# NARSTO News

*A North American Consortium for Atmospheric Research in Support of Air-Quality Management*

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## *NARSTO News* Feature: Pacific 2001

### 1. Background

The Lower Fraser Valley (LFV) airshed (Figure 1) contains the majority of the population of British Columbia and continues to have a high population growth. Because of its unique geographic features and this large population, the valley experiences the interaction of urban, suburban, marine, and agricultural emissions of air pollutants and their reaction products. As such, fine particulate matter (PM) and surface ozone dominate the air-quality agendas of the public, planners, and policy makers at all levels of government. The application of the Canada Wide Standard (CWS) on ozone and PM in the LFV is inevitable.

The issues of PM and ozone are closely intertwined. To address these issues in the LFV, the processes that lead to both ozone and PM formation, processing, and distribution must be fully understood before sound abatement policies can be made. The best way to achieve this in a cost-effective way is through models. A comprehensive scientific data set, related to PM and ozone formation, must be obtained concurrently, together with representative meteorological processes, to serve as the basis for model evaluation and enhancement.

The planned study, PACIFIC 2001, is aimed at providing this needed information to ensure that adequate scientific knowledge is available to modelers of regulatory and air-quality research communities. It is also aimed at yielding new information on PM and ozone, to reduce uncertainties regarding pollution sources, formation, and distribution. To achieve this overall objective, specific goals are set to:

- determine the horizontal and vertical distribution of PM and ozone in the LFV airshed. In particular, to determine the transition from an emission-dominated regime to a formation-controlled regime in the valley;
- determine the physical and chemical characteristics of PM in the LFV airshed, and to determine the changes in these properties in the region;
- identify the major physical and chemical processes in the formation of secondary aerosols and ozone;
- determine the roles of biogenic and anthropogenic (transportation sector) emissions in secondary organic aerosol and ozone formation; and
- provide an integrated data base for evaluation of regional PM and ozone computer models.

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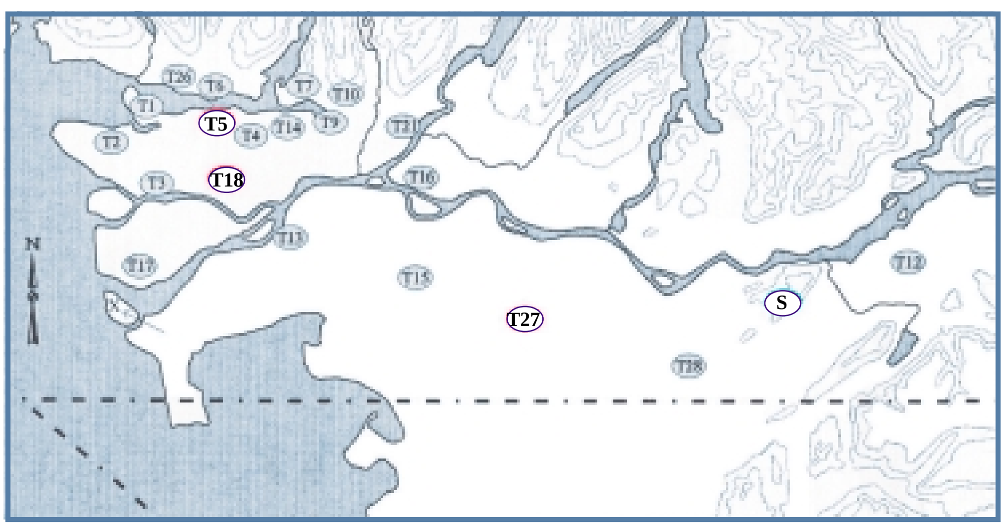


Figure 1. Lower Fraser Valley map. The marked locations are the GVRD Air Monitoring Network sites. The Cassier Tunnel site is at T5, Burnaby South High School site is at T18, while the Langley Poppy High School site is at T27. The Sumas Mountain site (S) is a new site.

## In this edition...



**The *NARSTO News* is published biannually for the purpose of communicating NARSTO activities and progress to members of the extended NARSTO community. Persons wishing to comment on the newsletter or submit material for publication are invited to do so by contacting either Diane Fleshman or Jake Hales in the NARSTO Management Coordinator's office, at the following address:**


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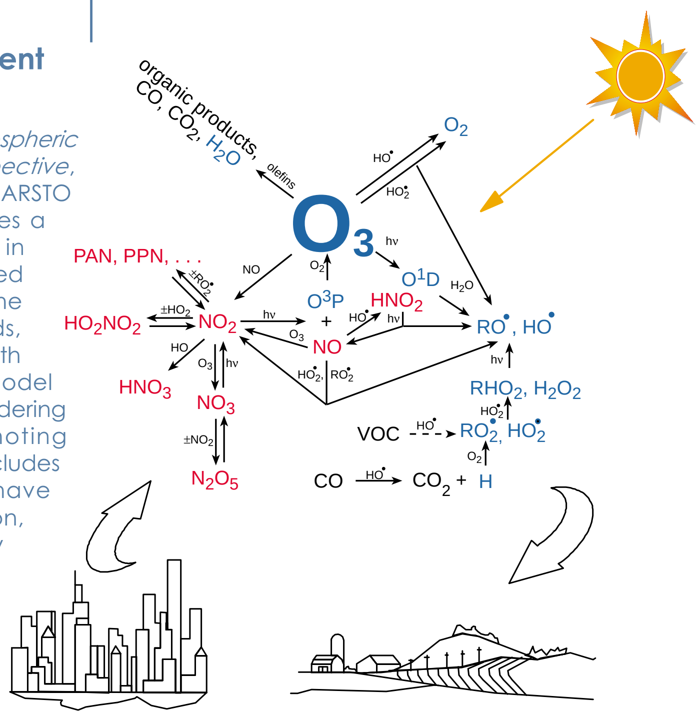
## NARSTO Ozone Assessment Document Published

The NARSTO Report, *An Assessment of Tropospheric Ozone Pollution - A North American Perspective*, was printed in July 2000. Combined with the NARSTO Critical Review Papers, this document provides a two-part assessment of tropospheric ozone in Canada, the U.S., and Mexico, and is intended for use by both scientists and members of the policy community. Besides examining trends, emissions, transport, and chemistry associated with ozone pollution, the Document examines model applications as tools for ozone analysis, considering advantages and disadvantages, and noting cautionary points in model use. The report concludes that although current regulatory controls have significant positive impact on ozone pollution, these measures have been largely offset by increasing population and human activity in many situations.




