1800 - 530)	1080 (690 - 1470)	-1500 (-2080 - -910)	-220 (-410 - -30)
Levy et al.(2005)	WSU	ICLUS_BC	-490 (-1610 - 640)	1120 (710 - 1520)	-1370 (-1910 - -830)	-230 (-420 - -40)
Levy et al.(2005)	WSU	Woods & Poole	-260 (-1280 - 770)	1110 (710 - 1510)	-1130 (-1560 - -690)	-240 (-440 - -50)
Levy et al.(2005)	WSU	Census_2000	-10 (-380 - 360)	460 (300 - 620)	-390 (-550 - -240)	-80 (-130 - -20)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.

Table A-2. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al. (2004)	CMU	ICLUS_A1	480 (80 - 890)	290 (100 - 490)	250 (80 - 410)	-60 (-100 - -20)
Bell et al. (2004)	CMU	ICLUS_A2	430 (70 - 800)	260 (90 - 440)	230 (80 - 380)	-60 (-90 - -20)
Bell et al. (2004)	CMU	ICLUS_BC	430 (70 - 780)	270 (90 - 450)	210 (70 - 350)	-50 (-90 - -20)
Bell et al. (2004)	CMU	Woods & Poole	350 (40 - 660)	260 (80 - 430)	150 (50 - 250)	-50 (-90 - -20)
Bell et al. (2004)	CMU	Census_2000	150 (30 - 270)	110 (40 - 180)	60 (20 - 100)	-10 (-20 - 0)
Bell et al. (2004)	GNM	ICLUS_A1	40 (-160 - 240)	-50 (-140 - 50)	30 (-30 - 100)	50 (0 - 100)
Bell et al. (2004)	GNM	ICLUS_A2	30 (-160 - 220)	-50 (-130 - 40)	30 (-30 - 80)	50 (0 - 100)
Bell et al. (2004)	GNM	ICLUS_BC	20 (-170 - 210)	-60 (-150 - 30)	20 (-30 - 80)	50 (0 - 100)
Bell et al. (2004)	GNM	Woods & Poole	10 (-170 - 190)	-60 (-150 - 30)	10 (-30 - 50)	60 (10 - 110)
Bell et al. (2004)	GNM	Census_2000	-20 (-80 - 50)	-30 (-70 - 0)	0 (-10 - 20)	10 (0 - 30)
Bell et al. (2004)	Harvard	ICLUS_A1	240 (-20 - 510)	220 (70 - 360)	-20 (-90 - 50)	50 (0 - 100)
Bell et al. (2004)	Harvard	ICLUS_A2	220 (-20 - 470)	200 (60 - 330)	-20 (-80 - 40)	50 (0 - 90)
Bell et al. (2004)	Harvard	ICLUS_BC	230 (-10 - 470)	200 (60 - 340)	-20 (-80 - 40)	50 (0 - 90)
Bell et al. (2004)	Harvard	Woods & Poole	200 (-30 - 420)	190 (60 - 320)	-30 (-80 - 20)	40 (0 - 80)
Bell et al. (2004)	Harvard	Census_2000	80 (0 - 170)	80 (30 - 140)	0 (-20 - 10)	10 (0 - 20)

Table A-2 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al. (2004)	Illinois-1	ICLUS_A1	570 (160 - 980)	260 (90 - 430)	250 (80 - 410)	60 (0 - 130)
Bell et al. (2004)	Illinois-1	ICLUS_A2	520 (150 - 890)	240 (80 - 400)	220 (70 - 370)	60 (0 - 120)
Bell et al. (2004)	Illinois-1	ICLUS_BC	510 (150 - 870)	250 (80 - 410)	210 (70 - 350)	50 (-10 - 110)
Bell et al. (2004)	Illinois-1	Woods & Poole	440 (120 - 760)	240 (80 - 400)	160 (50 - 260)	40 (-10 - 100)
Bell et al. (2004)	Illinois-1	Census_2000	170 (50 - 300)	110 (40 - 180)	60 (20 - 100)	10 (0 - 30)
Bell et al. (2004)	Illinois-2	ICLUS_A1	530 (160 - 900)	210 (70 - 360)	210 (60 - 350)	110 (30 - 190)
Bell et al. (2004)	Illinois-2	ICLUS_A2	480 (150 - 820)	200 (60 - 330)	180 (60 - 310)	100 (30 - 180)
Bell et al. (2004)	Illinois-2	ICLUS_BC	480 (150 - 810)	210 (70 - 350)	170 (50 - 290)	100 (30 - 170)
Bell et al. (2004)	Illinois-2	Woods & Poole	420 (130 - 710)	200 (60 - 340)	130 (40 - 210)	90 (20 - 160)
Bell et al. (2004)	Illinois-2	Census_2000	160 (50 - 270)	90 (30 - 150)	50 (10 - 80)	20 (10 - 40)
Bell et al. (2004)	NERL	ICLUS_A1	10 (-210 - 230)	-40 (-120 - 50)	100 (20 - 180)	-50 (-100 - 0)
Bell et al. (2004)	NERL	ICLUS_A2	10 (-190 - 200)	-40 (-120 - 40)	90 (20 - 160)	-50 (-90 - 0)
Bell et al. (2004)	NERL	ICLUS_BC	-10 (-210 - 190)	-50 (-130 - 40)	80 (10 - 150)	-50 (-90 - 0)
Bell et al. (2004)	NERL	Woods & Poole	-50 (-230 - 120)	-50 (-130 - 30)	50 (0 - 100)	-50 (-100 - 0)
Bell et al. (2004)	NERL	Census_2000	-20 (-90 - 40)	-30 (-60 - 10)	20 (0 - 30)	-10 (-30 - 0)

Table A-2 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al. (2004)	WSU	ICLUS_A1	-150 (-760 - 470)	280 (70 - 490)	-370 (-670 - -60)	-50 (-150 - 40)
Bell et al. (2004)	WSU	ICLUS_A2	-140 (-700 - 410)	240 (60 - 430)	-330 (-610 - -60)	-50 (-140 - 40)
Bell et al. (2004)	WSU	ICLUS_BC	-110 (-640 - 430)	250 (60 - 440)	-310 (-560 - -50)	-50 (-140 - 40)
Bell et al. (2004)	WSU	Woods & Poole	-60 (-540 - 430)	250 (60 - 440)	-250 (-450 - -50)	-60 (-150 - 40)
Bell et al. (2004)	WSU	Census_2000	0 (-170 - 170)	100 (30 - 180)	-80 (-150 - -10)	-20 (-40 - 10)
Ito et al. (2005)	CMU	ICLUS_A1	2180 (1090 - 3270)	1320 (790 - 1860)	1120 (670 - 1560)	-260 (-370 - -150)
Ito et al. (2005)	CMU	ICLUS_A2	1950 (970 - 2940)	1180 (710 - 1650)	1020 (610 - 1430)	-250 (-350 - -140)
Ito et al. (2005)	CMU	ICLUS_BC	1920 (960 - 2890)	1210 (720 - 1690)	950 (570 - 1330)	-230 (-330 - -130)
Ito et al. (2005)	CMU	Woods & Poole	1570 (740 - 2410)	1160 (690 - 1620)	660 (400 - 930)	-250 (-350 - -140)
Ito et al. (2005)	CMU	Census_2000	690 (370 - 1010)	480 (290 - 670)	260 (160 - 370)	-50 (-80 - -30)
Ito et al. (2005)	GNM	ICLUS_A1	180 (-370 - 720)	-210 (-460 - 40)	150 (-10 - 320)	230 (100 - 360)
Ito et al. (2005)	GNM	ICLUS_A2	140 (-360 - 650)	-210 (-440 - 20)	130 (-20 - 280)	220 (100 - 350)
Ito et al. (2005)	GNM	ICLUS_BC	80 (-420 - 590)	-250 (-490 - -10)	110 (-30 - 250)	220 (100 - 350)
Ito et al. (2005)	GNM	Woods & Poole	50 (-430 - 520)	-270 (-500 - -30)	60 (-50 - 160)	260 (120 - 390)
Ito et al. (2005)	GNM	Census_2000	-80 (-250 - 90)	-150 (-250 - -50)	0 (-30 - 40)	60 (30 - 90)

Table A-2 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ito et al. (2005)	Harvard	ICLUS_A1	1090 (370 - 1810)	970 (570 - 1370)	-110 (-300 - 80)	230 (100 - 360)
Ito et al. (2005)	Harvard	ICLUS_A2	1000 (350 - 1660)	880 (520 - 1240)	-90 (-260 - 80)	220 (100 - 340)
Ito et al. (2005)	Harvard	ICLUS_BC	1030 (380 - 1670)	900 (530 - 1270)	-80 (-230 - 80)	200 (90 - 320)
Ito et al. (2005)	Harvard	Woods & Poole	890 (280 - 1490)	840 (490 - 1190)	-130 (-270 - 10)	180 (70 - 290)
Ito et al. (2005)	Harvard	Census_2000	380 (160 - 610)	360 (210 - 510)	-20 (-70 - 30)	40 (10 - 70)
Ito et al. (2005)	Illinois-1	ICLUS_A1	2560 (1470 - 3660)	1170 (700 - 1630)	1110 (660 - 1550)	290 (100 - 470)
Ito et al. (2005)	Illinois-1	ICLUS_A2	2340 (1340 - 3340)	1070 (640 - 1500)	1010 (600 - 1410)	260 (90 - 430)
Ito et al. (2005)	Illinois-1	ICLUS_BC	2280 (1310 - 3260)	1120 (670 - 1570)	930 (560 - 1300)	240 (80 - 390)
Ito et al. (2005)	Illinois-1	Woods & Poole	1970 (1110 - 2840)	1090 (650 - 1520)	700 (420 - 990)	180 (40 - 330)
Ito et al. (2005)	Illinois-1	Census_2000	780 (450 - 1120)	480 (290 - 670)	260 (150 - 360)	50 (10 - 90)
Ito et al. (2005)	Illinois-2	ICLUS_A1	2390 (1400 - 3390)	950 (560 - 1340)	930 (540 - 1310)	510 (290 - 730)
Ito et al. (2005)	Illinois-2	ICLUS_A2	2180 (1270 - 3080)	890 (520 - 1250)	820 (480 - 1170)	470 (270 - 670)
Ito et al. (2005)	Illinois-2	ICLUS_BC	2160 (1260 - 3050)	940 (550 - 1320)	780 (460 - 1100)	440 (250 - 630)
Ito et al. (2005)	Illinois-2	Woods & Poole	1870 (1090 - 2650)	900 (530 - 1270)	560 (330 - 800)	410 (230 - 590)
Ito et al. (2005)	Illinois-2	Census_2000	710 (420 - 1010)	410 (240 - 570)	200 (120 - 290)	100 (60 - 150)

Table A-2 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ito et al. (2005)	NERL	ICLUS_A1	50 (-540 - 650)	-160 (-390 - 70)	450 (230 - 680)	-230 (-370 - -100)
Ito et al. (2005)	NERL	ICLUS_A2	20 (-510 - 560)	-160 (-380 - 50)	400 (200 - 610)	-220 (-340 - -90)
Ito et al. (2005)	NERL	ICLUS_BC	-40 (-570 - 480)	-210 (-420 - 10)	370 (190 - 560)	-210 (-330 - -90)
Ito et al. (2005)	NERL	Woods & Poole	-240 (-710 - 230)	-240 (-460 - -20)	220 (90 - 350)	-220 (-350 - -90)
Ito et al. (2005)	NERL	Census_2000	-100 (-270 - 60)	-120 (-210 - -40)	80 (40 - 120)	-60 (-90 - -30)
Ito et al. (2005)	WSU	ICLUS_A1	-650 (-2300 - 1000)	1240 (670 - 1810)	-1650 (-2470 - -830)	-240 (-500 - 20)
Ito et al. (2005)	WSU	ICLUS_A2	-630 (-2120 - 870)	1090 (590 - 1590)	-1500 (-2240 - -750)	-220 (-470 - 20)
Ito et al. (2005)	WSU	ICLUS_BC	-480 (-1920 - 960)	1130 (610 - 1640)	-1370 (-2050 - -680)	-230 (-470 - 10)
Ito et al. (2005)	WSU	Woods & Poole	-240 (-1540 - 1060)	1120 (610 - 1630)	-1110 (-1650 - -570)	-250 (-500 - 0)
Ito et al. (2005)	WSU	Census_2000	0 (-460 - 460)	450 (250 - 660)	-380 (-570 - -190)	-80 (-140 - -10)
Schwartz (2005)	CMU	ICLUS_A1	730 (100 - 1370)	450 (140 - 760)	370 (120 - 630)	-90 (-150 - -20)
Schwartz (2005)	CMU	ICLUS_A2	660 (80 - 1230)	400 (120 - 670)	340 (110 - 580)	-80 (-150 - -20)
Schwartz (2005)	CMU	ICLUS_BC	650 (90 - 1210)	410 (130 - 690)	320 (100 - 540)	-80 (-140 - -20)
Schwartz (2005)	CMU	Woods & Poole	540 (50 - 1030)	390 (120 - 670)	230 (70 - 380)	-80 (-150 - -20)
Schwartz (2005)	CMU	Census_2000	240 (50 - 430)	160 (50 - 280)	90 (30 - 150)	-20 (-30 - 0)

