



United States
Environmental
Protection Agency



Our Nation's Air

STATUS AND TRENDS THROUGH 2008



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HIGHLIGHTS

Improving air quality and taking action on climate change are priorities for the EPA. This summary report presents EPA's most recent evaluation of our nation's air quality status and takes a closer look at the relationship between air quality and climate change.

LEVELS OF SIX COMMON POLLUTANTS CONTINUE TO DECLINE

- Cleaner cars, industries, and consumer products have contributed to cleaner air for much of the U.S.
- Since 1990, nationwide air quality has improved significantly for the six common air pollutants. These six pollutants are ground-level ozone, particle pollution (PM_{2.5} and PM₁₀), lead, nitrogen dioxide (NO₂), carbon monoxide (CO), and sulfur dioxide (SO₂). Nationally, air pollution was lower in 2008 than in 1990 for:
 - 8-hour ozone, by 14 percent
 - annual PM_{2.5} (since 2000), by 19 percent
 - PM₁₀, by 31 percent
 - Lead, by 78 percent
 - NO₂, by 35 percent
 - 8-hour CO, by 68 percent
 - annual SO₂, by 59 percent
- Despite clean air progress, approximately 127 million people lived in counties that exceeded any national ambient air quality standard (NAAQS) in 2008, as shown in Figure 1. Ground-level ozone and

particle pollution still present challenges in many areas of the country.

- Nationally, for the period from 2001 to 2008, annual PM_{2.5} concentrations were 17 percent lower in 2008 compared to 2001. 24-hour PM_{2.5} concentrations were 19 percent lower in 2008 compared to 2001.
- Ozone levels did not improve in much of the East until 2002, after which there was a significant decline. 8-hour ozone concentrations were 10 percent lower in 2008 than in 2001. This decline is largely due to reductions in oxides of nitrogen (NO_x) emissions required by EPA's rule to reduce ozone in the East, the NO_x State Implementation Plan (SIP) Call. EPA tracks progress toward meeting these reductions through its NO_x Budget Trading Program.

LEVELS OF MANY TOXIC AIR POLLUTANTS HAVE DECLINED

- Toxic air pollutants such as benzene, 1,3-butadiene, styrene, xylenes, and toluene decreased by 5 percent or more per year between 2000 and 2005 at more than half of ambient monitoring sites. Other key contributors to cancer risk, such as carbon tetrachloride, tetrachloroethylene, and 1,4-dichlorobenzene, declined at most sites.
- Total emissions of toxic air pollutants have decreased by approximately 40 percent between 1990 and

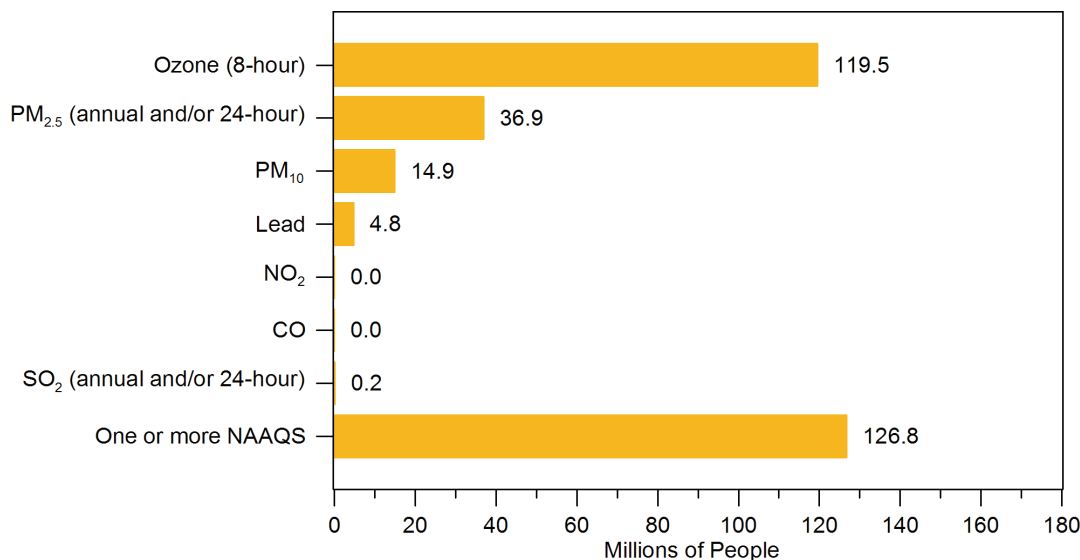


Figure 1. Number of people (in millions) living in counties with air quality concentrations above the level of the primary (health-based) National Ambient Air Quality Standards (NAAQS) in 2008.

Note: Projected population data for 2008 (U.S. Census Bureau, 2008).

2005. Control programs for mobile sources and facilities such as chemical plants, dry cleaners, coke ovens, and incinerators are primarily responsible for these reductions.

ACID RAIN AND HAZE ARE DECLINING

- EPA's NO_x SIP Call and Acid Rain Program have contributed to significant improvements in air quality and environmental health. The required reductions in SO₂ and NO_x have led to significant decreases in atmospheric deposition, which have contributed to improved water quality in lakes and streams. For example, between 1989-1991 and 2006-2008, wet sulfate deposition decreased more than 30 percent and wet nitrate deposition decreased more than 30 percent in parts of the East.
- Between 1998 and 2007, visibility in scenic areas improved throughout the country. Eight areas—Mt. Rainier National Park, WA; Great Gulf Wilderness, NH; Snoqualmie Pass, WA; Olympia, WA; Columbia Gorge, WA; Starkey, OR; Presque Isle, ME, and Bridgton, ME—showed notable improvement on days with the worst visibility.

CLIMATE CHANGE AND INTERNATIONAL TRANSPORT: IMPROVING OUR UNDERSTANDING

- In 2007, the U.N. Intergovernmental Panel on Climate Change (IPCC) concluded that climate

change is happening now, as evident from observations of increases in global average air and ocean temperatures, widespread snow melt, and rising average sea levels.

- Research is continuing to improve our understanding of the effects of air pollution on climate. For example, tropospheric ozone (a greenhouse gas) has a warming effect on climate. Black carbon particle pollution has warming effects, while aerosols containing sulfates and organic carbon tend to have cooling effects. Also, research is continuing to investigate the effects of climate change on future air pollution levels.
- Ongoing studies continue to improve our understanding about air pollution movement between countries and continents.

MORE IMPROVEMENTS ANTICIPATED

- EPA expects air quality to continue to improve as recent regulations are fully implemented and states work to meet current and recently revised national air quality standards. Key regulations include the Locomotive Engines and Marine Compression-Ignition Engines Rule, the Tier II Vehicle and Gasoline Sulfur Rule, the Heavy-Duty Highway Diesel Rule, the Clean Air Non-Road Diesel Rule, and the Mobile Source Air Toxics Rule.

SOURCES-TO-EFFECTS CONTINUUM



Because air pollution harms human health and damages the environment, EPA tracks pollutant emissions. Air pollutants are emitted from a variety of sources including stationary fuel combustion, industrial processes, highway vehicles, and non-road sources. These pollutants react in and are transported through the atmosphere. EPA; other federal agencies; and state, local, and tribal agencies monitor air quality at locations throughout the U.S. Data collected through ambient monitoring are used in models to estimate population and environmental exposures. Personal health monitoring is conducted via special studies to better understand actual dosage of pollutants. EPA uses monitoring data, population exposure estimates, and personal dosage data to better understand health effects of air pollutants. Ambient monitoring data and models are also used to estimate environmental exposures to air pollutants.

HEALTH, ENVIRONMENTAL, AND CLIMATE IMPACTS

Air pollution can affect our health in many ways. Numerous scientific studies have linked air pollution to a variety of health problems including: (1) aggravation of respiratory and cardiovascular disease; (2) decreased lung function; (3) increased frequency and severity of respiratory symptoms such as difficulty breathing and coughing; (4) increased susceptibility to respiratory infections; (5) effects on the nervous system, including the brain, such as IQ loss and impacts on learning, memory, and behavior; (6) cancer; and (7) premature death. Some sensitive individuals appear to be at greater risk for air pollution-related health effects, for example, those with pre-existing heart and lung diseases (e.g., heart failure/ischemic heart disease, asthma, emphysema, and chronic bronchitis), diabetics, older adults, and children. In 2008, approximately 127 million people lived in counties that exceeded national air quality standards.

Air pollution also damages our environment. Ozone can damage vegetation, adversely impacting the growth of plants and trees. These impacts can reduce the ability of plants to uptake CO_2 from the atmosphere and indirectly affect entire ecosystems. Visibility is reduced by particles in the air that scatter and absorb light. Typical visual range in the eastern U.S. is 15 to 30 miles, approximately one-third of what it would be without man-made air pollution. In the West, the typical visual range is about 60 to 90 miles, or about one-half of the visual range under natural conditions.

Pollution in the form of acids and acid-forming compounds (such as sulfur dioxide [SO_2] and oxides of nitrogen [NO_x]) can deposit from the atmosphere to the Earth's surface. This acid deposition can be either dry or wet. Wet deposition is more commonly known as acid rain. Acid rain can occur anywhere and, in some areas, rain can be 100 times more acidic than natural precipitation. Acid deposition can be a very serious regional problem, particularly in areas downwind from high SO_2 - and NO_x -emitting sources (e.g., coal burning power plants, smelters, and factories). Acid deposition can have many harmful ecological effects in both land and water systems. While acid deposition can damage tree foliage directly, it more commonly stresses trees by

changing the chemical and physical characteristics of the soil. In lakes, acid deposition can kill fish and other aquatic life.

Air pollution can also impact the Earth's climate. Different types of pollutants affect the climate in different ways, depending on their specific properties and the amount of time they stay in the atmosphere. Any pollutant that affects the Earth's energy balance is known as a "climate forcer." Some climate forcers absorb energy and lead to climate warming, while others reflect the sun's rays and prevent that energy from reaching the Earth's surface, leading to climate cooling. Climate forcers can either be gases or aerosols (solid or liquid droplets suspended in the air) and include many traditional air pollutants, such as ozone and different types of particle pollution.

Greenhouse gas (GHG): A gas that traps heat in the atmosphere. The principal greenhouse gases affected by human activities are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone, and fluorinated gases (hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], and sulfur hexafluoride [SF_6]).

Climate forcing pollutant: Any pollutant that affects the Earth's energy balance, including GHGs and aerosols. These pollutants are also called "radiative forcers." Some climate forcers absorb energy and warm the atmosphere (positive radiative forcing), while others cool it by reflecting sunlight back into space (negative radiative forcing).

Under normal conditions, most of the solar radiation reaching the Earth's surface is radiated back toward space. However, atmospheric greenhouse gases—like CO_2 , CH_4 , and ozone—can trap this energy and prevent the heat from escaping, somewhat like the glass panels of a greenhouse. Greenhouse gases (GHGs) are necessary to life as we know it because they keep the planet's surface warmer than it would otherwise be. However, as the concentrations of these gases continue to increase in the atmosphere, largely due to the burning of fossil fuels like coal and oil, the Earth's

Health, Environmental, and Climate Effects of Air Pollution

Pollutant	Health Effects	Environmental and Climate Effects
Ozone (O ₃)	Decreases lung function and causes respiratory symptoms, such as coughing and shortness of breath; aggravates asthma and other lung diseases leading to increased medication use, hospital admissions, emergency department (ED) visits, and premature mortality.	Damages vegetation by visibly injuring leaves, reducing photosynthesis, impairing reproduction and growth, and decreasing crop yields. Ozone damage to plants may alter ecosystem structure, reduce biodiversity, and decrease plant uptake of CO ₂ . Ozone is also a greenhouse gas that contributes to the warming of the atmosphere.
Particulate Matter (PM)	Short-term exposures can aggravate heart or lung diseases leading to symptoms, increased medication use, hospital admissions, ED visits, and premature mortality; long-term exposures can lead to the development of heart or lung disease and premature mortality.	Impairs visibility, adversely affects ecosystem processes, and damages and/or soils structures and property. Variable climate impacts depending on particle type. Most particles are reflective and lead to net cooling, while some (especially black carbon) absorb energy and lead to warming. Other impacts include changing the timing and location of traditional rainfall patterns.
Lead (Pb)	Damages the developing nervous system, resulting in IQ loss and impacts on learning, memory, and behavior in children. Cardiovascular and renal effects in adults and early effects related to anemia.	Harms plants and wildlife, accumulates in soils, and adversely impacts both terrestrial and aquatic systems.
Oxides of Sulfur (SO _x)	Aggravate asthma, leading to wheezing, chest tightness and shortness of breath, increased medication use, hospital admissions, and ED visits; very high levels can cause respiratory symptoms in people without lung disease.	Contributes to the acidification of soil and surface water and mercury methylation in wetland areas. Causes injury to vegetation and local species losses in aquatic and terrestrial systems. Contributes to particle formation with associated environmental effects. Sulfate particles contribute to the cooling of the atmosphere.
Oxides of Nitrogen (NO _x)	Aggravate lung diseases leading to respiratory symptoms, hospital admissions, and ED visits; increase susceptibility to respiratory infection.	Contributes to the acidification and nutrient enrichment (eutrophication, nitrogen saturation) of soil and surface water. Leads to biodiversity losses. Impacts levels of ozone, particles, and methane with associated environmental and climate effects.
Carbon Monoxide (CO)	Reduces the amount of oxygen reaching the body's organs and tissues; aggravates heart disease, resulting in chest pain and other symptoms leading to hospital admissions and ED visits.	Contributes to the formation of CO ₂ and ozone, greenhouse gases that warm the atmosphere.
Ammonia (NH ₃)	Contributes to particle formation with associated health effects.	Contributes to eutrophication of surface water and nitrate contamination of ground water. Contributes to the formation of nitrate and sulfate particles with associated environmental and climate effects.
Volatile Organic Compounds (VOCs)	Some are toxic air pollutants that cause cancer and other serious health problems. Contribute to ozone formation with associated health effects.	Contributes to ozone formation with associated environmental and climate effects. Contributes to the formation of CO ₂ and ozone, greenhouse gases that warm the atmosphere.
Mercury (Hg)	Causes liver, kidney, and brain damage and neurological and developmental damage.	Deposits into rivers, lakes, and oceans where it accumulates in fish, resulting in exposure to humans and wildlife.
Other Toxic Air Pollutants	Cause cancer; immune system damage; and neurological, reproductive, developmental, respiratory, and other health problems. Some toxic air pollutants contribute to ozone and particle pollution with associated health effects.	Harmful to wildlife and livestock. Some toxic air pollutants accumulate in the food chain. Some toxic air pollutants contribute to ozone and particle pollution with associated environmental and climate effects.

temperature is climbing above past levels. Such changes in temperature, along with changes in precipitation and other weather conditions due to climate change, may lead to even higher air pollution levels.

In addition to GHGs, other pollutants contribute to climate change. Black carbon (BC), a component of particle pollution, directly absorbs incoming and reflected solar radiation and reduces reflection of sunlight off of snow and ice. In these ways, BC contributes to increased absorption of energy at the Earth's surface and warming of the atmosphere. Recent studies suggest that BC may be having a significant impact on the Earth's climate. Other types of particles—particularly sulfates, nitrates, and some types of directly emitted organic carbon—are largely reflective and therefore have a net cooling impact on the atmosphere. Particles can also have important indirect effects on climate through impacts on clouds and precipitation.

The longer a pollutant stays in the atmosphere, the longer the effect associated with that pollutant will persist. Some climate forcing pollutants stay in the atmosphere for decades or centuries after they are emitted, meaning today's emissions will affect the climate far into the future. These pollutants, like CO_2 , tend to accumulate in the atmosphere so their net warming impact continues over time. Other climate forcers, such as ozone and BC, remain in the atmosphere for shorter periods of time so reducing

emissions of these pollutants may have beneficial impacts on climate in the near term. These short-lived climate forcers originate from a variety of sources, including the burning of fossil fuels and biomass, wildfires, and industrial processes. Short-lived climate forcing pollutants and their chemical precursors can be transported long distances and may produce particularly harmful warming effects in sensitive regions such as the Arctic.

SOURCES OF AIR POLLUTION

Air pollution consists of gas and particle contaminants that are present in the atmosphere. Gaseous pollutants include SO_2 , NO_x , ozone, carbon monoxide (CO), volatile organic compounds (VOCs), certain toxic air pollutants, and some gaseous forms of metals. Particle pollution ($\text{PM}_{2.5}$ and PM_{10}) includes a mixture of compounds. The majority of these compounds can be grouped into five categories: sulfate, nitrate, elemental (black) carbon, organic carbon, and crustal material.

Some pollutants are released directly into the atmosphere. These include gases, such as SO_2 , and some particles, such as crustal material and elemental carbon. Other pollutants are formed in the air. Ground-level ozone forms when emissions of NO_x and VOCs react in the presence of sunlight. Similarly, some particles are formed from other directly emitted pollutants. For example, particle sulfates result from SO_2 and ammonia (NH_3) gases reacting in the

EMISSIONS INCLUDED IN THIS REPORT



- PM emissions include directly emitted particles only. This report does not include gaseous emissions that condense in cooler air (i.e., condensibles) that form particles or emissions from fires and resuspended dust. Note that the emissions do not include secondarily formed pollutants resulting from other directly emitted pollutants.
- SO_2 , NO_x , VOCs, CO, and lead emissions originate from human activity sources only.
- NH_3 emissions primarily result from animal livestock operations and are estimated using population data (e.g., cattle, pigs, poultry) and management practices.
- 2008 emissions from industry were derived from the 2005 emissions inventory, except for SO_2 and NO_x emissions, which were derived from measured data from electric utilities.
- Highway vehicle emissions were based on emissions measurements from vehicle testing programs.
- Emissions data were compiled using the best methods and measurements available at the time.

atmosphere. Weather plays an important role in the formation of secondarily formed air pollutants, as discussed later in the Ozone and Particle Pollution sections.

EPA tracks direct emissions of air pollutants and emissions that contribute to the formation of key pollutants, also known as precursor emissions. Emissions data are compiled from many different organizations, including industry and state, tribal, and local agencies. Some emissions data are based on actual measurements while others are estimates.

Generally, emissions come from large stationary fuel combustion sources (such as electric utilities and industrial boilers), industrial and other processes (such as metal smelters, petroleum refineries, cement kilns, manufacturing facilities, and solvent utilization), and mobile sources including highway vehicles and non-road sources (such as recreational and construction equipment, marine vessels, aircraft, and locomotives). Sources emit different combinations of pollutants. For example, electric utilities release SO_2 , NO_x , and particles.

Figure 2 shows the distribution of national total emissions estimates by source category for specific pollutants in 2008. Electric utilities contribute about 70 percent of national SO_2 emissions. Agricultural operations (other processes) contribute over 80 percent of national NH_3 emissions. Almost 50 percent of the

national VOC emissions originate from solvent use (other processes) and highway vehicles. Highway vehicles and non-road mobile sources together contribute approximately 80 percent of national CO emissions. Pollutant levels differ across regions of the country and within local areas, depending on the size and type of sources present.

Fossil fuel combustion is the primary source contributing to CO_2 emissions (not shown in Figure 2). In 2007 (the most recent year for which data are available), fossil fuel combustion contributed almost 94 percent of total CO_2 emissions (source: <http://epa.gov/climatechange/emissions/usinventoryreport.html>). Major sources of fossil fuel combustion include electricity generation, transportation (including personal and heavy-duty vehicles), industrial processes, residential, and commercial. Electricity generation contributed approximately 42 percent of CO_2 emissions from fossil fuel combustion while transportation contributed approximately 33 percent.

Primary sources of CH_4 emissions (not shown) include livestock, landfills, and natural gas systems (including wells, processing facilities, and distribution pipelines). In 2007, these sources contributed about 64 percent of total U.S. CH_4 emissions. Other contributing sources include coal mining (10 percent) and manure management (8 percent).

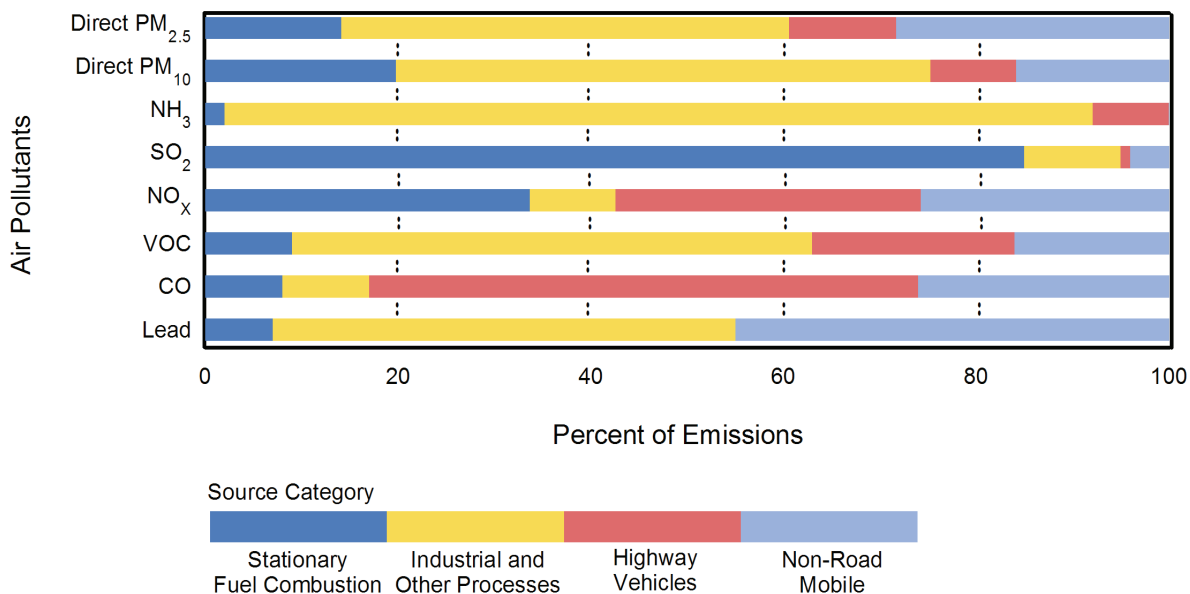


Figure 2. Distribution of national total emissions estimates by source category for specific pollutants, 2008.

TRACKING POLLUTANT EMISSIONS

Since 1990, national annual air pollutant emissions have declined, with the greatest percentage drop in lead emissions. NH_3 shows the smallest percentage drop (six percent), while direct $\text{PM}_{2.5}$ emissions have declined by over one-half, PM_{10} , NO_x , and VOC emissions have declined by over one-third, and SO_2 and CO emissions have declined by almost one-half, as shown in Table 1.

Table 1. Change in annual national emissions per source category (1990 vs. 2008) (thousand tons).

Source Category	$\text{PM}_{2.5}$	PM_{10}	NH_3	SO_2	NO_x	VOC	CO	Lead
Stationary Fuel Combustion	-773	-813	+43	-10,490	-5,323	+445	-228	-0.42
Industrial and Other Processes	-343	-217	-446	-731	-144	-3,150	-442	-2.80
Highway Vehicles	-213	-216	+153	-439	-4,386	-5,970	-71,389	-0.42
Non-Road Mobile	-17	-24	-28	+85	+474	-76	-3,411	-0.27
Total Change	-1,346	-1,270	-278	-11,575	-9,379	-8,751	-75,470	-3.91
Percent Change (1990 vs. 2008)	-58%	-39%	-6%	-50%	-36%	-35%	-53%	-79%

The combined emissions of the six common pollutants and their precursors ($\text{PM}_{2.5}$ and PM_{10} , SO_2 , NO_x , VOCs, CO, and lead) dropped 41 percent on average since 1990, as shown in Figure 3. This progress has occurred while the U.S. economy continued to grow, Americans drove more miles, and population and energy use increased. These emissions reductions were achieved through regulations and voluntary partnerships between federal, state, local, and tribal governments; academia; industrial groups; and environmental organizations. There was a notable reduction in vehicle miles traveled and energy consumed from 2007 to 2008. Factors likely contributing to this reduction include the nationwide spike in gasoline prices during 2008 and the economic recession that began in 2008. Figure 3 also shows total CO_2 emissions increasing by about 20 percent from 1990 to 2007 (<http://epa.gov/climatechange/emissions/userinventoryreport.html>).