The Assessment Document's publication marked the completion of a lengthy effort initiated as NARSTO's first major initiative by Analysis and Assessment Team Co-Chairs Ken Schere and George Hidy. Copies of the report have been distributed to the NARSTO membership as well as other interested parties in North America and Europe. Limited additional copies are available upon e-mail request to the Management Coordinator's office (jake@cgenv.com). In addition, the report is available as a downloadable file in Adobe Acrobat format on the NARSTO Web site. Interested persons can locate references to the Critical Review Papers on the Web site as well.

## NARSTO Executive Assembly/ESC Meeting Scheduled for April 17-18 in Toronto

The annual combined meeting of NARSTO's Executive Assembly and Executive Steering Committee is scheduled for April 17 and 18 at Environment Canada's facilities in Downsview, Ontario, located just north of Toronto. The meeting's theme will focus on future thrusts and networking with related research communities, including policy applications, health-effects research, and European efforts in pollution management. Persons interested in attending should contact the NARSTO Management Coordinator's office (jake@cgenv.com).

## NARSTO Model Comparison and Evaluation Study (MCES) Update

A major study comparing regional air-quality modeling systems used for regulatory purposes in the USA and Canada is being conducted under the auspices of NARSTO. The opportunity for such a study presented itself when, stimulated by the need to meet regulatory milestones for attainment of national standards and objectives for ozone in the two countries, many public and private groups modeled time periods in July 1995 in overlapping domains covering most of eastern North America. The study began taking shape at a workshop for interested parties in May 1998. Work groups focusing on emissions, meteorological, and air-quality modeling were formed and charged with developing comparison and evaluation protocols for models in their respective areas.

The study was conceived to take place in two phases. In the first phase the models were to be compared in their “native” mode, i.e., using the same input files and model configurations that each group used in their individual assessments, based on modeling a 12 to 14-day period in July 1995. The planners believed that, with a minimal amount of extra effort, existing model output files could be used readily for the comparison and valuable information would be gained on the relative performance of these disparate models, each of which was used in exercises having significant policy implications.

Based on the realization that such an approach would provide insufficient information to diagnose why models might yield different results, the second phase would approach the problem in a more comprehensive manner. It would also recognize the anticipated widespread desire to compare models with an aerosol simulation capability. Thus, in Phase 2 regional tropospheric aerosol models would be compared using harmonized model inputs. “Harmonization” means that models would be exercised, for example, on identical domains, employing the same horizontal gridding, topography, land use, vegetation distributions and emission inputs. Meteorological inputs would be as similar as possible, consistent with maintaining mass conservation. Additionally, participating models would be expected to have a process-analysis capability to further facilitate diagnostic analyses.

EPRI agreed to serve as the data processing center and to coordinate the study. This was considered desirable by participants for three reasons.

- As an organization having no vested interest in any of the models likely to be included in the comparison, EPRI would be perceived as neutral.
- The services provided would constitute a substantial in-kind contribution.
- Such services were necessary for the study to proceed.

The groups that agreed to participate in the study’s first phase and their models are listed in Table I. New York’s Department of Environmental Conservation and EPA also submitted separate modeling files for simulations conducted with fine (12 km) and coarse (36-km) grids on the same domains. We are expecting similar coarse-gridded files from ICF Consulting and from Environ. MSC will be sending files from a fine-gridded simulation. Four groups submitted files for 5-18 July 1995, and two for 7-18 July. Because SAQM was run for only a 5-day period, 11-15 July, the decision was made to defer indefinitely its inclusion in the comparison. Absolute model performance was assessed by comparing model outputs with observational data from AIRS, NARSTO-Northeast, the Southern Oxidants Study’s Nashville/Middle Tennessee Ozone Study, and Canadian monitoring stations.

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Table 1. NARSTO MCES Participants

| Participant/Sponsor | Meteorological Model | Air Quality Model (File Designation) | Grid-cell Size, km | Period Simulated |
|---|---|---|---|---|
| Meteorological Service of Canada | MC2 | CHRONOS* (ONT) | 40 and 10 | 5-18 July 1995 |
| US EPA | MM5 | CMAQ | 36 and 12 | 5-18 July 1995 |
| NYS Dept. of Environmental Conservation | RAMS3b | UAM-V | 36 and 12 | 5-18 July 1995 |
| NYS Dept. of Environmental Conservation | MM5 | SAQM (NYSD) | 12 | 11-15 July 1995 |
| North Carolina Supercomputing Center/Southeast States Air Resource Mgrs. | MM5 | MAQSIP (MCNC) | 36 | 5-18 July 1995 |
| Environ/Coordinating Research Council | MM5 | CAMx | 36 and 12 | 7-15 July 1995 |
| ICF Consulting/Southern Co. | MM5 | UAM-V (SAIF) | 36 and 12 | 7-18 July 1995 |

*CHRONOS is a chemical transport model constructed from MC2.

## Texas 2000 Air Quality Study (TexAQS 2000)

From August 1 to September 15, 2000 over 250 scientists and technicians from over 40 organizations participated in TexAQS 2000, a major air-quality study focussed on Houston, Texas. The study was one of the largest, most comprehensive and sophisticated studies of urban air quality that has ever been done in the US. It is estimated that over $20 million dollars were expended during the program directly and through "in kind" contributions.

The overall objective of the study was to provide a better understanding of the emissions, and the basic chemical, physical and meteorological processes that determine ozone and fine-particle distributions in eastern Texas, and to provide scientific understanding to policy makers to assist them in devising optimal ozone and PM management strategies.

Resources for the program included five aircraft; major chemistry sites at Laporte airport adjacent to the Houston Ship Channel, and on the 62nd floor of Williams Tower on the west side of Houston; EPA funded (U.of Texas GC-ARCH Program) aerosol/chemistry sites located up-, in-, and down-wind of the Ship Channel; and a well developed ozone/aerosol monitoring network supported by TNRCC, the City of Houston, and a consortium of industries in the Houston area. Meteorological resources included five wind profilers, and three rawinsonde launch sites.

