REGIONAL AIR QUALITY

I. INTRODUCTION

Currently, more than half the U.S. population lives in areas that do not meet the health-based air quality standards established by the USEPA. As a nation we pay the price for poor air quality every day. We pay in human lives – with tens of thousands of deaths each year as a result of exposure to poor air quality. In terms of the cost to the U.S. economy – estimated health costs are $14 - $55 billion annually and reduced crop yields cost an additional $3-$5 billion each year.

The nation's ability to improve and forecast air quality is impaired by our limited understanding of the emissions of precursors and the processes that form and transport air pollutants and their precursors. For example, this has been identified by the NRC as a key issue in their recent report "Air Quality Management in the United States." To address this concern the Air Quality Program within NOAA's Weather and Water Mission Goal has articulated two primary goals:

1. Provide sound science to support informed air quality decision-making at national, state, and local levels
2. Provide reliable and timely operational air quality forecast guidance nation-wide.

Research at ESRL on regional air quality is designed to support these NOAA-wide goals through laboratory experiments, intensive field studies, and modeling studies. The research is focused on improving understanding of the processes responsible for poor air quality, ultimately leading to an improved predictive capability for air quality management and forecast applications. There is also a strong emphasis on working with stakeholders to identify needs up front, and then communicating research results to air quality decision-makers in a timely, user-friendly manner.

II. KEY ACHIEVEMENTS (last 4 years)

- ***Discoveries Related to Emission Inventories:*** ESRL has used top-down techniques (instrumented ground sites, ships, and aircraft; satellite retrievals; and modeling studies) to make several key findings about inventories developed using "bottom-up" approaches including:
    - Regulatory inventories underestimated the O_3-forming ethylene/propylene emissions from petrochemical industries by more than an order of magnitude.
    - Long-term trends in measured urban CO/NO_X ratios suggest that current NO_X inventories do not accurately reflect actual emissions.
    - The emission of many smog-forming urban volatile organic compounds (VOCs), relative to CO is poorly quantified in official inventories.
    - Data from space-based sensors were used to quantify EPA-mandated reductions in NO_X emissions from power plants in the Ohio River Valley. A regional model was used to estimate the impact of these reductions on regional O_3 levels.

  Bottom Line: ESRL's research shows that bottom-up estimates of emissions can be substantially in error, by factors of 2-100 or more, for several of the most important atmosphere-polluting chemical species and from many of the largest emission source types.
- ***Laboratory Kinetics Contributions:*** The OH reactivity and UV photolysis rates of several key biogenic aldehydes and acetone were quantified. These data allow calculation of HO_X production in the upper troposphere and ozone production in the lower troposphere.
- ***The Role of Meteorology:*** Local meteorology can greatly influence pollution formation. The land-sea breeze cycle plays a major role in determining O_3 concentrations in the Houston area.

- ***Regional Implications:*** Ozone formed in large urban areas can adversely impact regional air quality. For example, the amount of O_3 in the industrially impacted Houston plume was found to be 2-3 times higher than that measured in the plume downwind of Dallas.
- ***Nighttime Chemistry and Daytime Air Quality:*** ESRL has investigated the chemical processing of NO_x, O_3, VOC, and aerosol at night through the development and deployment of instruments to measure NO_3 and N_2O_5. Key findings include:
  - Conversion of N_2O_5 to nitrate on aerosol, one of the most important ways to produce soluble nitrate and remove NO_x to soluble nitrate, is often slower and far more variable than previously recognized. These uptake coefficients are an important input to regional air quality models for the prediction of both summertime ozone and wintertime aerosol nitrate (Figure 1).

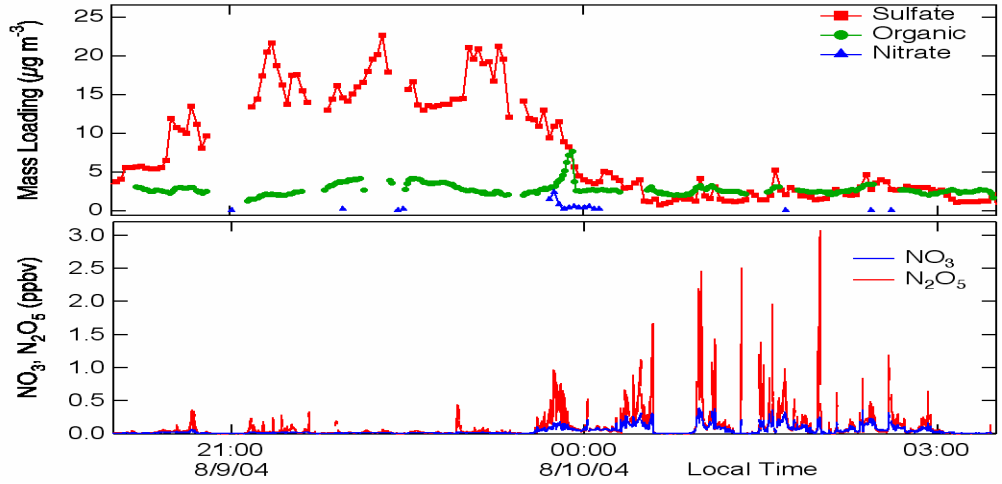

Figure 1: Variability in NO_3, N_2O_5, and the mass loading of sulfate and organic aerosol from a P-3 flight on August 9-10, 2004 showing a clear anti-correlation between aerosol sulfate and N_2O_5 levels.