Table A-2 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (2005)	GNM	ICLUS_A1	60 (-260 - 380)	-70 (-220 - 80)	50 (-40 - 150)	80 (0 - 160)
Schwartz (2005)	GNM	ICLUS_A2	50 (-250 - 340)	-70 (-210 - 60)	40 (-40 - 130)	80 (0 - 150)
Schwartz (2005)	GNM	ICLUS_BC	30 (-270 - 320)	-90 (-230 - 50)	40 (-40 - 120)	80 (0 - 150)
Schwartz (2005)	GNM	Woods & Poole	20 (-260 - 300)	-90 (-230 - 50)	20 (-40 - 80)	90 (10 - 170)
Schwartz (2005)	GNM	Census_2000	-30 (-130 - 70)	-50 (-110 - 10)	0 (-20 - 20)	20 (0 - 40)
Schwartz (2005)	Harvard	ICLUS_A1	370 (-50 - 790)	330 (100 - 560)	-40 (-150 - 70)	80 (0 - 150)
Schwartz (2005)	Harvard	ICLUS_A2	340 (-40 - 720)	300 (90 - 510)	-30 (-130 - 70)	70 (0 - 150)
Schwartz (2005)	Harvard	ICLUS_BC	350 (-30 - 720)	300 (90 - 520)	-30 (-120 - 70)	70 (0 - 140)
Schwartz (2005)	Harvard	Woods & Poole	300 (-50 - 660)	290 (80 - 490)	-50 (-130 - 40)	60 (-10 - 130)
Schwartz (2005)	Harvard	Census_2000	130 (0 - 270)	120 (40 - 210)	-10 (-40 - 20)	10 (0 - 30)
Schwartz (2005)	Illinois-1	ICLUS_A1	860 (230 - 1500)	390 (120 - 670)	370 (110 - 630)	100 (-10 - 200)
Schwartz (2005)	Illinois-1	ICLUS_A2	790 (210 - 1370)	360 (110 - 610)	340 (100 - 570)	90 (-10 - 180)
Schwartz (2005)	Illinois-1	ICLUS_BC	770 (200 - 1340)	380 (120 - 640)	310 (100 - 530)	80 (-10 - 170)
Schwartz (2005)	Illinois-1	Woods & Poole	670 (160 - 1180)	370 (120 - 630)	240 (70 - 410)	60 (-20 - 150)
Schwartz (2005)	Illinois-1	Census_2000	270 (70 - 470)	160 (50 - 280)	90 (30 - 150)	20 (-10 - 40)

Table A-2 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (2005)	Illinois-2	ICLUS_A1	810 (230 - 1380)	320 (100 - 550)	310 (90 - 530)	170 (50 - 300)
Schwartz (2005)	Illinois-2	ICLUS_A2	730 (210 - 1260)	300 (90 - 510)	280 (80 - 470)	160 (40 - 270)
Schwartz (2005)	Illinois-2	ICLUS_BC	730 (210 - 1250)	320 (90 - 540)	260 (70 - 450)	150 (40 - 260)
Schwartz (2005)	Illinois-2	Woods & Poole	640 (180 - 1100)	310 (90 - 520)	190 (50 - 330)	140 (30 - 240)
Schwartz (2005)	Illinois-2	Census_2000	250 (70 - 420)	140 (40 - 240)	70 (20 - 120)	40 (10 - 60)
Schwartz (2005)	NERL	ICLUS_A1	20 (-330 - 360)	-60 (-190 - 80)	150 (20 - 280)	-80 (-160 - 0)
Schwartz (2005)	NERL	ICLUS_A2	10 (-310 - 320)	-60 (-180 - 70)	140 (20 - 250)	-70 (-150 - 0)
Schwartz (2005)	NERL	ICLUS_BC	-20 (-320 - 290)	-70 (-200 - 60)	130 (20 - 230)	-70 (-140 - 0)
Schwartz (2005)	NERL	Woods & Poole	-80 (-360 - 200)	-80 (-210 - 40)	80 (0 - 150)	-70 (-150 - 0)
Schwartz (2005)	NERL	Census_2000	-40 (-140 - 60)	-40 (-100 - 10)	30 (0 - 50)	-20 (-40 - 0)
Schwartz (2005)	WSU	ICLUS_A1	-220 (-1180 - 740)	420 (90 - 750)	-560 (-1030 - -80)	-80 (-240 - 70)
Schwartz (2005)	WSU	ICLUS_A2	-210 (-1080 - 660)	370 (80 - 660)	-510 (-940 - -70)	-80 (-220 - 70)
Schwartz (2005)	WSU	ICLUS_BC	-160 (-1000 - 680)	380 (80 - 680)	-460 (-860 - -60)	-80 (-220 - 60)
Schwartz (2005)	WSU	Woods & Poole	-90 (-850 - 680)	380 (80 - 680)	-380 (-700 - -60)	-80 (-230 - 60)
Schwartz (2005)	WSU	Census_2000	0 (-270 - 270)	160 (40 - 280)	-130 (-240 - -20)	-30 (-60 - 10)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.

Table A-3. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Ages 65 and Up) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (1995); Schwartz (1994a); Moolgavkar et al. (1997); Schwartz (1994b); Moolgavkar et al. (1997)	CMU	ICLUS_A1	5190 (-400 - 13460)	3220 (160 - 8160)	2510 (130 - 6460)	-530 (-1340 - -10)
	CMU	ICLUS_A2	4630 (-390 - 12010)	2850 (140 - 7220)	2280 (120 - 5870)	-490 (-1260 - -10)
	CMU	ICLUS_BC	4580 (-350 - 11860)	2920 (150 - 7400)	2130 (110 - 5490)	-460 (-1180 - -10)
	CMU	Woods & Poole	3880 (-430 - 10150)	2850 (140 - 7280)	1520 (80 - 3950)	-490 (-1240 - -10)
	CMU	Census_2000	1670 (-60 - 4360)	1200 (60 - 3090)	580 (30 - 1510)	-110 (-290 - 0)
	GNM	ICLUS_A1	300 (-1760 - 2390)	-570 (-1690 - 550)	390 (-310 - 1070)	470 (-90 - 970)
	GNM	ICLUS_A2	220 (-1680 - 2130)	-570 (-1610 - 470)	330 (-290 - 930)	460 (-20 - 940)
	GNM	ICLUS_BC	80 (-1840 - 1970)	-670 (-1760 - 440)	290 (-290 - 850)	460 (-80 - 970)
	GNM	Woods & Poole	10 (-2100 - 2410)	-710 (-2140 - 400)	170 (-270 - 730)	550 (-70 - 1590)
	GNM	Census_2000	-250 (-1120 - 490)	-400 (-1070 - 120)	20 (-130 - 220)	130 (-20 - 350)
	Harvard	ICLUS_A1	2530 (-920 - 6560)	2440 (90 - 6040)	-370 (-1370 - 460)	460 (-90 - 1200)
	Harvard	ICLUS_A2	2320 (-820 - 5990)	2200 (80 - 5430)	-320 (-1220 - 420)	440 (-80 - 1140)
	Harvard	ICLUS_BC	2410 (-740 - 6180)	2270 (90 - 5600)	-270 (-1100 - 410)	410 (-80 - 1070)
	Harvard	Woods & Poole	2130 (-830 - 5540)	2180 (70 - 5410)	-420 (-1180 - 250)	380 (-110 - 990)
	Harvard	Census_2000	940 (-220 - 2440)	950 (30 - 2370)	-90 (-360 - 120)	90 (-30 - 230)

Table A-3 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Ages 65 and Up) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (1995); Schwartz (1994a); Moolgavkar et al. (1997); Schwartz (1994b); Moolgavkar et al. (1997)	Illinois-1	ICLUS_A1	6050 (90 - 15300)	2910 (150 - 7200)	2580 (120 - 6630)	560 (-180 - 1470)
	Illinois-1	ICLUS_A2	5500 (80 - 13910)	2660 (140 - 6590)	2330 (110 - 5980)	510 (-170 - 1340)
	Illinois-1	ICLUS_BC	5410 (70 - 13660)	2780 (150 - 6880)	2150 (100 - 5540)	470 (-170 - 1240)
	Illinois-1	Woods & Poole	4850 (0 - 12320)	2780 (140 - 6920)	1710 (80 - 4410)	360 (-220 - 990)
	Illinois-1	Census_2000	1940 (40 - 4950)	1240 (60 - 3110)	600 (30 - 1560)	100 (-50 - 280)
	Illinois-2	ICLUS_A1	5650 (180 - 14170)	2450 (100 - 5960)	2180 (60 - 5610)	1020 (10 - 2600)
	Illinois-2	ICLUS_A2	5120 (160 - 12840)	2270 (100 - 5520)	1920 (50 - 4940)	930 (10 - 2380)
	Illinois-2	ICLUS_BC	5110 (160 - 12790)	2410 (110 - 5840)	1820 (50 - 4690)	890 (10 - 2260)
	Illinois-2	Woods & Poole	4630 (140 - 11610)	2400 (110 - 5860)	1410 (40 - 3640)	830 (-10 - 2110)
	Illinois-2	Census_2000	1780 (60 - 4490)	1090 (50 - 2710)	470 (10 - 1230)	220 (0 - 560)
	NERL	ICLUS_A1	70 (-2150 - 2340)	-440 (-1490 - 550)	950 (-130 - 2420)	-450 (-1120 - 100)
	NERL	ICLUS_A2	10 (-2040 - 2060)	-470 (-1480 - 480)	930 (10 - 2350)	-450 (-1140 - 30)
	NERL	ICLUS_BC	-140 (-2770 - 2610)	-600 (-2250 - 740)	940 (10 - 2880)	-480 (-1520 - 40)
	NERL	Woods & Poole	-620 (-2960 - 1350)	-670 (-1820 - 350)	510 (-90 - 1420)	-460 (-1250 - 30)
	NERL	Census_2000	-310 (-1140 - 410)	-350 (-940 - 110)	170 (-40 - 470)	-130 (-340 - 20)

Table A-3 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Ages 65 and Up) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (1995); Schwartz (1994a); Moolgavkar et al. (1997); Schwartz (1994b); Moolgavkar et al. (1997)	WSU	ICLUS_A1	-1480 (-8380 - 5060)	3050 (-110 - 7740)	-4030 (-10240 - 350)	-500 (-1610 - 490)
	WSU	ICLUS_A2	-1420 (-7750 - 4460)	2670 (-110 - 6770)	-3630 (-9230 - 320)	-460 (-1490 - 460)
	WSU	ICLUS_BC	-1050 (-6720 - 4590)	2770 (-100 - 7000)	-3340 (-8460 - 300)	-490 (-1500 - 430)
	WSU	Woods & Poole	-650 (-6570 - 4570)	2810 (-100 - 7440)	-2930 (-7760 - 180)	-540 (-1590 - 440)
	WSU	Census_2000	30 (-1810 - 1920)	990 (-30 - 2170)	-820 (-1870 - 70)	-140 (-410 - 100)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.
**These studies were pooled to estimate respiratory hospital admissions for ages 65 and up.

Table A-4. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Age < 1) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Burnett et al. (2001)	CMU	ICLUS_A1	1250 (290 - 2220)	830 (350 - 1310)	630 (270 - 1000)	-210 (-330 - -80)
	CMU	ICLUS_A2	2060 (450 - 3700)	1370 (580 - 2160)	1070 (460 - 1690)	-370 (-590 - -150)
	CMU	ICLUS_BC	1550 (340 - 2770)	1040 (440 - 1640)	780 (340 - 1240)	-270 (-440 - -110)
	CMU	Woods & Poole	1830 (390 - 3280)	1110 (470 - 1750)	1050 (450 - 1670)	-340 (-530 - -140)
	CMU	Census_2000	1290 (330 - 2260)	880 (370 - 1390)	600 (250 - 940)	-190 (-300 - -70)
	GNM	ICLUS_A1	190 (-350 - 730)	-160 (-380 - 70)	110 (-30 - 260)	230 (60 - 400)
	GNM	ICLUS_A2	310 (-630 - 1250)	-290 (-680 - 100)	180 (-70 - 430)	420 (120 - 720)
	GNM	ICLUS_BC	200 (-500 - 910)	-230 (-530 - 60)	130 (-60 - 310)	310 (90 - 540)
	GNM	Woods & Poole	170 (-630 - 980)	-280 (-610 - 40)	130 (-100 - 360)	330 (80 - 570)
	GNM	Census_2000	10 (-540 - 570)	-250 (-520 - 10)	50 (-80 - 180)	220 (60 - 380)
	Harvard	ICLUS_A1	710 (50 - 1390)	620 (260 - 980)	-80 (-250 - 80)	180 (40 - 320)
	Harvard	ICLUS_A2	1230 (100 - 2380)	1040 (430 - 1660)	-130 (-400 - 140)	320 (70 - 580)
	Harvard	ICLUS_BC	940 (90 - 1790)	790 (330 - 1260)	-90 (-290 - 110)	240 (50 - 430)
	Harvard	Woods & Poole	1100 (110 - 2090)	890 (370 - 1410)	-60 (-310 - 190)	270 (40 - 490)
	Harvard	Census_2000	820 (160 - 1490)	680 (280 - 1090)	-20 (-140 - 110)	160 (30 - 290)

Table A-4 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Age < 1) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Burnett et al. (2001)	Illinois-1	ICLUS_A1	1570 (580 - 2560)	740 (320 - 1170)	640 (270 - 1020)	180 (-10 - 380)
	Illinois-1	ICLUS_A2	2650 (980 - 4350)	1270 (540 - 2010)	1070 (450 - 1690)	310 (-20 - 640)
	Illinois-1	ICLUS_BC	1990 (730 - 3260)	970 (420 - 1540)	780 (330 - 1240)	230 (-10 - 480)
	Illinois-1	Woods & Poole	2350 (860 - 3860)	1100 (470 - 1740)	990 (420 - 1570)	260 (-30 - 560)
	Illinois-1	Census_2000	1600 (600 - 2610)	880 (370 - 1380)	560 (240 - 880)	160 (-10 - 340)
	Illinois-2	ICLUS_A1	1610 (650 - 2580)	630 (260 - 1000)	600 (240 - 960)	380 (150 - 620)
	Illinois-2	ICLUS_A2	2740 (1110 - 4380)	1090 (460 - 1740)	990 (400 - 1580)	650 (250 - 1060)
	Illinois-2	ICLUS_BC	2060 (840 - 3300)	840 (350 - 1340)	730 (300 - 1170)	490 (190 - 790)
	Illinois-2	Woods & Poole	2350 (940 - 3770)	950 (400 - 1520)	820 (330 - 1320)	570 (210 - 930)
	Illinois-2	Census_2000	1610 (650 - 2580)	760 (320 - 1220)	500 (200 - 800)	350 (130 - 560)
	NERL	ICLUS_A1	-40 (-600 - 520)	-130 (-340 - 80)	270 (70 - 470)	-180 (-330 - -20)
	NERL	ICLUS_A2	-100 (-1050 - 850)	-250 (-600 - 110)	450 (130 - 780)	-310 (-570 - -40)
	NERL	ICLUS_BC	-100 (-810 - 610)	-200 (-470 - 70)	330 (90 - 570)	-230 (-430 - -30)
	NERL	Woods & Poole	-100 (-920 - 720)	-230 (-520 - 60)	410 (120 - 700)	-280 (-510 - -50)
	NERL	Census_2000	-160 (-700 - 390)	-220 (-450 - 20)	230 (70 - 400)	-180 (-320 - -30)

Table A-4 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Age < 1) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Burnett et al. (2001)	WSU	ICLUS_A1	-430 (-1930 - 1100)	790 (280 - 1300)	-1010 (-1690 - -310)	-210 (-520 - 100)
	WSU	ICLUS_A2	-770 (-3300 - 1800)	1290 (450 - 2140)	-1690 (-2830 - -520)	-370 (-910 - 180)
	WSU	ICLUS_BC	-540 (-2410 - 1380)	980 (340 - 1630)	-1230 (-2060 - -370)	-290 (-700 - 130)
	WSU	Woods & Poole	-510 (-2610 - 1640)	990 (340 - 1650)	-1320 (-2320 - -290)	-180 (-620 - 280)
	WSU	Census_2000	-190 (-1570 - 1220)	820 (280 - 1360)	-800 (-1360 - -230)	-210 (-500 - 90)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.