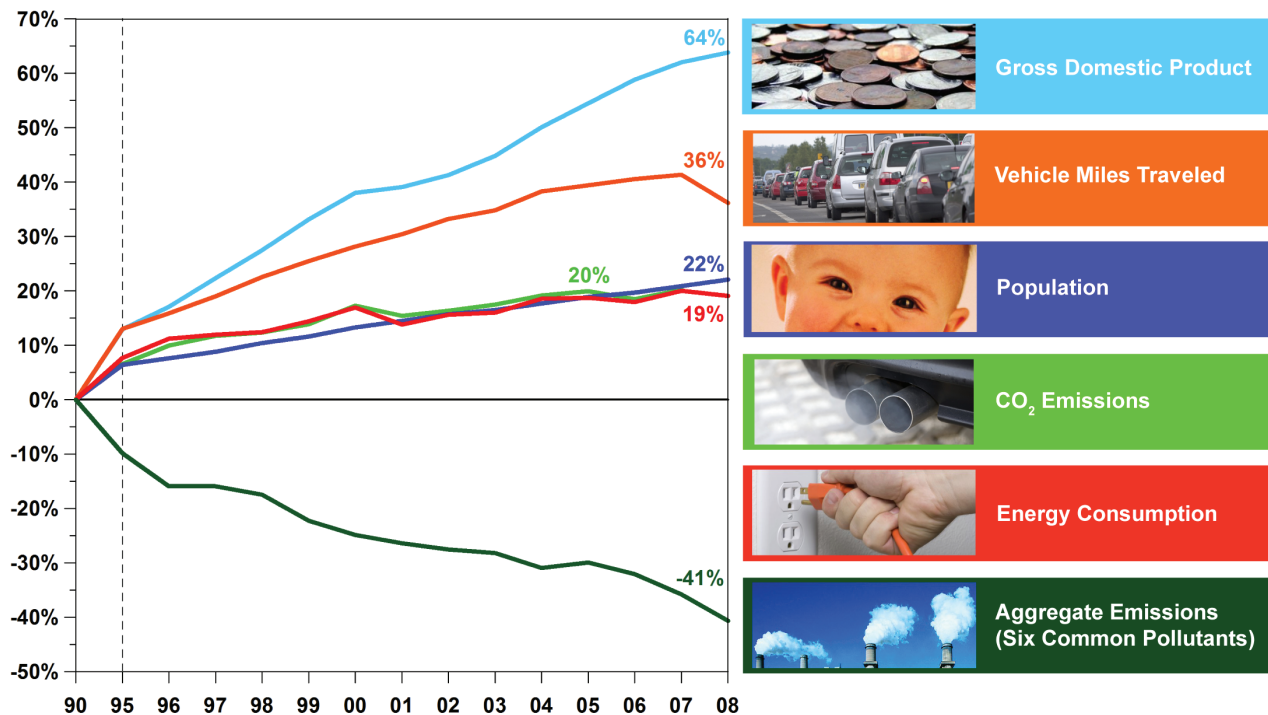


Figure 3. Comparison of growth measures and emissions, 1990-2008.

Note: CO_2 emissions estimates are from 1990 to 2007.

SIX COMMON POLLUTANTS

To protect public health and the environment, EPA has established, and regularly reviews, national air quality standards for six common air pollutants also known as “criteria” pollutants: ground-level ozone, particle pollution (PM_{2.5} and PM₁₀), lead, nitrogen dioxide (NO₂), carbon monoxide (CO), and sulfur dioxide (SO₂).

TRENDS IN NATIONAL AIR QUALITY CONCENTRATIONS

Monitors across the country measure air quality. Monitored levels of the six common pollutants show improvement since the Clean Air Act was amended in 1990. Figure 4 shows national trends between 1990 and 2008 in the common pollutants relative to their air quality standards. Most pollutants show a steady decline throughout the time period. Lead declined in the 1990s because all lead was removed from automotive gasoline and stationary source control programs were implemented to lower concentrations in areas above the national standard (year-to-year fluctuations in lead concentrations are influenced by emissions changes

due to operating schedules or other industrial facility activities, such as plant closings, on measurements at nearby monitors). The trend for lead shown in Figure 4 is relative to the decision announced by EPA on October 15, 2008, to strengthen the standard to 0.15 µg/m³ (maximum three-month average) from 1.5 µg/m³ (maximum quarterly average). Ozone and PM_{2.5} trends are shown relative to standards that were revised in 2008 and 2006, respectively. These trends are not smooth and show year-to-year influences of weather conditions that contribute to the formation, dispersion, and removal of these pollutants from the air. Ozone was generally level in the 1990s and showed a notable decline after 2002, mostly due to oxides of nitrogen (NO_x) emissions reductions in the East.

Many areas still have air quality problems caused by one or more pollutants. Ozone and particle pollution continue to present air quality challenges throughout much of the U.S., with many individual monitors measuring concentrations above, or close to, national air quality standards.

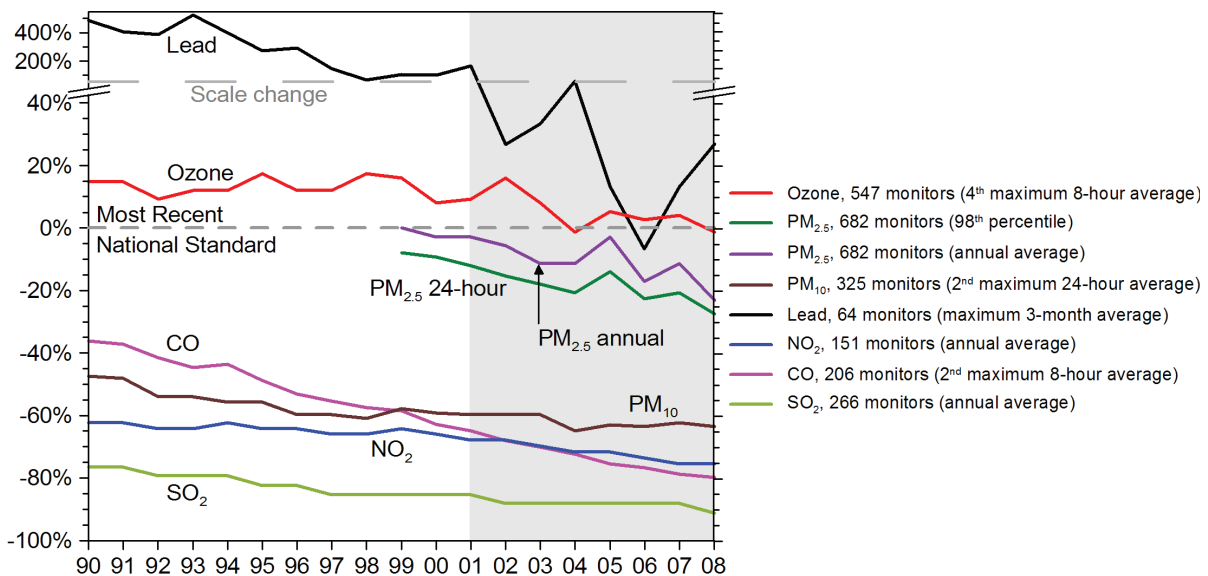
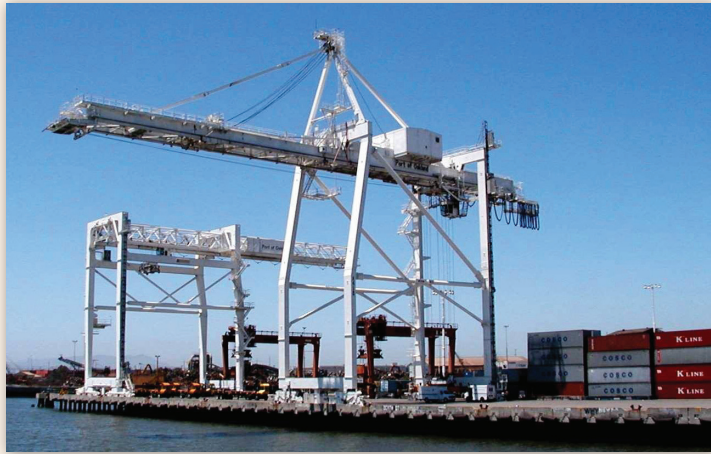


Figure 4. Comparison of national levels of the six common pollutants to the most recent national ambient air quality standards, 1990–2008. National levels are averages across all monitors with complete data for the time period.

Note: Air quality data for PM_{2.5} start in 1999. Trends from 2001 through 2008 (using the larger number of monitors operating since 2001) are the focus of graphics in the following sections.

ENVIRONMENTAL JUSTICE



Integrating environmental justice into our programs and regulatory process is one of EPA's top priorities. We're working to ensure that people of all races, cultures, and incomes are treated fairly and benefit equally from EPA's actions to protect public health and the environment. The agency recognizes that improving environmental health at the local level will bring economic and social benefits to the entire community.

To get an accurate picture of local air quality and sources of emissions that are of major concern, some communities have performed local assessments. Understanding the risks at the local level enables communities to target problem areas and tailor emissions reduction strategies that will

improve air quality. EPA has been working in partnership with the West Oakland Toxic Reduction Collaborative to identify and address sources of pollution that are harming public health. West Oakland, CA, is a low-income community of 25,000 people, approximately 90 percent of whom are people of color. West Oakland is impacted by emissions from traffic and the transport of goods and produce. The efforts of the Collaborative, EPA Region 9, and a host of community organizations have resulted in a commitment from the Port of Oakland to reduce risk from port-related diesel pollutants by 85 percent by 2020 and to support cleanup of the fleet of 2,000 heavy duty trucks serving the Port. Community partners include the local health department, labor unions, the West Oakland Commerce Association, environmental advocacy organizations, the University of San Francisco, elected officials, and many other organizations.

The Collaborative's accomplishments include setting up a "truck information center" to facilitate compliance by more than 2,000 truckers with new state truck standards. At least two industrial recyclers are working with the Collaborative's Land Use work group to relocate their operations out of residential areas into industrial areas in order to reduce toxics exposure while retaining businesses in the community. Dozens of households have been trained on indoor air quality and assessment and control by way of the Healthy Homes work group. The Health Impacts Assessment (HIA) work group piloted two applications on an HIA methodology; one at a senior center, which resulted in mitigation measures. The Alternative Fuels work group facilitated the piloting of a dozen applications of alternative fuels including biodiesel and compressed natural gas.

One of the resources used by the Collaborative is the Community Action for a Renewed Environment grant program, which offers communities an innovative way to address risks from multiple sources of toxic air pollutants. EPA offers other kinds of support to help inform and empower citizens to make local decisions concerning the health of their communities. For example, EPA maintains the Air Toxics Community Assessment and Risk Reduction Projects database to inform communities about past community-level air toxics assessments and lessons learned (<http://www.epa.gov/ttn/atw/urban/mainwks.html>). EPA has also engaged many communities in its Collision Repair Campaign (CRC), a voluntary program that reduces and eliminates harmful air toxics from collision repair and/or auto body shops across the nation. These sources affect many environmental justice communities. The CRC has trained over 750 people, representing close to 500 repair shops. EPA estimates that the CRC has reduced volatile organic compound emissions by 31 tons and particle emissions by 40 tons in 2008.

Through efforts like these, EPA can build on the progress we've made so far, accelerate environmental improvements, and ensure communities that are behind catch up – and continue to keep pace.

AIR QUALITY IN NONATTAINMENT AREAS

Under the Clean Air Act, EPA and state, local, and tribal air quality planning agencies work together to identify areas of the U.S. that do not meet the EPA's National Ambient Air Quality Standards (NAAQS). These areas, known as nonattainment areas, must develop plans to reduce air pollution. Each year, EPA tracks air quality progress in nonattainment areas by reviewing changes in measured concentrations with respect to the standards. Table 2 identifies the nonattainment areas throughout the U.S. and shows how many of these areas were above or below one or more of the standards as of 2008.

Over time, air quality has improved in nonattainment areas for all six common pollutants. All of the areas designated as nonattainment for CO, SO₂, and NO₂ showed air quality levels below their respective standards as of December 2008. Only two nonattainment areas were above the original standard for lead (1.5 µg/m³)—Herculaneum and Dent Township, MO. For ozone, annual PM_{2.5}, and PM₁₀, a number of areas were still exceeding the standards: 31, 21, and 18 areas, respectively. Furthermore, 31 new areas were designated as nonattainment with the revised 24-hour PM_{2.5} standard in October 2009. Figure 5 shows trends for average concentrations of particle pollution and ozone in those nonattainment areas. Although many areas were still above the standard in 2008, there have been improvements in the

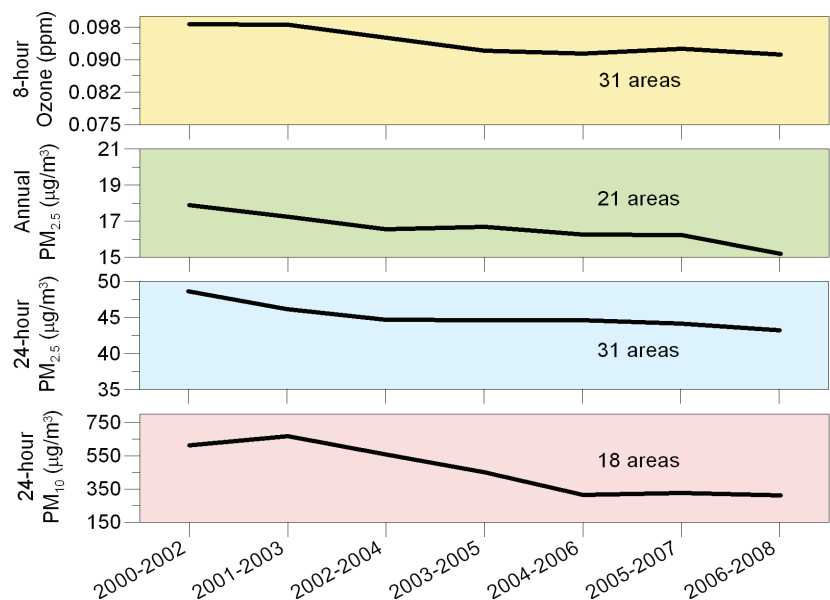
Pollutant Standard	Year NAAQS Established	Number of Nonattainment Areas	Number of These Nonattainment Areas Still Above NAAQS Levels in 2008
Ozone (8-hour)	1997	113	31
Annual PM _{2.5}	1997	39	21
24-hour PM _{2.5}	2006	31	31
24-hour PM ₁₀	1987	87	18
Lead (max quarterly)	1978	13	2
Annual NO ₂	1985	1	0
CO (8-hour)	1985	43	0
Annual SO ₂	1987	54	0

Table 2. Status of original nonattainment areas for one or more standards as of 2008.

Notes: Designations for the recently revised standard for lead (2008) are to be determined and therefore are not included in this table. Depending on the form of the standard, this table and the graphic below compare data from one, two, or three years with the level of the standard. For information about air quality standards, visit <http://www.epa.gov/air/criteria.html>. For information about air trends design values, visit <http://www.epa.gov/air/airtrends/values.html>.

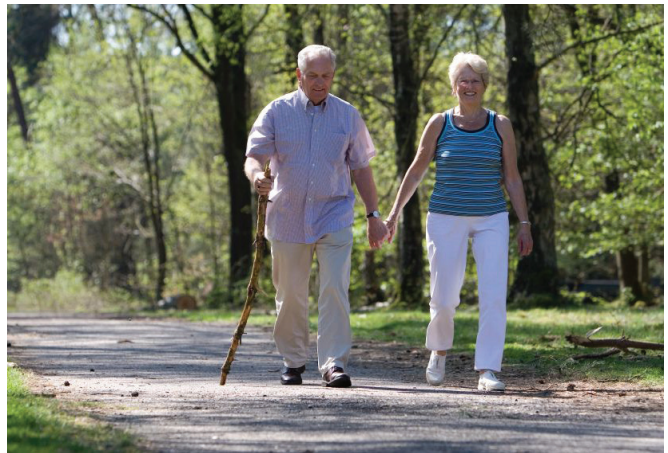
The current status of all designated nonattainment areas can be found at the EPA Green Book website (<http://www.epa.gov/oar/oaqps/greenbk/>). Nonattainment area maps for 8-hour ozone (based on the 1997 ozone standard) and PM_{2.5} (based on the 1997 PM_{2.5} standard) can be generated from information on the GIS download area of the website (http://www.epa.gov/oar/oaqps/greenbk/gis_download.html).

Figure 5. Air quality trends in nonattainment areas above the NAAQS in 2008.



concentration levels in the nonattainment areas. For example, between 2000 and 2008, ozone areas showed a 7 percent improvement, and annual PM_{2.5} areas showed an 11 percent improvement.

Despite these improvements, many areas still have work to do. It is important to note that EPA periodically reviews the standards, and their scientific basis, and revises the standards as appropriate to protect public health and the environment. This means that although areas may be making progress in reducing air pollution, over time they may need to implement additional control measures to meet new air quality standards. In addition, some areas that met previous standards may now need to implement controls to meet new, more protective standards.



NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

The Clean Air Act requires EPA to set two types of NAAQS for the six common air pollutants:

1. Primary standards protect public health with an adequate margin of safety, including the health of at-risk populations such as asthmatics, children, and older adults.
2. Secondary standards protect public welfare from adverse effects, including visibility impairment and known or anticipated effects on the environment (e.g., vegetation, soils, water, and wildlife).

The Clean Air Act requires periodic review of the standards and the science upon which they are based. The standards as of October 2009 are shown below, along with the date the most recent review was completed.

Pollutant	Primary Standard(s)	Secondary Standard(s)	Date Last Review Completed
Ozone ¹	0.075 ppm (8-hour)	Same as primary	2008
PM _{2.5}	15 µg/m ³ (annual) 35 µg/m ³ (24-hour)	Same as primary	2006
PM ₁₀	150 µg/m ³ (24-hour)	Same as primary	2006
Lead	0.15 µg/m ³ (3-month)	Same as primary	2008
NO ₂	0.053 ppm (annual)	Same as primary	1996
CO	9 ppm (8-hour) 35 ppm (1-hour)	None; no evidence of adverse welfare effects at current ambient levels	1994
SO ₂	0.03 ppm (annual) 0.14 ppm (24-hour)	0.5 ppm (3-hour)	1996

¹ On September 16, 2009, EPA announced that it is reconsidering the current levels of the ozone primary and secondary standards.

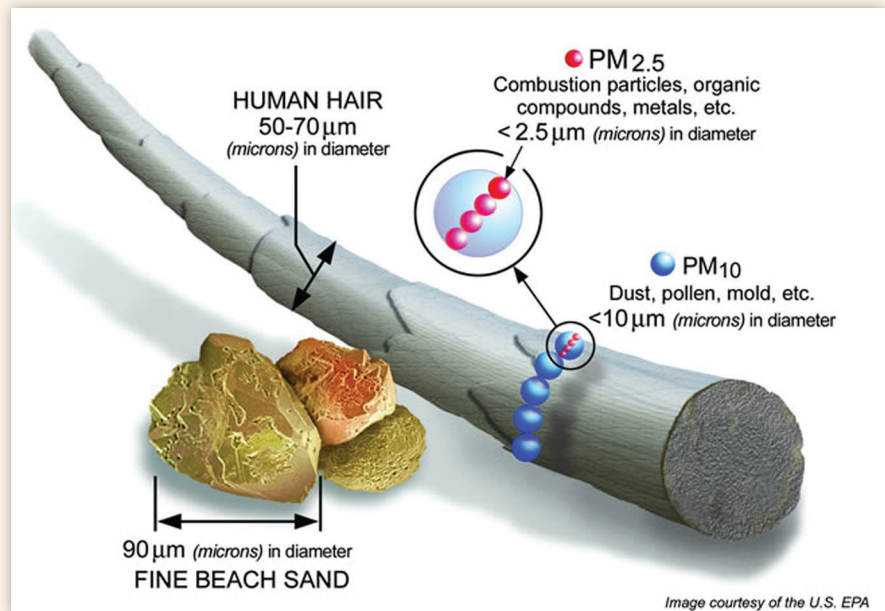
Units of measure are parts per million (ppm) or micrograms per cubic meter (µg/m³) of air. For more information about the standards, visit <http://www.epa.gov/air/criteria.html>.

PROCESS FOR REVIEWING AIR QUALITY STANDARDS

Before new standards are established, EPA compiles and evaluates the latest scientific knowledge to assess the health and welfare effects associated with each pollutant. Based on this scientific assessment, EPA staff prepare risk and policy assessments regarding the potential need to revise the standards to ensure that they protect public health with an adequate margin of safety and that they protect the environment and public welfare from known or anticipated adverse effects. These assessments undergo rigorous review by the scientific community, industry, public interest groups, the general public, and an independent review board of external experts known as the Clean Air Scientific Advisory Committee (CASAC) before any decisions are made by the EPA Administrator.

The history of EPA's national ambient air quality standards for particulate matter provides an excellent example of how this iterative review process leads to changes to the standards over time.

EPA first established air quality standards for particulate matter (PM) in 1971. These standards limited the amount of Total Suspended Particulate (TSP) in ambient air. They were not significantly revised until 1987, when EPA changed the standard to focus on inhalable particles smaller than, or equal to, 10 microns in diameter (PM_{10}). In 1997, EPA established new standards for fine particles smaller than 2.5 microns in diameter ($PM_{2.5}$). This decision was based on new evidence linking these smaller particles to serious health problems including premature death, aggravation of respiratory and cardiovascular



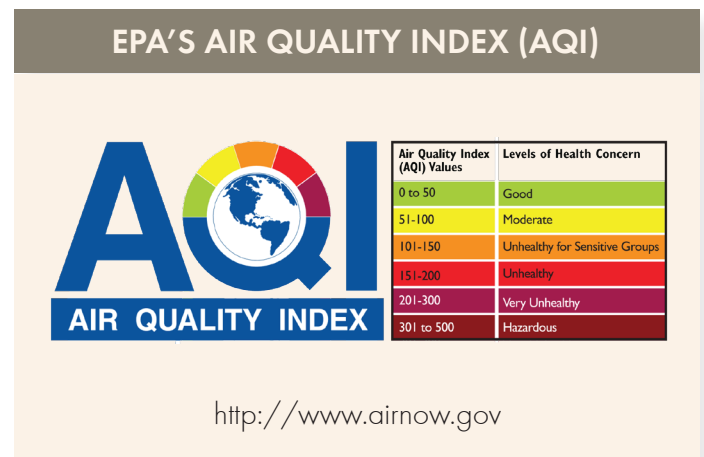
disease, and increased respiratory symptoms. At that time, EPA also retained the standards for PM_{10} to ensure continued protection against the effects of exposure to coarse particles. In 2006, based on the latest scientific information, EPA revised the 24-hour standard for $PM_{2.5}$ while retaining the annual $PM_{2.5}$ standard set in 1997. Furthermore, EPA retained the 24-hour standard for PM_{10} but revoked the annual PM_{10} standard because available evidence no longer suggested a link between long-term exposures to ambient concentrations of coarse particles and adverse health effects.



TRENDS IN “UNHEALTHY” AIR QUALITY DAYS

The Air Quality Index (AQI) relates daily air pollution concentrations for ozone, particle pollution, NO₂, CO, and SO₂ to health concerns for sensitive groups and for the general public. A value of 100 generally corresponds to the national air quality standard for each pollutant. Values below 100 are considered satisfactory. Values above 100 are considered unhealthy—first for certain sensitive groups of people, then for everyone as the AQI values increase.