  - Measurements from aircraft and tall towers have shown that NO_3 and N_2O_5 tend to occur in discrete, poorly mixed plumes aloft, and that their lifetimes are long enough to allow nocturnal transport of NO_x and O_3. This contrasts with the conventional picture of the role of these compounds developed mainly from surface level observations.
  - The uptake of N_2O_5 to chloride-containing aerosol results in surprisingly efficient production of $ClNO_2$. The sunrise photolysis of this compound may significantly impact oxidation chemistry in polluted coastal environments.

- ***SOA Findings:*** Secondary organic aerosol (SOA) is increasingly recognized as an important contributor to the atmospheric PM loading, which has important implications for public health, visibility, and the earth's radiation balance. ESRL scientists have found:
  - The highest PM mass loadings were observed in processed urban plumes, suggesting that secondary formation from urban precursors dominates over direct emissions.
  - Source estimates of organic aerosol in the U.S. suggest similar contributions from biomass burning, biogenic SOA and urban SOA (Figure 2).
  - The secondary organic aerosol formation is an order of magnitude or more higher than expected from the measured VOC precursors and their particulate mass yields derived from smog-chamber studies.

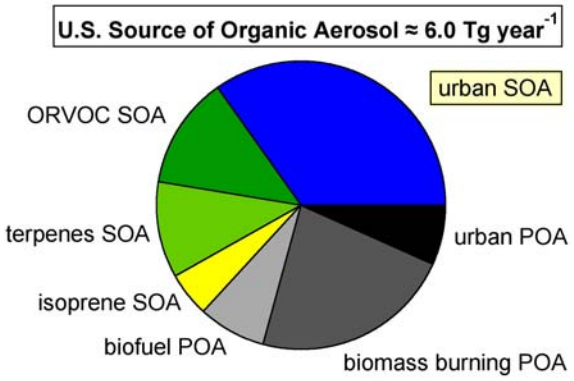

Figure 2: Estimated sources of organic aerosol in the U.S. POA - primary organic aerosol, SOA – secondary organic aerosol, ORVOC – other reactive VOCs

III. PAYOFFS

- The errors documented in regulatory emissions inventories are sufficiently large to confound the development of scientifically sound control strategies based on anthropogenic emissions reductions. The improved emission inventories lead to more effective management strategies for air quality and ultimately better air quality.
- Nocturnal chemistry significantly affects the fate of NO_X (also O_3, VOC, and aerosol) in the atmosphere. This new insight will allow a more complete quantification of the impact of transported NO_X on regional air quality and the formation and distribution of nitrate aerosol in the atmosphere.
- Current models are woefully inadequate in the description of secondary organic aerosols. As a result, the effects of changes in precursor emissions - whether deliberate or the result of climate change - can at present not be predicted with any degree of confidence. This clearly has profound implications for air quality and climate forcing.
- Collectively, the ESRL work to improve the quantification of emissions and to enhance understanding of the underlying chemical and physical processes that control the formation and distribution of O_3 and PM has greatly benefited air quality management and improved air quality forecasts.

IV. FUTURE PLANS

NOAA/ESRL will continue the current approach of employing targeted laboratory studies, bi-annual intensive field studies coupled with model development, and modeling studies to close the information gaps that severely limit the accuracy of model forecasts and the effectiveness of air quality control strategies. Focus areas include:

- Assisting air quality managers in California – The next major regional air quality assessment will be in California in 2010.
- Further investigation of nighttime chemistry, including nocturnal oxidation and nitrate aerosol formation.
- Advancing the understanding of processes responsible for the formation and growth of secondary organic aerosols.
- Investigating the linkages between air quality and climate through the application of top-down techniques to forcing agents and their precursors and working to improve the understanding of processes that link the two issues.
- Improving the understanding of transport and mixing in complex terrain – coastal zones, mountainous regions, urban areas.

Select Publication Highlights

1. Gierczak, T., M. K. Gilles, S. Bauerle, and A. R. Ravishankara (2003), Reaction of hydroxyl radical with acetone. 1. Kinetics of the reactions of OH, OD, and ^{18}OH with acetone and acetone-d_6, *J. Phys. Chem. A*, *107*, doi:10.1021/jp027301a, pp. 025014-025020.

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