Table A-5. Estimated National and Regional O_3-Related Incidence of Emergency Room Visits for Asthma Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August**

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Peel et al. (2005); Wilson et al. (2005)	CMU	ICLUS_A1	1230 (-3370 - 4370)	850 (-2140 - 2910)	450 (-1130 - 1540)	-80 (-280 - 220)
	CMU	ICLUS_A2	1500 (-4120 - 5340)	1030 (-2580 - 3510)	570 (-1420 - 1940)	-100 (-350 - 270)
	CMU	ICLUS_BC	1300 (-3570 - 4620)	910 (-2280 - 3100)	480 (-1190 - 1620)	-90 (-300 - 230)
	CMU	Woods & Poole	1490 (-4150 - 5350)	1010 (-2530 - 3440)	600 (-1490 - 2030)	-110 (-390 - 300)
	CMU	Census_2000	1130 (-3050 - 3990)	830 (-2080 - 2830)	360 (-900 - 1220)	-60 (-200 - 160)
	GNM	ICLUS_A1	-80 (-1290 - 1130)	-240 (-1180 - 830)	80 (-320 - 450)	90 (-220 - 320)
	GNM	ICLUS_A2	-130 (-1700 - 1450)	-330 (-1480 - 1070)	90 (-390 - 550)	110 (-280 - 400)
	GNM	ICLUS_BC	-130 (-1520 - 1280)	-300 (-1300 - 950)	70 (-320 - 450)	100 (-250 - 350)
	GNM	Woods & Poole	-180 (-1850 - 1530)	-360 (-1470 - 1110)	70 (-390 - 520)	110 (-300 - 430)
	GNM	Census_2000	-220 (-1570 - 1190)	-320 (-1250 - 930)	30 (-210 - 260)	70 (-180 - 250)
	Harvard	ICLUS_A1	700 (-2300 - 2720)	680 (-1740 - 2340)	-60 (-440 - 410)	70 (-230 - 280)
	Harvard	ICLUS_A2	870 (-2840 - 3380)	850 (-2160 - 2910)	-70 (-530 - 500)	90 (-290 - 350)
	Harvard	ICLUS_BC	770 (-2480 - 2970)	750 (-1900 - 2560)	-50 (-440 - 410)	80 (-250 - 300)
	Harvard	Woods & Poole	900 (-2920 - 3490)	860 (-2190 - 2950)	-50 (-500 - 500)	100 (-310 - 370)
	Harvard	Census_2000	730 (-1870 - 2690)	690 (-1530 - 2370)	-20 (-250 - 220)	50 (-150 - 210)

Table A-5 cont'd. Estimated National and Regional O_3-Related Incidence of Emergency Room Visits for Asthma Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August**

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Peel et al. (2005); Wilson et al. (2005)	Illinois-1	ICLUS_A1	1370 (-3070 - 4740)	830 (-1820 - 2840)	460 (-1000 - 1560)	80 (-260 - 350)
	Illinois-1	ICLUS_A2	1710 (-3840 - 5920)	1050 (-2290 - 3580)	570 (-1240 - 1930)	100 (-310 - 430)
	Illinois-1	ICLUS_BC	1490 (-3840 - 5140)	930 (-2330 - 3160)	470 (-1190 - 1610)	80 (-320 - 380)
	Illinois-1	Woods & Poole	1760 (-4560 - 6090)	1080 (-2710 - 3690)	580 (-1450 - 1970)	100 (-400 - 480)
	Illinois-1	Census_2000	1290 (-3310 - 4450)	890 (-2230 - 3030)	340 (-860 - 1160)	60 (-230 - 270)
	Illinois-2	ICLUS_A1	1330 (-3390 - 4580)	760 (-1920 - 2610)	410 (-1060 - 1430)	160 (-410 - 540)
	Illinois-2	ICLUS_A2	1670 (-4260 - 5750)	980 (-2450 - 3330)	510 (-1310 - 1760)	190 (-500 - 660)
	Illinois-2	ICLUS_BC	1460 (-3700 - 5000)	860 (-2170 - 2950)	430 (-1100 - 1480)	160 (-440 - 580)
	Illinois-2	Woods & Poole	1720 (-4380 - 5910)	1010 (-2550 - 3460)	500 (-1290 - 1730)	210 (-540 - 720)
	Illinois-2	Census_2000	1240 (-3150 - 4260)	830 (-2090 - 2840)	290 (-750 - 1010)	120 (-310 - 410)
	NERL	ICLUS_A1	-90 (-1330 - 1160)	-210 (-1080 - 750)	190 (-490 - 700)	-70 (-280 - 210)
	NERL	ICLUS_A2	-130 (-1700 - 1450)	-280 (-1330 - 950)	240 (-600 - 870)	-90 (-340 - 250)
	NERL	ICLUS_BC	-130 (-1520 - 1270)	-260 (-1170 - 850)	200 (-500 - 720)	-80 (-300 - 220)
	NERL	Woods & Poole	-170 (-1810 - 1500)	-310 (-1310 - 970)	240 (-600 - 860)	-100 (-380 - 280)
	NERL	Census_2000	-200 (-1470 - 1130)	-280 (-1100 - 820)	140 (-340 - 490)	-60 (-230 - 170)

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Table A-5 cont'd. Estimated National and Regional O_3-Related Incidence of Emergency Room Visits for Asthma Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August**

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Peel et al. (2005); Wilson et al. (2005)	WSU	ICLUS_A1	0 (-1610 - 1610)	550 (-190 - 1270)	-490 (-1190 - 230)	-60 (-230 - 120)
	WSU	ICLUS_A2	-60 (-3800 - 3620)	1250 (-1260 - 3420)	-1170 (-3270 - 1250)	-140 (-640 - 210)
	WSU	ICLUS_BC	0 (-1680 - 1700)	570 (-200 - 1490)	-500 (-1290 - 230)	-60 (-250 - 120)
	WSU	Woods & Poole	-60 (-3760 - 3560)	1170 (-1410 - 3250)	-1120 (-3200 - 1460)	-110 (-630 - 270)
	WSU	Census_2000	190 (-3090 - 3000)	740 (-2120 - 2760)	-470 (-1820 - 1510)	-70 (-440 - 370)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.
**These studies were pooled to estimate respiratory emergency room visits.

Table A-6. Estimated National and Regional O_3-Related Incidence of Minor Restricted Activity Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ostro and Rothschild (1989)	CMU	ICLUS_A1	1637000 (411000 - 2868000)	1107000 (456000 - 1762000)	749000 (309000 - 1191000)	-219000 (-354000 - -85000)
	CMU	ICLUS_A2	1688000 (408000 - 2973000)	1142000 (470000 - 1817000)	785000 (324000 - 1248000)	-239000 (-386000 - -92000)
	CMU	ICLUS_BC	1582000 (387000 - 2783000)	1084000 (446000 - 1725000)	719000 (297000 - 1142000)	-220000 (-356000 - -84000)
	CMU	Woods & Poole	1818000 (390000 - 3251000)	1230000 (505000 - 1958000)	886000 (366000 - 1409000)	-298000 (-481000 - -115000)
	CMU	Census_2000	1436000 (406000 - 2471000)	1018000 (418000 - 1620000)	571000 (236000 - 908000)	-153000 (-248000 - -57000)
	GNM	ICLUS_A1	120000 (-545000 - 787000)	-224000 (-541000 - 94000)	120000 (-54000 - 295000)	224000 (50000 - 398000)
	GNM	ICLUS_A2	108000 (-604000 - 823000)	-260000 (-600000 - 80000)	116000 (-65000 - 297000)	252000 (60000 - 445000)
	GNM	ICLUS_BC	73000 (-597000 - 745000)	-262000 (-586000 - 63000)	99000 (-66000 - 265000)	236000 (55000 - 417000)
	GNM	Woods & Poole	58000 (-763000 - 881000)	-343000 (-723000 - 37000)	106000 (-103000 - 314000)	295000 (63000 - 529000)
	GNM	Census_2000	-78000 (-651000 - 497000)	-291000 (-602000 - 20000)	39000 (-85000 - 163000)	175000 (36000 - 314000)
	Harvard	ICLUS_A1	926000 (74000 - 1781000)	831000 (331000 - 1332000)	-90000 (-289000 - 109000)	186000 (31000 - 340000)
	Harvard	ICLUS_A2	990000 (95000 - 1887000)	872000 (347000 - 1398000)	-87000 (-290000 - 117000)	205000 (38000 - 372000)
	Harvard	ICLUS_BC	941000 (103000 - 1782000)	828000 (330000 - 1329000)	-74000 (-259000 - 111000)	187000 (32000 - 343000)
	Harvard	Woods & Poole	1131000 (113000 - 2152000)	972000 (387000 - 1560000)	-78000 (-305000 - 149000)	237000 (31000 - 443000)
	Harvard	Census_2000	872000 (156000 - 1591000)	775000 (306000 - 1246000)	-26000 (-159000 - 108000)	123000 (9000 - 237000)

Table A-6 cont'd. Estimated National and Regional O_3-Related Incidence of Minor Restricted Activity Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ostro and Rothschild (1989)	Illinois-1	ICLUS_A1	1959000 (715000 - 3209000)	1007000 (416000 - 1601000)	751000 (305000 - 1198000)	201000 (-7000 - 409000)
	Illinois-1	ICLUS_A2	2063000 (749000 - 3382000)	1074000 (443000 - 1707000)	778000 (317000 - 1242000)	210000 (-12000 - 433000)
	Illinois-1	ICLUS_BC	1934000 (702000 - 3170000)	1029000 (425000 - 1636000)	711000 (290000 - 1133000)	194000 (-12000 - 401000)
	Illinois-1	Woods & Poole	2333000 (829000 - 3843000)	1227000 (506000 - 1950000)	862000 (352000 - 1374000)	244000 (-29000 - 519000)
	Illinois-1	Census_2000	1681000 (622000 - 2745000)	1003000 (414000 - 1595000)	541000 (221000 - 862000)	137000 (-14000 - 288000)
	Illinois-2	ICLUS_A1	1941000 (761000 - 3125000)	862000 (349000 - 1379000)	676000 (265000 - 1088000)	403000 (148000 - 659000)
	Illinois-2	ICLUS_A2	2049000 (804000 - 3300000)	931000 (377000 - 1488000)	690000 (270000 - 1112000)	428000 (157000 - 699000)
	Illinois-2	ICLUS_BC	1927000 (757000 - 3103000)	895000 (362000 - 1430000)	635000 (249000 - 1023000)	397000 (145000 - 650000)
	Illinois-2	Woods & Poole	2362000 (924000 - 3806000)	1074000 (435000 - 1715000)	766000 (300000 - 1235000)	522000 (189000 - 856000)
	Illinois-2	Census_2000	1612000 (632000 - 2596000)	868000 (352000 - 1386000)	457000 (178000 - 737000)	287000 (102000 - 473000)
	NERL	ICLUS_A1	-76000 (-766000 - 617000)	-195000 (-488000 - 98000)	310000 (77000 - 543000)	-190000 (-356000 - -25000)
	NERL	ICLUS_A2	-109000 (-837000 - 620000)	-226000 (-536000 - 85000)	321000 (83000 - 559000)	-204000 (-384000 - -24000)
	NERL	ICLUS_BC	-130000 (-810000 - 551000)	-228000 (-523000 - 68000)	290000 (75000 - 506000)	-193000 (-361000 - -24000)
	NERL	Woods & Poole	-202000 (-1022000 - 620000)	-290000 (-630000 - 51000)	346000 (88000 - 604000)	-258000 (-481000 - -36000)
	NERL	Census_2000	-213000 (-781000 - 356000)	-257000 (-538000 - 25000)	209000 (57000 - 361000)	-164000 (-299000 - -30000)

Table A-6 cont'd. Estimated National and Regional O_3-Related Incidence of Minor Restricted Activity Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ostro and Rothschild (1989)	WSU	ICLUS_A1	-333000 (-2213000 - 1560000)	1057000 (353000 - 1765000)	-1176000 (-2020000 - -325000)	-214000 (-546000 - 119000)
	WSU	ICLUS_A2	-375000 (-2336000 - 1598000)	1080000 (355000 - 1807000)	-1221000 (-2095000 - -339000)	-234000 (-596000 - 130000)
	WSU	ICLUS_BC	-301000 (-2119000 - 1530000)	1029000 (342000 - 1719000)	-1103000 (-1895000 - -304000)	-226000 (-566000 - 115000)
	WSU	Woods & Poole	-460000 (-2622000 - 1717000)	1121000 (366000 - 1881000)	-1345000 (-2317000 - -364000)	-236000 (-671000 - 200000)
	WSU	Census_2000	2000 (-1476000 - 1490000)	972000 (328000 - 1619000)	-773000 (-1346000 - -195000)	-197000 (-458000 - 65000)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest thousand.