The program was very successful. Conditions were ideal for an air-quality study with a major ozone episode occurring during late August and early September. The large array of surface and airborne measurements deployed in the program resulted in an unprecedented characterization, in space and time, of the concentrations of ozone/aerosol precursors, intermediates, and product species in eastern Texas over a range of conditions. Analysis of these data is just beginning, and will undoubtedly continue for a number of years. Although only a preliminary analysis has been done, several features of ozone/aerosol formation in the Houston area are emerging. These "findings" should be considered as only preliminary, as they may not hold up to more detailed analysis.

1. It appears that ozone is produced more efficiently by emissions from the Houston Ship Channel area than from other emission sources in the Houston area.

2. Concentrations of reactive hydrocarbons in the Houston Ship Channel are sufficiently high that they could have a significant impact on the rate, efficiency, and amount of ozone formed in the greater Houston area.

3. Land-sea breeze circulations can have a significant role in determining the maximum ozone that is formed, and where the maximum concentration is observed.

4. Biogenic hydrocarbons do not appear to contribute significantly to the hydrocarbon reactivity in either the Ship Channel or downtown Houston.

5. The spatial distribution of biogenic hydrocarbons appears to be consistent with emission inventories.

6. At a given location (Williams Tower), aerosol particle composition appears to vary greatly over relatively short periods of time (<1hr).

7. Power-plant plumes in the eastern part of Texas appear to have higher efficiencies of ozone production in areas with higher isoprene emissions than in areas with lower isoprene emissions.

8. High concentrations of pollutants, which appear to have been transported long distances, were found in the boundary layer.

9. Some power-plant plumes in the eastern half of Texas appear to have high concentrations of carbon monoxide.

10. Ozone formation appears to occur very rapidly in the Houston area under episodic conditions. Preliminary estimates indicate that the instantaneous rates could be as high as 100 ppb/hr.

11. On at least one flight, it appeared that refining and chemical complexes to the south and west of Houston contributed rapid, incremental production of 25 to 30 ppb of ozone in the plumes from each complex. It will take careful analysis of data from all such flights to develop a more complete picture of the contribution of these facilities to ozone production under different meteorological conditions.

***NARSTO News*** contribution by Pete Daum, Brookhaven National Laboratory

## Status Report: NARSTO Data Management Activities

### Data Archiving, Sharing, and Retrieval

The data holdings of NARSTO's Permanent Data Archive (PDA) are expected to grow significantly this year. The Quality Systems Science Center (QSSC) expects to receive large amounts of diverse data from studies conducted in 1999 at Atlanta, Nashville, and Philadelphia. In addition, studies conducted in 2000 or planned for 2001, such as TexAQS 2000, EPA Supersites, and Pacific 2001, have plans in place to archive their data in a timely manner. Currently, selected data from

NARSTO NE-1995 and a 1997-1998 Texas PM2.5 Sampling and Analysis Study are archived [http://eosweb.larc.nasa.gov/project/narsto/table_narsto.html].

For NARSTO projects planning their data collection activities and preparing to archive data, the data reporting conventions and format for submitting data are described in the NARSTO Data Management Handbook. NARSTO's Data Exchange Standard is a data file format that incorporates consistent metadata and measurement results in a self-documenting ASCII file. Data reporting conventions specific to particulate-matter sampling and analysis have recently been implemented as convenient picklists in Data Exchange Standard file templates available to data providers. Check the QSSC web site at http://cdiac.esd.ornl.gov/programs/NARSTO/ for more information.

Successful data archiving is important to the ultimate success of NARSTO. The long-term usefulness of the data will be realized only by ensuring that all data sets are quality assured, suitably documented, and archived in consistent and documented formats. Timeliness in submitting data to the PDA is also crucial. NARSTO seeks a balance between protecting the data originator's intellectual property rights and the obligation to provide relevant information to the scientific community.

The philosophy behind the creation and operation of the PDA is that it should satisfy the "20-year test." That is, someone 20 years from now, not familiar with the data or how they were obtained, should be able to find data of interest and then fully understand and use the data solely with the aid of the documentation archived with the data. The PDA is designed to meet this requirement and is maintained by the Langley Research Center's NASA DAAC. The archive has the responsibility to securely store the data files and beyond that, to enter the metadata into a searchable data index that facilitates potential users finding and then obtaining the data. A web-based search and data retrieval system is available.

To complement the PDA, a web-based Data and Information Sharing Tool (DIST), which fulfills a broader data access function than the PDA, is maintained by the QSSC. The DIST is an index of NARSTO and NARSTO-related data sets beyond those found in the PDA. As a clearinghouse, it provides data users access to a larger number of data sources. These data sets include (1) NARSTO results from historical and some more recent studies that have not consistently formatted or quality assured their data and (2) non-NARSTO studies with valuable data of interest to the atmospheric research community. Data originators can conveniently enter their metadata and link their data into the searchable DIST index at their earliest convenience. The DIST data retrieval tool also enables projects to quickly share data among investigators. Data originators control access to their metadata and data. DIST output capabilities also facilitate metadata and data archiving to the PDA.

## Data Management Support for Projects

The Quality Systems Science Center (QSSC), managed by Oak Ridge National Laboratory, is providing assistance to NARSTO research managers, principal investigators, and data managers. A good example of this is our work with Central California Air Quality Study database managers.

The QSSC is providing data management support to the U.S. EPA PM Supersites Program. In consultation with EPA and the Data Coordinators of the Supersite projects, the QSSC, with the financial support of EPA, is coordinating three activities. The first is supporting the development and maintenance of a consistent set of metadata for the Supersites' measurement data. Metadata are the data that describe, for measured results, the succinct answers to the questions what, where, when, how, why, and by whom? Several working groups have been established early on in the process to develop consensus on, for example, formats for site names, variable names, units, methods, and flags. Weekly teleconference discussions keep the process moving. The Supersites Program will be providing quality-assured data to the QSSC for archiving in accordance with the published NARSTO guidelines. The second task is the implementation of the NARSTO Data and Information Sharing Tool (DIST) for the Supersites Program to support sharing of data among investigators and to use DIST's output capabilities to facilitate data archiving. The addition of new features and modifications to metadata will be made as necessary for effective implementation. The addition of new DIST users, system administration, and user support is included in this support. The third task is to support the sharing of data using DIST among Supersites Program participants. A Supersite FTP Site will be implemented for this purpose. Supersite project data coordinators may add and maintain data on the FTP site to allow program-wide access to data, instead of permitting access to secure project systems.

