THE NATIONAL ACADEMIES

REPORT IN BRIEF

Global Sources of Local Pollution

An Assessment of Long-Range Transport of Key Air Pollutants To and From the United States

Recent advances in air pollution monitoring and modeling provide ample evidence that many important air pollutants, including ozone, particulate matter, mercury, and persistent organic pollutants, can be transported long distances from where they were emitted, affecting the environment on international and intercontinental scales. Characterizing the magnitude and impacts of transported pollution remains difficult, but some of these impacts could be considered 'significant' from a regulatory and public health perspective. The report recommends that the United States, working with the international research community, develop an integrated observation and modeling system to determine the sources of pollution, enhance our ability to quantify its impacts, and design effective response strategies.

Pollutants emitted from factories, traffic, and cooking stoves half a world away could make the air you breathe in the United States more hazardous to your health. Air pollutants emitted by your lawn mower or the local electric power plant could help push air pollution levels in Europe over local air quality standards.

Recent atmospheric studies have demonstrated that pollutants near the Earth's surface can be swept up to higher altitudes, where strong winds transport the pollutants across oceans and continents. Many types of air pollutants can be carried far from their sources, from soot particles in diesel vehicle exhaust to pesticides from agricultural operations and ozone precursors and mercury emitted by coal-burning power plants. The problem of transported pollution may get worse in coming years, as living standards in the developing world—and thus industrial and transportation emissions—increase. As a result, officials with the responsibility to maintain environmental quality need to understand how, when, and where long-range transport of pollutants may lead to violations of National Ambient Air Quality Standards or other regulatory guidelines, and plan accordingly.

It remains difficult, however, to characterize how pollution transported aloft ultimately affects air quality or ecosystems at ground-level, and to partition observed pollution into domestic and foreign components. These difficulties stem from a variety of limitations and uncertainties in modeling and observational capabilities.

In response to these challenges, the U. S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and the National Science Foundation have co-sponsored this National Research Council report to explore the emissions and long-range

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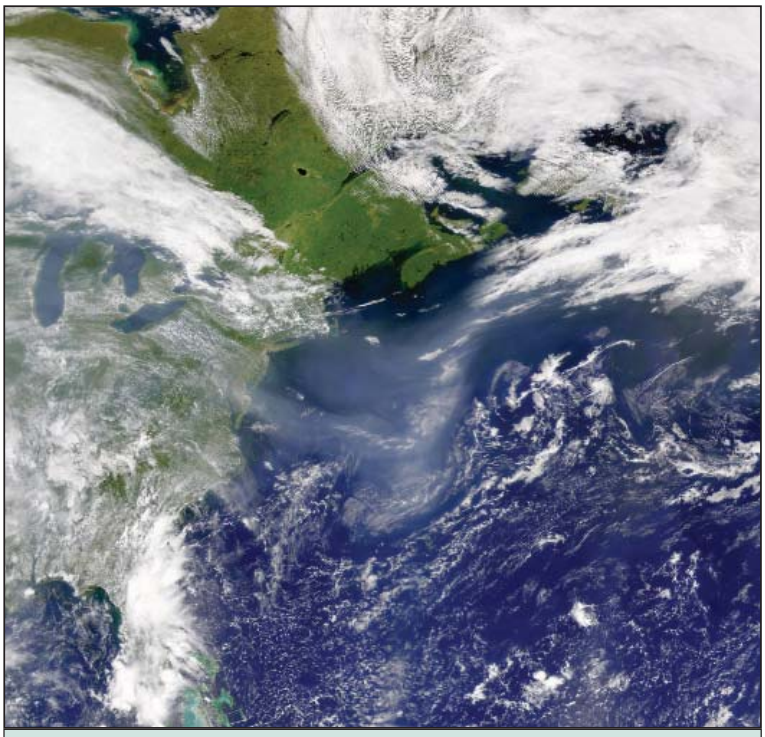
transport issues associated with four specific pollutant classes: ozone and its precursors, fine particulate matter and its precursors, mercury, and persistent organic pollutants[1]. Specifically, this study considered the impacts of long-range pollution transport on air quality, ground-level deposition and accumulation of pollutants, and the effects on radiative forcing relevant to climate change in the United States. The report reviews the impacts of U.S. emissions on environmental quality elsewhere, and the ways in which U.S. and foreign emissions and their impacts may change in the future. The report details how better research and information management tools might improve ability to quantify the impacts and implications of long-range transport of pollution.



This Sea-viewing Wide Field-of-view Sensor (SeaWiFS) image taken on June 28, 2001, shows a shroud of aerosol draped over much of the eastern United States. The aerosol could be a mixture of pollution, smoke, and cirrus clouds; many eastern cities, including Washington, DC, and Baltimore, MD, were under poor air quality advisories at the time this image was captured. Credit: NASA Earth Observatory.