Figure 6 shows the number of days on which the AQI was above 100 for selected metropolitan areas from 2001-2008. All areas experienced fewer unhealthy days in 2008 compared to 2001. However, Cleveland, Sacramento, San Diego, Dallas, and San Francisco experienced more unhealthy days in 2008 than in 2007. All of the increases in unhealthy days are due to ozone and/or particle pollution. Weather



conditions, as well as emissions, contribute to ozone and particle pollution formation. Many areas in the Midwest and eastern U.S. experienced fewer unhealthy days in 2008 compared to 2007, mostly due to weather conditions less conducive to ozone formation in these areas in 2008.

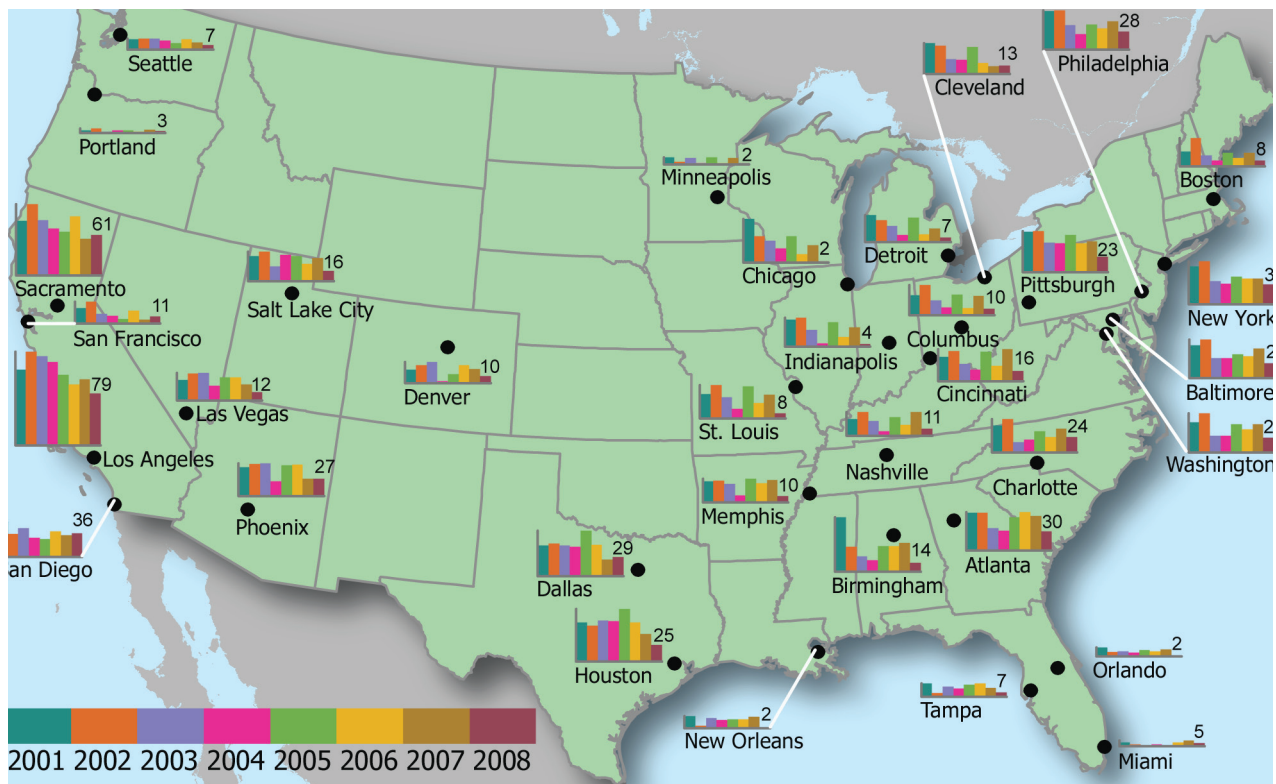


Figure 6. Number of days on which AQI values were greater than 100 during 2001-2008 in selected cities.

OZONE

Ozone is a molecule composed of three oxygen atoms. It is formed throughout the lower part of the Earth's atmosphere through a series of chemical reactions involving sunlight and ozone precursors such as volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). Carbon monoxide (CO) and methane (CH_4) also contribute to ozone formation. These precursors are emitted from a variety of man-made sources including industrial facilities, power plants, landfills, and motor vehicles. Precursor emissions from natural sources such as lightning, soil, and trees also contribute to ozone formation. Ozone at ground level is associated with adverse health and welfare effects, and EPA has set

national standards and designed control programs to protect against this "bad" ozone (see Figure 7). Additionally, ozone occurring throughout the tropospheric (lower) region of the Earth's atmosphere acts as a greenhouse gas (GHG), trapping heat from the sun and warming the Earth's surface. Ozone that occurs higher up in the stratospheric region of the atmosphere is generally natural in origin and forms a protective layer that shields life on Earth from the sun's harmful rays. EPA works to protect this "good" ozone in the upper atmosphere through regulations on ozone-depleting substances like chlorofluorocarbons (CFCs).

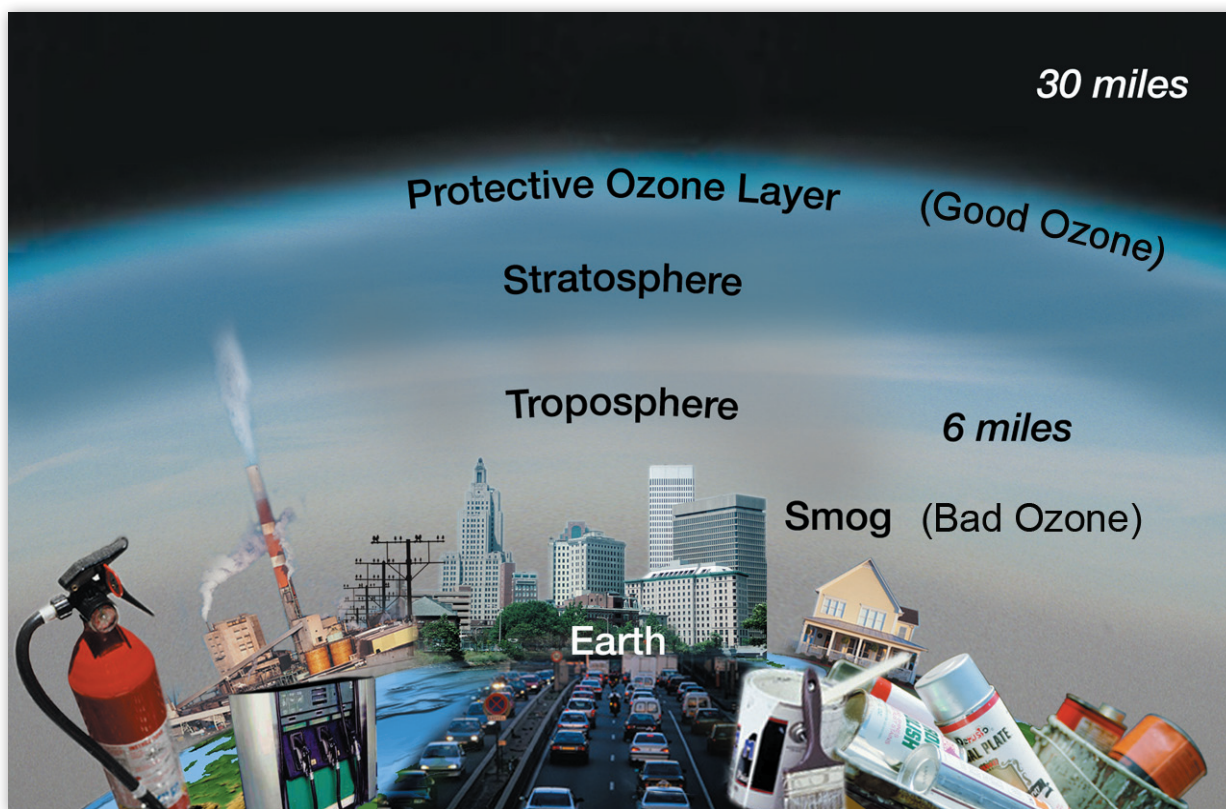


Figure 7. Ozone occurs both in the Earth's upper atmosphere (stratosphere) and at ground level (troposphere). Most of the adverse health and environmental effects of ozone are associated with ozone in the troposphere, while ozone in the stratosphere actually protects the Earth from harmful solar radiation.

TRENDS IN GROUND-LEVEL OZONE CONCENTRATIONS

Nationally, ground-level ozone concentrations were 10 percent lower in 2008 than in 2001, as shown in Figure 8. The trend showed a notable decline after 2002. Though concentrations in 2008 were among the lowest since 2002, many areas measured concentrations above the 2008 national air quality standard for ozone (0.075 ppm). When comparing two three-year periods (2001-2003 and 2006-2008), 97 percent of the sites show a decline or little change in ozone concentrations, as shown in Figure 9. Sites that showed the greatest improvement were in or near the following metropolitan areas: Anderson, IN; Chambersburg, PA;

Chicago, IL; Cleveland, OH; Houston, TX; Michigan City, IN; Milwaukee, WI; New York, NY; Racine, WI; Watertown, NY; and parts of Los Angeles, CA. However, other parts of Los Angeles showed a notable increase in ground-level ozone concentrations. Ozone trends can vary locally, as shown by the presence of increases and decreases at nearby sites.

Twenty-three sites showed an increase of greater than 0.005 ppm. Of the 23 sites that showed an increase, 12 sites measured concentrations above the 2008 ozone standard in the 2006-2008 time period.¹ These sites are located in or near the following metropolitan areas: Atlanta, GA; Baton Rouge, LA; Birmingham, AL; Denver, CO; El Centro, CA; Los Angeles, CA; San Diego, CA; and Seattle, WA.

Figure 8. National 8-hour ozone air quality trend, 2001-2008 (average of annual fourth highest daily maximum 8-hour concentrations in ppm).

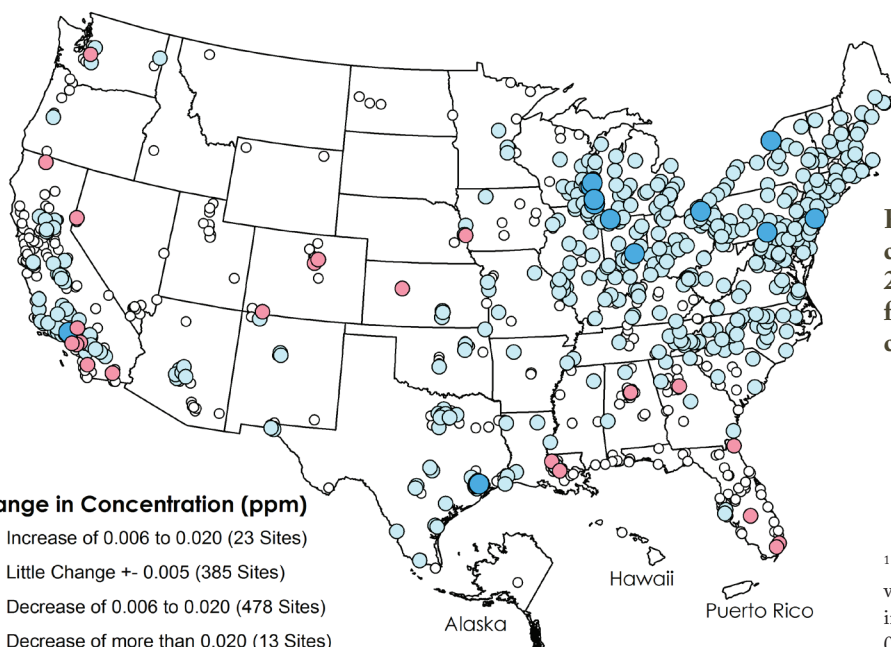
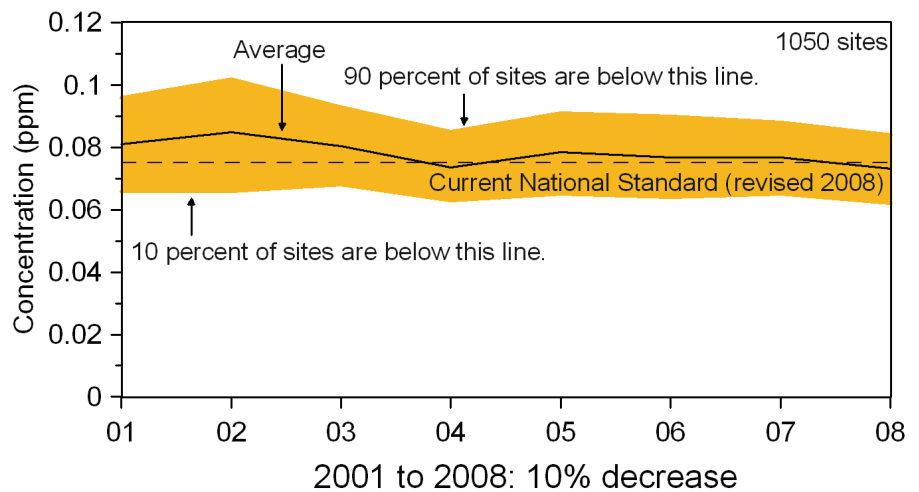


Figure 9. Change in ozone concentrations in ppm, 2001-2003 vs. 2006-2008 (three-year average of annual fourth highest daily maximum 8-hour concentrations).

¹ On September 16, 2009, EPA announced it would reconsider the 2008 ozone NAAQS, which included primary and secondary standards of 0.075 ppm (8-hour average). EPA will propose any revisions to the standards by December 2009 and issue a final decision by August 2010.

Figure 10 shows a snapshot of ozone concentrations in 2008. The highest ozone concentrations were located in California. Note that the high concentration shown in Wyoming occurred at one site due to an unusual combination of local emission and atmospheric conditions on a winter day. Thirty-two percent of all sites were above 0.075 ppm, the level of the 2008 standard.

WEATHER INFLUENCES OZONE

In addition to emissions, weather plays an important role in the formation of ozone. A large number of hot, dry days can lead to higher ozone levels in any given year, even if ozone-forming emissions do not increase. To better evaluate the progress and effectiveness of emissions reduction programs, EPA uses a statistical model to estimate the influence of atypical weather on ozone formation.

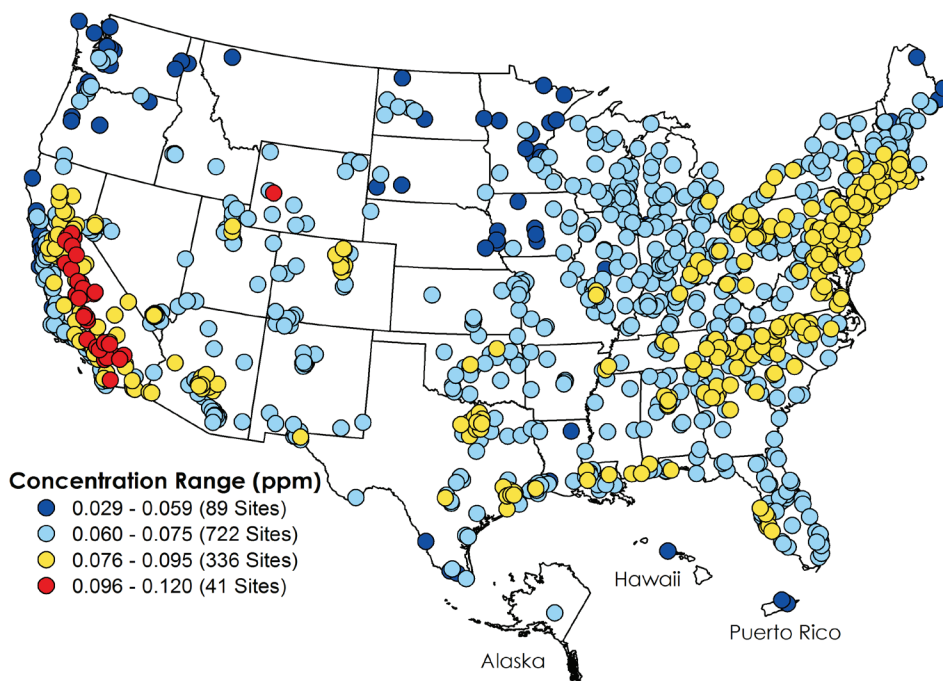


Figure 10. Ozone concentrations in ppm, 2008 (fourth highest daily maximum 8-hour concentration).



Figure 11 shows ozone trends for 2001 through 2008, averaged across selected sites before and after adjusting for weather. Across these selected sites, observed ozone levels show a decrease of approximately eight percent between 2001 and 2008, compared with a larger decrease of approximately 11 percent after removing the influence of weather variations. By examining the data separately for California vs. the eastern U.S., it is clear that the majority of the ozone improvement, after adjusting for weather, occurred in the East (on the order of 15 percent).

The largest changes in both observed and weather-adjusted ozone in the East occurred during the period of 2002 to 2004 and was especially noticeable

between 2003 and 2004 for the weather-adjusted trend. This relatively abrupt change in ozone levels coincides with the large NO_x emission reductions brought about by implementation of the NO_x SIP Call rule, which began in 2003 and was fully implemented in 2004. This significant improvement in ozone continues into 2008, i.e., weather-adjusted levels in 2008 are the lowest over the eight-year period. In 2007, weather conditions contributed to higher than average ozone formation in the East, as shown by the large difference between adjusted and observed ozone. In contrast, 2008 showed a small difference between adjusted and observed ozone indicating that weather variation had less of an impact on ozone formation.

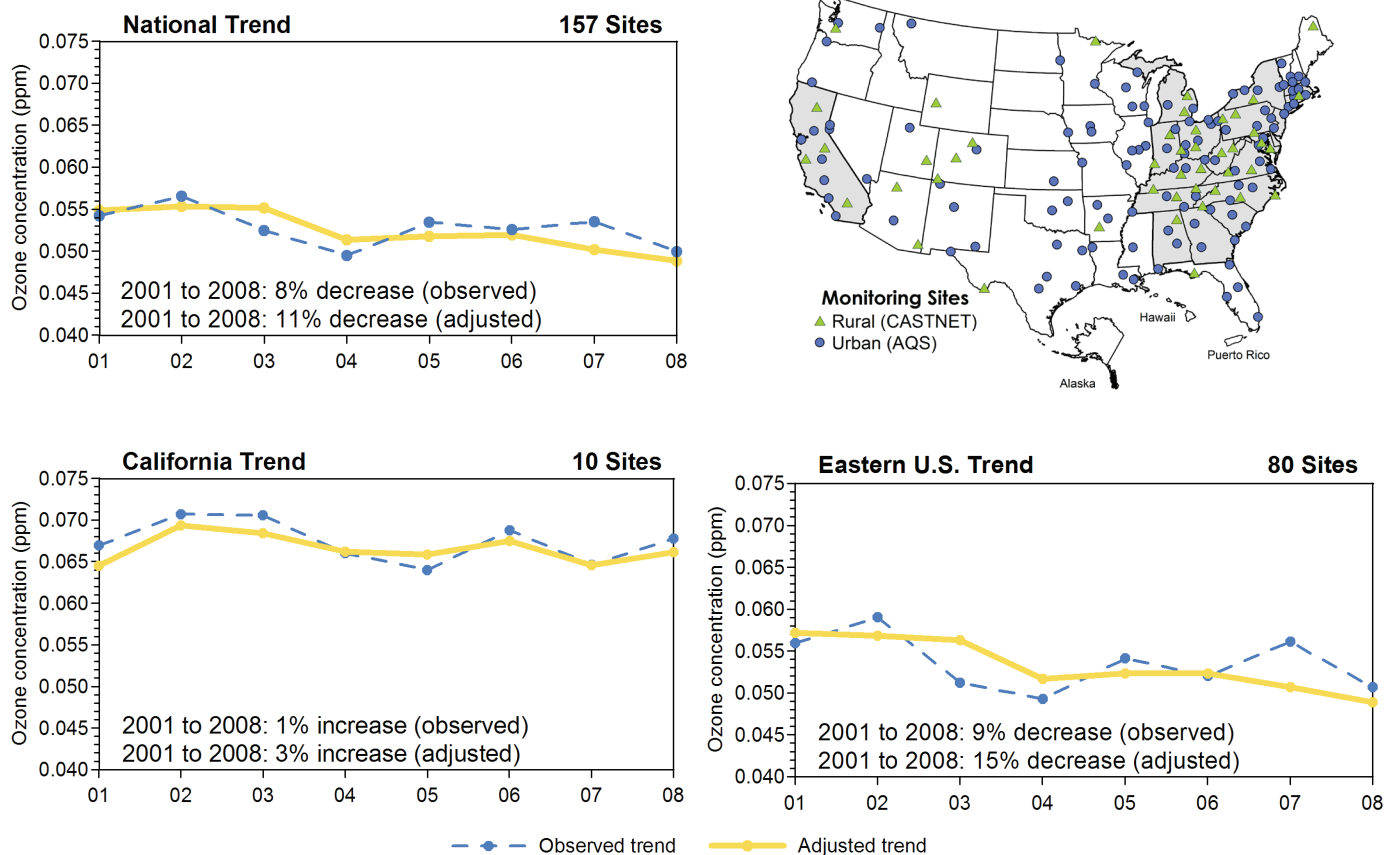


Figure 11. Trends in average summertime daily maximum 8-hour ozone concentrations in ppm (May-September), before and after adjusting for weather nationally, in California, and in eastern states, and the location of rural and urban monitoring sites used in the averages.

Notes: Urban areas are represented by multiple monitoring sites. Rural areas are represented by a single monitoring site. For more information about the Air Quality System (AQS), visit <http://www.epa.gov/ttn/airs/airsaqs>. For more information about the Clean Air Status and Trends Network (CASTNET), visit <http://www.epa.gov/castnet/>.

OZONE'S EFFECTS ON CLIMATE

The Intergovernmental Panel on Climate Change (IPCC) indicates that tropospheric ozone is the third most important GHG after carbon dioxide (CO₂) and methane (CH₄) in terms of global average climate forcing, as shown in Figure 12.

