Will Curbing Air Pollution Reduce Global Warming?
Air Pollution as a Climate Forcing Workshop

Tropospheric ozone (O_3), black carbon (BC) aerosols, and methane (CH_4) together may contribute more to global-mean surface warming than carbon dioxide (CO_2). These pollutants also have short atmospheric lifetimes compared to CO_2, and their control might have visible positive effects within a short period of time. In addition, O_3 and BC cause significant health problems. Understanding both the climate and health concerns of these pollutants should enable the formulation of more rational and cost-effective regulatory controls. To address these issues, the workshop *Air Pollution as a Climate Forcing* was organized by a committee headed by NASA Goddard Institute for Space Studies scientist **James Hansen,** and hosted by the IPRC at the East-West Center April 29–May 3, 2002.

Workshop participants came from a variety of communities (atmospheric science, air pollution control technology, societal impact, and policy) and countries to discuss such questions as: What actions need to be taken to reduce the emission of these pollutants? Can the climate and health benefits from a given emission reduction in a particular pollutant be quantified? The presentations focused on the sources of the pollutants, estimated magnitude of emissions, atmospheric chemical and physical responses to the emissions and their sinks, impacts on climate and health, currently available and future technologies for reducing emissions, and policies needed to curb emissions.

The climate effects of changes in concentrations of different trace gases have often been quantified by computing the "climate forcing"—the change in the global mean radiative heating rate for the troposphere when a particular perturbation is introduced into a model with set temperatures. This definition was critically reviewed at the meeting, and although participants noted its limitations, they felt that the climate-forcing concept was useful for evaluating different perturbations within the same framework.

Reports on methane showed that the post-industrial increase in CH_4 has led to a climate forcing of 0.55W/m^2 (with an uncertainty of ±20%), but the rate of increase appears to have slowed over the last decade. The impact of a specific reduction in CH_4 concentrations on the heat budget can be predicted fairly accurately. The actual sources and sinks of CH_4, however, are not understood well enough to reliably quantify the effects of particular emission reductions. Future reductions might be possible through recapturing CH_4 emissions from coal burning and from landfills, and through controlling carbon monoxide (CO) and volatile organic carbon (VOC) emissions in landfills, biofuel use, and waste treatment.

Tropospheric O_3 forms through lightning and through the interaction of other pollutants. Our ability to predict a greenhouse impact of O_3 reduction, therefore, depends on our ability to predict a specified reduction in its precursors. The ability to model the chemistry of these precursors ranges from good (for CH_4) to fair (for NOx, CO, and VOC emissions). Verification of reductions in O_3 from precursor emissions in atmospheric observations is difficult and not likely to improve greatly. Possibilities for reducing tropospheric O_3 are found in road transport, biofuel use, power plants, air and ship transport, fossil fuel production and handling of the products. The existing pollution regulations in Europe and North America are examples of how midlatitude O_3 can be curbed in the free troposphere.

Black Carbon (BC) was the aerosol given most attention at the workshop. BC absorbs sunlight and has a net warming effect on the atmosphere. Observations suggest that BC contributes significantly to climate forcing, amounting to + 0.5 W/m^{-2} or more. BC is emitted during incomplete combustion. Among the main sources of BC

worldwide are residential coal and biofuels for heating and cooking (~40%), diesel motors (~10%), coal plants (~5%), while open burning of fields and forests contributes about 50%. These percentages all have fairly large uncertainties, as it is very difficult to inventory the many sources of BC, especially in the developing world, where dung, grasses and wood are used for heating and cooking.

BC emissions can be reduced through improved combustion, switching to fuels that emit less BC in combustion, and capturing BC through filters. Though these actions sound straightforward, the interplay between fuel efficiency and emissions complicates decision making. For example, using diesel fuel reduces fuel consumption, because it is more efficient than gasoline, but it also emits much more BC, especially if it is not of high-grade. The huge increase in fuel projected for transportation in the developing world, which uses mainly low-quality diesel, makes this question particularly relevant.

Determining the general effects of aerosols—of which some have a cooling and others a warming effect—on global temperatures and on health is extremely complex. As aerosols move away from their source, they react chemically with each other and atmospheric gases; as a consequence they may change their nature and their interaction with light, and thus their effect on the heat budget. Aerosol dynamics models are being developed that describe the ways in which aerosols interact with each other and develop in size, depending upon their concentrations and distance from their source.