The QSSC and the Supersites working groups are leveraging the considerable technical, measurement, and data-management knowledge and system resources that already exist across the Supersite projects, NARSTO, EPA, and externally, to address these activities in a coordinated and efficient manner. Other NARSTO, EPA, and similar atmospheric research projects are encouraged to take advantage of these results and contribute their experience and data. This coordinated effort is a prime example of why NARSTO was formed and how it can function, and is a model for future cooperation.

***NARSTO News*** contribution by Sig Christensen, Les Hook, and Jeff West

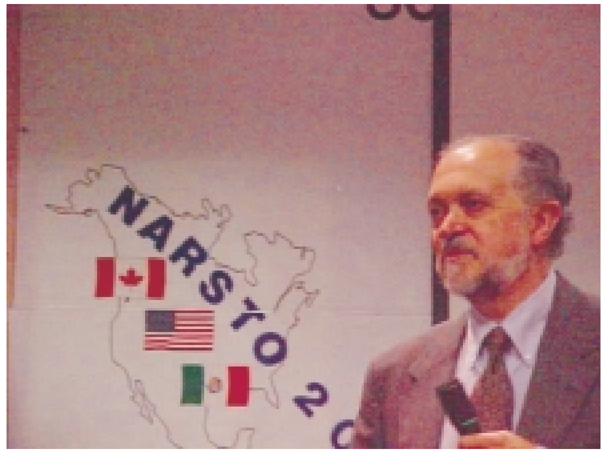
## NARSTO Symposium in Mexico A Huge Success!

The first NARSTO symposium on the scientific and policy issues associated with fine particulate matter in the atmosphere of the North American continent was held last October 23-26 in Querétaro Mexico. This symposium was broadly attended by scientists and policy makers from all three member countries. The meeting provided a forum for the presentation of the results from recent scientific research on atmospheric aerosols and was designed to feature the payoff of such research to national and international decision processes. Over 200 people registered for the symposium that featured 15 technical sessions and over 80 papers.

Lic. Armando Rivera Castillejos, Secretaría de Desarrollo Sustentable, Government of Querétaro opened the plenary session. The State of Querétaro has developed a sophisticated mobile monitoring station for air pollutants, was on display for the meeting participants to view. Lic. Enrique Provencio, Director General of the Instituto Nacional de Ecología, welcomed the participants to Mexico and to the important business of scientific collaboration and technical interchange. He expressed gratitude for the efforts of Pacific Northwest National Laboratory and the Desert Research Institute, who worked with the Instituto Nacional de Ecología in organizing the symposium. Adrian Fernandez Bremauntz, Symposium Chair and Director General de Gestión e Información Ambiental of the Instituto Nacional de Ecología, then described the objectives of the meeting, and introduced his co-chairs, Jake Hales of Envair, and Don McKay of Environment Canada. Finally, the Governador de Estado de Queretaro, Ing. Ignacio Loyola Vera, offered his best wishes for a good meeting in the days to come and noted his great pleasure that NARSTO had selected Querétaro for this important symposium.

The first keynote address was given by Mario Molina, Nobel laureate and professor at the Massachusetts Institute of Technology. He discussed the problem of CFCs and stratospheric ozone loss, and noted that this issue provides a good example demonstrating that global environmental problems can be solved through international agreement. He commented that we are now faced with problems of climate change and global air pollution that are more difficult to solve. Mario expressed great optimism that through cleaner technologies and international agreements, solutions to these problems can also be implemented.

Peter Lunn of the U.S. Department of Energy discussed the importance of tropospheric aerosols not only to air quality and exposure and health, but also to global change and to energy policy. He noted the importance of international collaborations such as NARSTO in building bridges between countries with issues of common concern. He then offered an overview of current research programs in the U.S. Federal agencies that are relevant to interests being discussed in the symposium.




Mario Molina Giving Kenote Address

Don McKay described the ongoing aerosol research programs in Canada. In May 2000, the government of Canada declared fine particulate matter less than 10 micrometers in size to be a "toxic substance." A new Canadian science assessment of particulate matter is expected by the end of 2003. This science assessment will be used in the formulation of Canada-wide standards. The ongoing NARSTO PM assessment will be useful to the Canadian government and many scientists from Canada are participating. Don also serves as the Public-Sector Co-Chair for NARSTO.

The afternoon plenary session included two presentations on the importance of aerosol observations from space. Michael King of the National Aeronautics And Space Administration gave an overview of the various satellite sensor systems being developed by Europe, Japan, and the United States and the advantages and disadvantages of each of these systems for aerosol applications. Because the remote sensing of aerosol properties, especially aerosol size distribution and single-scattering albedo, is exceedingly difficult, no one sensor system is capable of providing totally unambiguous information. Hence a careful intercomparison of derived products from different sensors, together with a comprehensive network of ground-based sun photometer and sky radiometer systems, is required to advance our quantitative understanding of global aerosol characteristics.

Joyce Penner of the University of Michigan described an effort to compare the satellite-observed and model-predicted concentrations of tropospheric aerosols. Based on this model comparison study, the ability of the global models to reproduce the aerosol mixing ratios at the surface can be described as acceptable for sulfate. However, improvement is need for the other aerosol species, such as organic and black carbon. For dust the model-observation comparison showed a better agreement with surface observations in the Northern than in the Southern Hemisphere. In summary, Joyce noted that analysis of the AVHRR comparisons indicates that significant uncertainties remain in both the ability to retrieve aerosol optical thickness from satellites and in the ability to model aerosol effects on the radiation budget.