At any given location, the local ozone concentrations are the sum of three separate components: (1) ozone produced by local emissions and meteorology, (2) transported ozone produced elsewhere in the region, and (3) ozone transported on hemispheric scales (global background levels of ozone) (Dentener, 2004). The time scales and mechanisms for ozone formation, transport, and destruction vary across these three contributors. Local formation typically occurs on the scale of hours, whereas regional and hemispheric transport can occur over days and weeks, respectively. Traditionally, most efforts to improve ozone air quality have been aimed at reducing the local and regional

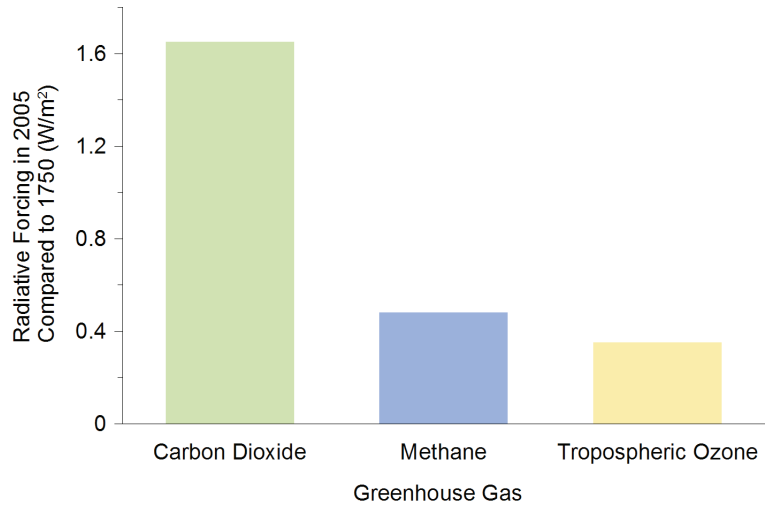
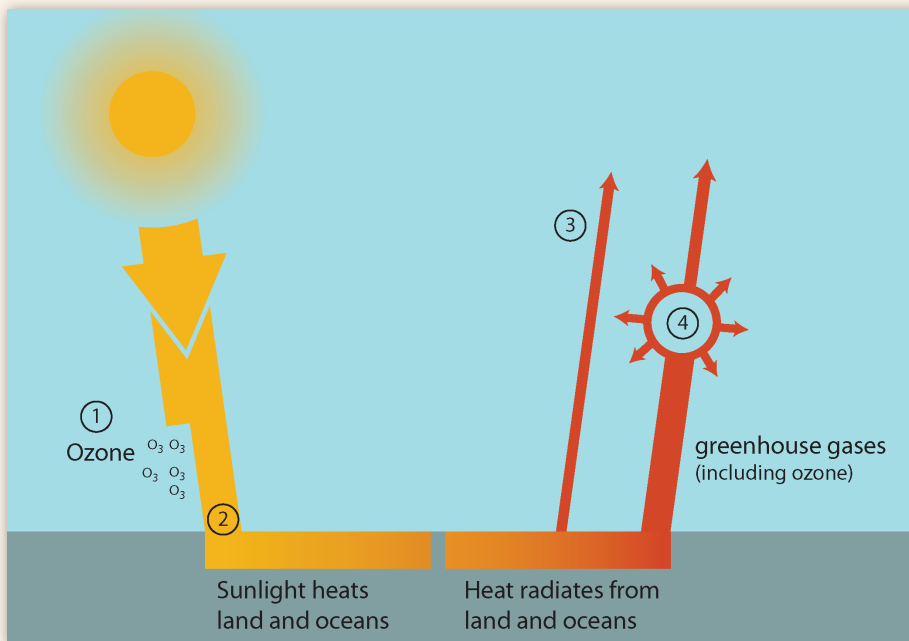


Figure 12. Net radiative forcing (Watts per m²) associated with the three most important GHGs, based on concentrations in 2005 compared to pre-industrial levels. As these GHGs increased, absorption of radiation by these gases and consequent warming of the atmosphere also increased. (Source: National Academy of Sciences, 2005)

UNDERSTANDING THE CONTRIBUTION OF TROPOSPHERIC OZONE TO CLIMATE CHANGE



As solar energy passes through the Earth's atmosphere, some of it is absorbed or scattered by water vapor, aerosols, clouds, and gases like ozone. Tropospheric ozone warms the atmosphere partly by absorbing this direct and reflected energy from the sun (yellow in figure). Most of the atmospheric warming from tropospheric ozone comes from absorption of infrared energy radiated back toward space from the Earth's surface. The tendency for ozone to absorb reflected energy and "trap" heat is especially significant over surfaces such as ice and snow, which normally reflect a large percentage of incoming solar radiation back to space.

- (1) Sunlight absorbed by ozone warms the air.
- (2) Sunlight absorbed by land and oceans warms the Earth's surface.
- (3) Energy radiates from land and oceans to space.
- (4) Most energy radiated from land and oceans is absorbed by greenhouse gases, including ozone, which warm the air and re-radiate energy in all directions.

Radiative forcing: The change in the energy balance between incoming solar radiation and exiting infrared radiation, typically measured in watts per square meter (W/m^2). Positive radiative forcing tends to warm the surface of the Earth while negative forcing generally leads to cooling.

contributions via controls of local VOC emissions and local/regional NO_x emissions. These efforts have resulted in significant improvements in ground-level ozone concentrations over the U.S. in recent years. It should be noted that global background levels of ozone are very important for climate considerations because ozone formed from emissions in U.S. urban areas and regions represents only a fraction of the overall global ozone and its resulting impacts on warming. Global ozone background levels are determined by global emissions of CH_4 , CO , NO_x , and VOCs, as well as natural processes like lightning and transport from the stratosphere. Numerous field studies have shown that these global background ozone concentrations can approach 40 ppb (Jacob, 2007) and have been increasing in recent years (Parrish, 2009).

CONTROL STRATEGIES

Current U.S. ozone reduction strategies have tended to focus on reducing peak concentrations rather than background levels and have also focused more on NO_x reductions than on reductions of other ozone precursors in most locations. While such strategies have been successful in reducing ground-level ozone concentrations for the purpose of meeting the National Ambient Air Quality Standards (NAAQS) and protecting public health, it may be necessary to re-evaluate these control programs for their impact on climate.

Reducing the emissions of ozone precursors will generally decrease ozone production and cool the atmosphere. In some cases, however, reducing one precursor by itself may not be sufficient. Reductions in NO_x alone, for example, increase the lifetime of CH_4 , which has a warming influence on the atmosphere. To be most beneficial for climate and air quality, ozone reduction strategies involving NO_x should also target reductions in CH_4 , VOCs, and/or CO , which contribute substantially to global background levels of ozone (Quinn, 2008).



PARTICLE POLLUTION

Particle pollution refers to two classes of particles—fine and coarse. These classes are based in part on long-established information about differences in sources, properties, and atmospheric behavior. EPA has set national standards to protect against the health and welfare effects associated with exposures to fine and coarse particles. Fine particles are generally considered to be less than or equal to 2.5 micrometers (μm) in aerodynamic diameter, or $\text{PM}_{2.5}$. Coarse particles are those between 2.5 and 10 μm in diameter. PM_{10} (particles generally less than or equal to 10 μm in diameter) is the indicator used for the coarse particle standard.

TRENDS IN $\text{PM}_{2.5}$ CONCENTRATIONS

There are two national air quality standards for $\text{PM}_{2.5}$: an annual standard ($15 \mu\text{g}/\text{m}^3$) and a 24-hour standard ($35 \mu\text{g}/\text{m}^3$). Nationally, annual and 24-hour $\text{PM}_{2.5}$ concentrations declined by 17 and 19 percent, respectively, between 2001 and 2008, as shown in Figure 13.

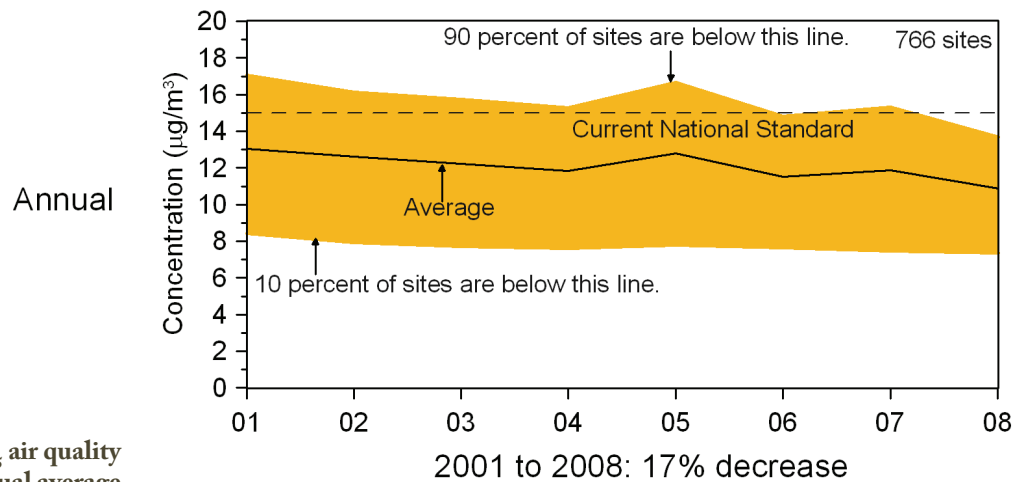
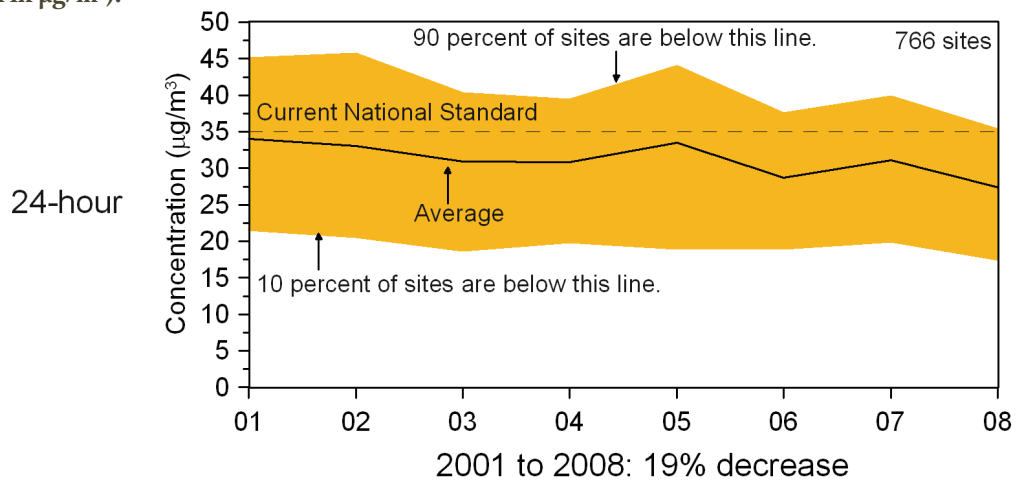


Figure 13. National $\text{PM}_{2.5}$ air quality trends, 2001-2008 (annual average concentration and 98th percentile of 24-hour concentration in $\mu\text{g}/\text{m}^3$).



For each monitoring location, the maps in Figure 14 show whether annual and 24-hour $PM_{2.5}$ concentrations increased, decreased, or stayed about the same since the beginning of the decade. When comparing two three-year periods, 2001-2003 and 2006-2008, almost all of the sites show a decline or little change in $PM_{2.5}$ concentrations. Sixteen sites in California, Illinois, Indiana, Michigan, Ohio, Utah, and West Virginia showed the greatest decreases in annual $PM_{2.5}$ concentrations. Four of the 565 sites showed an increase in annual $PM_{2.5}$ concentrations greater than $1 \mu\text{g}/\text{m}^3$. These sites were located in Montana, Arizona, and Wisconsin. Of the four sites that showed an increase in annual $PM_{2.5}$ concentrations, none were above the level of the annual $PM_{2.5}$ standard for the most recent three-year period of data (2006-2008). Five

sites in California, Montana, Oregon, Pennsylvania, and Utah showed decreases greater than $15 \mu\text{g}/\text{m}^3$ in 24-hour $PM_{2.5}$ concentrations. Nineteen sites showed an increase in 24-hour $PM_{2.5}$ concentrations greater than $3 \mu\text{g}/\text{m}^3$. Of the 19 sites that showed an increase for the most recent three-year period of data, seven measured concentrations above the level of the 24-hour $PM_{2.5}$ standard. These sites are located in or near the following metropolitan areas: Virginia Beach, VA; Butte-Silver Bow, MT; Nogales, AZ; Seattle, WA; Albany, GA; Redding, CA; and Chico, CA (note: Virginia Beach was above the standard due to the effects of a wildfire in North Carolina). Due to the influence of local sources, it is possible for sites in the same general area to show opposite trends, as in the case of the Denver area for the 24-hour standard.

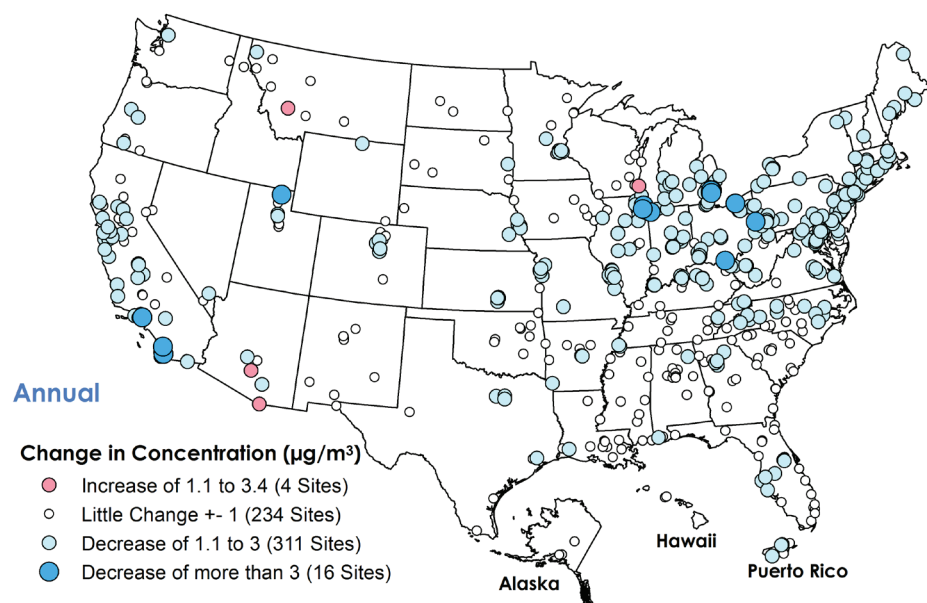
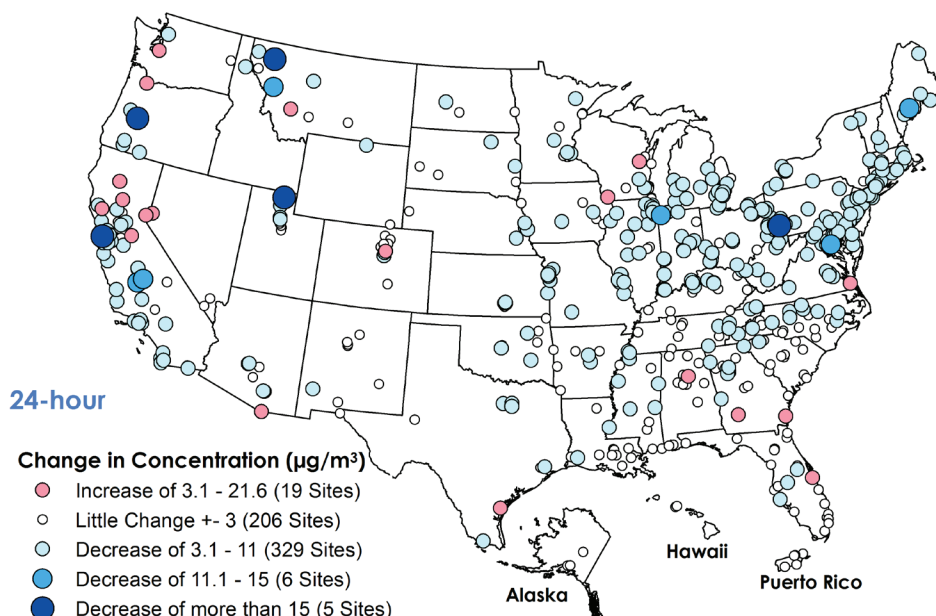


Figure 14. Change in $PM_{2.5}$ concentrations in $\mu\text{g}/\text{m}^3$, 2001-2003 vs. 2006-2008 (3-year average of annual average and 98th percentile of 24-hour concentrations).



In 2008, the highest annual average $PM_{2.5}$ concentrations were in California, Arizona, and Hawaii, as shown in Figure 15. The highest 24-hour $PM_{2.5}$ concentrations were in California and Virginia. Wildfires played a role in both state's $PM_{2.5}$ levels.

Some sites showed high 24-hour $PM_{2.5}$ concentrations but low annual $PM_{2.5}$ concentrations, and vice versa. Sites that show high 24-hour concentrations but low or moderate annual concentrations exhibit substantial variability from season to season. For example, sites

in the Northwest generally show low concentrations in warm months but are prone to much higher concentrations in the winter. Factors that contribute to the higher levels in the winter are extensive woodstove use coupled with prevalent cold temperature inversions that trap pollution near the ground. Nationally, more sites exceeded the level of the 24-hour $PM_{2.5}$ standard than the annual $PM_{2.5}$ standard, as indicated by yellow and red dots on the maps below. Of the 18 sites that exceeded the annual standard and 55 sites that exceeded the 24-hour standard, 14 sites exceeded both.

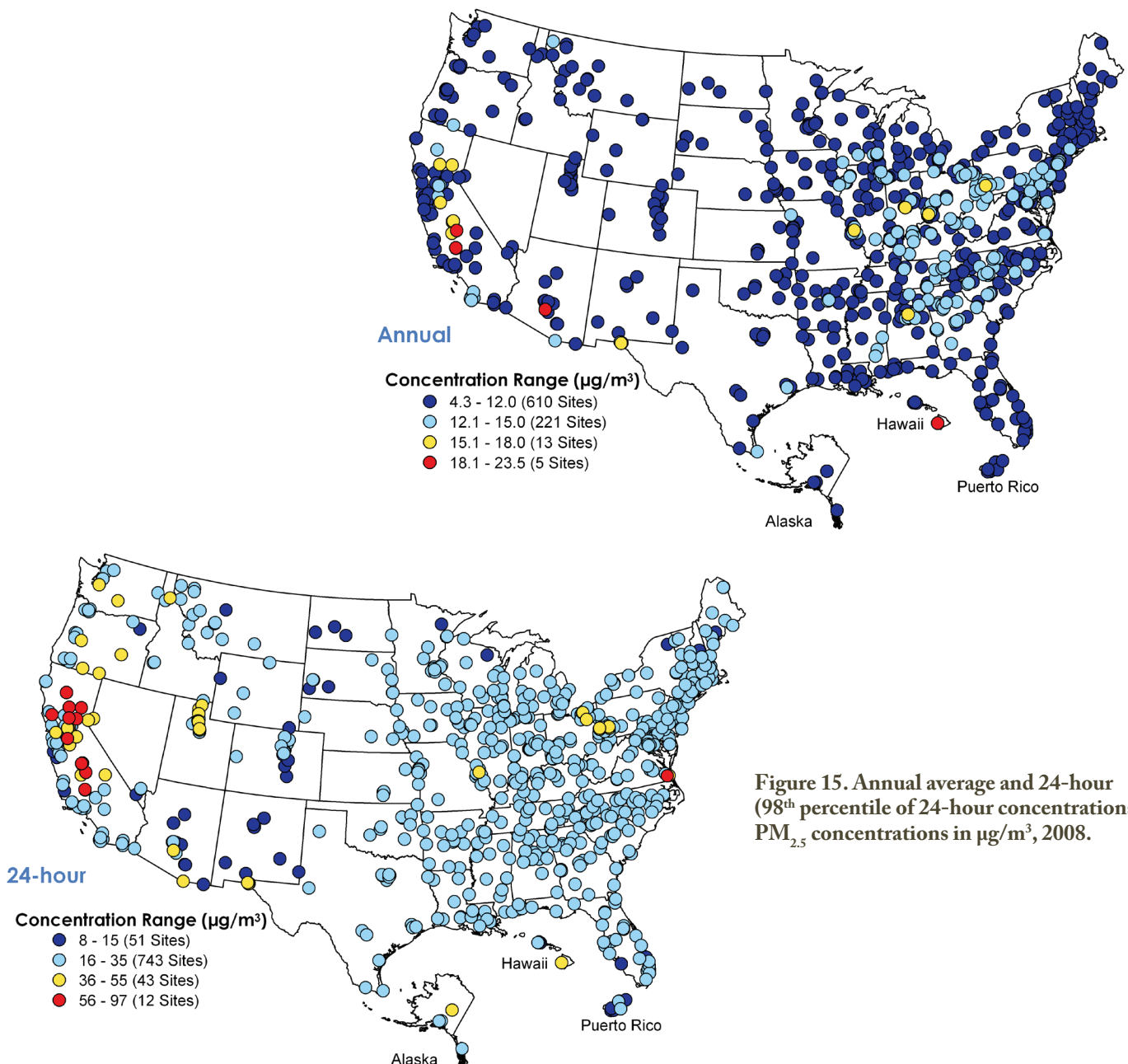


Figure 15. Annual average and 24-hour (98th percentile of 24-hour concentrations) $PM_{2.5}$ concentrations in $\mu\text{g}/\text{m}^3$, 2008.

WEATHER INFLUENCES PM_{2.5}

In addition to emissions, weather plays an important role in the formation of PM_{2.5}. Figure 16 shows trends in PM_{2.5} from 2001 through 2008, before and after adjusting for weather. PM_{2.5} levels are monitored throughout the year, and separate graphs are shown

for the warm and cool months. These separate graphs are shown due to the seasonal variability of the components that make up PM_{2.5}, as described in the next section. After adjusting for weather, PM_{2.5} concentrations have decreased by approximately 17 percent in both the warm and cool seasons between 2001 and 2008.

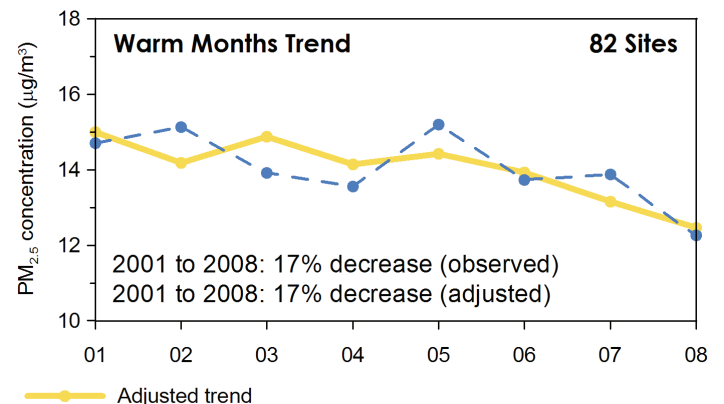
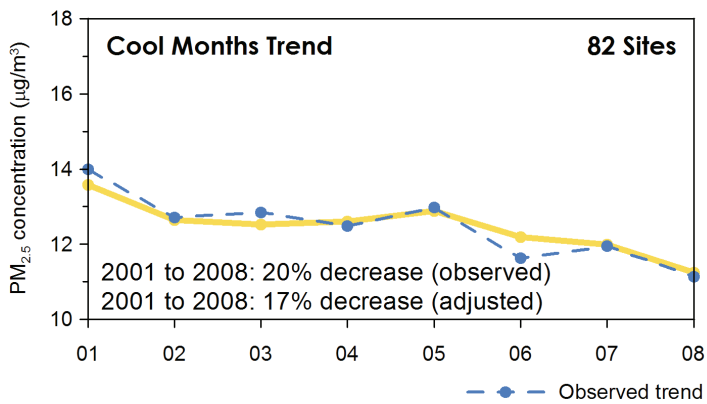
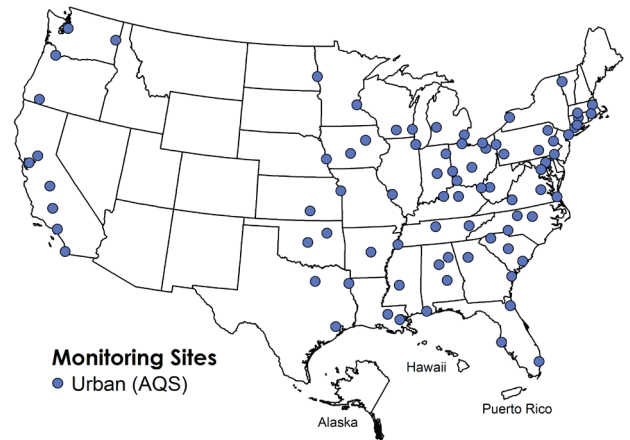
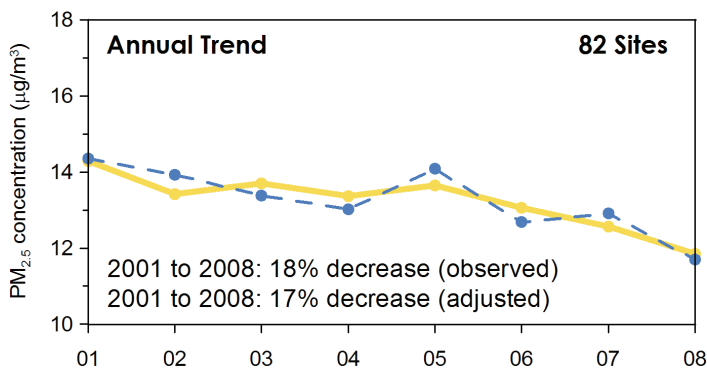


Figure 16. Trends in annual, cool-month (October–April) and warm-month (May–September) average PM_{2.5} concentrations in µg/m³ (before and after adjusting for weather), and the location of urban monitoring sites used in the average.