Evidence was presented on the long-range transport of ozone and other pollutants. North American pollutants travel to Europe, particularly during times of strong westerlies. The meteorological conditions favoring long-range travel are linked to the North Atlantic Oscillation and mid-latitude cyclones. Asian pollutants travel to Hawaii and California. The change in pollutants as they travel can significantly alter their effects on incoming solar radiation. For example, as the sand lofted during storms in the Gobi Desert passes over industrial areas with BC and other pollutants in China, it changes its properties and absorbs more sunlight in the higher atmosphere, making the atmosphere warmer and more stable; clouds burn off and don't form as readily, changing the water cycle. Modeling results suggest that the higher BC content in northern China may contribute to droughts in that region. Another modeling study suggests that controlling BC emissions would have a rapid effect on temperature, while the effects of reducing CO_2 would take much longer to appear.

The technology speakers provided a thought-provoking twist to the workshop. Our energy supply comes mainly from fossil fuels and biomass burning, which are not only major sources of CH_4, and BC emissions, and tropospheric O_3 precursors, but also of CO_2 emissions. The technology sector, therefore, views the control of both air pollutants and CO_2 under the topic of *carbon management.* Carbon management must consider three things: energy efficiency, carbon filtering or decarbonization of energy sources, and CO_2 sequestration from the atmosphere.

The sources of greatest carbon emissions in the U.S. are the burning of fuel for electricity production and for transportation. Electricity, itself, is clean, and switching to electricity for energy in the developing world will greatly curb the growth rate of air pollution; the generation of electricity, however, can emit much CO_2. In 2000, electricity generation was the source of 40% of CO_2 emissions in the US. By increasing energy efficiency and changing the energy source, the emissions related to electricity can be curbed. For instance, the generation of electricity can be made much more efficient: Central power stations now use about 3 units of energy for every unit delivered, but new technologies can lower this to a 2:1 ratio. Even better, electricity can be generated by using procedures that emit little or no CO_2. For example, the use of coal emits 900g CO_2 per kilowatt-hour, natural gas 400g, photovoltaic cells 200g (with technological improvements only 100g), and wind a negligible amount.

There is also room for more efficient electricity use. For instance, refrigerators today use between 4 to 5 times less energy than 30 years ago, even though they have become bigger. Air-conditioning is a good candidate for greater efficiency in the US. In the developing world, greater efficiency can be found with cooking stoves.

Transportation fuel is another large source of CO_2, accounting for 33% of CO_2 emission in the US. Global CO_2 emissions from transportation are projected to increase 75% over the next 25 years (International Energy Agency), most of the increase coming from the developing world. Transportation fuel is also a major source of BC and O_3. Achieving a cleaner atmosphere requires vehicles powered by energy other than fossil fuels, for instance, hydrogen. Renewable energy sources such as solar and wind power are well suited for producing hydrogen and, as mentioned above, emit little CO_2.

The technologies for more efficient energy use and for sources of non-carbon based energy, such as hydropower, turbines without dams, geothermal, wind, and solar,

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Second IPRC Annual Symposium

The Second Annual IPRC Symposium was held on May 16 and 17, 2002, at the East-West Center in Honolulu. This symposium allows the IPRC scientists to present their research highlights to each other in a formal setting. It is a time to pause and reflect upon the progress of the IPRC as a whole and to identify areas for future research. This sharing makes common research threads visible, encouraging future collaborations and the solicitation of helpful suggestions.

A total of 39 talks were given by each of the IPRC researchers, as well as by Fei-Fei Jin (University of Hawaii, School of Ocean and Earth Science and Technology) and Ming Feng (Commonwealth Scientific & Industrial Research Organisation, Australia). There were eight sessions, covering the following topics: Atmosphere-Ocean Interactions, Pacific Climate Variability, Oceanic Processes in the Kuroshio, Dynamics of the Western Boundary Currents, Oceanic Processes and Modeling, Global Climate Change and Variability, Regional and Global Atmospheric Modeling, the Asia-Pacific Data-Research Center, and the Computer Network. The list of symposium talks and their presenters can be found under *Seminars and Workshops* at the IPRC website: http://iprc.soest@hawaii.edu.

IPRC researchers assembled in front of the Imin Conference Center, East-West Center.

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exist—a point often mentioned at the workshop. This technology, however, is not making an inroad because coal and oil are still so cheap. Other reasons for not adopting new technologies are that shoppers tend to go for the low purchase price rather than the long-term savings through energy efficiency, that current regulations in the US favor central power station generation over distributed and renewable generation, and that implementation of such technologies as hydrogen-fueled motors, requires huge and costly changes in infrastructure.

In sum, reducing air pollution will curb global warming and much technology for such reduction is already available. To bring about the needed changes, though, individuals, industry, and especially governments must take vigorous action.

The full workshop report is available at www.giss.nasa.gov/meetings/pollution02/. Workshop sponsors were the National Aeronautics and Space Administration, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the National Science Foundation, the Goddard Space Flight Center, Earth Sciences Directorate, the Hewlett Foundation, the California Air Resources Board, the California Energy Commission, the International Pacific Research Center, and the East-West Center.