Marjorie Shepherd of Environment Canada described the current NARSTO Particulate Matter (PM) Assessment, which is being coordinated by three co-chairs: Pete McMurry of University of Minnesota, Jim Vickery of US EPA, and herself. This effort will be the second major assessment of NARSTO following the Ozone Assessment published in July 2000. This PM Assessment is expected to support various programs underway in each country. In Canada it will be a foundation for the 2003 review of the PM Canada-Wide Standard and will support implementation of that standard. In the US it will be available in time to assist with the development of State Implementation Plans starting in 2003. It will support the joint international work leading up to negotiation of a PM Annex under the Canada/US Air Quality Accord. In Mexico it will support the PROAIRE program to improve air quality in Mexico City. It also fits with the goals for improving air quality under the Commission for Environmental Cooperation under NAFTA.

The final event of the first day was a panel session on the science and policy issues associated with tropospheric aerosols. Francisco Guzmán, of the Instituto Mexicano del Petróleo chaired the panel. Panelists included Adrián Fernández of the Instituto Nacional de Ecología, Alan Hansen of EPRI, Mauricio Hernández of the Instituto Nacional de Salud Publica , Mario Molina of MIT, Carlos Santos-Burgoa of the Instituto de Salud Ambiene y Trabajo, and Walter Vergara of the World Bank. Each panelist presented an issue of primary concern in the way science and policy connections are made on the issue of atmospheric aerosols. All panelists agreed that further collaborative scientific efforts are needed to better define the problems associated with degradation in air quality due to atmospheric aerosols and that better communication is needed between the scientists and the decision makers who determine environmental policy.

All 15 technical sessions at the symposium were well attended and poster papers were also available for viewing throughout the meeting. Four training classes were offered and more than 40 certificates were given to students who elected to attend classes in Aerosol Measurements (taught by Judy Chow, DRI), Integrated Air Quality Modeling (taught by Christian Seigneur, AES), Data Validation, Management, and Interpretation Methods (taught by John Watson, DRI), and Particle Risk Assessment (taught by John Evans, Harvard). An exhibit room was set up with 8 vendors demonstrating air-quality instrumentation and methods for analysis.

The symposium also included social events. The most notable event by far was the Noche Mexicana, an evening celebrating Mexican food, music, and dance. We will all remember the hospitality offered to the NARSTO symposium participants by our Mexican hosts and this meeting will go down as one for the history books!

Meeting sponsors included the U.S. Department of Energy, the U.S. Environmental Protection Agency, the Meteorological Service of Canada, Environment Canada, the California Air Resources Board, the National Oceanic and Atmospheric Administration, EPRI, the U.S. National Park Service, the North American Commission for Environmental Cooperation, and the Mexican Instituto Nacional de Ecología. The meeting was organized by Pacific Northwest National Laboratory and the Desert Research Institute.

***NARSTO News*** contribution by Sylvia Edgerton

## Pacific 2001 . . . *Continued*

Based on the data from the regular monitoring stations in the valley and the results from previous studies, it has been decided that the optimal time window for the field experiment is from the middle of August to the middle of September. This period experiences the highest PM mass concentration. Details of the project planning and the scientific means are further outlined below.

### 2. Organizational Structure and Partnership

Pacific 2001 is effectively a collection of several Canadian research projects, with additional activities that link these projects together. Pacific 2001's objectives reflect the combination of those of the member projects. The member projects include the Georgia Basin Ecosystem Initiative (GBEI), the Panel on Energy Research and Development (PERD) project on the transportation sector contribution to urban particulate matter, the Toxics Substance Research Initiative (TSRI) project on urban air quality, and the Natural Science and Engineering Research Council (NSERC) project on biogenic PM formation.

Objectives of these member projects overlap, creating opportunities for close linkages. Additional projects within Pacific 2001 are initiated to connect and coordinate the various activities of these main projects. Within this framework a comprehensive data set will be collected that not only satisfies the needs of the main components but also provides a much clearer overall picture of fine PM in the valley.

Environment Canada is leading the Pacific 2001 study with overall planning and with managerial support from both the Meteorological Service of Canada and the

*(Continued on page 8)*

## Pacific 2001 . . . *Continued*

Environment Canada Yukon and Pacific Region. It is also providing the majority of the funding for this project. Partners in the project include Canadian federal agencies from PERD, TSRI, the National Research Council Institute of Aeronautical Research, the Canadian Forestry Service, the B.C. Ministry of Environment, Lands and Parks (through GBEI), and the private sector through the Canadian Petroleum Producers Institute (CPPI), and the GVRD Lower Fraser Valley Air Quality Network. Partners from seven Canadian universities are expecting funding through the Canadian Foundation for Climate and Atmospheric Sciences, with additional support from other sources.

The Pacific Northwest National Laboratory (PNNL) of US Department of Energy will conduct the Pacific Northwest 2001 Project (PNW 2001) as a sister project to the Pacific 2001. The PNW 2001 will be funded by DOE and EPA and will focus on the Puget Sound to study air-pollution inflow into the Seattle area. Through coordination, PNW 2001 programs will complement Pacific 2001 on the southwest sector of the LFV, in providing data on the vertical structures of the chemical and physical properties of the atmosphere.

### 3. Field Campaign Components and Mode of Operations

Both ground and airborne measurements are to be carried out during the Pacific 2001 field study. At ground sites, a broad range of measurements will be conducted to address PM characterization as well as formation processes, particularly those related to precursor gases and oxidants. A special study is also planned to determine particulate-matter emissions from the transportation sector, as well as the impact of biogenic sources on PM formation in the Valley.