Table A-7. Estimated National and Regional O_3-Related Incidence of School Loss Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Chen et al. (2000); Gilliland et al. (2001)	CMU	ICLUS_A1	522000 (96000 - 1183000)	356000 (126000 - 806000)	241000 (86000 - 544000)	-75000 (-167000 - -25000)
	CMU	ICLUS_A2	745000 (128000 - 1689000)	509000 (180000 - 1151000)	351000 (125000 - 793000)	-115000 (-255000 - -38000)
	CMU	ICLUS_BC	599000 (104000 - 1356000)	414000 (147000 - 935000)	276000 (98000 - 623000)	-91000 (-202000 - -30000)
	CMU	Woods & Poole	679000 (100000 - 1540000)	450000 (159000 - 1018000)	347000 (124000 - 785000)	-118000 (-263000 - -39000)
	CMU	Census_2000	545000 (113000 - 1235000)	389000 (138000 - 880000)	222000 (79000 - 502000)	-66000 (-147000 - -21000)
	GNM	ICLUS_A1	50000 (-171000 - 265000)	-71000 (-168000 - 34000)	42000 (-18000 - 97000)	79000 (15000 - 138000)
	GNM	ICLUS_A2	67000 (-264000 - 389000)	-115000 (-260000 - 41000)	57000 (-29000 - 137000)	125000 (25000 - 219000)
	GNM	ICLUS_BC	44000 (-222000 - 304000)	-98000 (-216000 - 29000)	42000 (-25000 - 106000)	100000 (20000 - 175000)
	GNM	Woods & Poole	35000 (-277000 - 344000)	-123000 (-257000 - 22000)	45000 (-39000 - 124000)	114000 (19000 - 200000)
	GNM	Census_2000	-29000 (-282000 - 201000)	-123000 (-382000 - 10000)	18000 (-33000 - 87000)	76000 (12000 - 224000)
	Harvard	ICLUS_A1	299000 (4000 - 676000)	267000 (91000 - 602000)	-32000 (-95000 - 35000)	64000 (8000 - 144000)
	Harvard	ICLUS_A2	445000 (14000 - 1006000)	389000 (133000 - 876000)	-43000 (-132000 - 52000)	99000 (14000 - 224000)
	Harvard	ICLUS_BC	362000 (16000 - 818000)	316000 (108000 - 711000)	-32000 (-102000 - 42000)	78000 (10000 - 176000)
	Harvard	Woods & Poole	422000 (11000 - 954000)	360000 (123000 - 812000)	-31000 (-120000 - 61000)	93000 (8000 - 210000)
	Harvard	Census_2000	347000 (47000 - 783000)	302000 (102000 - 681000)	-9000 (-59000 - 42000)	54000 (3000 - 121000)

Table A-7 cont'd. Estimated National and Regional O_3-Related Incidence of School Loss Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Chen et al. (2000); Gilliland et al. (2001)	Illinois-1	ICLUS_A1	633000 (192000 - 1428000)	323000 (115000 - 728000)	244000 (85000 - 550000)	66000 (-7000 - 150000)
	Illinois-1	ICLUS_A2	925000 (279000 - 2087000)	478000 (170000 - 1078000)	350000 (122000 - 790000)	97000 (-13000 - 219000)
	Illinois-1	ICLUS_BC	743000 (224000 - 1677000)	391000 (139000 - 882000)	275000 (96000 - 621000)	77000 (-11000 - 175000)
	Illinois-1	Woods & Poole	880000 (260000 - 1988000)	451000 (160000 - 1018000)	336000 (118000 - 759000)	93000 (-18000 - 211000)
	Illinois-1	Census_2000	659000 (205000 - 1488000)	390000 (139000 - 881000)	209000 (74000 - 473000)	59000 (-7000 - 134000)
	Illinois-2	ICLUS_A1	638000 (214000 - 1441000)	276000 (96000 - 625000)	226000 (76000 - 510000)	136000 (42000 - 306000)
	Illinois-2	ICLUS_A2	937000 (314000 - 2117000)	415000 (144000 - 938000)	321000 (108000 - 726000)	201000 (62000 - 454000)
	Illinois-2	ICLUS_BC	755000 (253000 - 1706000)	340000 (118000 - 769000)	254000 (85000 - 574000)	161000 (50000 - 363000)
	Illinois-2	Woods & Poole	893000 (297000 - 2019000)	397000 (138000 - 899000)	295000 (97000 - 665000)	201000 (61000 - 454000)
	Illinois-2	Census_2000	650000 (218000 - 1468000)	343000 (120000 - 776000)	184000 (61000 - 416000)	122000 (37000 - 276000)
	NERL	ICLUS_A1	-25000 (-274000 - 202000)	-65000 (-230000 - 34000)	106000 (20000 - 307000)	-66000 (-198000 - -4000)
	NERL	ICLUS_A2	-50000 (-378000 - 284000)	-104000 (-318000 - 42000)	151000 (30000 - 409000)	-98000 (-272000 - -5000)
	NERL	ICLUS_BC	-50000 (-312000 - 219000)	-88000 (-237000 - 30000)	117000 (23000 - 294000)	-79000 (-201000 - -4000)
	NERL	Woods & Poole	-67000 (-372000 - 249000)	-107000 (-284000 - 26000)	139000 (26000 - 350000)	-99000 (-250000 - -6000)
	NERL	Census_2000	-84000 (-301000 - 146000)	-105000 (-276000 - 12000)	86000 (20000 - 216000)	-64000 (-163000 - -5000)

Table A-7 cont'd. Estimated National and Regional O_3-Related Incidence of School Loss Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be June, July, and August*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Chen et al. (2000); Gilliland et al. (2001)	WSU	ICLUS_A1	-134000 (-1049000 - 555000)	363000 (96000 - 1079000)	-416000 (-1212000 - -89000)	-81000 (-314000 - 42000)
	WSU	ICLUS_A2	-212000 (-1560000 - 767000)	510000 (133000 - 1528000)	-599000 (-1751000 - -130000)	-124000 (-481000 - 64000)
	WSU	ICLUS_BC	-153000 (-1206000 - 647000)	419000 (110000 - 1245000)	-468000 (-1362000 - -101000)	-103000 (-393000 - 49000)
	WSU	Woods & Poole	-197000 (-1434000 - 695000)	430000 (110000 - 1292000)	-543000 (-1611000 - -100000)	-84000 (-386000 - 90000)
	WSU	Census_2000	-27000 (-1638000 - 1623000)	465000 (81000 - 1547000)	-392000 (-1298000 - -24000)	-101000 (-477000 - 130000)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest thousand.

**These studies were pooled to estimate school loss days.

Table A-8. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al.(2005)	CMU	ICLUS_A1	2550 (880 - 4220)	1550 (740 - 2360)	1310 (630 - 2000)	-310 (-480 - -140)
Bell et al.(2005)	CMU	ICLUS_A2	2290 (780 - 3810)	1380 (660 - 2110)	1200 (570 - 1830)	-290 (-460 - -130)
Bell et al.(2005)	CMU	ICLUS_BC	2260 (780 - 3740)	1410 (670 - 2150)	1120 (530 - 1710)	-270 (-430 - -120)
Bell et al.(2005)	CMU	Woods & Poole	1860 (560 - 3150)	1360 (640 - 2070)	790 (380 - 1210)	-290 (-460 - -130)
Bell et al.(2005)	CMU	Census_2000	830 (320 - 1340)	570 (270 - 870)	320 (150 - 490)	-70 (-110 - -30)
Bell et al.(2005)	GNM	ICLUS_A1	200 (-640 - 1040)	-250 (-630 - 140)	180 (-70 - 430)	270 (70 - 470)
Bell et al.(2005)	GNM	ICLUS_A2	160 (-620 - 940)	-250 (-610 - 100)	150 (-80 - 380)	260 (70 - 460)
Bell et al.(2005)	GNM	ICLUS_BC	90 (-680 - 870)	-300 (-670 - 70)	130 (-90 - 340)	260 (70 - 450)
Bell et al.(2005)	GNM	Woods & Poole	50 (-680 - 790)	-320 (-680 - 40)	70 (-100 - 230)	300 (90 - 510)
Bell et al.(2005)	GNM	Census_2000	-100 (-370 - 170)	-180 (-330 - -20)	10 (-60 - 70)	70 (20 - 120)
Bell et al.(2005)	Harvard	ICLUS_A1	1280 (180 - 2390)	1140 (530 - 1750)	-130 (-420 - 170)	270 (70 - 470)
Bell et al.(2005)	Harvard	ICLUS_A2	1180 (180 - 2190)	1030 (480 - 1590)	-110 (-380 - 150)	260 (70 - 450)
Bell et al.(2005)	Harvard	ICLUS_BC	1210 (220 - 2200)	1060 (490 - 1630)	-90 (-330 - 150)	240 (60 - 420)
Bell et al.(2005)	Harvard	Woods & Poole	1050 (120 - 1980)	990 (450 - 1530)	-160 (-380 - 60)	220 (40 - 390)
Bell et al.(2005)	Harvard	Census_2000	460 (110 - 820)	430 (200 - 670)	-20 (-100 - 50)	50 (10 - 100)

Table A-8 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al.(2005)	Illinois-1	ICLUS_A1	3010 (1330 - 4690)	1370 (650 - 2090)	1300 (620 - 1990)	340 (60 - 620)
Bell et al.(2005)	Illinois-1	ICLUS_A2	2750 (1210 - 4300)	1260 (600 - 1920)	1190 (560 - 1810)	310 (50 - 560)
Bell et al.(2005)	Illinois-1	ICLUS_BC	2690 (1180 - 4200)	1310 (630 - 2000)	1100 (520 - 1670)	280 (40 - 520)
Bell et al.(2005)	Illinois-1	Woods & Poole	2340 (1000 - 3690)	1280 (610 - 1960)	840 (400 - 1280)	220 (-10 - 450)
Bell et al.(2005)	Illinois-1	Census_2000	950 (420 - 1480)	570 (270 - 870)	320 (150 - 480)	60 (0 - 120)
Bell et al.(2005)	Illinois-2	ICLUS_A1	2810 (1280 - 4340)	1120 (520 - 1720)	1090 (500 - 1680)	600 (260 - 940)
Bell et al.(2005)	Illinois-2	ICLUS_A2	2570 (1170 - 3970)	1040 (490 - 1600)	970 (440 - 1500)	550 (240 - 860)
Bell et al.(2005)	Illinois-2	ICLUS_BC	2540 (1160 - 3920)	1100 (510 - 1690)	920 (420 - 1420)	520 (230 - 810)
Bell et al.(2005)	Illinois-2	Woods & Poole	2220 (1010 - 3440)	1060 (500 - 1630)	670 (310 - 1040)	490 (210 - 770)
Bell et al.(2005)	Illinois-2	Census_2000	860 (400 - 1330)	490 (230 - 750)	250 (110 - 380)	130 (50 - 200)
Bell et al.(2005)	NERL	ICLUS_A1	60 (-850 - 970)	-190 (-550 - 160)	530 (180 - 870)	-270 (-480 - -70)
Bell et al.(2005)	NERL	ICLUS_A2	30 (-800 - 850)	-200 (-520 - 130)	480 (170 - 790)	-250 (-450 - -60)
Bell et al.(2005)	NERL	ICLUS_BC	-50 (-860 - 760)	-240 (-580 - 90)	440 (150 - 730)	-250 (-440 - -60)
Bell et al.(2005)	NERL	Woods & Poole	-280 (-1010 - 450)	-280 (-620 - 50)	260 (60 - 460)	-260 (-460 - -60)
Bell et al.(2005)	NERL	Census_2000	-120 (-390 - 140)	-150 (-290 - -10)	100 (30 - 170)	-70 (-130 - -20)

Table A-8 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al.(2005)	WSU	ICLUS_A1	-780 (-3310 - 1760)	1440 (580 - 2310)	-1940 (-3210 - -670)	-280 (-680 - 130)
Bell et al.(2005)	WSU	ICLUS_A2	-750 (-3050 - 1550)	1270 (500 - 2040)	-1770 (-2920 - -620)	-260 (-640 - 120)
Bell et al.(2005)	WSU	ICLUS_BC	-580 (-2790 - 1640)	1310 (530 - 2100)	-1620 (-2680 - -560)	-270 (-640 - 100)
Bell et al.(2005)	WSU	Woods & Poole	-310 (-2320 - 1710)	1310 (530 - 2090)	-1330 (-2180 - -480)	-290 (-670 - 100)
Bell et al.(2005)	WSU	Census_2000	-10 (-740 - 710)	540 (220 - 860)	-460 (-770 - -160)	-90 (-190 - 10)
Levy et al.(2005)	CMU	ICLUS_A1	3600 (2180 - 5010)	2180 (1500 - 2870)	1850 (1270 - 2430)	-440 (-580 - -290)
Levy et al.(2005)	CMU	ICLUS_A2	3230 (1950 - 4520)	1950 (1340 - 2570)	1700 (1160 - 2230)	-410 (-550 - -280)
Levy et al.(2005)	CMU	ICLUS_BC	3180 (1930 - 4440)	1990 (1370 - 2620)	1580 (1080 - 2080)	-390 (-520 - -260)
Levy et al.(2005)	CMU	Woods & Poole	2620 (1520 - 3710)	1920 (1310 - 2520)	1120 (770 - 1470)	-420 (-550 - -280)
Levy et al.(2005)	CMU	Census_2000	1170 (740 - 1600)	810 (550 - 1060)	460 (310 - 600)	-100 (-130 - -60)
Levy et al.(2005)	GNM	ICLUS_A1	290 (-430 - 1000)	-350 (-670 - -20)	250 (40 - 470)	380 (210 - 550)
Levy et al.(2005)	GNM	ICLUS_A2	230 (-430 - 890)	-360 (-660 - -50)	210 (20 - 410)	370 (210 - 530)
Levy et al.(2005)	GNM	ICLUS_BC	130 (-520 - 790)	-420 (-730 - -110)	180 (0 - 360)	370 (210 - 530)
Levy et al.(2005)	GNM	Woods & Poole	70 (-550 - 690)	-450 (-750 - -140)	100 (-40 - 240)	420 (250 - 600)
Levy et al.(2005)	GNM	Census_2000	-140 (-370 - 90)	-250 (-380 - -120)	10 (-40 - 60)	100 (60 - 150)