PM_{2.5} COMPOSITION

The chemical composition of PM_{2.5} is characterized in terms of five major components that generally comprise the mass of PM_{2.5}: sulfate, nitrate, organic carbon (OC), elemental carbon (also called black carbon, BC), and crustal material.

Figure 17 shows regional differences in the composition of PM_{2.5} nationwide. On average, sulfate is the largest component by mass in the eastern U.S. Generally, the largest sources of sulfate in the eastern U.S. are electric utilities and industrial boilers. OC is the next largest component in the East. The primary sources of OC are highway vehicles, non-road mobile, waste burning, wildfires, and vegetation. Next is nitrate; the largest sources of nitrate originate from highway vehicles, non-road mobile, electric utilities, and industrial boilers. Elemental carbon is a small component of the overall PM_{2.5} composition (typically 5-10 percent in

U.S. cities). Elemental carbon is directly emitted from incomplete combustion processes such as fossil fuel and biomass burning. Crustal material is typically a small fraction of PM_{2.5} mass, although two cities show higher than average values (Birmingham, AL and Detroit, MI). Crustal material comes from suspended soil and metallurgical operations.

In the West, OC is generally the largest estimated component of PM_{2.5} by mass. Fireplaces and woodstoves are important contributors to OC in the West. On an annual average basis, nitrate, sulfate, or crustal material can also represent substantial components of PM_{2.5} for the western U.S. The composition varies from city to city and may vary by geography. For example, in southern California and port cities in the Northwest, emissions from marine vessels also likely contribute a significant portion of PM_{2.5} sulfate.

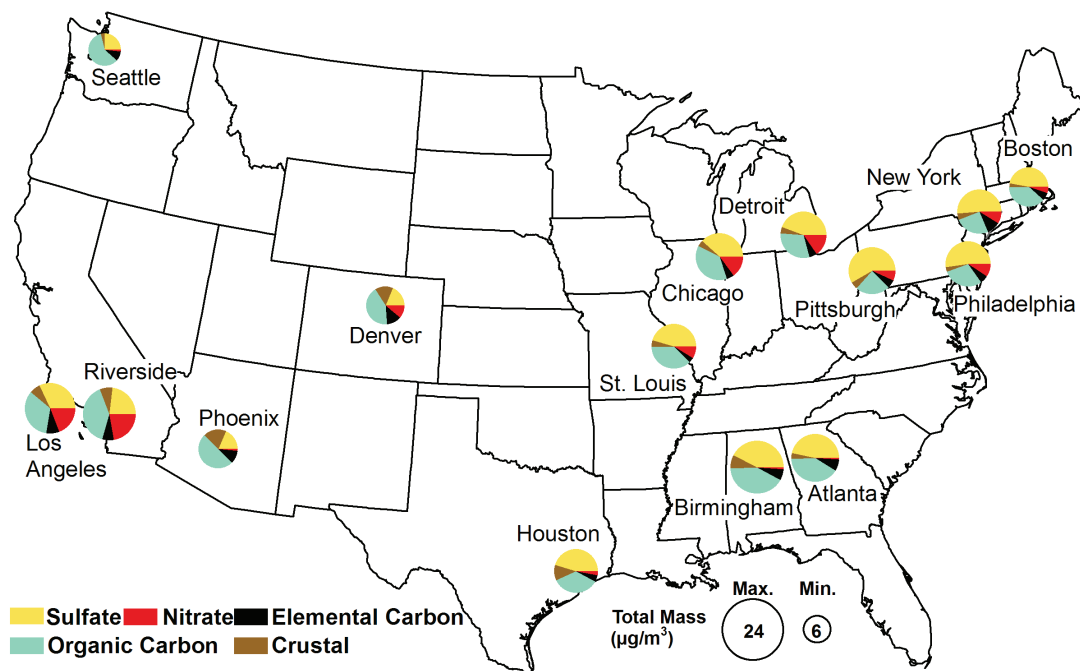


Figure 17. Four-season average of PM_{2.5} composition for 15 U.S. cities.

The maps in Figure 18 reveal somewhat different patterns between seasons. While sulfate is a major component in the eastern U.S. in the spring, fall, and (particularly) summer, the sulfate contribution during winter is offset by larger amounts of nitrate in the Midwest and OC in the Southeast. Nitrate is lower in the spring and fall, particularly in the southeastern cities and is essentially zero during the summer in the eastern U.S. Crustal material is a substantial summertime component in Houston, TX, and is generally low elsewhere in the East during all seasons. In the West, wintertime OC and elemental carbon are generally the largest components of $PM_{2.5}$, followed by nitrate. Nitrate can represent a larger percentage in the spring and fall. Crustal material represents a relatively high percentage year-round in arid Phoenix, AZ and Denver, CO.

It is important to note that although studies have begun to focus on how different constituents of particulate matter (PM) may affect health outcomes, at this point there is no conclusive evidence that any component is “harmless”—studies continue to link numerous components to health effects and the evidence does not support excluding any PM component or source from regulation. Thus, though different ambient mixtures of PM may be observed in different geographical areas and during different seasons, EPA continues to regulate $PM_{2.5}$ and PM_{10} by mass and most control strategies are designed to reduce mass rather than individual components from particular sources.

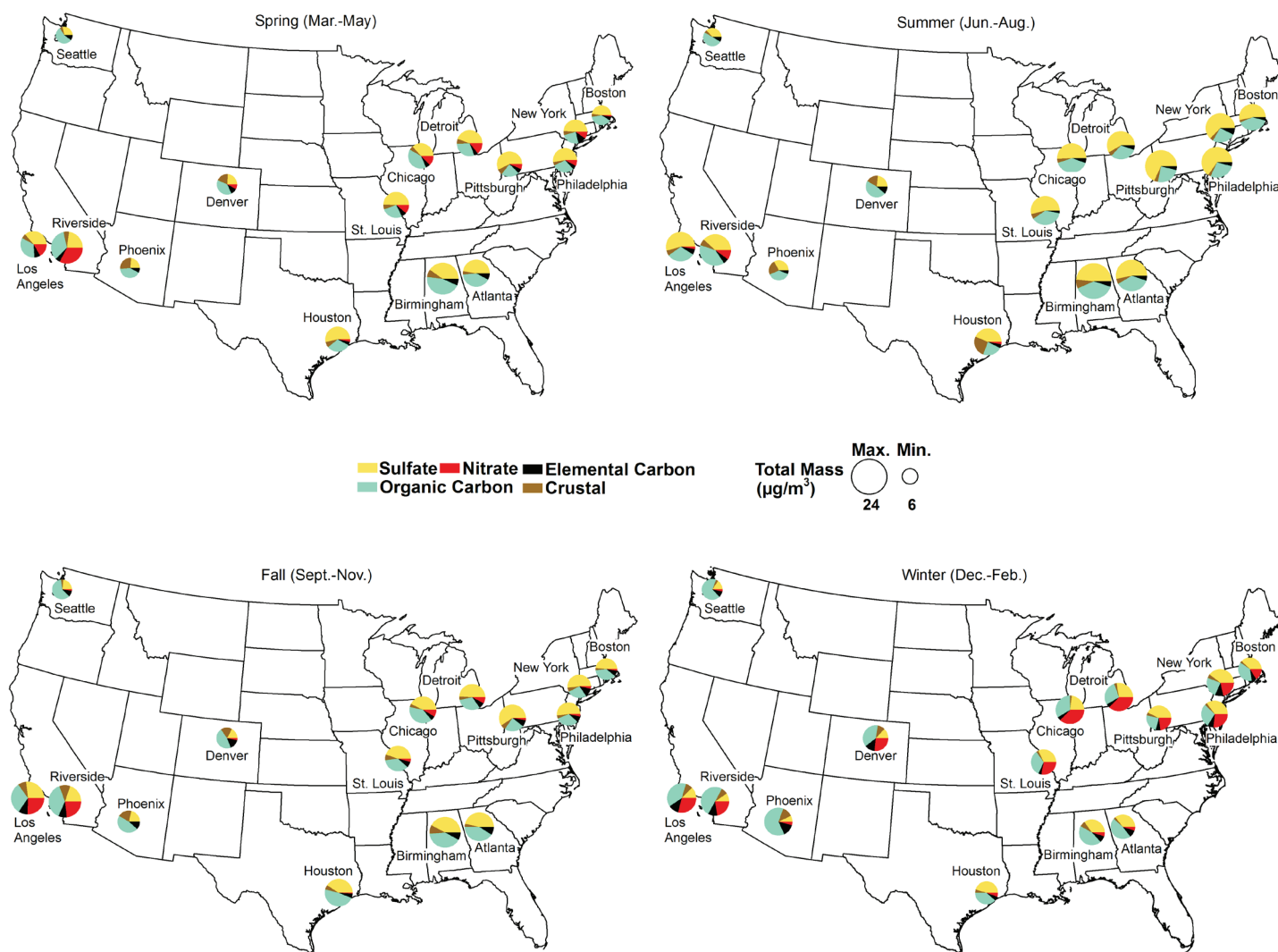


Figure 18. $PM_{2.5}$ composition by season for 15 U.S. cities.

PARTICLES' EFFECTS ON CLIMATE

Particles have both direct and indirect effects on climate. The direct effects come from particles' ability to absorb and scatter light. The different types of particles have different impacts on climate: some warm (positive forcing); others cool (negative forcing). The net effect for all particles in the atmosphere is cooling, as scattering generally dominates (National Academy of Sciences, 2005), though effects can vary dramatically by region.

Particles also have important indirect effects on climate. For example, different particles can increase or decrease the reflectivity of clouds, leading to cooling or warming effects. Particles also influence cloud lifetime and precipitation, and may affect droughts, rainfall, and stream flows. However, there remains relatively high scientific uncertainty about these indirect effects (National Academy of Sciences, 2005).

As shown in Figure 19, the direct effects of particles on climate are significant even when compared to carbon dioxide (CO₂), the most important greenhouse gas. However, the direction of the climate impact from particles (warming vs.

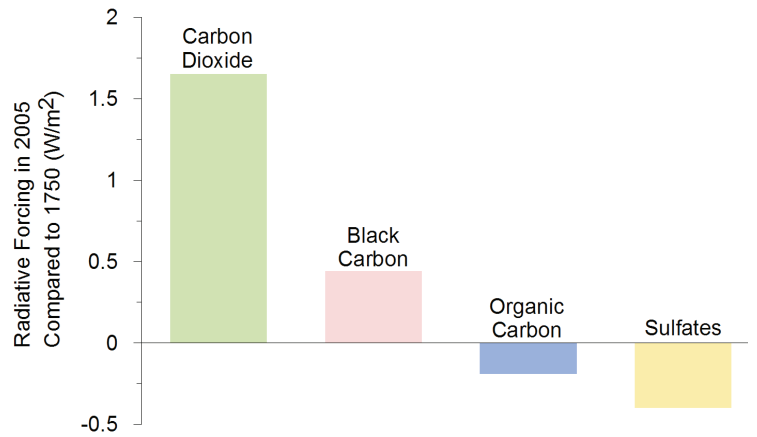


Figure 19. Net radiative forcing (Watts per m²) associated with the presence of different pollutants in the atmosphere, based on concentrations in 2005 compared to pre-industrial levels. (Source: Black carbon data [IPCC, 2007]. Carbon dioxide, organic carbon, sulfates data [National Academy of Sciences, 2005].)

cooling) varies by particle type and location of emission, which makes designing control strategies more challenging. Sources emitting BC also emit OC and may emit NO_x and SO₂, all of which form particles that tend to have a cooling effect. Thus, while the health benefits of reducing all types of emissions

RETROFITTING DIESEL ENGINES

From the farm to the interstate highway to the neighborhood grocery store, diesel engines are found in every corner of society. Despite EPA's stringent diesel engine and fuel standards, which, for new engines, are being phased in over the next decade, 20 million engines already in use continue to emit relatively large amounts of oxides of nitrogen (NO_x) and fine particulate matter (PM_{2.5}). Both of these pollutants contribute to serious health conditions, such as asthma, and worsen heart and lung disease. In addition, diesel engines emit black carbon and carbon dioxide, which contribute to global climate change.

Fortunately, a variety of cost-effective technologies can dramatically reduce harmful emissions, save fuel, and help our nation meet its clean air and sustainability goals. In 2000, to address the concerns of both new and existing diesel engines, EPA created the National Clean Diesel Campaign (NCDC), a partnership program that incorporates traditional regulatory approaches and innovative non-regulatory approaches to achieve results.

In 2008, for the first time, Congress appropriated funding under the Energy Policy Act of 2005 to reduce emissions from diesel engines in the nation's existing fleet. In the first year of the program, the EPA's NCDC distributed \$49.2 million to initiate diesel emission reduction projects and programs across the country. In addition, the American Recovery and Reinvestment Act of 2009 provided \$300 million in new funding for national and state programs to support the implementation of verified and certified diesel emissions reduction technologies.

As a result of this funding and NCDC projects across the country, hundreds of thousands of tons of pollutants and air toxics will be reduced over the lifetime of the program.



contributing to ambient PM are relatively clear, the net climate impact of PM emissions reduction strategies will depend on the relative amounts of each of these components reduced from controlled sources.

TRENDS IN PM₁₀ CONCENTRATIONS

Nationally, 24-hour PM₁₀ concentrations declined by 19 percent between 2001 and 2008, as shown in Figure 20.

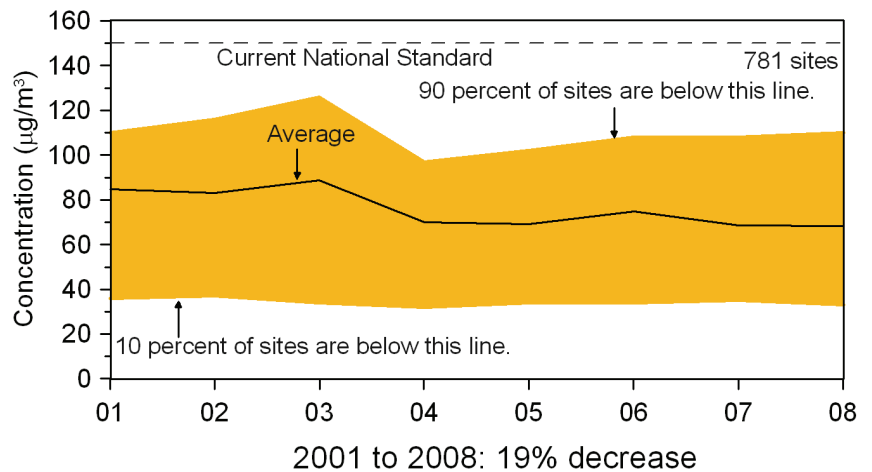


Figure 20. National PM₁₀ air quality trend, 2001-2008 (second maximum 24-hour concentration in µg/m³).

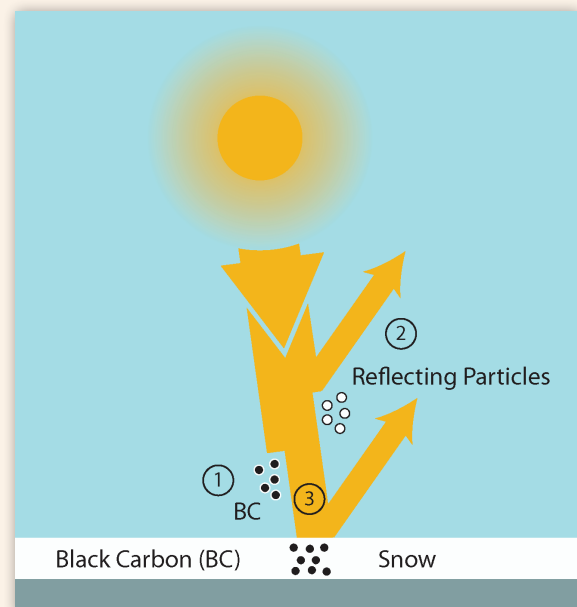
UNDERSTANDING LINKAGES BETWEEN BLACK CARBON AND CLIMATE

Black carbon (BC) is emitted directly as a result of incomplete combustion of fuels, generally from man-made sources. Many BC particles are too small to be visible. One-half to two-thirds of BC emissions in the U.S. come from the burning of fossil fuels, while the remainder comes from biomass burning. Unless specifically controlled, diesel engines are major producers of BC.

BC emissions are a component of fine particle pollution, which causes adverse health effects. BC emissions also lead to climate warming by absorbing incoming and reflected sunlight in the atmosphere (direct effects) and by darkening clouds, snow, and ice, thereby reducing the reflection of light back into space (indirect effects). Other effects may include changes in precipitation and cloud patterns. The total climate impact of BC currently in the atmosphere has been estimated to be anywhere from 10 percent to more than 60 percent as large as the climate impact from carbon dioxide (CO₂). These effects may be concentrated in regions such as the Arctic and the Himalayas, where glaciers provide critical fresh water reservoirs for nearly 1.3 billion people.

Actions taken to reduce emissions of BC could produce almost immediate benefits for climate: while CO₂ remains in the atmosphere for decades to centuries, freshly emitted BC is in the atmosphere for a very short time. Reducing BC today may reduce climate forcing in the near term.

Considerable uncertainty remains regarding the levels of BC emissions from various sources, the transport of these emissions around the globe, and the net impacts of BC and co-emitted pollutants such as organic carbon on the Earth's energy balance and global climate patterns.



- (1) Sunlight absorbed by BC particles warms the air.
- (2) Other types of particles scatter or reflect light and cool the atmosphere.
- (3) Sunlight absorbed by BC and some other particles on snow speeds up melting and results in less sunlight reflected.

When comparing two 3-year periods, 2001-2003 and 2006-2008, most sites showed a decline or little change in PM_{10} , as shown in Figure 21. Twenty-seven sites located in the Southwest, South Carolina, Missouri, Wyoming, and Montana showed a decline greater than $50 \mu\text{g}/\text{m}^3$. Ninety-one sites showed an increase of greater than $10 \mu\text{g}/\text{m}^3$ over the trend period. Five of these sites (Houston, TX; Albany, GA; Phoenix, AZ; Butte-Silver Bow, MT; and Trinity County, CA) showed large increases of $50 \mu\text{g}/\text{m}^3$ or more.

AZ; Butte-Silver Bow, MT; and Trinity County, CA) showed large increases of $50 \mu\text{g}/\text{m}^3$ or more.

Figure 22 shows that in 2008, the highest PM_{10} concentrations were located in California, Arizona, and New Mexico. Within these areas some sites showed a decline greater than $50 \mu\text{g}/\text{m}^3$. Highest concentrations are largely located in dry and/or industrial areas with a high number of coarse particle sources.

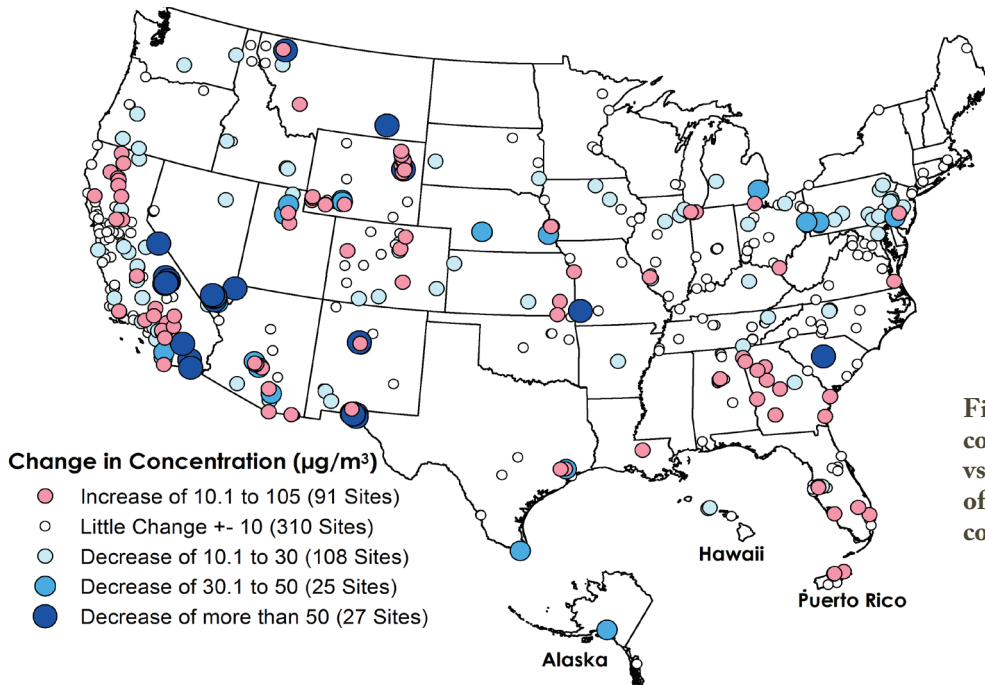
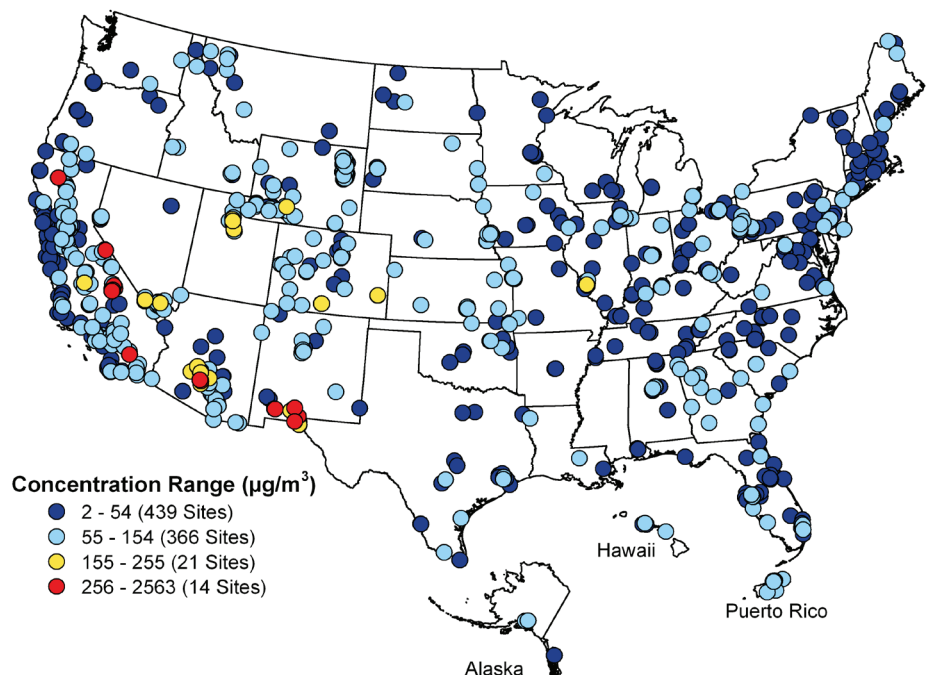


Figure 21. Change in PM_{10} concentrations in $\mu\text{g}/\text{m}^3$, 2001-2003 vs. 2006-2008 (3-year average of second maximum 24-hour concentrations).

Figure 22. PM_{10} concentrations in $\mu\text{g}/\text{m}^3$, 2008 (second maximum 24-hour concentration).

Note: $2563 (\mu\text{g}/\text{m}^3)$ is from a site located in the Mono Basin nonattainment area where the major source of PM_{10} is from a dry lake bed (Mono Lake).



COOKSTOVE POLLUTION THREATENS PUBLIC HEALTH AND CLIMATE

Roughly half of the world's population—especially in Asia, Africa, and parts of Latin America—uses wood, dung, coal, or other solid fuels for cooking and heating. This leads to extraordinarily high indoor concentrations of fine particle pollution, carbon monoxide, and other toxic pollutants. The World Health Organization estimates that indoor stove use leads to an estimated 1.5 million premature deaths each year, mostly among women and young children, making it the fourth most serious health risk factor in poor developing countries after undernourishment, unsafe sex, and unsafe water, sanitation, and hygiene. Fuel wood collection also limits economic and educational opportunities for women and children and can put substantial pressure on local forests and ecosystems.