Four main ground sites have been identified as suitable to address these aspects of the objectives, thus deploying different sets of chemical and physical measurements at the individual locations. In combination these sites, together with the existing GVRD monitoring sites, also serve the purpose of detecting the spatial differences in the chemical parameters being measured. These four locations are shown in Figure 1. They are

- the Cassier Tunnel site, where the measurements represent the emissions from the mostly light-duty transportation sector;
- Burnaby South High School, which represents an urban/suburban setting in the Vancouver urban center, where a mixture of primary particles and secondary PM is expected. The secondary PM at this site is expected to have significant impact from anthropogenic precursors such as the oxidation of aromatic hydrocarbons;
- Langley Poppy High School, where the transition from an urban setting to the rural setting is expected to take place, and where the formation of particulate matter from agricultural practices in the valley is expected. This location is also expected to experience significant PM evolution from those observed at either Burnaby South High School and the Cassier Tunnel;
- a forest site that also has influences from urban pollution. This site is currently intended at Sumas Mountain on the eastern part of the valley. The main task of this site is to understand the formation process of biogenic PM from precursors such as monoterpenes in the presence of pollutants, and how this process will impact on the PM in the valley overall. In addition, measurements also will be carried out at this site to focus on the impact of various PM components on visibility reduction and the role of $NH_3$ on the PM formation in this part of the valley.

Additional locations are considered where limited measurements may be made. These locations are near the boundaries, such as the Reifel Island and eastern edge of the valley located east of Abbotsford. Their purposes are to provide boundary conditions at the western boundary of the LFV and to study the formation and evolution of $NH_3$ related aerosols at the eastern edge.

Vertical distribution of certain parameters, such as $O_3$ and meteorological parameters, in the lower part of the atmosphere also will be assessed from tethered balloons in the vicinity of both the Burnaby South High School and the Langley Poppy High School sites. This will be further aided by a scanning lidar that will be based at the Langley site.

To address the spatial and temporal variability of parameters related to PM, airborne measurements will be carried out from a Convair 580 and a Cessna 188 aircraft. The former platform will be used to map the spatial and vertical PM distributions and column concentrations of $O_3$ and CO in the valley using remote sensing techniques including lidar and a Fourier transform spectrometer and to provide boundary conditions on $O_3$ and particle size distributions for model domains for the LFV. On the latter platform, in situ profiles of particle-size distribution, $O_3$, CO, NMHCs, PM chemical properties, and meteorolgical parameters to connect with ground level measurements.

Selected measurement methods address different aspects of pollution behavior, and can be grouped into five categories, as follows:

- Measurements related to the PM precursors and the oxidation environment in which PM is formed.
- Measurements related to the characterization of PM and its evolution process.
- Measurements related to the emission of PM and its precursors in the valley. This will be carried out for one particle size, the Cassiar Tunnel.

- Measurements related to the mapping of fine PM horizontal and vertical distribution in the valley, and
- Measurements of meteorological parameters in the valley.

Measurements at each site and from the aircraft are discussed in separate sections further below.

### 3.1. Measurements at the Cassier Tunnel site

The goal of measurements at this site is to reduce uncertainties in mobile-source emission inventories, and hence provide data for model development and evaluation. Duration of the emission study will be from 7-10 days. For most measurements, two sets of instruments will be deployed, one at each end of the tunnel. In addition to the tunnel measurements, fuel and lubricating oil surveys will be conducted. The results will be compared with tailpipe emission data from traditional laboratory-based measurements, particularly for mass emission rates and chemical profiles. The results also will be compared to PART5 and/or MOBILE6 to evaluate their performance for the Lower Fraser Valley settings. For some measurements, different sampling and analytical techniques will be used to ensure accuracy of the measurements.

### 3.2. Measurements at the Burnaby South High School site

Measurements at the Burnaby South High School site are intended to address all issues, with an emphasis on the mixing of primary particles with the secondary PM produced by conversion of anthropogenic hydrocarbons. The planned instrument packages therefore include those in all five categories.

### 3.3. Measurements at the Langley Poppy High School site

Measurements at the Langley Poppy High School site are similarly intended to address all issues, with an emphasis on transitions from the urban mix to a suburban/rural setting, particularly the impact of agricultural sources on PM formation and evolution. Similar to the instrument package at Burnaby South High School, this site's package will include measurements in all five categories.

### 3.4. Measurements at the Sumas Mountain site

Different from the other three sites, this forest site is dedicated to the question of secondary biogenic particle production from forestry precursors, particularly in the presence of urban pollution. Emission inventories for the Lower Fraser Valley indicate strong sources of precursor monoterpenes from the north shore mountains in the Lower Fraser Valley, for example, in the mountains north of North Vancouver and north of Maple Ridge, as well as south of the US-Canada border. Based on the current emission inventories, studies using the ISOPART model (a Lagrangian model) indicate significant contributions to valley PM levels from these biogenic sources. The forest site probably will be located on Sumas Mountain, near the eastern end of the Lower Fraser Valley.

Strong visibility attenuation occurs often at the eastern end of the valley. This haze has distinctly different characteristics from those found over the urban areas and appears to be white, a feature expected to result from ammonia emissions. Hence, at the Sumas Mountain site, additional measurements will be conducted to probe the chemical composition of the haze-related PM as well as the roles of ammonia emissions on particle formation.

## 4. Airborne measurement components

The airborne measurement component consists of remote sensing of aerosol backscattering, as well as in-situ observations of particle size distribution and $O_3$ and CO concentrations. In-situ measurement of meteorological parameters will be conducted simultaneously with the chemical measurements. The airborne platforms will perform initial- and boundary-condition measurements for the model domain, as well as measurements to compare with model simulations.

Two aircraft will be deployed for Pacific 2001, the NRC IAR Convair 580 and the CFS Cessna 188. In parallel to the two Canadian aircraft, the Pacific Northwest National Laboratory (PNNL) of the US Department of Energy will launch the Pacific Northwest 2001 (PNW 2001) as a sister program to Pacific 2001. PNNL, supported by US DOE and US EPA, will field an aircraft at the same time in the Lower Fraser Valley and Puget Sound area to investigate air-quality issues. Len Barrie of the PNNL is leading the US aircraft program, with an emphasis on the PM and smog components in the region. This will strongly complement the existing Pacific 2001 airborne programs.

### 4.1 The Convair 580

The main mission for the Convair 580 is to carry out mapping of PM distribution in the valley through remote sensing using lidar, and to provide critical meteorological data, such as boundary meteorological conditions. The Convair has an airborne time of approximately 4-5 hours per flight and a ceiling of about 23,000 ft. Due to restrictions on air space, the Convair's main missions will be flown at altitudes between 14,000 – 18,000 ft with profiling at set points on the western and southern edges of the flight tracks. The aircraft has a large payload and can accommodate upward- and downward- looking lidars. It also has many other capabilities. A single flight will cover the Lower Fraser Valley with about 9 planned north-south lidar remote sensing legs and will still be able to carry out boundary-condition measurements, as demonstrated during the

*(Continued on page 10)*

## Pacific 2001 . . . *Continued*

Pacific '93 experiment. An alternative flight calls for east-west legs to achieve a better picture of the spatial variability in the valley. A restriction is that it cannot easily fly in the boundary layer below 1500 ft.