Table A-8 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Levy et al.(2005)	Harvard	ICLUS_A1	1810 (870 - 2740)	1600 (1090 - 2120)	-180 (-430 - 70)	380 (210 - 550)
Levy et al.(2005)	Harvard	ICLUS_A2	1670 (820 - 2520)	1460 (990 - 1930)	-160 (-380 - 70)	370 (210 - 530)
Levy et al.(2005)	Harvard	ICLUS_BC	1700 (870 - 2540)	1490 (1010 - 1970)	-130 (-330 - 80)	340 (190 - 490)
Levy et al.(2005)	Harvard	Woods & Poole	1480 (690 - 2270)	1400 (940 - 1850)	-220 (-410 - -40)	300 (150 - 450)
Levy et al.(2005)	Harvard	Census_2000	650 (350 - 950)	610 (410 - 810)	-30 (-100 - 30)	70 (30 - 110)
Levy et al.(2005)	Illinois-1	ICLUS_A1	4240 (2820 - 5670)	1930 (1320 - 2540)	1840 (1260 - 2420)	470 (240 - 710)
Levy et al.(2005)	Illinois-1	ICLUS_A2	3890 (2580 - 5190)	1780 (1220 - 2340)	1670 (1140 - 2200)	430 (210 - 650)
Levy et al.(2005)	Illinois-1	ICLUS_BC	3790 (2520 - 5070)	1850 (1270 - 2430)	1550 (1060 - 2030)	400 (190 - 600)
Levy et al.(2005)	Illinois-1	Woods & Poole	3300 (2160 - 4440)	1810 (1240 - 2380)	1180 (810 - 1560)	310 (110 - 500)
Levy et al.(2005)	Illinois-1	Census_2000	1340 (890 - 1790)	810 (550 - 1060)	450 (300 - 590)	90 (40 - 140)
Levy et al.(2005)	Illinois-2	ICLUS_A1	3970 (2670 - 5260)	1580 (1070 - 2080)	1540 (1040 - 2040)	850 (560 - 1130)
Levy et al.(2005)	Illinois-2	ICLUS_A2	3620 (2440 - 4810)	1470 (1000 - 1950)	1370 (920 - 1820)	780 (520 - 1040)
Levy et al.(2005)	Illinois-2	ICLUS_BC	3580 (2420 - 4750)	1550 (1060 - 2050)	1300 (870 - 1720)	740 (490 - 980)
Levy et al.(2005)	Illinois-2	Woods & Poole	3140 (2110 - 4170)	1500 (1020 - 1980)	950 (640 - 1260)	690 (450 - 920)
Levy et al.(2005)	Illinois-2	Census_2000	1220 (820 - 1620)	690 (470 - 910)	350 (240 - 460)	180 (120 - 240)

Table A-8 cont'd. Estimated National and Regional O_3-Related Incidence of All Cause Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Levy et al.(2005)	NERL	ICLUS_A1	90 (-680 - 850)	-270 (-570 - 30)	750 (450 - 1040)	-390 (-560 - -210)
Levy et al.(2005)	NERL	ICLUS_A2	40 (-660 - 740)	-280 (-550 - 0)	670 (410 - 930)	-360 (-520 - -190)
Levy et al.(2005)	NERL	ICLUS_BC	-70 (-760 - 610)	-340 (-630 - -60)	620 (380 - 860)	-350 (-510 - -190)
Levy et al.(2005)	NERL	Woods & Poole	-400 (-1010 - 220)	-400 (-680 - -120)	370 (200 - 540)	-370 (-530 - -200)
Levy et al.(2005)	NERL	Census_2000	-180 (-400 - 50)	-210 (-330 - -90)	140 (80 - 200)	-100 (-150 - -60)
Levy et al.(2005)	WSU	ICLUS_A1	-1090 (-3230 - 1050)	2040 (1300 - 2770)	-2730 (-3800 - -1670)	-390 (-740 - -50)
Levy et al.(2005)	WSU	ICLUS_A2	-1060 (-3000 - 890)	1800 (1140 - 2450)	-2490 (-3460 - -1520)	-360 (-680 - -40)
Levy et al.(2005)	WSU	ICLUS_BC	-810 (-2680 - 1070)	1850 (1190 - 2520)	-2280 (-3170 - -1390)	-380 (-700 - -70)
Levy et al.(2005)	WSU	Woods & Poole	-430 (-2130 - 1280)	1850 (1190 - 2510)	-1870 (-2590 - -1160)	-410 (-730 - -80)
Levy et al.(2005)	WSU	Census_2000	-20 (-630 - 600)	760 (490 - 1030)	-650 (-910 - -400)	-130 (-220 - -40)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.

Table A-9. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al. (2004)	CMU	ICLUS_A1	810 (130 - 1480)	490 (160 - 820)	410 (140 - 690)	-100 (-170 - -30)
Bell et al. (2004)	CMU	ICLUS_A2	720 (110 - 1330)	440 (150 - 730)	380 (130 - 630)	-90 (-160 - -30)
Bell et al. (2004)	CMU	ICLUS_BC	710 (120 - 1310)	450 (150 - 740)	350 (120 - 590)	-90 (-150 - -30)
Bell et al. (2004)	CMU	Woods & Poole	580 (70 - 1100)	430 (140 - 710)	250 (80 - 410)	-90 (-160 - -30)
Bell et al. (2004)	CMU	Census_2000	250 (60 - 450)	180 (60 - 290)	100 (30 - 160)	-20 (-40 - -10)
Bell et al. (2004)	GNM	ICLUS_A1	60 (-270 - 400)	-80 (-230 - 80)	60 (-40 - 160)	90 (0 - 170)
Bell et al. (2004)	GNM	ICLUS_A2	50 (-260 - 360)	-80 (-220 - 60)	50 (-40 - 140)	80 (10 - 160)
Bell et al. (2004)	GNM	ICLUS_BC	30 (-280 - 340)	-90 (-240 - 60)	40 (-50 - 130)	80 (10 - 160)
Bell et al. (2004)	GNM	Woods & Poole	20 (-280 - 310)	-100 (-240 - 50)	20 (-40 - 90)	90 (10 - 180)
Bell et al. (2004)	GNM	Census_2000	-30 (-140 - 80)	-50 (-120 - 10)	0 (-20 - 30)	20 (0 - 40)
Bell et al. (2004)	Harvard	ICLUS_A1	400 (-40 - 850)	360 (110 - 600)	-40 (-160 - 80)	90 (10 - 170)
Bell et al. (2004)	Harvard	ICLUS_A2	370 (-30 - 780)	320 (100 - 550)	-30 (-140 - 70)	80 (10 - 160)
Bell et al. (2004)	Harvard	ICLUS_BC	380 (-20 - 780)	330 (100 - 560)	-30 (-130 - 70)	80 (0 - 150)
Bell et al. (2004)	Harvard	Woods & Poole	330 (-40 - 700)	310 (100 - 530)	-50 (-140 - 40)	70 (0 - 140)
Bell et al. (2004)	Harvard	Census_2000	140 (0 - 280)	130 (40 - 220)	-10 (-40 - 20)	20 (0 - 30)

Table A-9 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al. (2004)	Illinois-1	ICLUS_A1	950 (270 - 1620)	430 (140 - 720)	410 (130 - 690)	110 (-10 - 220)
Bell et al. (2004)	Illinois-1	ICLUS_A2	870 (250 - 1480)	400 (130 - 660)	370 (120 - 620)	100 (-10 - 200)
Bell et al. (2004)	Illinois-1	ICLUS_BC	850 (240 - 1450)	410 (140 - 690)	340 (110 - 570)	90 (-10 - 180)
Bell et al. (2004)	Illinois-1	Woods & Poole	730 (200 - 1270)	400 (130 - 670)	260 (90 - 430)	70 (-20 - 160)
Bell et al. (2004)	Illinois-1	Census_2000	290 (90 - 500)	180 (60 - 290)	100 (30 - 160)	20 (-10 - 40)
Bell et al. (2004)	Illinois-2	ICLUS_A1	880 (270 - 1500)	350 (110 - 590)	340 (110 - 580)	190 (50 - 320)
Bell et al. (2004)	Illinois-2	ICLUS_A2	810 (250 - 1360)	330 (110 - 550)	300 (90 - 520)	170 (50 - 300)
Bell et al. (2004)	Illinois-2	ICLUS_BC	800 (250 - 1350)	350 (110 - 580)	290 (90 - 490)	160 (50 - 280)
Bell et al. (2004)	Illinois-2	Woods & Poole	690 (210 - 1170)	330 (110 - 560)	210 (60 - 350)	150 (40 - 260)
Bell et al. (2004)	Illinois-2	Census_2000	260 (80 - 450)	150 (50 - 250)	70 (20 - 130)	40 (10 - 70)
Bell et al. (2004)	NERL	ICLUS_A1	20 (-340 - 380)	-60 (-200 - 80)	170 (30 - 310)	-90 (-170 - 0)
Bell et al. (2004)	NERL	ICLUS_A2	10 (-320 - 340)	-60 (-190 - 70)	150 (30 - 270)	-80 (-160 - 0)
Bell et al. (2004)	NERL	ICLUS_BC	-20 (-340 - 310)	-80 (-210 - 60)	140 (20 - 250)	-80 (-150 - 0)
Bell et al. (2004)	NERL	Woods & Poole	-90 (-380 - 200)	-90 (-220 - 40)	80 (0 - 160)	-80 (-160 - 0)
Bell et al. (2004)	NERL	Census_2000	-40 (-140 - 60)	-50 (-100 - 10)	30 (0 - 60)	-20 (-40 - 0)

Table A-9 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Bell et al. (2004)	WSU	ICLUS_A1	-240 (-1270 - 780)	460 (110 - 810)	-610 (-1120 - -100)	-90 (-250 - 70)
Bell et al. (2004)	WSU	ICLUS_A2	-240 (-1160 - 690)	400 (90 - 710)	-560 (-1020 - -90)	-80 (-230 - 70)
Bell et al. (2004)	WSU	ICLUS_BC	-180 (-1070 - 710)	420 (100 - 730)	-510 (-930 - -80)	-90 (-230 - 60)
Bell et al. (2004)	WSU	Woods & Poole	-90 (-900 - 710)	410 (100 - 730)	-410 (-750 - -80)	-90 (-250 - 60)
Bell et al. (2004)	WSU	Census_2000	0 (-280 - 280)	170 (40 - 290)	-140 (-260 - -20)	-30 (-70 - 10)
Ito et al. (2005)	CMU	ICLUS_A1	3620 (1810 - 5440)	2200 (1320 - 3090)	1860 (1110 - 2600)	-440 (-620 - -250)
Ito et al. (2005)	CMU	ICLUS_A2	3250 (1610 - 4890)	1960 (1180 - 2750)	1700 (1020 - 2380)	-410 (-580 - -240)
Ito et al. (2005)	CMU	ICLUS_BC	3200 (1600 - 4800)	2010 (1200 - 2810)	1580 (950 - 2210)	-390 (-550 - -220)
Ito et al. (2005)	CMU	Woods & Poole	2610 (1230 - 4000)	1920 (1150 - 2700)	1100 (660 - 1540)	-410 (-580 - -240)
Ito et al. (2005)	CMU	Census_2000	1140 (610 - 1680)	790 (470 - 1110)	440 (260 - 610)	-90 (-130 - -50)
Ito et al. (2005)	GNM	ICLUS_A1	290 (-620 - 1200)	-350 (-760 - 70)	260 (-20 - 530)	380 (160 - 600)
Ito et al. (2005)	GNM	ICLUS_A2	240 (-600 - 1080)	-350 (-740 - 30)	210 (-30 - 460)	370 (160 - 580)
Ito et al. (2005)	GNM	ICLUS_BC	140 (-700 - 980)	-420 (-820 - -20)	180 (-50 - 420)	370 (170 - 580)
Ito et al. (2005)	GNM	Woods & Poole	80 (-710 - 870)	-450 (-830 - -60)	100 (-80 - 270)	430 (200 - 650)
Ito et al. (2005)	GNM	Census_2000	-140 (-420 - 150)	-240 (-410 - -80)	10 (-60 - 70)	100 (40 - 150)