An unvented, traditional stove in Ethiopia produces high indoor smoke levels for a woman and young child. (Credit: John Mitchell, U.S. EPA)

Use of clean and efficient cookstoves and fuels would significantly improve public health and could also provide important climate benefits. It is estimated that an improved cookstove typically reduces carbon dioxide-equivalent emissions by 1 to 4 tons per year—almost as much as taking a typical U.S. car off the road. Crude, traditional cookstoves account for about a quarter of global black carbon emissions, which contribute to regional and global warming, though the net climate impact

also depends on co-emissions of other (primarily reflecting) particles.

In 2002, the EPA and 13 partners launched the Partnership for Clean Indoor Air (PCIA) to help households adopt clean cooking and heating practices to improve health, livelihood, and quality of life. Today, PCIA has over 310 active partner organizations working in over 115 countries around the world (<http://www.PCIAonline.org>). Already, key PCIA partners have reported helping 2.4 million households adopt clean cooking and heating practices, reducing harmful exposures for more than 18 million people.



An improved plancha stove with a chimney in Guatemala significantly lowers indoor smoke levels. (Credit: Richard Grinnell, HELPS International, <http://www.helpsintl.org>)

TRENDS IN LEAD CONCENTRATIONS

Concentrations of lead decreased 48 percent between 2001 and 2008, as shown in Figure 23. Average concentrations are shown for 24 sites near large stationary sources and 101 sites that are not near stationary industrial sources. The typical average concentration near a stationary source (e.g., metals processors, battery manufacturers, and mining operations) is approximately eight times the typical concentration at a site that is not near a stationary industrial source. There are significant year-to-year changes in lead concentrations at sites near stationary sources; these reflect changes in emissions due to changes in operating schedules and plant closings. For example, lead concentrations declined between 2001 and 2002, mostly due to lower lead concentrations at sites in Herculaneum, MO.

Figure 24 shows lead concentrations in 2008. Of the 110 sites shown, 23 sites in 12 counties exceeded the 2008 lead standard (0.15 $\mu\text{g}/\text{m}^3$). These sites are located in Alabama, Florida, Illinois, Indiana, Minnesota, Missouri, Ohio, Pennsylvania, Tennessee, and Texas. All of these sites are located near stationary lead sources. New requirements for monitoring near additional stationary lead sources will be implemented in 2010. Approximately 250 new locations will be monitoring lead concentrations.

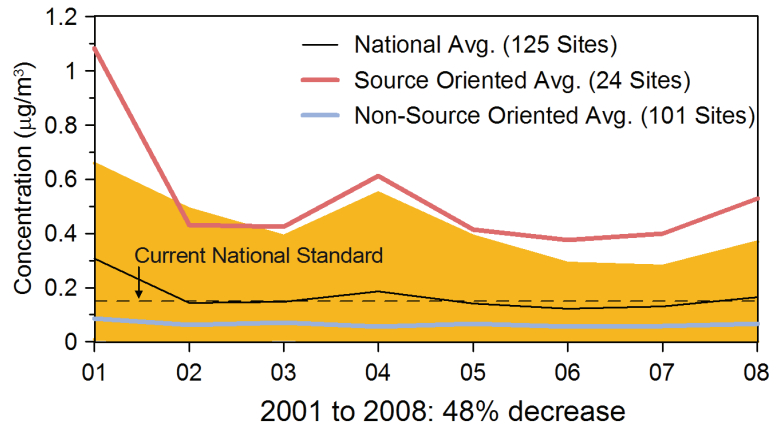


Figure 23. National lead air quality trend, 2001-2008 (maximum 3-month average in $\mu\text{g}/\text{m}^3$).

Note: 90 percent of sites are shown in the orange area.

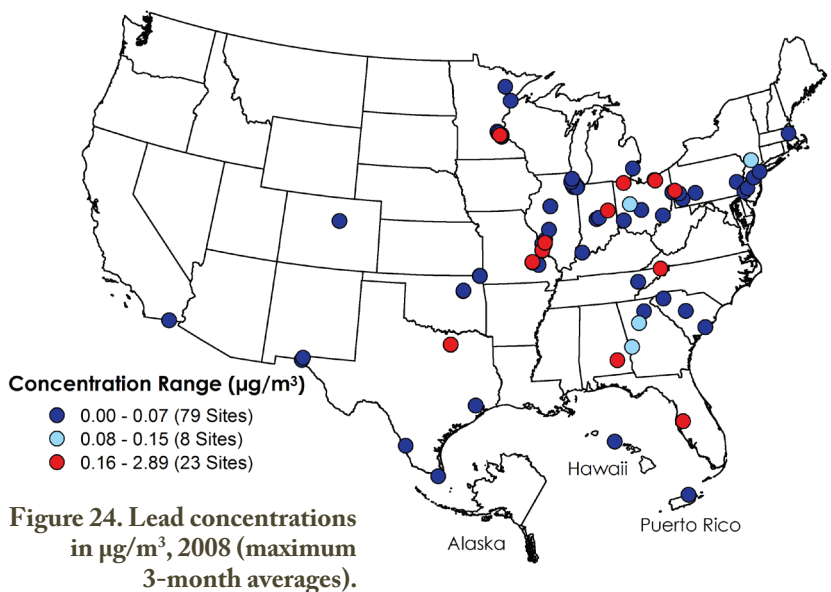


Figure 24. Lead concentrations in $\mu\text{g}/\text{m}^3$, 2008 (maximum 3-month averages).

Note: The number of sites in Figure 24 (110) differs from the number of sites in Figure 23 (125) due to differences in the requirements for lead data to be considered complete for each figure.

EPA STRENGTHENS THE NATIONAL AMBIENT AIR QUALITY STANDARD FOR LEAD

On October 15, 2008, EPA strengthened the National Ambient Air Quality Standard for lead. The level for the previous lead standard was 1.5 $\mu\text{g}/\text{m}^3$, not to be exceeded as an average for a calendar quarter, based on an indicator of lead in total suspended particles (TSP). The new standard, also in terms of lead in TSP, has a level of 0.15 $\mu\text{g}/\text{m}^3$, not to be exceeded as an average for any three-month period within three years.

In conjunction with the revision of the lead standard, EPA also modified the lead air quality monitoring rules. Ambient lead monitoring is now required near lead emissions sources emitting one or more tons per year, and also in urban areas with a population equal to or greater than half a million people. Monitoring sites are required to sample every sixth day.

NO₂, CO, AND SO₂

TRENDS IN NO₂, CO, AND SO₂ CONCENTRATIONS

Nationally, concentrations of nitrogen dioxide (NO₂) decreased 27 percent between 2001 and 2008, as shown in Figure 25. In 2008, NO₂ concentrations were the lowest of the eight-year period. All recorded concentrations were well below the level of the annual standard (0.053 ppm).

Nationally, concentrations of 8-hour carbon monoxide (CO) decreased 41 percent between 2001 and 2008, as shown in Figure 26. In 2008, CO concentrations were the lowest

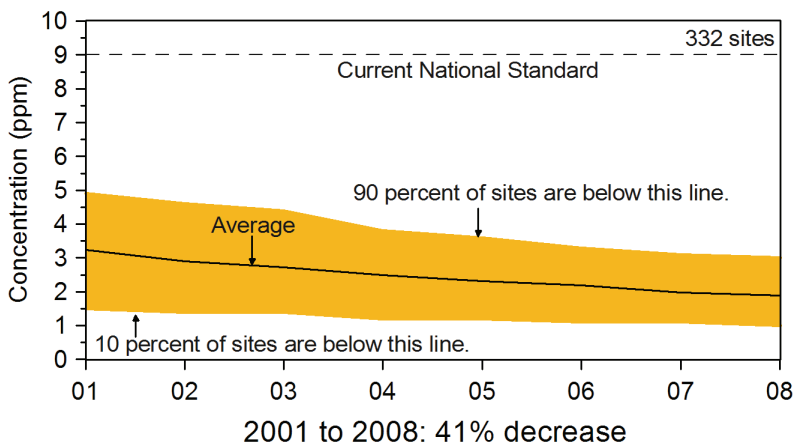


Figure 26. National CO air quality trend, 2001-2008 (second maximum 8-hour average in ppm).

Downward trends in NO₂, CO, and SO₂ are the result of various national emissions control programs. Even though concentrations of these pollutants are low with respect to national standards, EPA continues to track these gaseous pollutants because of their contribution to other air pollutants (e.g., ozone and PM_{2.5}) and reduced visibility. Additionally, national ambient air quality standards for these pollutants are under review.

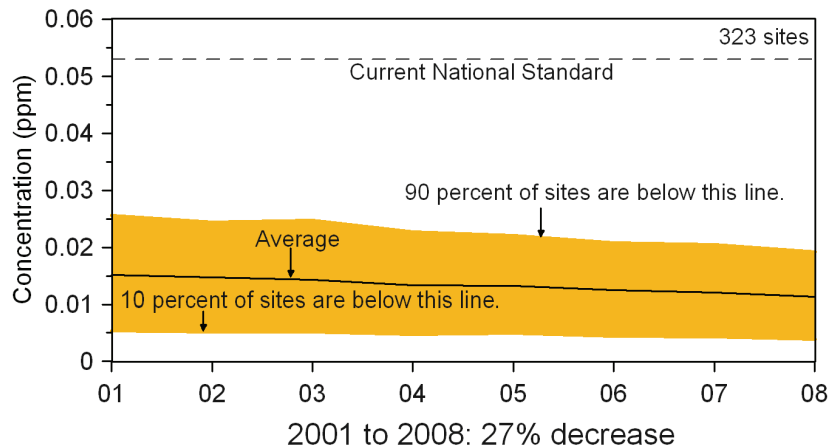


Figure 25. National NO₂ air quality trend, 2001-2008 (annual average in ppm).

in the past eight years. All concentrations were below the 8-hour standard (9 ppm) and 1-hour standard (35 ppm).

Nationally, concentrations of sulfur dioxide (SO₂) decreased 30 percent between 2001 and 2008, as shown in Figure 27. In 2008, annual SO₂ concentrations were the lowest of the eight-year period. One site in Hawaii showed concentrations above the level of the annual standard (0.03 ppm) and two sites in Hawaii showed concentrations above the level of the 24-hour standard (0.14 ppm). These high measurements were caused by emissions from a nearby volcano.

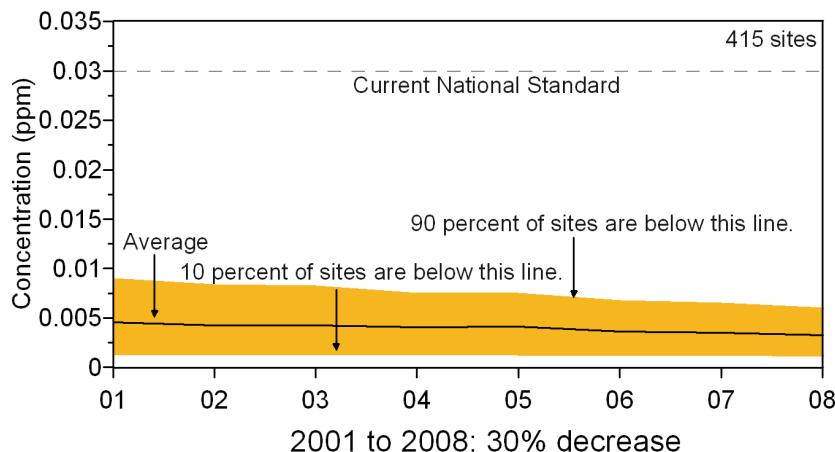


Figure 27. National SO₂ air quality trend, 2001-2008 (annual average in ppm).

TRENDS IN TOXIC AIR POLLUTANT CONCENTRATIONS

Under the Clean Air Act, EPA regulates 187 toxic air pollutants. Toxicity levels, or the potential for adverse effects on human health, vary from pollutant to pollutant. For example, a few pounds of a relatively toxic pollutant may have a greater health effect than several tons of emissions of a less toxic pollutant. Toxicity levels can vary by orders of magnitude between pollutants. EPA recommends a set of benchmark toxicity levels for estimating the effects of exposure to individual toxic air pollutants. For more information, visit <http://www.epa.gov/ttn/atw/toxsource/table1.pdf>.

Because ambient monitoring data are so limited for toxic air pollutants, EPA frequently relies on ambient modeling studies to better define trends in toxic air pollutants. One such modeling study, the National-Scale Air Toxic Assessment (NATA), is a nationwide study of ambient levels, inhalation exposures, and health risks associated with emissions of 180 toxic air pollutants (a subset of the Clean Air Act's

list of 187 toxic air pollutants and diesel particulate matter). NATA examines individual pollutant effects as well as cumulative effects of many air pollutants on human health.

Figure 28 shows the estimated lifetime cancer risk across the continental U.S. by county based on 2002 NATA model estimates. The national average cancer risk level in 2002 is 36 in a million. Many urban areas as well as transportation corridors show a risk above the national average. From a national perspective, benzene is the most significant toxic air pollutant for which cancer risk could be estimated, contributing over 30 percent of the average individual cancer risk identified in the 2002 assessment. Though not included in the figure, exposure to diesel exhaust is also widespread. EPA has not adopted specific risk estimates for diesel exhaust but has concluded that diesel exhaust is a likely human carcinogen and ranks with the other substances that the national-scale assessment suggests pose the greatest relative risk to human health.

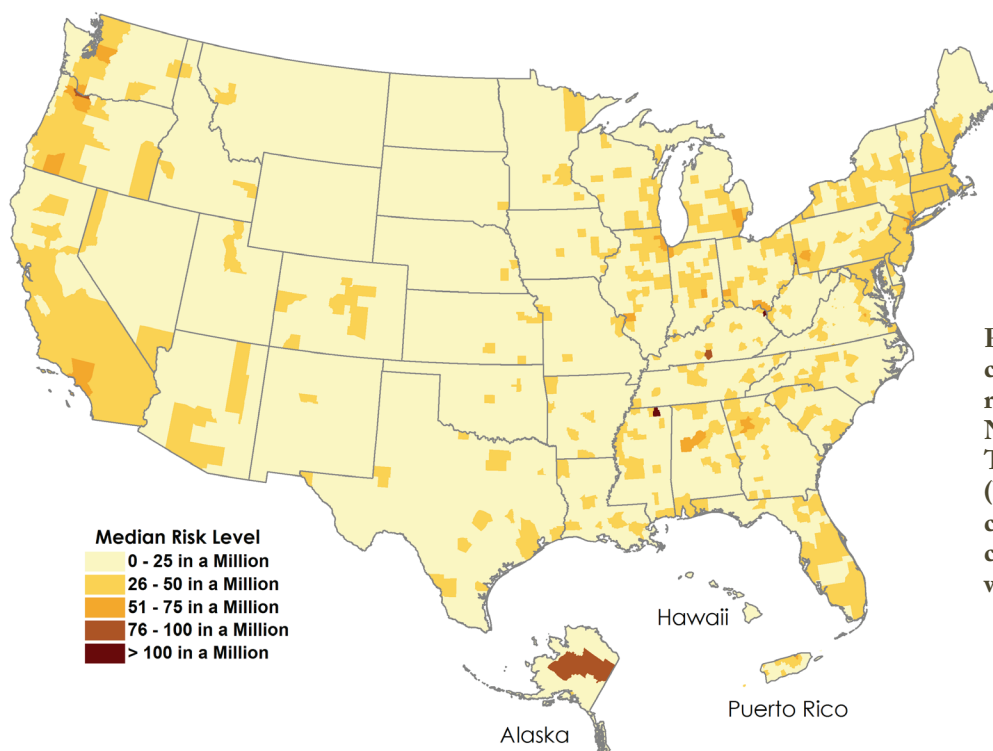


Figure 28. Estimated county-level cancer risk from the 2002 National-Scale Air Toxics Assessment (NATA2002). Darker colors show greater cancer risk associated with toxic air pollutants.

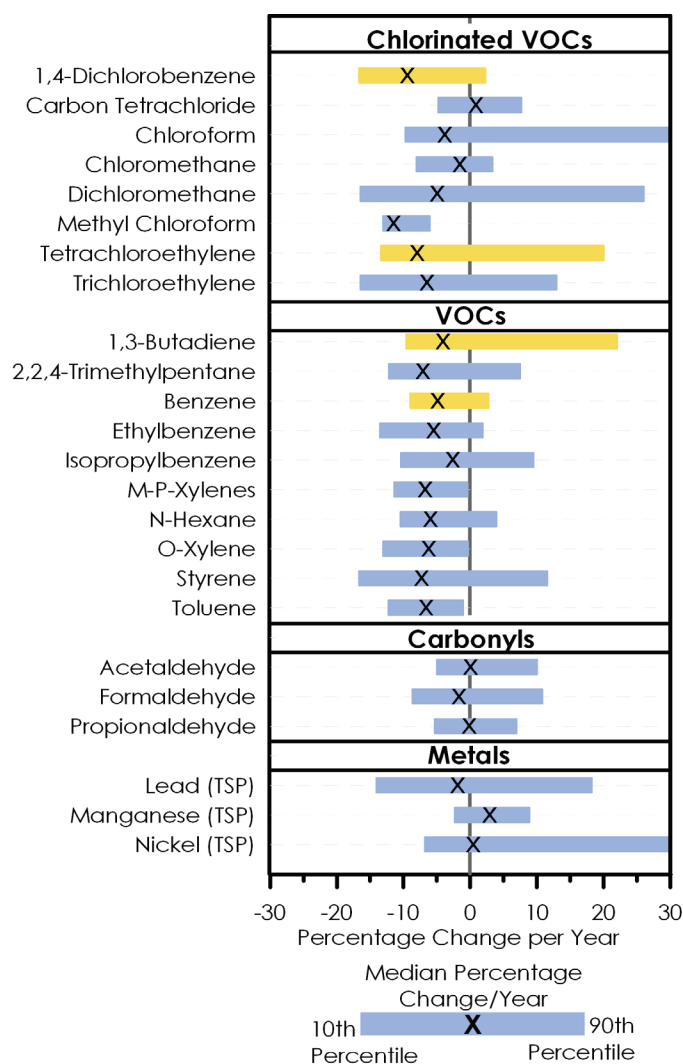
Figure 29 shows the trends in ambient monitoring levels for some of the important toxic air pollutants identified by NATA. When the median percent change per year (marked by an x for each pollutant shown) is below zero, the majority of sites in the U.S. show a decrease in concentrations. Ambient monitoring data show that for some of the toxic air pollutants of greatest widespread concern to public health (shown in yellow), 1,3-butadiene, benzene, tetrachloroethylene, and 1,4-dichlorobenzene, concentration levels are declining at most sites. Concentrations of volatile organic compounds (VOCs) such as 1,3-butadiene, benzene, styrene, xylenes, and toluene decreased by approximately 5 percent or more per year at more than half of all monitoring sites. Concentrations of carbonyls such as formaldehyde, acetaldehyde, and propionaldehyde were equally likely to have increased or decreased (another carbonyl of interest, acrolein, was not reliably measured in 2000 so no trend is shown for it). Chlorinated VOCs such as tetrachloroethylene, dichloromethane, and methyl chloroform decreased at more than half of all monitoring sites, but decreases among these species were much less consistent from site to site than among the other VOCs shown. Lead particles decreased in concentration at most monitoring sites; trends in other metals are less reliable due to the small number of sampling sites available for analysis.

In 2003, in an effort to improve accuracy and geographic coverage of monitoring, EPA, working with its state and local partners, launched the National Air Toxics Trends Station (NATTS) program, a national

monitoring network for toxic air pollutants. The principal objective of the NATTS network is to provide long-term monitoring data across representative areas of the country for NATA priority pollutants (e.g., benzene, formaldehyde, 1,3-butadiene, acrolein, and hexavalent chromium) in order to establish overall trends. The initial 23 sites were established between 2003 and 2005; two sites were added in 2007 and two more in 2008 for a total of 27 NATTS sites. In addition, the list of pollutants monitored was expanded to include polycyclic aromatic hydrocarbons (PAHs), of which naphthalene is the most prevalent. In addition to the NATTS program, about 300 monitoring sites—operated by state, local, and tribal agencies—are currently collecting data to help track toxic air pollutants levels across the country.

Figure 29. Distribution of changes in ambient concentrations at U.S. toxic air pollutant monitoring sites, 2000-2005 (percent change in annual average concentrations). (Source: McCarthy M.C., Hafner H.R., Chinkin L.R., and Charrier J.G. [2007] Temporal variability of selected air toxics in the United States. *Atmos. Environ.* 41 [34], 7180-7194)

Notes: 10th and 90th percentiles are excluded if fewer than 10 monitoring sites were available for analyses. For chloroform and nickel, the 90th percentile percent changes per year are cut off at 30. TSP = total suspended particulate.



ATMOSPHERIC DEPOSITION

Pollution in the form of acids and acid-forming compounds such as oxides of sulfur (SO_x) and oxides of nitrogen (NO_x) can deposit from the atmosphere to the Earth's surface. Figure 30 illustrates how this deposition can occur through rain or snow (wet deposition), clouds or fog (occult deposition), and gases and particles (dry deposition). Nitrogen and sulfur interactions in the environment are highly complex: while both are essential nutrients for growth and productivity, excess amounts of either nitrogen or sulfur can impair the structure and function of ecosystems.

Some of the most serious impacts of excess nitrogen and sulfur are acidification and nutrient enrichment—an increase in nutrients available in the ecosystem. This process is known as eutrophication in aquatic

ecosystems. Eutrophication involves excessive plant growth and decay, which can lead to a lack of oxygen, impairment of water quality, and damage to fish and animal populations. Acidification causes a cascade of effects in terrestrial and aquatic ecosystems such as slower plant growth, injury or death of forest vegetation, and localized extinction of fish and other aquatic species. In some ecosystems, excess sulfur also contributes to increased mercury methylation—the transformation of mercury emissions into a highly toxic form of mercury associated with a range of adverse effects in humans and animals. Sources of mercury emissions include coal combustion, municipal and medical waste incineration, and mining of metals for industry. More information about EPA's mercury program can be found at <http://www.epa.gov/mercury>.

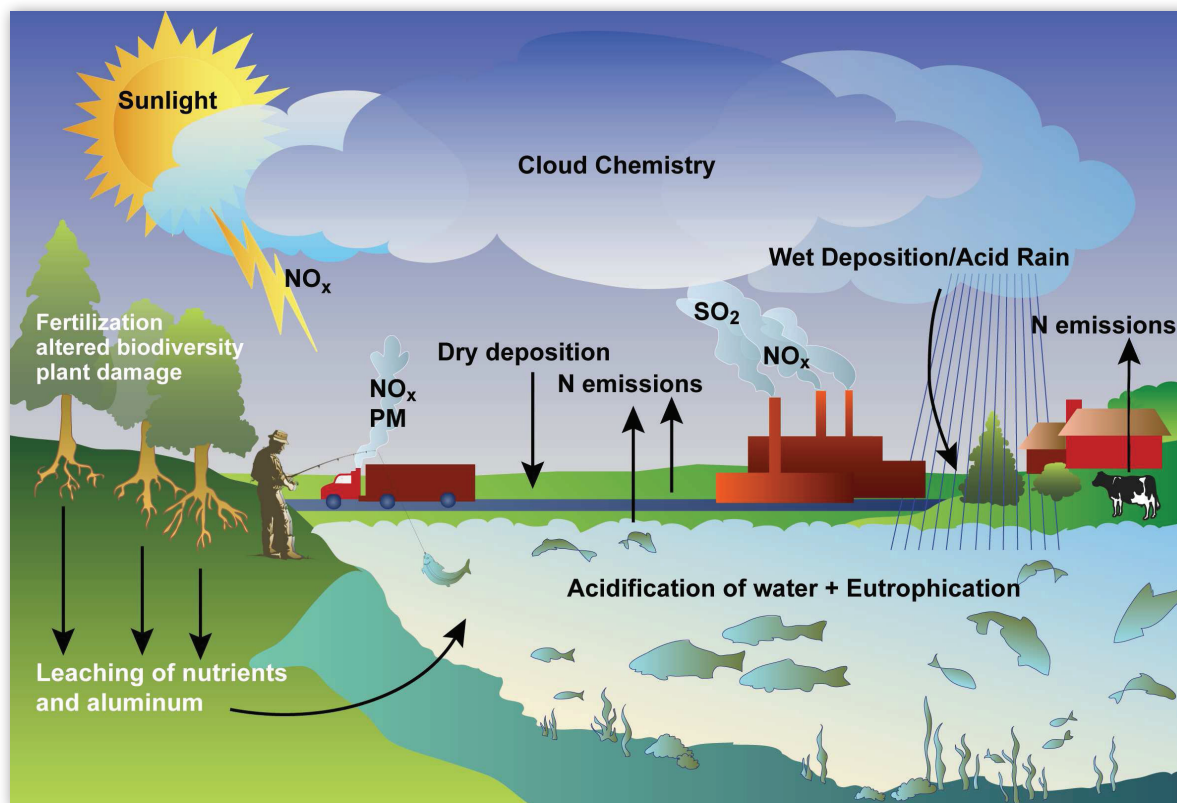


Figure 30. Nitrogen (N) and sulfur cycling and interactions in the environment.