The Convair flight plans calls for mostly meridional legs of lidar tracks over the Lower Fraser Valley, with the eastern boundary at 121°52'30"W and the western boundary at 123°50'13"W These tracks are to be extended from 48°29'N to 49°50' N over the mountain tops. These boundaries correspond to the model domain of planned Models 3 application to the region. Plans call for vertical profiling at the western boundary and southern boundary of the domain. The plans also call for upwind meteorological soundings west of Vancouver Island. This will be accomplished either by profiling or through dropsondes. The Convair's flight plans also call for nighttime missions to understand the continued spatial evolution of PM from daytime and changes in the boundary-layer structure in the valley. Nighttime missions may be limited due to logistical reasons.

### 4.2 The CFS Cessna 188

The CFS Cessna 188 is a small aircraft with a high degree of maneuverability. Its main attractions are three fold: low cost, ability to operate low in the boundary layer, and flexibility in flight planning.

The planned CFS mission will support the ground-based measurements from the ground sites at Burnaby South High School, Langley Poppy High School, and Sumas Mountain. Tight integration of the measurements from the Cessna with those on the ground will provide a clearer picture of the chemical and thermal structure of lower boundary layer. In addition, flights will be dispatched to collect filter samples in identified plumes for chemical characterization studies.

## 5. Quality Assurance and Data Management

A formal Quality Assurance and Data Management Program will be operated by the Meteorological Service of Canada, Air Quality Measurements and Analysis Division. The QA Program will focus on ensuring that principal investigators for the program: (1) develop suitable Quality Assurance Project Plans (QAPjPs), (2) pre-define Data Quality Objectives (DQOs), (3) incorporate QA procedures into their measurement systems, (4) carry out measurements in accordance with their QAPjPs, and (5) at the closure of the study, determine and report their final Data Quality Indicators (DQIs). Included in the QA Program will be a limited performance audit to be carried out during the field campaign. Given the complexity of most of the measurements, it will not be possible to audit all measurements used in the campaign. Hence, individual PIs will be responsible for designing and implementing their own methods for assuring the accuracy, precision, completeness, comparability, and representativeness of their measurements. Performance audits will be conducted only on ozone and flow measurements. During the audits, on-site checks will also be made to ensure that the QA/QC elements of the QAPjPs are being conducted as planned.

The Data Management Program will focus on ensuring that data are collected and archived properly and efficiently. The goal will be to produce both metadata and data archives for all surface measurement data (note that aircraft, lidar and balloon data will not be part of this activity). A workshop on Data Management will be held prior to the field campaign (April/May of 2001) to standardize the data handling and archiving methods for the study. Individual PIs will be responsible for submitting their final, quality-controlled data to the database within two years of the field study. To assist staff with data submission, computer templates will be created and staff will be trained on their use. Assistance and training will also be given to any staff wishing to use AQRB's RDMQ™ software to quality control and manage their data. Ultimately, the Pacific 2001 Surface Database will become part of the NAtChem (National Atmospheric Chemistry) family of chemical databases and will be accessible through the World Wide Web. The following key activities constitute the QA and Data Management Program (by year):

In 2000:

- Prepare a formal QA Plan for the study.
- Prepare individual QA Project Plans by the principle investigators.
- Design databases for both the metadata and the surface measurement data.
- Host a formal Pacific2001 Data Workshop for field study participants.
- Design templates to assist campaign staff with data submission.

In 2001

- Train staff on data submission templates and methods.
- Assist staff in the adaptation of the RDMQ™ software system for quality controlling data.
- Carry out performance audits during the field campaign.
- Design a Web-based data access system for surface data.

In 2002

- Prepare a formal QA report for the field campaign.
- Populate the metadata and data bases.
- Quality assure the data submissions to the database.
- Provide a Web-based data access system for the surface data.

The ultimate deliverable of the QA and DM activity will be an accessible database of surface-measurement data accompanied by information on the quality of the data.

### 6. Major events

The following major events are planned for Pacific 2001:

- Field Study: August 8 – September 4, 2001
- Initial Field Study Meta Data Report: October 2001
- First data submission to Data Center: December 2001
- Second data submission to Data Center: March 2002
- Workshop in Vancouver: April 2002
- Final data submission to Data Center: December 2002
- Special session at the AGU (or the CMOS): December 2002 (or May 2003)

### 7. Project management

Shao-Meng Li is the project leader for Pacific 2001, with the support of the Environment Canada management team of Bruce Thomson, Keith Puckett, and Maris Lusis. The persons with responsibilities for the operation of the individual components of the programs are listed here.

- Kurt Anlauf – Responsible for the activities at the Langley High School site
- Jeff Brook – Responsible for activities at the Burnaby South High School site
- Lisa Graham – Responsible for tunnel study at the Cassier Tunnel
- Richard Leaitch – Responsible for the Sumas Mountain site
- Jochen Rudolph – Responsible for the activities at the forest site
- Walter Strapp – Responsible for aircraft operation
- Kevin Strawbridge – Responsible for Convair 580 lidar mapping and ground scanning lidar
- Bob Vet – Responsible for Quality Assurance and Data Management Program
- Allen Wiebe – Responsible for the Abbotsford East site

***NARSTO News*** contribution by Shao-Meng Li, Environment Canada

## Model Comparison . . . *Continued*

The study did not progress as expeditiously as the workshop attendees had hoped. Some of the participating groups were overly optimistic about the pace of their progress toward completing the in-house modeling exercises that were to provide the grist for the mill. Another year would elapse before they would be able to send their model output files to EPRI.

In the interim, the draft protocols for comparing and evaluating the emissions, meteorological and air quality models were completed and reviewed by the respective workgroups. These protocols established systematic procedures for generating a variety of materials that would characterize the comparability of input data to the air-quality models and model performance using a large suite of metrics.