Quantifying Transported Pollution

A wide variety of evidence shows that the four pollutant classes addressed in this study travel through the atmosphere on international scales, including transport across the Pacific and Atlantic oceans. Several techniques are used to gather this information. Satellite observations provide large-scale, multi-year records of a limited number of atmospheric chemical species. Atmospheric analyses carried out at strategically located observatories, or on mobile observing platforms such as aircraft or balloons, provide detailed measurements of multiple pollutants, but on a very limited spatial scale. Chemical transport models piece together these varied observations with information about emissions, meteorology, and atmospheric dynamics, to help establish the source location, where pollution originates, and the receptor location, where the pollution is detected.

Current ability to characterize long-range transport and its impacts is limited by uncertainties in emission source strengths, incomplete understanding of the chemical and physical transformations that take place during transport, poorly characterized mechanisms of pollutant transfer between different layers of the atmosphere, and the fact that few air quality research and monitoring sites are equipped to distinguish long-range pollutant contributions from the larger pollutant inputs of local and regional sources.

Transported Pollution Can Be 'Significant'

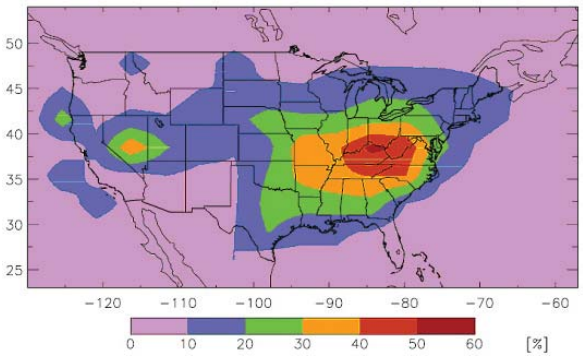
The characteristics of long-range transport vary by pollutant. For ozone, transport influences come primarily in the form of broad, diffuse increases in 'background' atmospheric concentrations, whereas for particulate matter, long range transport influences are primarily evident in episodic, concentrated pollution plumes. For both ozone and particulate matter, the main health concern is direct inhalation of airborne pollutants. The amount of pollution being transported on international scales is generally quite small compared to domestic sources, but as neither ozone nor particulate matter have a 'threshold' for health impacts, even small incremental increases in ambient concentrations can have negative health impacts in recipient regions. From a regulatory perspective, the concern is that transported pollution could lead occasionally to violations of local air quality standards.

For mercury and persistent organic pollutants, the main concern is that transport of these long-lived species leads to their gradual accumulation in terrestrial and aquatic ecosystems and can increase human

[1] Long-lived greenhouse gases, such as CO2 (recently ruled to be "pollutant" by the U.S. Supreme Court), have long been known to undergo global-scale transport, but the Committee's charge did not include consideration of such gases.

exposure via the food chain. There are also concerns about the eventual re-release of 'legacy' emissions that have been stored in soils, forests, snowpacks, and other environmental reservoirs.

Overall, the report concludes that pollutants from foreign sources can, in some instances, have significant impacts on U.S. ambient pollution concentrations and deposition rates, and can, to varying degrees, affect U.S. environmental goals. Similarly, long-range transport of pollutants originating in the United States can significantly affect the environment in other countries. The relative importance of long-range pollutant contributions from foreign sources is likely to increase as nations institute stricter air quality standards that result in tougher emissions controls on domestic sources.



Mercury deposited in the U.S. environment comes from both domestic and foreign man-made pollution sources, from natural sources, and from re-emission of legacy pollution. This map shows a model simulation estimate of the percent of total mercury deposition coming from domestic, anthropogenic sources. Red indicates the areas with the highest fraction of domestic emissions.
Credit: Selin et al. 2007

Opportunities for Vital Research

This report recommends a variety of research activities that are needed to advance understanding of long-range transport and its impacts for each of the four pollutant species analyzed. It also identifies several cross-cutting opportunities for better characterization of long-range transport of all pollutants. This includes:

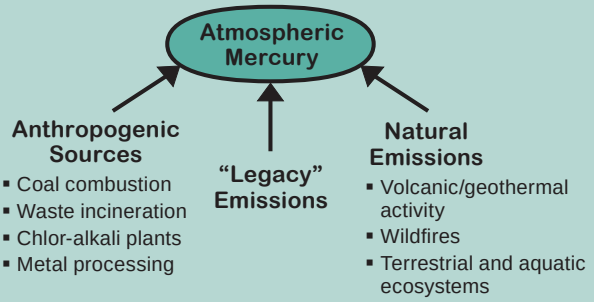
- advancing fingerprinting techniques (such as ratios of pollutant gases and particles, isotopic analyses, and single-particle analysis systems), to better identify source-specific characteristics for individual pollutants and complex particles;
- improving the accuracy, timeliness, resolution, multi-pollutant coverage, and inter-comparability of Northern Hemisphere emission inventories;
- improving the ability to model the dynamic and meteorological processes governing how pollutants move between the atmospheric boundary layer and free troposphere;

Case Study: Mercury

Mercury in the atmosphere comes as emissions resulting from human activities, from natural emissions, and 'legacy' sources- previously emitted mercury that continues to be recycled between the air, water and land surfaces, and is therefore present in the environment for long periods of time.

