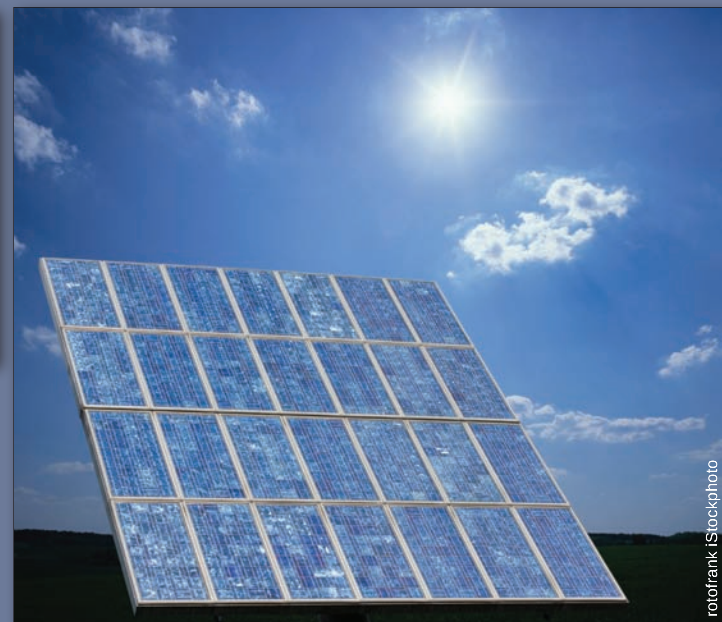
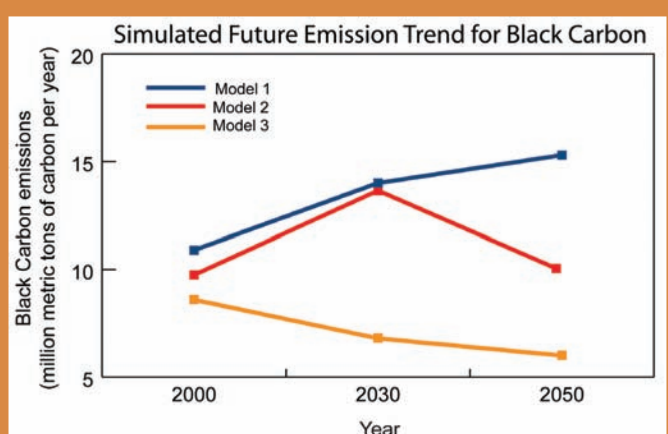


What is the critical uncertainty in predicting long-term climate effects from short-lived pollutants?

The climate impacts of short-lived gases and particles depend mainly on emission forecasts far into the future. Currently, the possible range of reasonable emissions projections is very large, For example, projected changes in black carbon emissions from 2000 to 2050 range from -30 percent to +40 percent, depending on the scenario.

Future climate studies must seriously address this very difficult issue of producing realistic and consistent 100-year emissions scenarios for short-lived gases and particles. Because the future will always be uncertain, a wide range of social, economic and technological development pathways must be used. These pathways will be determined by local and regional air quality actions taken around the globe.



Three plausible but very different emissions trends used in three different climate models to project levels of black carbon particles (soot).