TRENDS IN ATMOSPHERIC DEPOSITION

In recent decades, acid deposition in the U.S. has declined significantly. Between 1989-1991 and 2006-2008, wet sulfate deposition decreased over 30 percent in the Northeast and Midwest, as shown in Figure 31. In addition, wet nitrate deposition decreased by about 30 percent in the Mid-Atlantic and Northeast and 20 percent in the Midwest. These reductions have led to the improvement of water quality in lakes and streams.

Most of these improvements are due to reductions in SO_2 and NO_x emissions from electric utilities and industrial boilers. The Acid Rain Program and the NO_x SIP Call in the East have led to significant reductions in SO_2 and NO_x emissions.

- SO_2 emissions from Acid Rain Program sources have been reduced by more than 8 million tons from 1990 levels, or about 52 percent. Compared to 1980 levels, SO_2 emissions from power plants have dropped by almost 10 million tons, or about 56 percent. In 2008, annual SO_2 emissions fell by over 1,300,000 tons from 2007 levels.
- NO_x emissions from sources subject to the NO_x SIP Call program have been reduced by about 4 million tons from 1990 levels so that emissions in 2008 were less than half the level anticipated without the Acid Rain and NO_x SIP Call programs.

Despite significant progress, acid deposition remains a challenge for many areas of the country. Deposition

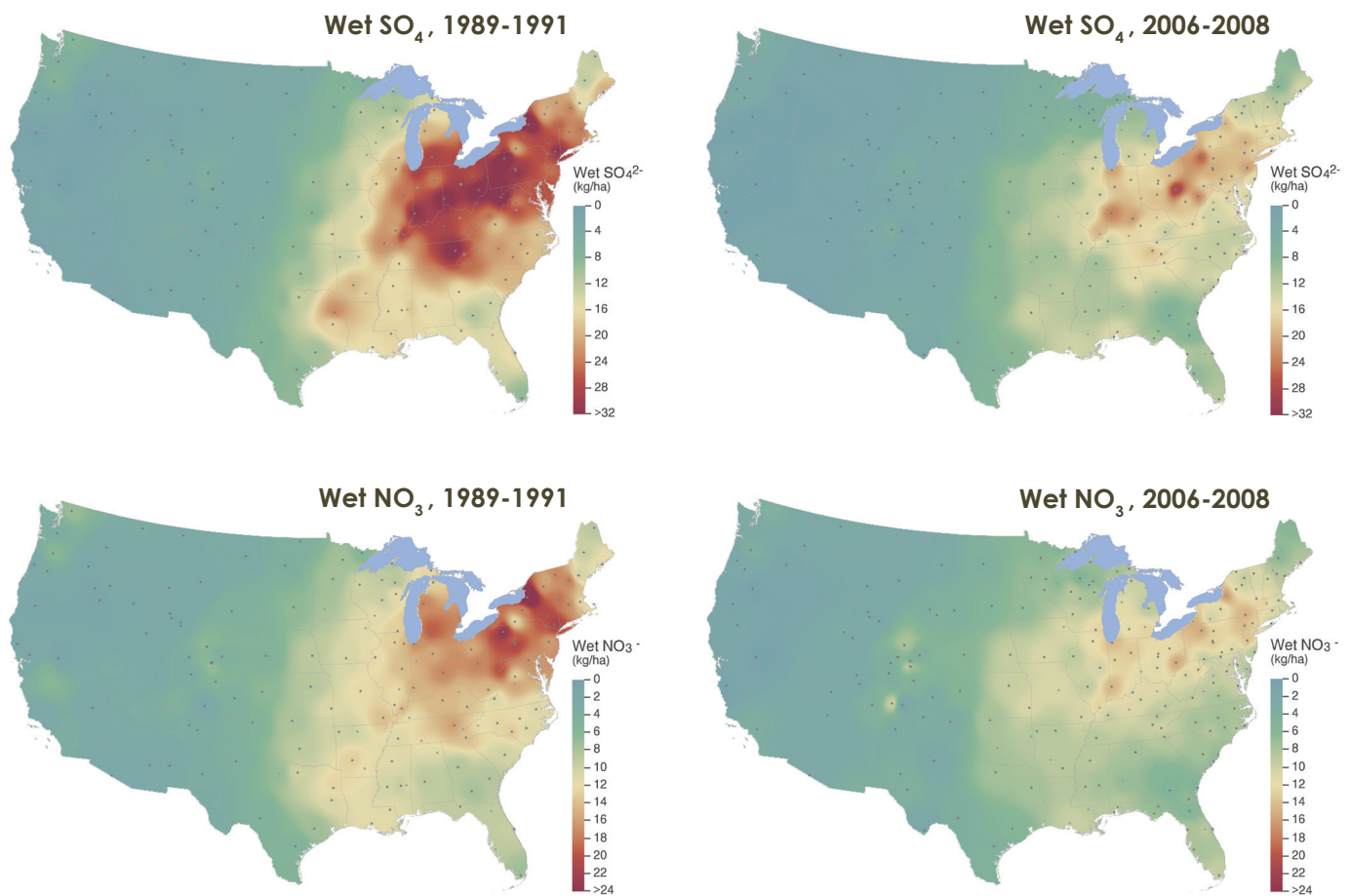


Figure 31. Three-year average deposition of sulfate (wet SO_4^{2-}) and nitrate (wet NO_3^-) in 1989-1991 and 2006-2008 in kg/ha. Dots show monitoring locations. (Data source: National Atmospheric Deposition Program, <http://nadp.sws.uiuc.edu>)

Atmospheric Deposition

of both nitrogen and sulfur is generally higher in the eastern U.S. than in the West. Fossil fuel combustion and nitrogen fertilizer use contribute to relatively high rates of nitrogen deposition in the East, with the Midwest and Northeast generally experiencing the highest levels of deposition. In the East, deposition exceeding 18 kg sulfur per hectare per year occurs near some SO₂ sources, with high deposition particularly notable along the Ohio River Valley extending across Pennsylvania.

EPA is currently conducting a joint review of the NO_x and SO_x secondary standards and looking at the relationship between acid deposition and ecological effects such as acidification and eutrophication. This review, which is scheduled to be completed in 2012, will address residual acid deposition in the U.S. Because NO_x, SO_x, and their associated transformation products are linked in terms of both atmospheric chemistry and environmental effects, a joint assessment of the scientific information, associated risks, and standards is essential to ensuring appropriate environmental protection.

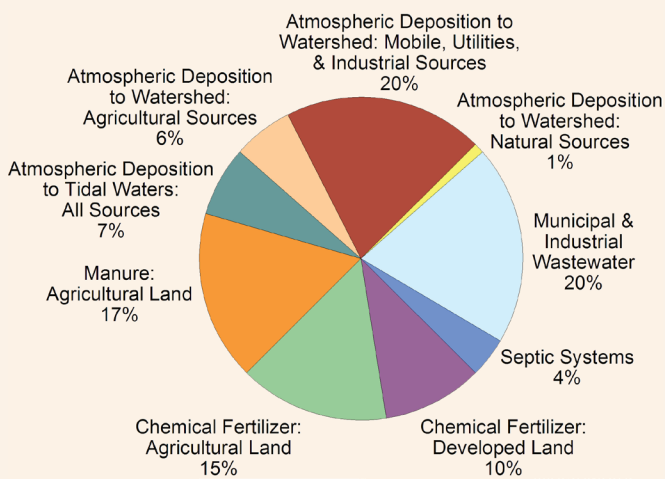
DEPOSITION OF AIR POLLUTANTS TO THE CHESAPEAKE BAY

The Chesapeake Bay's airshed is an area containing air pollutant emission sources that contribute 75 percent of nitrogen deposited into the Bay and its watershed. Defined in this manner, the Chesapeake Bay airshed is about 570,000 square miles, or seven times the size of the watershed. Nitrogen and chemical contaminants from air pollution, such as mercury and polychlorinated biphenyls (PCBs), contribute to poor water quality in the region. Air pollution is generated by a variety of sources including power plants, industrial facilities, farming operations, and highway vehicles and non-road engines. About 34 percent of the amount of nitrogen added to the Bay and its watershed on a yearly basis (loading) comes from atmospheric deposition.

National air quality control programs for both stationary and mobile sources, including the Clean Air Interstate Rule, the Tier-2 Light Duty Vehicle Rule, the Non-Road Engine Rule, the Heavy-Duty Diesel Engine Rule, and the Locomotive/



Chesapeake Bay airshed



Sources of nitrogen loading to the Bay

Marine Engine Rule, are reducing nitrogen emissions and, therefore, nitrogen deposition onto the Bay and watershed. Data from 30 long-term monitoring sites within the Chesapeake watershed (National Atmospheric Deposition Program and Atmospheric Integrated Research Monitoring Network) show a decrease of about 30 percent in nitrate and ammonium deposition from 1985 to 2005.

EPA estimates that by 2020, nitrogen deposition to the Chesapeake Bay will decline 46 percent from 1985 levels.

VISIBILITY IN SCENIC AREAS

TRENDS IN VISIBILITY

EPA and the National Park Service monitor visibility trends in 155 of the 156 national parks and wilderness areas, where clear views are an important value for visitors (i.e., Class I areas). States are required to adopt progress goals every ten years for improving visibility, or visual range, from baseline conditions (represented by the five-year average conditions between 2000 and 2004). The ultimate goal is to achieve natural background conditions, or conditions which existed before manmade pollution, by 2064. The Regional Haze Rule, published in 1999, requires states to identify the most effective means of preserving conditions in Class I areas when visibility is at its best—based on the 20 percent best or cleanest visibility days monitored—and to gradually improve visibility when it is most impaired—based on the 20 percent worst visibility days monitored.

Long-term trends indicate that visibility is improving. Figure 32 shows this progress. A number of Class I areas show improving visibility or decreasing haze (indicated by the downward pointing arrows) for the worst visibility days: Mt. Rainier National Park, WA; Great Gulf Wilderness, NH; Snoqualmie Pass, WA; Olympia, WA; Columbia Gorge, WA; Starkey, OR; Presque Isle, ME; and Bridgton, ME. Only Hawaii Volcanoes National Park shows increasing haze. Most locations also show improving visibility (decreasing haze) for the best visibility days. Considerable

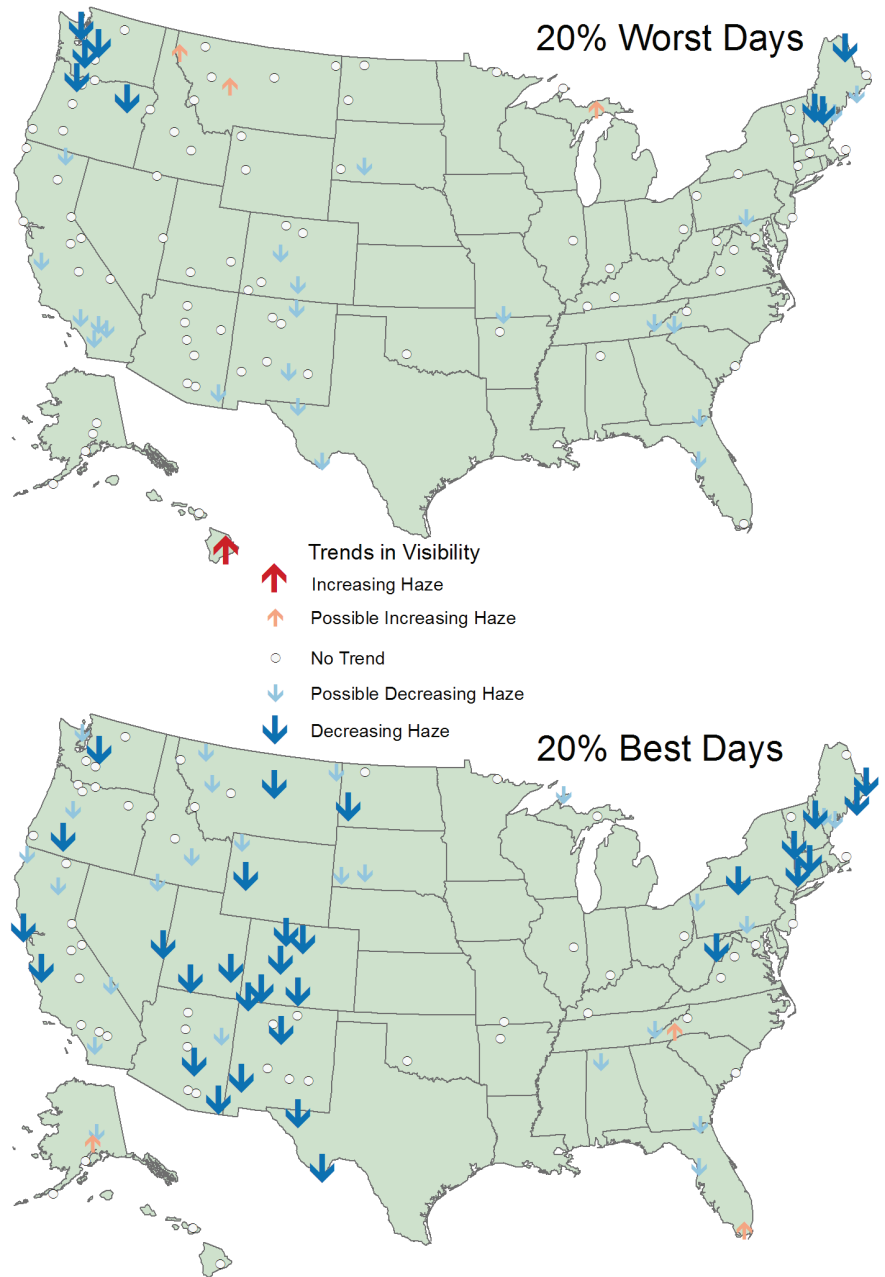


Figure 32. Trends in visibility on the 20 percent worst and best visibility days, 1998-2007. (Source: National Park Service/Air Resources Division, <http://www.nature.nps.gov/air/>)

Note: Visibility trends using a haze index for the annual average for the 20 percent best and worst visibility days are based on aerosol measurements collected at Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring sites. The haze index is measured in deciviews (dv), a visibility metric based on the light extinction coefficient that expresses incremental changes in perceived visibility. Sites having at least six years of complete data were used to compute the change in dv per year over the trend period and its statistical significance.

additional progress is needed to achieve natural visibility. Implementation of the Regional Haze Rule and other planned regulatory programs will reduce emissions of visibility impairing pollutants and ensure that the improvement in visibility continues.

States determine whether they are meeting their visibility goals by comparing visibility conditions from one five-year average to another (e.g., 2000-2004 to 2013-2017). The glide path to natural visibility

conditions in 2064 for the Shenandoah National Park is shown in Figure 33 and demonstrates the minimum rate of progress or improvement in visibility that should occur over time to meet the goal of natural conditions. In 2007, states were required to submit plans demonstrating how they would achieve natural visibility conditions by 2064. EPA requires monitoring to verify that progress is being made to improve visibility in the Class I areas.

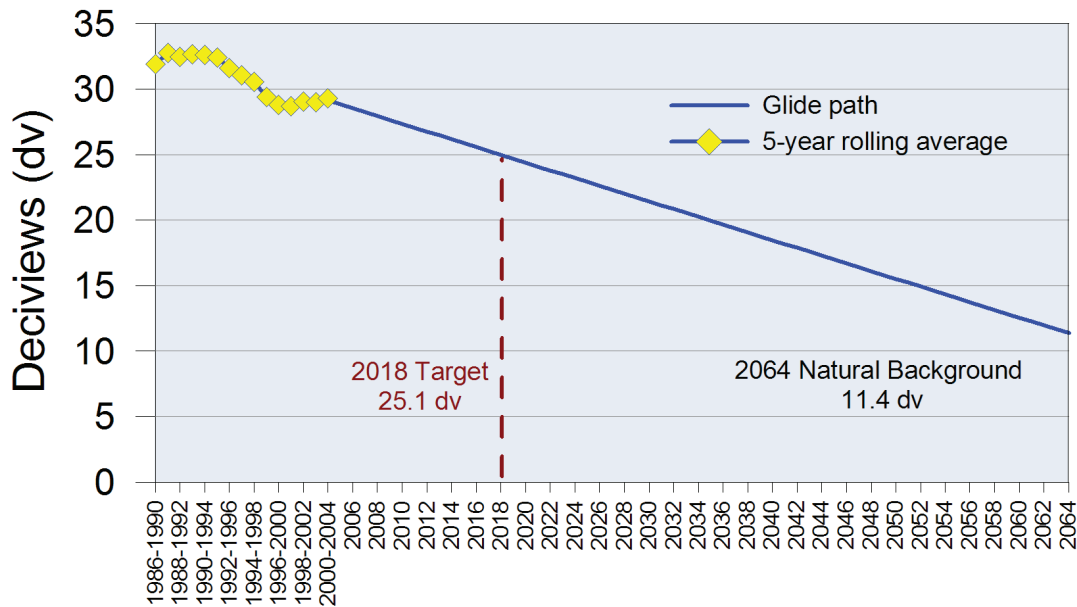


Figure 33. Glide path to natural conditions in 2064 for Shenandoah (deciviews) compared to 2000-2004 baseline conditions. (Source: Visibility Improvement State and Tribal Association of the Southeast—VISTAS)

Notes: A change of one deciview (dv) is a change in visibility that is discernable. The figure shows a five-year rolling average for the 20 percent worst visibility days.



CLIMATE CHANGE AND AIR QUALITY

CLIMATE AND AIR QUALITY

Climate and air quality are closely coupled. As discussed in previous sections of this report, conventional pollutants, such as ozone and particle pollution, not only affect public health but also contribute to climate change. Ozone is a significant greenhouse gas (GHG) and particles can influence the climate by scattering, reflecting, and/or absorbing incoming solar radiation and interacting with various cloud processes (see Ozone and Particle Pollution sections). Climate and meteorology directly influence ambient concentrations of particles and ozone, in part by affecting emissions of precursors from natural sources such as plants and trees. Thus, though climate and air quality are often treated as separate issues, there are important interactions that need to be considered and addressed.

Ozone and black carbon (BC) both affect public health and climate. Their impacts differ from those of long-lived GHGs because ozone and particle pollution generally stay in the atmosphere for only a few days or weeks. Therefore, these short-lived pollutants may not travel as far and tend to be unevenly distributed in the atmosphere. Long-lived GHGs like carbon dioxide (CO₂) persist in the atmosphere over decades to centuries and eventually become fairly evenly distributed throughout the Earth's atmosphere. Because

they persist, long-lived GHGs will continue to exert influence over climate, meteorology, and air pollution levels far into the future.

Because ozone and BC have short atmospheric lifetimes, reducing these emissions has a strong, immediate climate benefit. While controlling long-lived GHGs is essential for addressing climate effects in the long term, controlling short-lived climate pollutants may be a good strategy to reduce the rate of climate change in the near-term. Reducing short-lived climate pollutants can supplement programs to reduce the long-lived climate pollutants.

Given the links between climate and air quality, the National Academy of Sciences (NAS) recommended in its 2004 report, *Air Quality Management in the United States*, that air pollution and climate change policies be developed through an integrated approach. A number of strategies being discussed for climate—energy efficiency, renewable energy, and reducing the number of vehicle miles traveled—will provide reductions in emissions that contribute to multiple air quality concerns such as ozone and particle pollution, toxic air pollutants, atmospheric deposition, and visibility. These kinds of approaches are “win-win,” providing improvements to air quality while also reducing the adverse risks and impacts associated with climate change.



RECENT TRENDS IN GREENHOUSE GAS EMISSIONS AND CLIMATE

EPA, in collaboration with other government agencies, tracks both changes in climate and changes in GHG emissions. Figure 34 shows the trends in domestic GHG emissions over time. Total U.S. emissions increased 17 percent from 1990 to 2007. Primary contributors to this increase include an increased consumption of fossil fuels to generate electricity and a significant decrease (14 percent) in hydropower generation (electric power generated using water power) used to meet this demand.

A number of EPA scientists participate on the Intergovernmental Panel on Climate Change (IPCC), an international scientific body that provides information about the causes of climate change and its potential effects on the environment. In a series of comprehensive reports completed in 2007, the IPCC concluded 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.” Global mean surface temperatures have been rising and the IPCC reported that since the mid 20th century, most of the observed increase is very likely due to the observed increase in human-made GHG concentrations.

CLIMATE’S EFFECTS ON AIR QUALITY

Due to climate change, the IPCC predicted “declining air quality in cities.” In summarizing the impact of climate change on ozone and particle pollution, the IPCC concluded that “future climate change may cause significant air quality degradation by changing the dispersion rate of pollutants; the chemical environment for ozone and particle pollution generation; and the strength of emissions from the biosphere, fires, and dust.” Though a great deal of uncertainty remains regarding the expected future impacts of climate change on air quality, recent research suggests that such effects may be very significant, particularly on a local or regional scale.

Ground-level ozone is influenced by shifts in the weather, such as the periodic occurrence of heat waves. Changes in the weather that might result from climate change, such as warmer temperatures and more or less frequent episodes of stagnant air, therefore also have the potential to affect ground-level ozone. The potential impact of climate change on particle pollution is less well understood, but recent studies have begun to look at this relationship.

A 2009 report by EPA (EPA Assessment, 2009) investigates the potential impacts of climate change on both ozone and particle pollution (while holding emissions constant). With regard to ozone, the

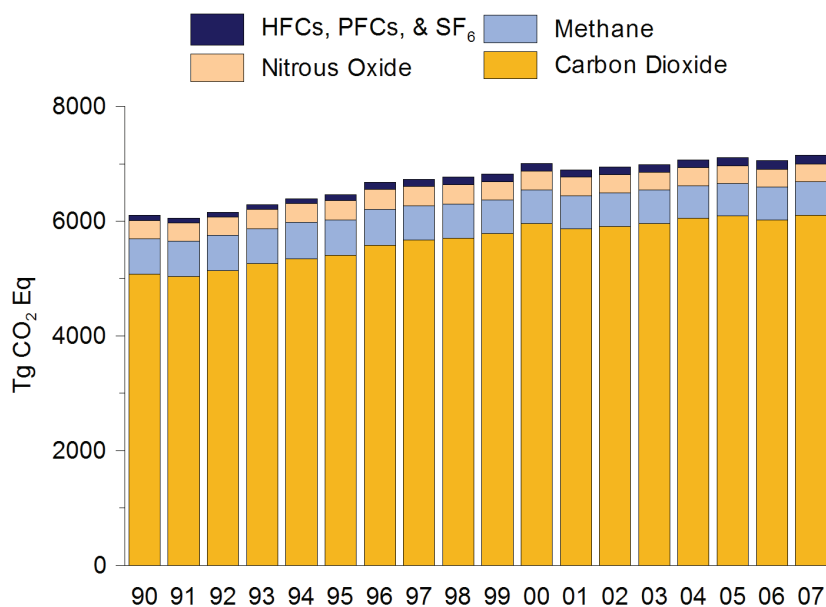


Figure 34. Domestic greenhouse gas emissions in teragrams of carbon dioxide equivalents (Tg CO₂ eq), 1990-2007. (Source: <http://epa.gov/climatechange/emissions/usinventoryreport.html>)

Notes: A teragram is equal to 1 million metric tons. Emissions in the figure include fluorocarbons (HFCs, PFCs) and sulfur hexafluoride (SF₆).

assessment indicates climate change (between the present and 2050) has the potential to:

- Produce significant increases in summertime average ground-level ozone concentrations in many regions by 2 to 8 parts per billion, as shown in Figure 35
- Exacerbate peak ozone concentrations on days where weather is already conducive to high ozone concentrations
- Lengthen the ozone season
- Increase emissions of ozone precursors from natural sources

In general, while this type of modeling study cannot precisely predict what the future will hold, it does demonstrate the potential for global climate change to exacerbate ground-level ozone pollution across the U.S. The findings of this study indicate that, where climate change-induced increases in ground-level ozone do occur, damaging effects on ecosystems, agriculture, and health may be pronounced, due to increases in average pollutant concentrations and the frequency of extreme pollution events. Further studies are needed to understand how changes in future emissions patterns will affect climate and air quality interactions.