Table A-9 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ito et al. (2005)	Harvard	ICLUS_A1	1820 (620 - 3010)	1610 (950 - 2280)	-180 (-500 - 140)	380 (170 - 600)
Ito et al. (2005)	Harvard	ICLUS_A2	1670 (580 - 2760)	1460 (860 - 2060)	-150 (-440 - 130)	370 (170 - 570)
Ito et al. (2005)	Harvard	ICLUS_BC	1710 (640 - 2780)	1500 (880 - 2120)	-130 (-390 - 140)	340 (150 - 530)
Ito et al. (2005)	Harvard	Woods & Poole	1470 (470 - 2480)	1400 (820 - 1980)	-220 (-460 - 10)	300 (110 - 490)
Ito et al. (2005)	Harvard	Census_2000	630 (260 - 1010)	600 (350 - 850)	-30 (-110 - 50)	70 (20 - 120)
Ito et al. (2005)	Illinois-1	ICLUS_A1	4260 (2440 - 6080)	1940 (1160 - 2720)	1840 (1100 - 2590)	470 (170 - 780)
Ito et al. (2005)	Illinois-1	ICLUS_A2	3890 (2220 - 5550)	1780 (1070 - 2500)	1670 (1000 - 2350)	430 (150 - 710)
Ito et al. (2005)	Illinois-1	ICLUS_BC	3800 (2170 - 5430)	1860 (1110 - 2600)	1550 (920 - 2170)	390 (130 - 660)
Ito et al. (2005)	Illinois-1	Woods & Poole	3280 (1840 - 4730)	1810 (1090 - 2540)	1170 (700 - 1640)	300 (60 - 550)
Ito et al. (2005)	Illinois-1	Census_2000	1300 (750 - 1860)	790 (470 - 1110)	430 (260 - 600)	80 (20 - 150)
Ito et al. (2005)	Illinois-2	ICLUS_A1	3980 (2320 - 5630)	1580 (940 - 2230)	1540 (900 - 2190)	850 (480 - 1210)
Ito et al. (2005)	Illinois-2	ICLUS_A2	3620 (2120 - 5120)	1470 (870 - 2080)	1370 (800 - 1940)	780 (440 - 1110)
Ito et al. (2005)	Illinois-2	ICLUS_BC	3580 (2100 - 5070)	1560 (920 - 2190)	1300 (760 - 1840)	730 (420 - 1050)
Ito et al. (2005)	Illinois-2	Woods & Poole	3110 (1820 - 4410)	1500 (890 - 2110)	940 (550 - 1330)	680 (380 - 980)
Ito et al. (2005)	Illinois-2	Census_2000	1180 (690 - 1670)	680 (400 - 950)	340 (200 - 480)	170 (100 - 250)

Table A-9 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ito et al. (2005)	NERL	ICLUS_A1	90 (-890 - 1070)	-270 (-650 - 110)	750 (370 - 1120)	-390 (-610 - -160)
Ito et al. (2005)	NERL	ICLUS_A2	40 (-850 - 930)	-270 (-620 - 80)	670 (340 - 1010)	-360 (-570 - -150)
Ito et al. (2005)	NERL	ICLUS_BC	-70 (-950 - 800)	-340 (-700 - 20)	620 (310 - 930)	-350 (-550 - -150)
Ito et al. (2005)	NERL	Woods & Poole	-400 (-1180 - 390)	-400 (-760 - -40)	370 (150 - 580)	-360 (-580 - -150)
Ito et al. (2005)	NERL	Census_2000	-170 (-450 - 100)	-210 (-360 - -60)	130 (60 - 210)	-100 (-150 - -40)
Ito et al. (2005)	WSU	ICLUS_A1	-1080 (-3820 - 1670)	2060 (1110 - 3000)	-2740 (-4100 - -1380)	-400 (-830 - 40)
Ito et al. (2005)	WSU	ICLUS_A2	-1040 (-3520 - 1440)	1810 (970 - 2650)	-2490 (-3720 - -1250)	-370 (-770 - 40)
Ito et al. (2005)	WSU	ICLUS_BC	-790 (-3190 - 1600)	1870 (1010 - 2730)	-2280 (-3410 - -1140)	-390 (-790 - 10)
Ito et al. (2005)	WSU	Woods & Poole	-400 (-2560 - 1770)	1860 (1010 - 2710)	-1850 (-2750 - -950)	-410 (-820 - 0)
Ito et al. (2005)	WSU	Census_2000	0 (-760 - 760)	750 (410 - 1090)	-630 (-940 - -310)	-130 (-230 - -20)
Schwartz (2005)	CMU	ICLUS_A1	1220 (170 - 2270)	740 (230 - 1260)	620 (190 - 1050)	-150 (-260 - -40)
Schwartz (2005)	CMU	ICLUS_A2	1090 (140 - 2050)	660 (210 - 1120)	570 (180 - 960)	-140 (-240 - -40)
Schwartz (2005)	CMU	ICLUS_BC	1080 (150 - 2010)	680 (210 - 1150)	530 (160 - 900)	-130 (-230 - -40)
Schwartz (2005)	CMU	Woods & Poole	890 (80 - 1700)	650 (200 - 1110)	380 (120 - 640)	-140 (-240 - -40)
Schwartz (2005)	CMU	Census_2000	390 (80 - 710)	270 (80 - 460)	150 (50 - 260)	-30 (-60 - -10)

Table A-9 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (2005)	GNM	ICLUS_A1	100 (-430 - 630)	-120 (-360 - 130)	90 (-70 - 250)	130 (0 - 260)
Schwartz (2005)	GNM	ICLUS_A2	80 (-410 - 570)	-120 (-340 - 110)	70 (-70 - 220)	130 (10 - 250)
Schwartz (2005)	GNM	ICLUS_BC	50 (-440 - 540)	-140 (-370 - 90)	60 (-70 - 200)	130 (10 - 250)
Schwartz (2005)	GNM	Woods & Poole	30 (-440 - 490)	-150 (-380 - 80)	30 (-70 - 140)	150 (10 - 280)
Schwartz (2005)	GNM	Census_2000	-50 (-220 - 120)	-80 (-180 - 20)	0 (-30 - 40)	30 (0 - 70)
Schwartz (2005)	Harvard	ICLUS_A1	610 (-80 - 1310)	550 (160 - 930)	-60 (-250 - 120)	130 (0 - 260)
Schwartz (2005)	Harvard	ICLUS_A2	560 (-70 - 1200)	490 (140 - 840)	-50 (-220 - 110)	120 (10 - 240)
Schwartz (2005)	Harvard	ICLUS_BC	580 (-50 - 1200)	510 (150 - 870)	-40 (-200 - 110)	110 (0 - 230)
Schwartz (2005)	Harvard	Woods & Poole	500 (-90 - 1090)	480 (140 - 820)	-80 (-210 - 60)	100 (-10 - 210)
Schwartz (2005)	Harvard	Census_2000	220 (0 - 440)	210 (60 - 350)	-10 (-60 - 40)	20 (0 - 50)
Schwartz (2005)	Illinois-1	ICLUS_A1	1430 (380 - 2490)	660 (200 - 1110)	620 (190 - 1050)	160 (-20 - 330)
Schwartz (2005)	Illinois-1	ICLUS_A2	1310 (340 - 2280)	600 (190 - 1020)	560 (170 - 950)	150 (-20 - 310)
Schwartz (2005)	Illinois-1	ICLUS_BC	1280 (340 - 2230)	630 (200 - 1060)	520 (160 - 880)	130 (-20 - 290)
Schwartz (2005)	Illinois-1	Woods & Poole	1120 (270 - 1970)	620 (190 - 1040)	400 (120 - 680)	100 (-40 - 250)
Schwartz (2005)	Illinois-1	Census_2000	450 (120 - 780)	270 (80 - 460)	150 (50 - 250)	30 (-10 - 70)

Table A-9 cont'd. Estimated National and Regional O_3-Related Incidence of Non-Accidental Mortality Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (2005)	Illinois-2	ICLUS_A1	1340 (380 - 2300)	540 (160 - 910)	520 (150 - 890)	290 (80 - 500)
Schwartz (2005)	Illinois-2	ICLUS_A2	1220 (350 - 2100)	500 (150 - 850)	460 (130 - 790)	260 (70 - 460)
Schwartz (2005)	Illinois-2	ICLUS_BC	1210 (350 - 2080)	530 (160 - 900)	440 (120 - 750)	250 (60 - 430)
Schwartz (2005)	Illinois-2	Woods & Poole	1060 (300 - 1830)	510 (150 - 870)	320 (90 - 550)	230 (60 - 410)
Schwartz (2005)	Illinois-2	Census_2000	410 (120 - 700)	230 (70 - 400)	120 (30 - 200)	60 (10 - 110)
Schwartz (2005)	NERL	ICLUS_A1	30 (-540 - 600)	-90 (-320 - 130)	250 (30 - 470)	-130 (-260 - 0)
Schwartz (2005)	NERL	ICLUS_A2	10 (-510 - 530)	-90 (-300 - 110)	230 (30 - 420)	-120 (-240 - 0)
Schwartz (2005)	NERL	ICLUS_BC	-30 (-540 - 480)	-120 (-330 - 100)	210 (30 - 390)	-120 (-240 - 0)
Schwartz (2005)	NERL	Woods & Poole	-140 (-600 - 330)	-140 (-350 - 70)	130 (0 - 250)	-120 (-250 - 0)
Schwartz (2005)	NERL	Census_2000	-60 (-230 - 110)	-70 (-160 - 20)	50 (0 - 90)	-30 (-70 - 0)
Schwartz (2005)	WSU	ICLUS_A1	-370 (-1970 - 1240)	700 (150 - 1250)	-930 (-1720 - -130)	-140 (-390 - 120)
Schwartz (2005)	WSU	ICLUS_A2	-350 (-1800 - 1100)	610 (130 - 1100)	-840 (-1560 - -120)	-130 (-370 - 110)
Schwartz (2005)	WSU	ICLUS_BC	-270 (-1670 - 1130)	630 (130 - 1130)	-770 (-1430 - -110)	-130 (-370 - 100)
Schwartz (2005)	WSU	Woods & Poole	-150 (-1420 - 1130)	630 (140 - 1130)	-640 (-1170 - -100)	-140 (-390 - 100)
Schwartz (2005)	WSU	Census_2000	0 (-460 - 450)	260 (60 - 460)	-220 (-410 - -30)	-40 (-110 - 20)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.

Table A-10. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Ages 65 and Up) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (1995); Schwartz (1994a); Moolgavkar et al. (1997); Schwartz (1994b); Moolgavkar et al. (1997)	CMU	ICLUS_A1	8640 (-670 - 22390)	5350 (270 - 13580)	4170 (210 - 10740)	-880 (-2230 - -20)
	CMU	ICLUS_A2	7700 (-640 - 19970)	4740 (240 - 12010)	3790 (190 - 9770)	-820 (-2090 - -20)
	CMU	ICLUS_BC	7620 (-590 - 19730)	4860 (240 - 12310)	3540 (180 - 9130)	-770 (-1970 - -10)
	CMU	Woods & Poole	6450 (-710 - 16880)	4740 (230 - 12110)	2520 (130 - 6560)	-810 (-2070 - -20)
	CMU	Census_2000	2780 (-100 - 7250)	2000 (90 - 5140)	960 (50 - 2520)	-180 (-480 - 0)
	GNM	ICLUS_A1	500 (-2920 - 3970)	-950 (-2810 - 910)	650 (-520 - 1780)	790 (-160 - 1610)
	GNM	ICLUS_A2	360 (-2790 - 3550)	-950 (-2680 - 790)	550 (-480 - 1550)	760 (-30 - 1560)
	GNM	ICLUS_BC	130 (-3060 - 3280)	-1110 (-2930 - 740)	480 (-480 - 1420)	760 (-130 - 1610)
	GNM	Woods & Poole	10 (-3490 - 4010)	-1190 (-3560 - 670)	290 (-450 - 1210)	910 (-120 - 2650)
	GNM	Census_2000	-420 (-1860 - 810)	-670 (-1770 - 200)	40 (-210 - 370)	210 (-40 - 580)
	Harvard	ICLUS_A1	4210 (-1530 - 10900)	4050 (160 - 10040)	-610 (-2290 - 760)	770 (-150 - 2000)
	Harvard	ICLUS_A2	3860 (-1360 - 9960)	3660 (140 - 9040)	-530 (-2030 - 700)	730 (-130 - 1900)
	Harvard	ICLUS_BC	4010 (-1220 - 10280)	3770 (140 - 9310)	-450 (-1830 - 680)	680 (-140 - 1770)
	Harvard	Woods & Poole	3550 (-1390 - 9210)	3620 (120 - 9000)	-700 (-1960 - 420)	630 (-180 - 1640)
	Harvard	Census_2000	1570 (-370 - 4050)	1570 (50 - 3950)	-150 (-590 - 200)	150 (-50 - 390)

Table A-10 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Ages 65 and Up) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (1995); Schwartz (1994a); Moolgavkar et al. (1997); Schwartz (1994b); Moolgavkar et al. (1997)	Illinois-1	ICLUS_A1	10050 (150 - 25450)	4840 (250 - 11970)	4290 (200 - 11030)	930 (-300 - 2450)
	Illinois-1	ICLUS_A2	9140 (130 - 23120)	4430 (230 - 10950)	3870 (180 - 9950)	840 (-290 - 2230)
	Illinois-1	ICLUS_BC	8990 (120 - 22720)	4630 (240 - 11430)	3580 (170 - 9220)	780 (-290 - 2070)
	Illinois-1	Woods & Poole	8070 (10 - 20480)	4630 (240 - 11520)	2840 (130 - 7330)	600 (-360 - 1640)
	Illinois-1	Census_2000	3230 (60 - 8240)	2060 (100 - 5170)	1000 (50 - 2600)	170 (-90 - 470)
	Illinois-2	ICLUS_A1	9400 (290 - 23560)	4080 (170 - 9910)	3620 (100 - 9330)	1700 (20 - 4320)
	Illinois-2	ICLUS_A2	8520 (270 - 21350)	3780 (160 - 9180)	3190 (90 - 8220)	1550 (20 - 3950)
	Illinois-2	ICLUS_BC	8510 (270 - 21280)	4000 (180 - 9720)	3030 (90 - 7800)	1470 (10 - 3760)
	Illinois-2	Woods & Poole	7700 (230 - 19310)	3990 (170 - 9750)	2340 (70 - 6050)	1370 (-10 - 3510)
	Illinois-2	Census_2000	2960 (100 - 7470)	1820 (80 - 4500)	780 (20 - 2040)	360 (0 - 930)
	NERL	ICLUS_A1	110 (-3570 - 3890)	-720 (-2490 - 910)	1580 (-220 - 4020)	-750 (-1860 - 170)
	NERL	ICLUS_A2	10 (-3390 - 3430)	-790 (-2460 - 800)	1550 (20 - 3910)	-750 (-1890 - 50)
	NERL	ICLUS_BC	-240 (-4600 - 4340)	-1000 (-3740 - 1220)	1560 (10 - 4800)	-800 (-2520 - 60)
	NERL	Woods & Poole	-1030 (-4930 - 2240)	-1120 (-3030 - 590)	850 (-160 - 2360)	-770 (-2080 - 60)
	NERL	Census_2000	-510 (-1900 - 690)	-580 (-1560 - 190)	280 (-70 - 780)	-210 (-570 - 40)