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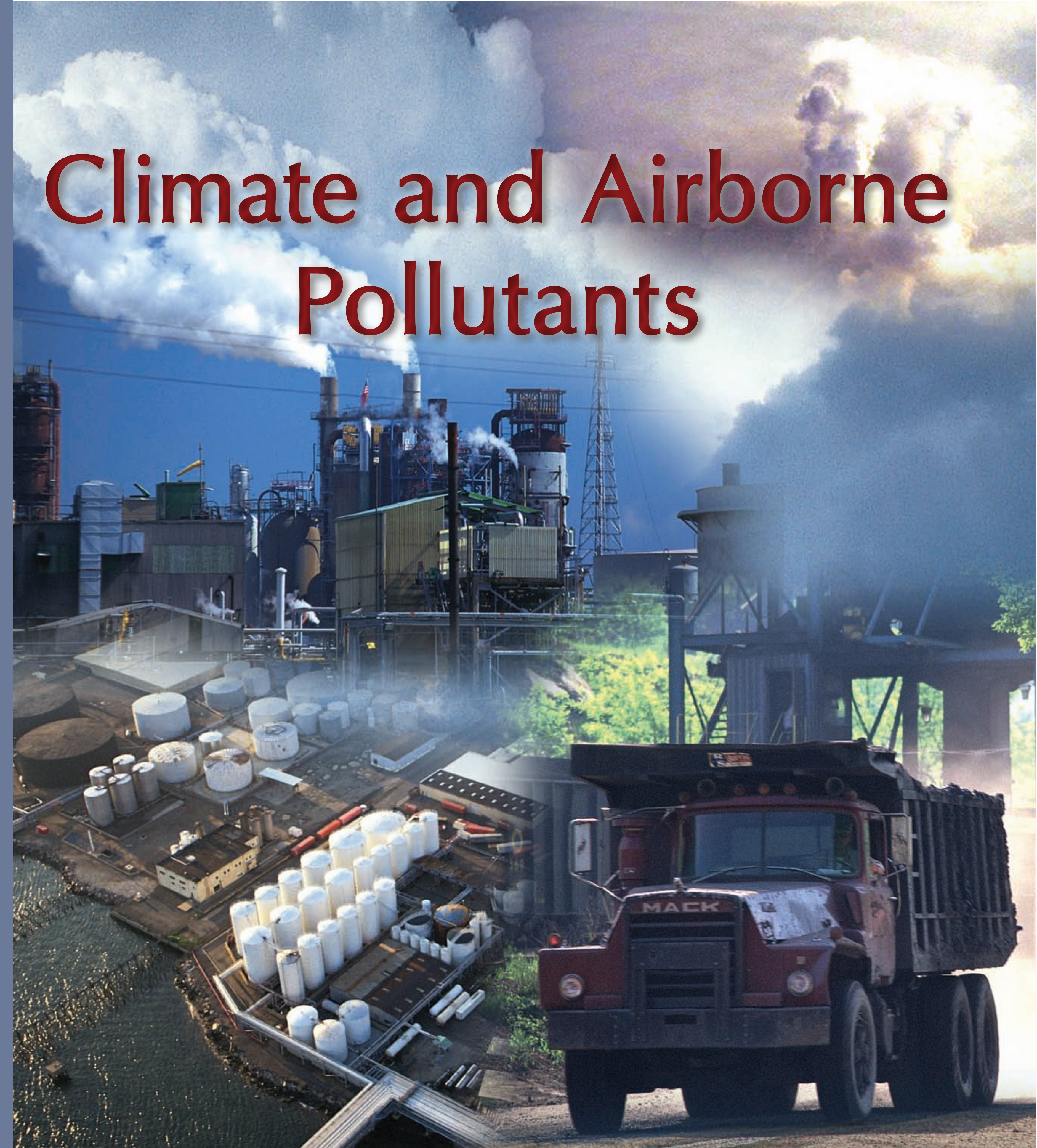


Climate and Airborne Pollutants

Findings and Summary of the U.S. Climate Change Science Program
Synthesis and Assessment Product 3.2

Climate Projections Based on Emissions Scenarios for Long-lived and Short-lived Radiatively Active Gases and Aerosols

Changes in human emissions of short-lived gases and particles may significantly influence climate in the twenty-first century.

What are long-lived gases and short-lived gases and particles, and why do they matter to climate?

Long-lived gases, such as carbon dioxide, methane, and nitrous oxide, typically stay in the atmosphere for decades to centuries, absorb energy, and warm our climate. Because of their longevity in the atmosphere, these gases accumulate and are distributed uniformly throughout the lower atmosphere. Since the Industrial Revolution began around 1800, emissions from human activities have increased the amount of carbon dioxide in the atmosphere by more than 30 percent.

On the other hand, short-lived gases and particles remain in the atmosphere for only about a day to a month. They are usually concentrated in the lowest part of the atmosphere, primarily near their sources. Ozone in the lower atmosphere is a short-lived gas that warms the surface climate and is also a major air pollutant. Short-lived particles, which are also pollutants, can either warm or cool, as they can either absorb or reflect sunlight. Sulfate particles, the greatest source of which is coal- and oil-fired power plants, reflect more sunlight than they absorb, thereby cooling the surface climate. Other particles, such as black carbon (soot), are dark and absorb energy from the sun, thereby warming the surface climate.

Lifetimes of important long-lived gases and short-lived gases and particles in the atmosphere and their effect on climate.

Gases and Particles	Average Lifetime	Effect on Climate
Long-lived gases		
Carbon Dioxide	more than 100 years	↑
Methane	10 years	↑
Nitrous Oxide	120 years	↑
Short-lived gases and particles		
Tropospheric Ozone	days to weeks	↑
Black Carbon	1 week	↑
Organic Carbon	1 week	↓
Dust	days	↓
Nitrate	1 week	↓
Sulfate	1 week	↓

Warming ↑ Cooling ↓

The concentrations of long-lived greenhouse gases, ozone, and short-lived particles all have increased dramatically over the last century due to human activity. Research suggests that the warming of the surface climate by increasing levels of both long-lived and short-lived greenhouse gases has been partially offset by increasing levels of those short-lived particles that reflect sunlight.

How Are Climate Projections Made?

Climate models have improved tremendously during the past several decades. They have become more capable of accounting for the impact that short-lived pollutants may have on climate change. Climate projections are made through the following steps:

Step 1: Projections of future climate first require *scenarios* of future emissions of long-lived greenhouse gases and important short-lived gases and particles. A scenario is a description of potential future conditions produced to inform decision-making that takes into account factors that may change such as policy, society, technology, and economic development.