For particle pollution, the results from EPA's assessment are less definitive. The report indicates that future climate conditions may be associated with a range of impacts—both increases and decreases—in particle concentrations in different regions and may also affect different components of particle pollution differently. Specifically, the study's limited findings show:

- Globally, particle pollution generally decreases as a result of simulated climate change (with manmade emissions held constant), due to increased atmospheric humidity and/or increased precipitation
- Regionally, simulated climate change produces both increases and decreases in particle pollution (on the order of a few percent) in 2050, depending on the region of the U.S., with the largest increases in the Midwest and Northeast
- The responses of the individual components of particle pollution (e.g., sulfate, nitrate, ammonium, BC, organic carbon) to climate change are highly variable, depending on the properties and transport characteristics of each component
- Particle pollution is expected to be influenced by meteorological factors such as precipitation, clouds, and temperature, all of which are affected by climate change

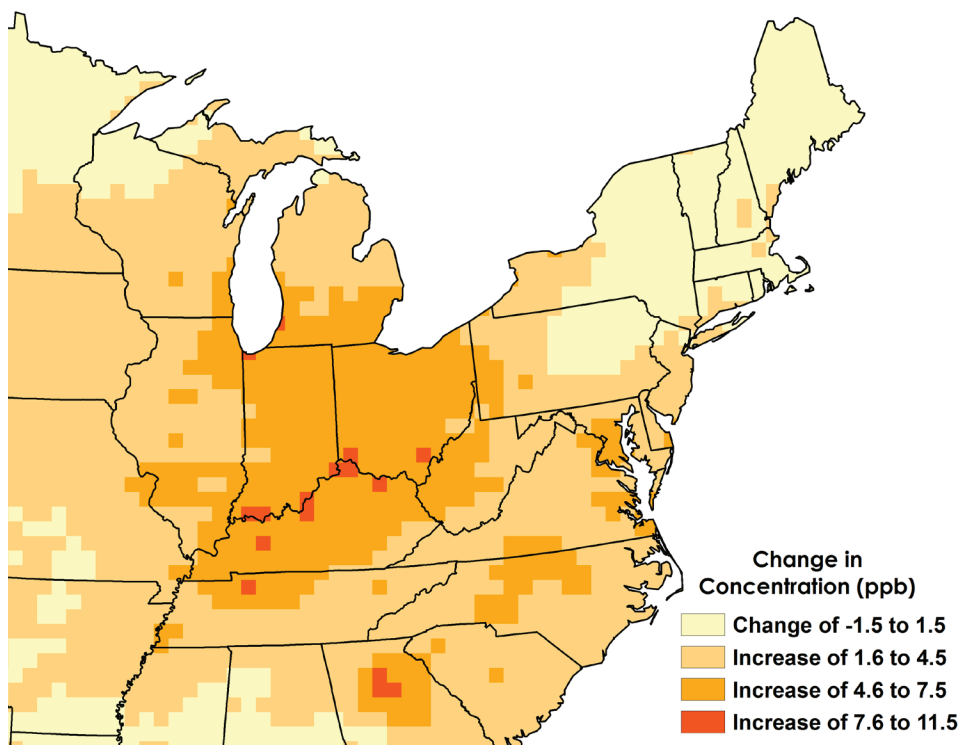


Figure 35. Increases in average summertime ozone concentrations in the eastern U.S., due to climate change, are predicted for 2050. (Source: Figure 33 from EPA Assessment, 2009. 2050s-minus-present differences in simulated summer mean maximum daily average 8-hour ozone concentrations; reproduced from Figure 2 in Hogrefe et al., 2004.)

IMPACTS OF SHORT-LIVED POLLUTANTS ON THE ARCTIC CLIMATE

Arctic temperatures have increased at almost twice the global average rate over the past 100 years (IPCC, 2007). Warming in the Arctic has been accompanied by an earlier onset of spring melt. During the 2007 melt season, Arctic sea ice dropped to the lowest levels observed since satellite measurements began in 1979, resulting in the first recorded complete opening of the Northwest Passage. As sea ice shrinks, less sunlight is reflected from the Earth's surface, leading to further warming.

Reducing emissions of carbon dioxide (CO₂) globally is essential to long-term global (and Arctic) climate stabilization, but will not significantly change the rate of warming in the Arctic over the next few decades due to the long lifetime of CO₂ in the atmosphere. However, reducing emissions of short-lived pollutants may impact Arctic climate on a more immediate timescale. Several short-lived pollutants, including black carbon (BC) and ozone, are contributing to the accelerated rates of warming.

BC emissions lead to climate warming by absorbing incoming and reflected sunlight in the atmosphere. BC deposited on ice increases the rate of warming and melting of the ice. Due to these effects, and because BC in the atmosphere causes more warming when it is present over reflective surfaces such as ice, BC has impacts in the Arctic and over other snow and ice covered areas. Ground-level ozone has also been shown to play an important role in seasonal Arctic warming trends (Shindell et al., 2006). Warming due to ground-level ozone is at a maximum during spring when transport of ozone is efficient, sunlight is abundant, and substantial ozone precursors have built up over the winter.



This image compares the average sea ice extent from September 2007 to September 2005; the red line indicates the long-term median from 1979 to 2000. (Data source: Courtesy of the National Snow and Ice Data Center, Boulder, CO; http://nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html)

INTERNATIONAL TRANSPORT OF AIR POLLUTION

TRANSPORT OF AIR POLLUTION AFFECTS THE U.S.

While domestic sources of emissions are the primary cause of air pollution in our country, the U.S. is both an importer and exporter of air pollution. Air pollution flows across boundaries—not only between the U.S. and our closest neighbors, Canada and Mexico, but also between North America, Europe, and Asia and, to some extent, between North America, Africa, and Central and South America. International flow of air pollutants into the U.S. contributes to observed concentrations of ozone and fine particles and deposition of mercury, persistent organic pollutants (POPs), and acid deposition.

The impact that international transport of air pollution has on our ability to attain air quality standards or other environmental objectives in the U.S. has yet to be fully characterized (except in areas that are immediately adjacent to cities or sources in Mexico or Canada). Estimates based on the available evidence are highly uncertain but suggest that the current contributions of international transport to observed concentrations and

deposition are small but are of the same magnitude as the air quality improvements expected from recent national emissions control programs. Figure 36 illustrates one estimate of the “footprint” of North American, European, and Asian emissions with respect to ammonium sulfate, a significant man-made component of fine particle pollution. Increased emissions of particle pollution, mercury, and ozone precursors associated with economic growth in developing countries may increase background levels of these pollutants in the U.S.

For ozone and particle pollution, increased background levels of these pollutants could potentially create difficulties for local and regional areas to achieve the National Ambient Air Quality Standards and long-term visibility improvement goals. Transported ozone and fine particles also contribute to radiative forcing and global and regional climate change.

For mercury and POPs, international flows contribute to deposition and eventual human and ecosystem chemical exposures. In some locations, especially in Alaska, international sources are the dominant source of ambient air contamination.

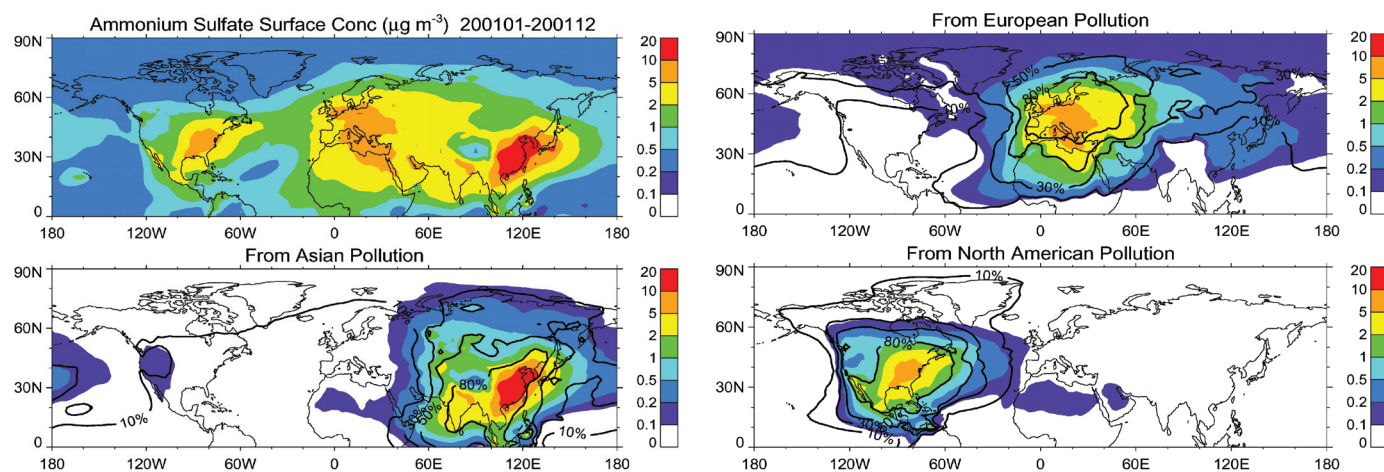


Figure 36. Annual average surface ammonium sulfate concentrations in the Northern Hemisphere in 2001 from NASA’s GOCART (Goddard Chemistry Aerosol Radiation and Transport) model (top left panel) and the amount from major source regions of Asia (second panel), Europe (third panel), and North America (last panel). Color scales are concentrations in $\mu\text{g}/\text{m}^3$ and the contour lines show the percentage contributions to the total ammonium sulfate in 10, 30, 50, and 80 percent intervals. (Source: Chin et al., 2007, *Atmospheric Chemistry and Physics*, 7: 5501-5517)

EFFORTS TO BETTER UNDERSTAND TRANSPORT OF AIR POLLUTION

EPA and other agencies are working via treaties and international cooperative efforts to address the international transport of air pollution. In 2008, EPA worked with the International Maritime Organization to adopt new emission standards for ocean-going vessels, a major source of air pollution in some coastal regions (see ship traffic patterns in Figure 37). In 2009, the National Academy of Sciences (NAS) completed a study funded by EPA, the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF), about the significance of international transport on air quality, deposition, and radiative forcing. This study, entitled “Global Sources of Local Pollution,” will contribute to

a 2010 assessment, co-led by EPA, of intercontinental transport in the northern hemisphere by the international Task Force on Hemispheric Transport of Air Pollution under the Convention on Long-Range Transboundary Air Pollution (LRTAP). The NAS study will also help inform U.S. participants on (1) negotiations on a global treaty to address mercury pollution that will be convened by the United Nations Environment Programme in 2010 and (2) ongoing negotiations under the global Stockholm Convention on Persistent Organic Pollutants, to which nine new toxic substances were added in 2008.

EPA continues to work bilaterally with air quality management authorities in Canada, Mexico, and other key countries, such as China and India, to help them address sources of air pollution, which ultimately helps to reduce the transport of air pollution into the U.S.

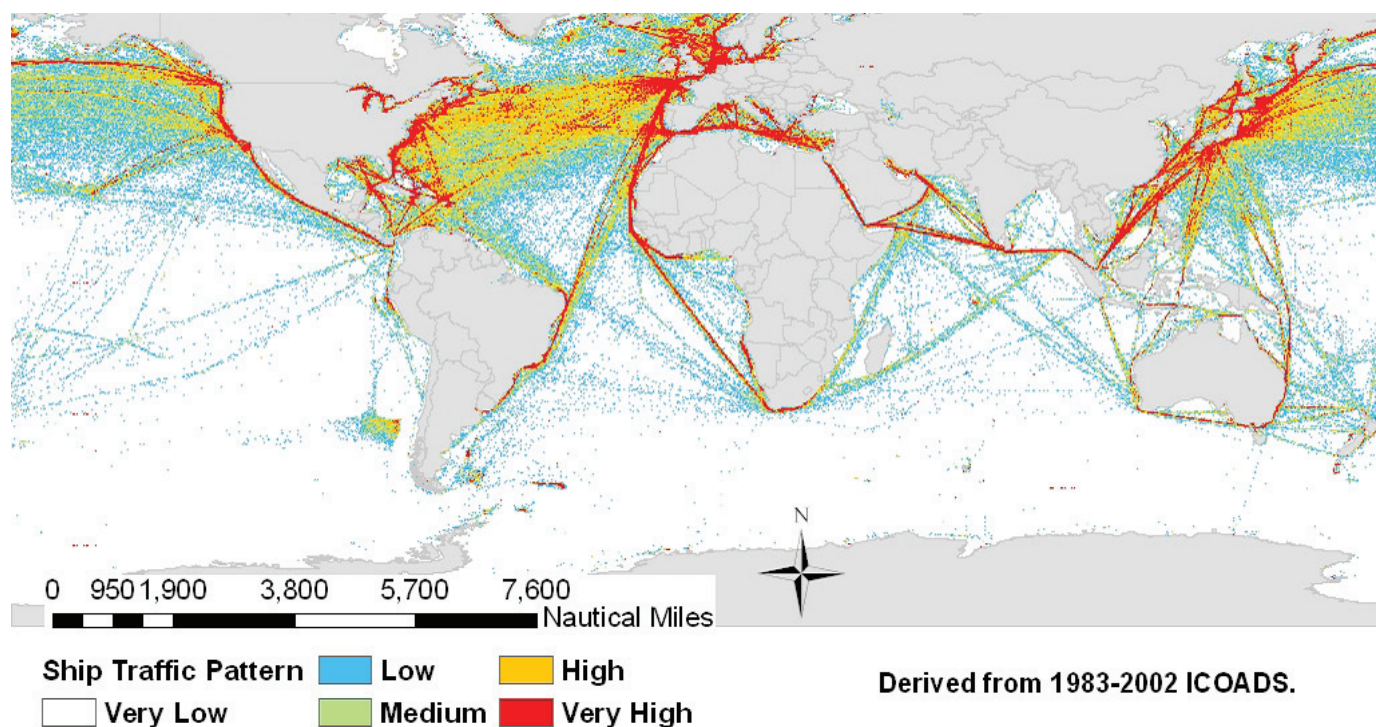


Figure 37. Marine shipping activity derived from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS).

APPENDIX

TERMINOLOGY

AQI	Air Quality Index	NO	nitric oxide
AQS	Air Quality System	NO _x	oxides of nitrogen
BC	black carbon	NO ₂	nitrogen dioxide
CASTNET	Clean Air Status and Trends Network	NSF	National Science Foundation
CFCs	chlorofluorocarbons	O ₃	ground-level ozone
CH ₄	methane	OC	organic carbon
CO	carbon monoxide	PAHs	polycyclic aromatic hydrocarbons
CO ₂	carbon dioxide	ppb	parts per billion
dv	deciviews	ppm	parts per million
EC	elemental carbon	PFCs	perfluorinated compounds
EPA	U.S. Environmental Protection Agency	PM	particulate matter (particle pollution)
GHG	greenhouse gas	PM _{2.5}	particulate matter (fine) 2.5 μm or less in size
HFCs	hydrofluorocarbons	PM ₁₀	particulate matter 10 μm or less in size
ICOADS	International Comprehensive Ocean-Atmosphere Data Set	POPs	persistent organic pollutants
IMPROVE	Interagency Monitoring of Protected Visual Environments	ppm	parts per million
IPCC	Intergovernmental Panel on Climate Change	SF ₆	sulfur hexafluoride
LRTAP	Long-Range Transboundary Air Pollution	SIP	state implementation plan
N	Nitrogen	SO _x	oxides of sulfur
NAAQS	National Ambient Air Quality Standards	SO ₂	sulfur dioxide
NAS	National Academy of Sciences	μm	micrometers (microns)
NASA	National Aeronautics and Space Administration	μg/m ³	micrograms per cubic meter
NATA	National-Scale Air Toxic Assessment	VOCs	volatile organic compounds
NATTS	National Air Toxics Trends Stations		
NEI	National Emissions Inventory		
NH ₃	ammonia		
NOAA	National Oceanic and Atmospheric Administration		

WEB SITES

Atmospheric Deposition

Acid Rain Program: <http://www.epa.gov/airmarkets/progsregs/arp/index.html>

Acid Rain Program 2006 Progress Report: <http://www.epa.gov/airmarket/progress/arp06.html>

National Atmospheric Deposition Program: <http://nadp.sws.uiuc.edu/>

Background/General Information

Air Quality Index: <http://www.airnow.gov>

Air Quality System: <http://www.epa.gov/ttn/airs/airsaqs/>

Air Quality System Detailed Data: <http://www.epa.gov/ttn/airs/airsaqs/detaildata>

Clean Air Research Program: <http://www.epa.gov/airscience>

EPA-Funded Particulate Matter Research Centers:

http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/outlinks.centers#19

Framework for Assessing the Public Health Impacts of Risk Management Decisions:

<http://www.epa.gov/ORD/npd/hhrp/files/hhrp-framework.pdf>

Health and Ecological Effects: <http://www.epa.gov/air/urbanair/>

HELPS International: <http://www.helpsintl.org>

Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air): <http://depts.washington.edu/mesaair/>

National Ambient Air Quality Standards: <http://www.epa.gov/air/criteria.html>

National Center for Environmental Assessment: <http://cfpub.epa.gov/ncea/>

National Particle Components Toxicity (NPACT) Initiative: <http://www.healtheffects.org/Pubs/NPACT.pdf>

Office of Air and Radiation: <http://www.epa.gov/air/>

Office of Air Quality Planning and Standards: <http://www.epa.gov/air/oaqps/>

Office of Atmospheric Programs: <http://www.epa.gov/air/oap.html>

Office of Transportation and Air Quality: <http://www.epa.gov/otaq/>

Climate Change

Climate change: <http://www.epa.gov/climatechange/>

U.S. Climate Change Science Program: <http://www.climatescience.gov>

Emissions and trends in greenhouse gases:

<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

Green Car Congress: <http://www.greencarcongress.com/2008/06/us-vehicle-mile.html>

Intergovernmental Panel on Climate Change: <http://www.ipcc.ch>

Traffic Volume Trends: <http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm>

Emissions and Control Programs

Emissions: <http://www.epa.gov/air/emissions/>

NO_x Budget Trading Program/NO_x SIP Call: <http://www.epa.gov/airmarkets/progsregs/nox/sip.html>

Toxic Air Pollutants

2002 National-Scale Air Toxics Assessment: <http://www.epa.gov/ttn/atw/nata2002/>

Measurements and Trends

Air Quality Trends: <http://www.epa.gov/airtrends/>

Air Trends Design Values: <http://www.epa.gov/air/airtrends/values.html>

Clean Air Status and Trends Network (CASTNET): <http://www.epa.gov/castnet/>

EPA Monitoring Network: <http://www.epa.gov/ttn/amtic/>

Local air quality trends: <http://www.epa.gov/airtrends/where.html>

National Air Monitoring Strategy Information: <http://www.epa.gov/ttn/amtic/monstratdoc.html>

National Core Monitoring Network: <http://www.epa.gov/ttn/amtic/ncore/index.html>

Trends in ozone adjusted for weather conditions: <http://www.epa.gov/airtrends/weather.html>

Visibility

National Park Service: <http://www.nature.nps.gov/air/>

Regional Haze Program: <http://www.epa.gov/visibility>

Visibility Information Exchange Web System (VIEWS): <http://vista.cira.colostate.edu/views/>

International Transport

International Maritime Organization: <http://www.imo.org>

FAA's Aviation Climate Change Research Initiative (ACCRI):

http://www.faa.gov/about/office_org/headquarters_offices/aep/aviation_climate/

Task Force on Hemispheric Transport of Air Pollution: <http://www.htap.org>

REFERENCES

Highlights

U.S. Census Bureau, *Population Division, Annual Estimates of the Resident Population by Selected Age Groups and Sex for Counties: April 1, 2000 to July 1, 2008*, available on the Internet at <http://www.census.gov/popest/counties/asrh/CC-EST2008-agesex.html>.

Ozone

National Academy of Sciences, National Research Council, *Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties*, National Academies Press, Washington, D.C. October, 2005.

Dentener, et. al., *The Impact of Air Pollutant and Methane Emission Controls on Tropospheric Ozone and Radiative Forcing: CTM Calculations for the period 1990-2030*, Atmospheric Chemistry and Physics Discussions, 4, 2004.

Jacob, Daniel et al., *Transboundary Influences on U.S. Background Ozone*, presented at the American Geophysical Union Fall Meeting, San Francisco, CA, December 14, 2007.

Parrish, David et al., *Air Quality Implications of Ozone in Air Entering the West Coast of North America*, presented at the Task Force on Measurements and Modeling - Task Force on Hemispheric Transport of Air Pollution Joint Workshop on Regional-Global and Air Quality-Climate Linkages, Paris, France, June 17, 2009.

Quinn, et. al., *Short-lived Pollutants in the Arctic: Their Climate Impact and Possible Mitigation Strategies*, Atmospheric Chemistry and Physics, 8, pg. 1723-1735 (2008).

Particle Pollution

Intergovernmental Panel on Climate Change, Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.

National Academy of Sciences, *Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties*, October 2005.

Climate Change and Air Quality

National Academy of Sciences, National Research Council, *Air Quality Management in the United States*, National Academies Press, Washington, D.C., 2004.

U.S. Environmental Protection Agency, *Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-level Ozone*, Office of Research and Development, National Center for Environmental Assessment, EPA/600/R-07/094F, April, 2009.

Shindell, et. al., *Role of Tropospheric Ozone Increases in 20th-Century Climate Change*, Journal of Geophysical Research, Geophysical Research Union, Vol. III, D08302, 2006.

International Transport of Air Pollution

National Academy of Sciences, National Research Council, *Global Sources of Local Pollution: An Assessment of Long-Range Transport of Key Air Pollutants to and from the United States*, National Academies Press, Washington, D.C. November, 2009.

METHODOLOGY USED IN THIS REPORT

1. In Figure 3 of this report, the trend line in “Aggregate Emissions” is derived by 1) determining the percentage change in emissions for each pollutant from 1990 to a later year (e.g., 2005) then 2) determining the average percentage change from among all pollutant emissions for that time period. In previous reports, this trend line was based on the percentage change in the yearly sum of the emissions from all individual pollutants. The earlier approach allowed carbon monoxide changes to dominate the overall trend line because emissions of carbon monoxide are about 10 times those of any other pollutant. The new approach results in an indicator that is more balanced among the pollutants.

2. In this report, figures and statistics involving air concentrations of all common pollutants are based on the inclusion of all valid measured concentrations even if these measured concentrations were affected by natural or other exceptional events. In previous reports, air concentrations that EPA had determined were affected by such events—and could therefore be excluded for regulatory purposes—were excluded from the figures and statistics. The new approach uses indicators that are more reflective of the air quality to which people have been exposed.



United States
Environmental
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Air Quality Assessment Division
Research Triangle Park, NC