Table A-10 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Ages 65 and Up) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Schwartz (1995); Schwartz (1994a); Moolgavkar et al. (1997); Schwartz (1994b); Moolgavkar et al. (1997)	WSU	ICLUS_A1	-2470 (-13930 - 8420)	5070 (-190 - 12870)	-6700 (-17020 - 590)	-840 (-2680 - 820)
	WSU	ICLUS_A2	-2370 (-12890 - 7420)	4430 (-190 - 11250)	-6030 (-15340 - 520)	-770 (-2480 - 770)
	WSU	ICLUS_BC	-1750 (-11180 - 7630)	4610 (-170 - 11650)	-5550 (-14060 - 500)	-810 (-2490 - 720)
	WSU	Woods & Poole	-1090 (-10920 - 7600)	4680 (-160 - 12370)	-4870 (-12900 - 300)	-890 (-2640 - 730)
	WSU	Census_2000	50 (-3000 - 3190)	1650 (-50 - 3600)	-1370 (-3110 - 120)	-230 (-680 - 160)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.
**These studies were pooled to estimate respiratory hospital admissions for ages 65 and up.

Table A-11. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Age < 1) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Burnett et al. (2001)	CMU	ICLUS_A1	2080 (480 - 3690)	1370 (580 - 2170)	1050 (450 - 1660)	-350 (-550 - -140)
	CMU	ICLUS_A2	3430 (750 - 6160)	2270 (970 - 3600)	1780 (760 - 2810)	-620 (-980 - -250)
	CMU	ICLUS_BC	2570 (570 - 4610)	1730 (740 - 2730)	1310 (560 - 2060)	-460 (-730 - -180)
	CMU	Woods & Poole	3040 (650 - 5460)	1840 (780 - 2910)	1750 (750 - 2770)	-560 (-880 - -230)
	CMU	Census_2000	2140 (550 - 3760)	1460 (620 - 2320)	990 (420 - 1570)	-310 (-500 - -120)
	GNM	ICLUS_A1	310 (-580 - 1210)	-260 (-630 - 120)	190 (-60 - 440)	380 (100 - 660)
	GNM	ICLUS_A2	510 (-1040 - 2080)	-490 (-1130 - 160)	300 (-110 - 720)	690 (190 - 1200)
	GNM	ICLUS_BC	340 (-830 - 1520)	-390 (-880 - 100)	210 (-90 - 520)	520 (140 - 900)
	GNM	Woods & Poole	280 (-1040 - 1620)	-470 (-1010 - 70)	220 (-160 - 590)	540 (130 - 960)
	GNM	Census_2000	20 (-890 - 940)	-420 (-860 - 10)	90 (-130 - 300)	360 (90 - 630)
	Harvard	ICLUS_A1	1190 (70 - 2310)	1030 (430 - 1630)	-140 (-410 - 140)	300 (60 - 540)
	Harvard	ICLUS_A2	2050 (170 - 3950)	1730 (720 - 2750)	-220 (-670 - 240)	540 (120 - 960)
	Harvard	ICLUS_BC	1560 (150 - 2980)	1310 (540 - 2090)	-150 (-480 - 180)	400 (80 - 710)
	Harvard	Woods & Poole	1820 (180 - 3480)	1480 (610 - 2350)	-100 (-510 - 320)	440 (70 - 810)
	Harvard	Census_2000	1370 (270 - 2470)	1140 (470 - 1810)	-30 (-240 - 180)	260 (40 - 480)

Table A-11 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Age < 1) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Burnett et al. (2001)	Illinois-1	ICLUS_A1	2610 (970 - 4260)	1230 (530 - 1950)	1060 (450 - 1690)	310 (-10 - 630)
	Illinois-1	ICLUS_A2	4410 (1620 - 7230)	2120 (900 - 3340)	1780 (750 - 2820)	520 (-30 - 1070)
	Illinois-1	ICLUS_BC	3310 (1220 - 5430)	1620 (690 - 2560)	1300 (550 - 2070)	390 (-20 - 800)
	Illinois-1	Woods & Poole	3910 (1430 - 6430)	1830 (780 - 2890)	1650 (700 - 2610)	430 (-50 - 930)
	Illinois-1	Census_2000	2660 (1000 - 4330)	1460 (620 - 2300)	930 (390 - 1470)	270 (-10 - 560)
	Illinois-2	ICLUS_A1	2670 (1090 - 4280)	1050 (440 - 1670)	990 (410 - 1590)	630 (240 - 1030)
	Illinois-2	ICLUS_A2	4550 (1850 - 7290)	1820 (760 - 2890)	1640 (670 - 2630)	1090 (420 - 1760)
	Illinois-2	ICLUS_BC	3430 (1390 - 5490)	1400 (580 - 2220)	1220 (500 - 1950)	810 (310 - 1320)
	Illinois-2	Woods & Poole	3900 (1570 - 6270)	1590 (660 - 2520)	1360 (540 - 2200)	950 (360 - 1550)
	Illinois-2	Census_2000	2680 (1090 - 4290)	1270 (530 - 2020)	830 (340 - 1330)	570 (220 - 940)
	NERL	ICLUS_A1	-70 (-990 - 860)	-220 (-560 - 130)	450 (120 - 780)	-290 (-550 - -40)
	NERL	ICLUS_A2	-170 (-1750 - 1410)	-410 (-1000 - 180)	750 (210 - 1300)	-510 (-950 - -60)
	NERL	ICLUS_BC	-170 (-1350 - 1010)	-330 (-780 - 120)	550 (150 - 940)	-390 (-720 - -50)
	NERL	Woods & Poole	-170 (-1520 - 1190)	-380 (-870 - 110)	680 (190 - 1170)	-470 (-850 - -80)
	NERL	Census_2000	-260 (-1160 - 640)	-360 (-750 - 40)	390 (120 - 660)	-300 (-540 - -50)

Table A-11 cont'd. Estimated National and Regional O_3-Related Incidence of Hospital Admissions for Respiratory Illness (Age < 1) Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Burnett et al. (2001)	WSU	ICLUS_A1	-710 (-3210 - 1830)	1310 (460 - 2170)	-1670 (-2810 - -510)	-350 (-860 - 170)
	WSU	ICLUS_A2	-1290 (-5490 - 3000)	2140 (740 - 3560)	-2810 (-4710 - -860)	-620 (-1520 - 300)
	WSU	ICLUS_BC	-890 (-4020 - 2300)	1630 (570 - 2710)	-2040 (-3430 - -620)	-480 (-1160 - 210)
	WSU	Woods & Poole	-840 (-4330 - 2720)	1640 (560 - 2740)	-2190 (-3860 - -470)	-300 (-1040 - 460)
	WSU	Census_2000	-310 (-2620 - 2040)	1360 (470 - 2260)	-1330 (-2260 - -380)	-340 (-830 - 150)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.

Table A-12. Estimated National and Regional O_3-Related Incidence of Emergency Room Visits for Asthma Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Peel et al. (2005); Wilson et al. (2005)	CMU	ICLUS_A1	2040 (-5600 - 7260)	1420 (-3570 - 4850)	750 (-1880 - 2560)	-130 (-470 - 360)
	CMU	ICLUS_A2	2490 (-6850 - 8870)	1710 (-4290 - 5840)	940 (-2370 - 3220)	-170 (-580 - 450)
	CMU	ICLUS_BC	2160 (-5940 - 7690)	1510 (-3790 - 5150)	790 (-1980 - 2690)	-140 (-500 - 390)
	CMU	Woods & Poole	2480 (-6900 - 8890)	1680 (-4210 - 5720)	990 (-2480 - 3380)	-190 (-650 - 500)
	CMU	Census_2000	1880 (-5070 - 6640)	1380 (-3460 - 4700)	600 (-1490 - 2030)	-90 (-330 - 260)
	GNM	ICLUS_A1	-130 (-2150 - 1890)	-400 (-1970 - 1390)	130 (-530 - 740)	140 (-370 - 530)
	GNM	ICLUS_A2	-210 (-2830 - 2420)	-550 (-2460 - 1790)	150 (-650 - 910)	180 (-470 - 670)
	GNM	ICLUS_BC	-220 (-2530 - 2130)	-490 (-2160 - 1580)	120 (-540 - 740)	160 (-420 - 590)
	GNM	Woods & Poole	-300 (-3080 - 2540)	-610 (-2440 - 1850)	120 (-650 - 870)	190 (-500 - 710)
	GNM	Census_2000	-370 (-2600 - 1970)	-530 (-2070 - 1550)	40 (-350 - 440)	110 (-300 - 420)
	Harvard	ICLUS_A1	1160 (-3820 - 4520)	1140 (-2900 - 3900)	-100 (-730 - 680)	120 (-390 - 460)
	Harvard	ICLUS_A2	1450 (-4730 - 5630)	1410 (-3590 - 4840)	-110 (-890 - 830)	150 (-480 - 580)
	Harvard	ICLUS_BC	1280 (-4130 - 4940)	1240 (-3160 - 4250)	-90 (-720 - 690)	130 (-420 - 500)
	Harvard	Woods & Poole	1500 (-4860 - 5810)	1430 (-3640 - 4900)	-80 (-840 - 830)	160 (-520 - 620)
	Harvard	Census_2000	1210 (-3110 - 4480)	1150 (-2540 - 3930)	-30 (-410 - 360)	90 (-250 - 340)

Table A-12 cont'd. Estimated National and Regional O_3-Related Incidence of Emergency Room Visits for Asthma Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Peel et al. (2005); Wilson et al. (2005)	Illinois-1	ICLUS_A1	2280 (-5110 - 7880)	1390 (-3020 - 4730)	760 (-1660 - 2590)	130 (-430 - 580)
	Illinois-1	ICLUS_A2	2850 (-6390 - 9840)	1750 (-3800 - 5950)	940 (-2060 - 3220)	160 (-520 - 710)
	Illinois-1	ICLUS_BC	2470 (-6390 - 8540)	1550 (-3870 - 5260)	790 (-1980 - 2680)	140 (-530 - 630)
	Illinois-1	Woods & Poole	2930 (-7590 - 10130)	1800 (-4510 - 6130)	960 (-2420 - 3270)	170 (-670 - 800)
	Illinois-1	Census_2000	2150 (-5510 - 7400)	1480 (-3710 - 5050)	570 (-1420 - 1930)	100 (-380 - 450)
	Illinois-2	ICLUS_A1	2220 (-5640 - 7610)	1270 (-3190 - 4340)	690 (-1770 - 2370)	260 (-680 - 900)
	Illinois-2	ICLUS_A2	2780 (-7090 - 9560)	1620 (-4080 - 5540)	850 (-2180 - 2920)	310 (-830 - 1090)
	Illinois-2	ICLUS_BC	2420 (-6160 - 8310)	1430 (-3610 - 4900)	710 (-1830 - 2450)	270 (-720 - 960)
	Illinois-2	Woods & Poole	2860 (-7290 - 9830)	1680 (-4230 - 5750)	830 (-2150 - 2880)	340 (-910 - 1200)
	Illinois-2	Census_2000	2060 (-5240 - 7080)	1380 (-3470 - 4720)	490 (-1250 - 1680)	190 (-520 - 680)
	NERL	ICLUS_A1	-150 (-2220 - 1920)	-350 (-1790 - 1250)	320 (-810 - 1170)	-120 (-460 - 340)
	NERL	ICLUS_A2	-210 (-2830 - 2410)	-470 (-2210 - 1580)	400 (-1000 - 1450)	-140 (-560 - 420)
	NERL	ICLUS_BC	-220 (-2530 - 2120)	-430 (-1940 - 1410)	330 (-830 - 1200)	-130 (-500 - 370)
	NERL	Woods & Poole	-290 (-3020 - 2490)	-510 (-2170 - 1610)	390 (-990 - 1420)	-160 (-630 - 470)
	NERL	Census_2000	-330 (-2450 - 1870)	-460 (-1820 - 1370)	230 (-560 - 810)	-100 (-390 - 280)

Table A-12 cont'd. Estimated National and Regional O_3-Related Incidence of Emergency Room Visits for Asthma Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Peel et al. (2005); Wilson et al. (2005)	WSU	ICLUS_A1	0 (-2670 - 2680)	910 (-320 - 2110)	-810 (-1970 - 380)	-100 (-380 - 190)
	WSU	ICLUS_A2	-110 (-6320 - 6010)	2070 (-2100 - 5690)	-1950 (-5440 - 2070)	-230 (-1070 - 360)
	WSU	ICLUS_BC	10 (-2800 - 2820)	940 (-340 - 2480)	-830 (-2140 - 390)	-110 (-420 - 210)
	WSU	Woods & Poole	-110 (-6250 - 5930)	1940 (-2350 - 5400)	-1860 (-5320 - 2420)	-190 (-1050 - 450)
	WSU	Census_2000	320 (-5140 - 4980)	1220 (-3530 - 4590)	-780 (-3020 - 2510)	-120 (-730 - 610)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest ten.
**These studies were pooled to estimate respiratory emergency room visits.