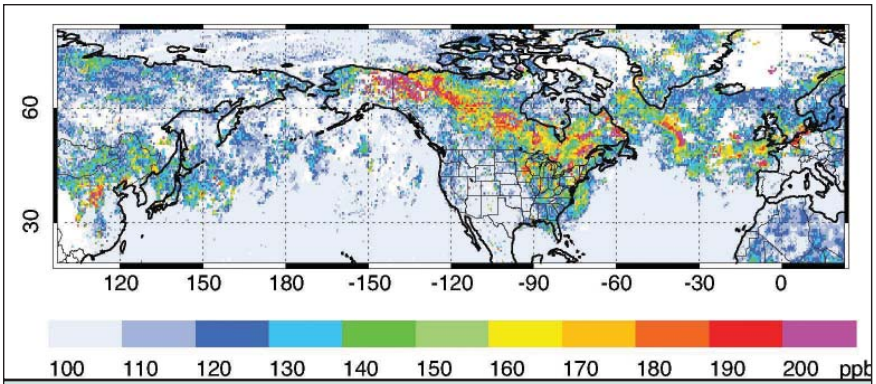
Once emitted from any source, mercury can be transformed to different chemical forms, transported through the atmosphere, and deposited long distances from the point of origin. Studies indicate that a range of 10% to 80% of the mercury deposited in the United States is from domestic man-made sources, depending on location, meaning that the remainder is from foreign emissions, domestic natural emissions or legacy sources.

These estimates rely largely on models, which cannot yet accurately represent all important aspects of the mercury cycle. Advancing our ability to attribute deposited mercury to local, regional or international sources requires not only more advanced models, but also better methods to directly measure mercury concentrations and deposition in the environment,



and to inventory emissions from both natural and man-made sources.

In coming years, it is expected that global mercury emissions will continue to increase, as the major man-made source, coal combustion, continues to grow in much of the world, especially in developing countries. Climate change could also affect global cycling of mercury in a variety of ways, for instance, by increasing the release of mercury from different environmental reservoirs and by changing the atmospheric chemistry and meteorology that affect mercury's transformation in the atmosphere and ultimate patterns of deposition.



Average carbon monoxide abundance in the free troposphere observed by the Terra/MOPITT satellite during an eight-day period in July 2004. Plumes of anthropogenic carbon monoxide pollution can be seen leaving Asia and crossing the Pacific Ocean, and plumes of pollution from Alaskan and Canadian forest fires can be seen crossing North America and the Atlantic Ocean towards Europe. Credit: D. Edwards, NCAR

- understanding how emissions from ships and aircraft affect atmospheric composition, and can complicate the detection of long-range pollutant transport from distant land-based sources.

The most effective way to improve ability to characterize long-range pollution transport and its impacts is to develop and implement an "integrated pollutant attribution system" that strengthens capabilities in emission inventories, atmospheric chemical and meteorological modeling, long-term ground-based observations, satellite remote sensing, and process-focused field studies. A key need is to foster closer integration among these research components, with a specific focus on source attribution.

The atmosphere connects all regions of the globe, and pollution emissions within any country can affect populations and ecosystems, well beyond national borders. Measures taken to decrease emissions in any region can have benefits that are distributed across the Northern Hemisphere. The United States, as both a source and recipient of long-range pollution, has an interest in remaining actively engaged in this issue, including support of more extensive international cooperation in research, assessment, and ultimately, emissions control efforts.

The Committee on The Significance of International Transport of Air Pollutants**: Charles Kolb** *(Chair),* Aerodyne Research, Inc.; **Tami Bond,** University of Illinois Urbana - Champaign; **Gregory Carmichael,** University of Iowa; **Kristie Ebi,** IPCC Working Group, Technical Support Unit**; David Edwards,** National Center for Atmospheric Research**; Henry Fuelberg,** Florida State University**; Mae Gustin,** University of Nevada, Reno**; Jiming Hao,** Tsinghua University, China**; Daniel Jacob,** Harvard University**; Daniel Jaffe,** University of Washington-Bothell**; Sonia Kreidenweis,** Colorado State University**; Michael Prather,** University of California, Irvine**; Staci Massey Simonich,** Oregon State University; **Mark Thiemens,** University of California, San Diego**; Katherine Law,** Centre National de la Recherche Scientifique**; Laurie Geller** (*Study Director*), National Research Council.

The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and the National Science Foundation. The members volunteered their time for this activity; their report is peer-reviewed and signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

EXPERT CONSENSUS REPORT

For more information, contact the Board on Atmospheric Sciences and Climate at (202) 334-3512 or visit http://nationalacademies.org/basc. Copies of *Global Sources of Local Pollution: An Assessment of Long-Range Transport of Key Air Pollutants To and From the United States* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.