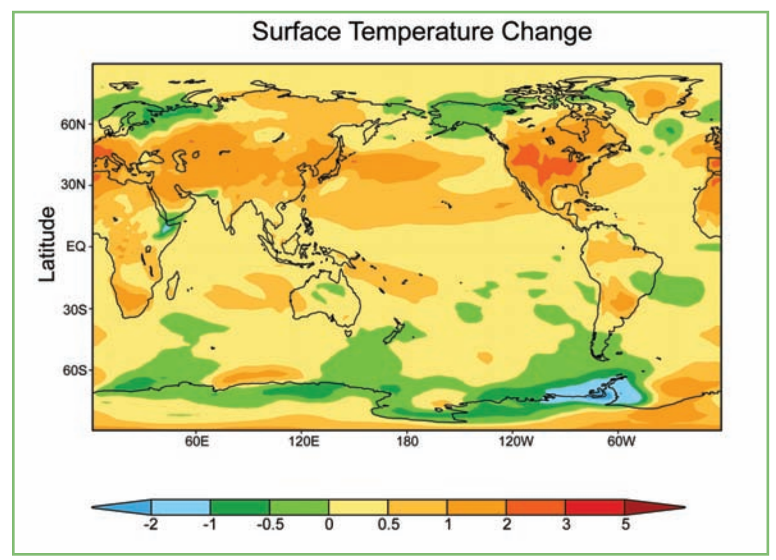
Step 2: Computer models of atmospheric transport and chemistry use the emissions scenarios to determine the concentrations of short-lived gases and particles and how they are distributed around the globe.

Step 3: Comprehensive computer climate models that take into account the atmosphere, land surface, ocean, and sea ice systems use the estimated global distributions of both the long-lived gases and short-lived gases and particles to understand past climates and to make projections of future climates resulting from both natural and human-caused changes affecting the climate.

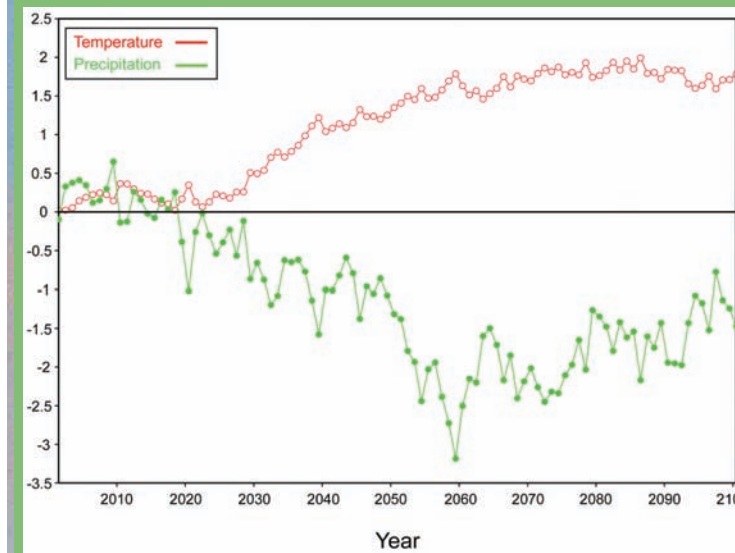
How will short-lived pollutants affect the climate in the future?

The climate impacts of projected changes in human emissions of short-lived gases and particles are potentially substantial when compared with projected increases in long-lived greenhouse gases. The projected changes in short-lived gases and particles affect the climate globally, even though they are concentrated near their sources.

- By 2050, two of the three climate models used to project long-term climate effects found that changes in short-lived pollutant concentrations will contribute 20 percent of the predicted globally averaged warming.
- By 2100, changes in the levels of short-lived gases and particles produce a substantial warming, if projected increases in black carbon and ozone and decreases in sulfate take place.
- Short-lived pollutants can cause increased climate responses far from their sources. For example, a climate model using projected changes in emissions and pollutant levels that occur primarily over Asia predicts significant increases in surface temperature and decreases in rainfall over the continental United States during the summertime throughout the second half of this century.
- Regional pollution control strategies could also benefit future climate. Reducing black carbon (soot) emissions in the domestic energy/power sector in Asia appears to offer the greatest potential for substantial, simultaneous improvements in local air quality and global climate. Reduction in emissions from ground transportation in North America would have similar beneficial impacts.



Global summer (June through August) surface temperature change in the twenty-first century due to changing emissions of short-lived gases and particles, in degrees Celsius (°C).



Twenty-first century temperature change in degrees Celsius (°C) and precipitation change in centimeters over the United States in summer (June through August) due to changes in emissions of short-lived gases and particles.

Projected changes in Asian emissions may produce significant increases in surface temperature and reduced rainfall over the summertime continental United States throughout the second half of the twenty-first century.