Table A-13. Estimated National and Regional O_3-Related Incidence of Minor Restricted Activity Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ostro and Rothschild (1989)	CMU	ICLUS_A1	2722000 (684000 - 4770000)	1841000 (758000 - 2929000)	1246000 (514000 - 1981000)	-365000 (-588000 - -141000)
	CMU	ICLUS_A2	2807000 (679000 - 4944000)	1899000 (782000 - 3022000)	1305000 (539000 - 2075000)	-398000 (-642000 - -153000)
	CMU	ICLUS_BC	2632000 (643000 - 4629000)	1803000 (742000 - 2869000)	1195000 (493000 - 1900000)	-366000 (-592000 - -140000)
	CMU	Woods & Poole	3023000 (649000 - 5407000)	2045000 (841000 - 3255000)	1474000 (608000 - 2343000)	-496000 (-800000 - -191000)
	CMU	Census_2000	2388000 (675000 - 4109000)	1693000 (695000 - 2695000)	949000 (392000 - 1509000)	-254000 (-412000 - -95000)
	GNM	ICLUS_A1	200000 (-907000 - 1309000)	-372000 (-900000 - 157000)	200000 (-91000 - 491000)	372000 (84000 - 662000)
	GNM	ICLUS_A2	180000 (-1005000 - 1368000)	-432000 (-997000 - 134000)	193000 (-108000 - 495000)	419000 (100000 - 740000)
	GNM	ICLUS_BC	122000 (-993000 - 1239000)	-436000 (-975000 - 105000)	165000 (-110000 - 441000)	392000 (92000 - 693000)
	GNM	Woods & Poole	96000 (-1270000 - 1465000)	-571000 (-1203000 - 62000)	176000 (-171000 - 523000)	491000 (104000 - 880000)
	GNM	Census_2000	-129000 (-1082000 - 827000)	-485000 (-1001000 - 34000)	64000 (-141000 - 270000)	291000 (60000 - 523000)
	Harvard	ICLUS_A1	1540000 (123000 - 2962000)	1382000 (551000 - 2215000)	-150000 (-480000 - 181000)	309000 (52000 - 566000)
	Harvard	ICLUS_A2	1646000 (157000 - 3139000)	1450000 (577000 - 2325000)	-145000 (-482000 - 194000)	341000 (63000 - 619000)
	Harvard	ICLUS_BC	1565000 (171000 - 2964000)	1377000 (548000 - 2210000)	-123000 (-430000 - 184000)	312000 (53000 - 570000)
	Harvard	Woods & Poole	1881000 (187000 - 3579000)	1617000 (643000 - 2594000)	-130000 (-507000 - 248000)	394000 (52000 - 737000)
	Harvard	Census_2000	1451000 (260000 - 2645000)	1289000 (509000 - 2072000)	-43000 (-265000 - 179000)	204000 (15000 - 394000)

Table A-13 cont'd. Estimated National and Regional O_3-Related Incidence of Minor Restricted Activity Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ostro and Rothschild (1989)	Illinois-1	ICLUS_A1	3258000 (1189000 - 5336000)	1675000 (692000 - 2663000)	1249000 (508000 - 1993000)	334000 (-11000 - 680000)
	Illinois-1	ICLUS_A2	3430000 (1245000 - 5625000)	1786000 (738000 - 2840000)	1295000 (527000 - 2065000)	349000 (-20000 - 720000)
	Illinois-1	ICLUS_BC	3216000 (1168000 - 5272000)	1711000 (706000 - 2720000)	1182000 (481000 - 1885000)	323000 (-20000 - 667000)
	Illinois-1	Woods & Poole	3880000 (1379000 - 6391000)	2040000 (842000 - 3243000)	1434000 (586000 - 2285000)	406000 (-49000 - 862000)
	Illinois-1	Census_2000	2796000 (1034000 - 4565000)	1668000 (689000 - 2652000)	900000 (368000 - 1433000)	228000 (-23000 - 480000)
	Illinois-2	ICLUS_A1	3227000 (1266000 - 5198000)	1434000 (580000 - 2293000)	1124000 (441000 - 1810000)	670000 (246000 - 1095000)
	Illinois-2	ICLUS_A2	3408000 (1337000 - 5488000)	1549000 (626000 - 2475000)	1148000 (450000 - 1849000)	711000 (261000 - 1163000)
	Illinois-2	ICLUS_BC	3205000 (1258000 - 5160000)	1488000 (603000 - 2377000)	1056000 (414000 - 1701000)	661000 (242000 - 1081000)
	Illinois-2	Woods & Poole	3928000 (1536000 - 6330000)	1786000 (724000 - 2853000)	1274000 (498000 - 2054000)	867000 (314000 - 1423000)
	Illinois-2	Census_2000	2680000 (1051000 - 4317000)	1443000 (586000 - 2304000)	760000 (296000 - 1226000)	478000 (170000 - 786000)
	NERL	ICLUS_A1	-126000 (-1274000 - 1025000)	-324000 (-811000 - 163000)	515000 (129000 - 903000)	-317000 (-592000 - -41000)
	NERL	ICLUS_A2	-182000 (-1392000 - 1031000)	-375000 (-891000 - 142000)	533000 (138000 - 930000)	-340000 (-638000 - -40000)
	NERL	ICLUS_BC	-216000 (-1346000 - 916000)	-379000 (-870000 - 113000)	483000 (125000 - 842000)	-320000 (-601000 - -39000)
	NERL	Woods & Poole	-336000 (-1700000 - 1031000)	-482000 (-1048000 - 85000)	575000 (147000 - 1005000)	-430000 (-799000 - -59000)
	NERL	Census_2000	-354000 (-1298000 - 593000)	-428000 (-896000 - 41000)	347000 (94000 - 601000)	-273000 (-497000 - -49000)

Table A-13 cont'd. Estimated National and Regional O_3-Related Incidence of Minor Restricted Activity Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Ostro and Rothschild (1989)	WSU	ICLUS_A1	-554000 (-3681000 - 2594000)	1758000 (587000 - 2936000)	-1956000 (-3359000 - -540000)	-356000 (-909000 - 199000)
	WSU	ICLUS_A2	-624000 (-3884000 - 2658000)	1795000 (591000 - 3006000)	-2030000 (-3485000 - -563000)	-389000 (-990000 - 215000)
	WSU	ICLUS_BC	-500000 (-3524000 - 2544000)	1711000 (569000 - 2859000)	-1835000 (-3152000 - -506000)	-376000 (-941000 - 191000)
	WSU	Woods & Poole	-765000 (-4360000 - 2855000)	1865000 (609000 - 3128000)	-2236000 (-3853000 - -606000)	-393000 (-1115000 - 333000)
	WSU	Census_2000	4000 (-2455000 - 2478000)	1617000 (545000 - 2693000)	-1285000 (-2238000 - -324000)	-328000 (-762000 - 108000)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest thousand.

Table A-14. Estimated National and Regional O_3-Related Incidence of School Loss Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Chen et al. (2000); Gilliland et al. (2001)	CMU	ICLUS_A1	868000 (159000 - 1967000)	593000 (210000 - 1340000)	401000 (142000 - 905000)	-125000 (-278000 - -41000)
	CMU	ICLUS_A2	1239000 (212000 - 2809000)	847000 (300000 - 1915000)	584000 (208000 - 1319000)	-191000 (-425000 - -63000)
	CMU	ICLUS_BC	996000 (173000 - 2256000)	688000 (244000 - 1555000)	459000 (163000 - 1037000)	-151000 (-336000 - -49000)
	CMU	Woods & Poole	1130000 (166000 - 2561000)	749000 (265000 - 1694000)	578000 (205000 - 1306000)	-197000 (-438000 - -65000)
	CMU	Census_2000	907000 (189000 - 2054000)	647000 (229000 - 1463000)	370000 (131000 - 835000)	-110000 (-245000 - -35000)
	GNM	ICLUS_A1	83000 (-285000 - 441000)	-118000 (-280000 - 56000)	70000 (-29000 - 162000)	131000 (24000 - 229000)
	GNM	ICLUS_A2	111000 (-439000 - 647000)	-192000 (-432000 - 69000)	95000 (-48000 - 228000)	208000 (42000 - 364000)
	GNM	ICLUS_BC	73000 (-368000 - 506000)	-163000 (-359000 - 49000)	71000 (-42000 - 175000)	166000 (33000 - 291000)
	GNM	Woods & Poole	59000 (-460000 - 572000)	-205000 (-428000 - 37000)	74000 (-65000 - 206000)	190000 (32000 - 332000)
	GNM	Census_2000	-48000 (-469000 - 333000)	-205000 (-635000 - 17000)	29000 (-54000 - 145000)	127000 (20000 - 373000)
	Harvard	ICLUS_A1	498000 (7000 - 1124000)	444000 (152000 - 1000000)	-53000 (-158000 - 58000)	107000 (13000 - 240000)
	Harvard	ICLUS_A2	741000 (24000 - 1673000)	646000 (220000 - 1456000)	-71000 (-220000 - 87000)	165000 (23000 - 372000)
	Harvard	ICLUS_BC	602000 (26000 - 1360000)	525000 (179000 - 1183000)	-53000 (-170000 - 70000)	130000 (17000 - 293000)
	Harvard	Woods & Poole	703000 (19000 - 1587000)	599000 (204000 - 1350000)	-52000 (-199000 - 102000)	155000 (14000 - 350000)
	Harvard	Census_2000	577000 (78000 - 1302000)	503000 (170000 - 1133000)	-15000 (-98000 - 70000)	90000 (6000 - 202000)

Table A-14 cont'd. Estimated National and Regional O_3-Related Incidence of School Loss Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Chen et al. (2000); Gilliland et al. (2001)	Illinois-1	ICLUS_A1	1052000 (320000 - 2374000)	536000 (191000 - 1210000)	405000 (141000 - 914000)	110000 (-12000 - 250000)
	Illinois-1	ICLUS_A2	1538000 (464000 - 3471000)	795000 (282000 - 1793000)	583000 (203000 - 1315000)	161000 (-22000 - 364000)
	Illinois-1	ICLUS_BC	1236000 (373000 - 2789000)	650000 (231000 - 1467000)	458000 (160000 - 1032000)	128000 (-18000 - 291000)
	Illinois-1	Woods & Poole	1464000 (433000 - 3306000)	750000 (267000 - 1694000)	559000 (196000 - 1262000)	155000 (-30000 - 351000)
	Illinois-1	Census_2000	1096000 (341000 - 2474000)	649000 (231000 - 1466000)	348000 (122000 - 786000)	98000 (-12000 - 222000)
	Illinois-2	ICLUS_A1	1061000 (356000 - 2397000)	460000 (160000 - 1039000)	376000 (126000 - 849000)	226000 (70000 - 509000)
	Illinois-2	ICLUS_A2	1559000 (523000 - 3521000)	690000 (240000 - 1560000)	534000 (179000 - 1207000)	334000 (104000 - 755000)
	Illinois-2	ICLUS_BC	1256000 (421000 - 2837000)	566000 (197000 - 1279000)	423000 (142000 - 954000)	268000 (83000 - 604000)
	Illinois-2	Woods & Poole	1486000 (494000 - 3357000)	661000 (230000 - 1495000)	490000 (162000 - 1107000)	335000 (102000 - 755000)
	Illinois-2	Census_2000	1081000 (363000 - 2442000)	571000 (199000 - 1291000)	306000 (102000 - 691000)	204000 (62000 - 459000)
	NERL	ICLUS_A1	-42000 (-456000 - 336000)	-108000 (-383000 - 57000)	176000 (32000 - 510000)	-110000 (-329000 - -6000)
	NERL	ICLUS_A2	-84000 (-628000 - 473000)	-172000 (-530000 - 70000)	252000 (49000 - 680000)	-163000 (-452000 - -8000)
	NERL	ICLUS_BC	-84000 (-518000 - 363000)	-147000 (-394000 - 51000)	195000 (38000 - 489000)	-132000 (-334000 - -7000)
	NERL	Woods & Poole	-111000 (-619000 - 414000)	-178000 (-472000 - 44000)	231000 (44000 - 581000)	-164000 (-415000 - -11000)
	NERL	Census_2000	-139000 (-501000 - 242000)	-175000 (-458000 - 20000)	143000 (33000 - 359000)	-107000 (-272000 - -9000)

Table A-14 cont'd. Estimated National and Regional O_3-Related Incidence of School Loss Days Attributable to Climate Change in 2050 During the O_3 Season, Taken to be May through September*

Study**	Climate Change Model	Population Projection to 2050	Estimated O_3-Related Incidence Attributable to Climate Change in 2050			
			National	Northeast	Southeast	West
Chen et al. (2000); Gilliland et al. (2001)	WSU	ICLUS_A1	-224000 (-1744000 - 923000)	604000 (159000 - 1794000)	-692000 (-2015000 - -149000)	-135000 (-523000 - 70000)
	WSU	ICLUS_A2	-353000 (-2595000 - 1276000)	848000 (221000 - 2542000)	-996000 (-2912000 - -217000)	-206000 (-800000 - 106000)
	WSU	ICLUS_BC	-254000 (-2006000 - 1076000)	697000 (182000 - 2070000)	-779000 (-2265000 - -167000)	-171000 (-654000 - 81000)
	WSU	Woods & Poole	-328000 (-2384000 - 1156000)	714000 (182000 - 2149000)	-903000 (-2679000 - -167000)	-140000 (-641000 - 149000)
	WSU	Census_2000	-45000 (-2724000 - 2699000)	774000 (134000 - 2572000)	-652000 (-2159000 - -41000)	-168000 (-793000 - 216000)

*The 95% confidence or credible intervals shown below the incidence estimates characterize only the uncertainty due to statistical error of the coefficient estimate in the concentration-response function. Incidences are rounded to the nearest thousand.

**These studies were pooled to estimate school loss days.