Meanwhile, EPRI staff were creating the scripts to convert the massive model output files to a format compatible with the software selected to produce the statistical tables and graphical plots that would document the models' relative and absolute performance. As the modeling output files began to be received and processing of the data proceeded, the magnitude of this part of the study became increasingly apparent. Implementing just the part of the model comparison protocol dealing with comparisons of observed and simulated ozone concentrations – $NO_x$, $NO_y$, and CO, which were also to be included in the protocol, aside – would generate

- 92 tables and 108 statistical plots,
- 12,096 map plots,
- 5604 time-series plots, and
- 7654 scatter plots.

Comparisons would be made for different averaging periods, times of day, and averages over different subdomains to investigate model performance over various temporal and spatial regimes. Clearly, just this partial selection of comparison products would be daunting to produce. Implementing the full protocol for species other than ozone and producing products comparing the models with one another, plus implementing the emission- and meteorological-model comparison protocols would have created a workload far exceeding the available resources of the small EPRI cadre. From the user's perspective, this prospective mountain of comparison materials would have been virtually impossible for any individual to look at, much less, to assimilate.

Responding to this situation, EPRI prepared an abbreviated list of products relating to model comparisons that includes the items in Table 2 and enlisted the aid of other participants to devise and exercise abbreviated protocols for comparing the emission and meteorological files used to drive the air-quality models.

Table 3 lists bias and gross error statistics over various averaging time intervals by day. Summary tables for values averaged over two sub-domains are shown for CMAQ exercised on its 36-km gridded domain. These types of metrics are somewhat arbitrarily labeled as "statistics of scientific interest" in the belief that they provide more diagnostic value than statistical metrics employing a minimum concentration threshold, such as those in Table 4, labeled "regulatory statistics." The metrics in Table 4 are normalized and raw bias and gross error between observations and simulated values, paired in space and time, above thresholds of 20, 40 and 60 ppb ozone. The example given is for CAMx

*(Continued on page 12)*

## Model Comparison . . . *Continued*

exercised on its 36-km gridded domain, averaged over two of the sub-domains.

By August 2000 most of the materials listed in Table 2 had been produced and posted on EPRI's web site for access by study participants. The following month a workshop, hosted by the Lake Michigan Air Directors Consortium, brought participants together to discuss results to date and plan what to do next. As it turned out, even this abbreviated collection of materials proved to be more than any of the participants could critically assess in the time available. Consequently, the information from this collection as well as that from other participants presented at the workshop was seen for the first time by a majority of the attendees. For this reason, no interpretation of comparisons to date will be given in this update.

In spite of these drawbacks, several important decisions emerged from the workshop:

1. Phase 1 would be split into two parts, A and B. Phase 1A would include work done to date, plus wrapping up loose ends of the comparative evaluation of the models in their native mode, using simulated ozone as the basis for comparison, and extending the comparison to include meteorological inputs. Phase 1B would extend the comparison to other species than ozone and would compare how the models respond to separate 50% across-the-board reductions in anthropogenic VOC and in anthropogenic $NO_x$ emissions.
2. Because the magnitude of the data processing and coordination tasks unexpectedly exceeded the available EPRI resources, additional resources would have to be made available for the completion of Phase 1.
3. Large apparent inconsistencies among the emissions files used by three groups would require investigation as to their cause. Emissions information would need to be supplied by the remaining groups to allow the comparison to be completed.
4. All participating groups would submit specified descriptions of the meteorological files used in their modeling to allow the comparison to be completed.
5. Phase 1B model runs would be completed in time for the comparative graphics and tables, including those for meteorological and emissions data, to be posted on the EPRI web site by 31 March 2001.
6. All participating groups would contribute to assimilating and interpreting results.
7. A final Phase 1 workshop would be held in July 2001 to reach a consensus on results and to discuss possibilities for conducting Phase 2.
8. By 30 September 2001, all study materials (data, protocols, workshop notes, graphics and tables) would be posted on the NARSTO web site.
9. By the same date, an article on the study would be prepared and submitted to a peer-reviewed journal.

At the time of this writing, the funds needed to complete Phase 1 have been pledged by groups including, Environment Canada, Texas Natural Resource Conservation Commission, Ontario Ministry of the Environment, Tennessee Valley Authority, and EPRI. On this basis, we have every expectation that we will be able to complete Phase 1 of this very important service to the air quality modeling community on schedule.

***NARSTO News*** contribution by Alan Hansen, EPRI

Table 2. Air Quality Model Comparison Materials

| Name | Description | No. |
|---|---|---|
| Observations Plot (map) | Hourly max O3 over eastern USA and Ontario domain | 14 |
| Contour Plot (map) | Simulated hourly or 8-hourly max O3 over modeling domain) | 232 |
| Scatter Plot | Sim. vs. obs. hourly or 8-hourly O3 averaged over modeling subdomains | 375 |
| Bias Plot (map) | Sim. minus obs. hourly or 8-hourly O3 averaged over modeling subdomains | 714 |
| Time-series plots | Sim. and obs. hourly O3 averaged over modeling subdomains | 88 |
| Statistical Tables | Statistics for scientific analyses (Table 3)<br>Raw bias, normalized bias, raw gross error and normalized gross error of 1-hour average ozone exceeding 20, 40 and 60 ppb for each day for each sub-domain<br><br>Raw bias and raw gross error for ozone averaged over 0600-0900 and 0200-0500 periods for each day in each sub-domain<br><br>Regulatory Statistics (Table 4)<br>Raw bias, normalized bias, raw gross error and normalized gross error of 1-hour average ozone exceeding 20, 40 and 60 ppb for each day for each sub-domain | 92 |
| Bar charts | Graphical renditions of information in statistical tables | TBD |
| Other plots and charts | Model-to-model comparison results | TBD |

## Table 3. Statistics of Scientific Interest for CMAQ, 36-km Gridding

| | 1-Hour Peak | | | | | | 8-Hour Peak | | | | | | Early Morning | | | Late Night | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | N | Mean Obs | Raw Bias | Norm Bias | Raw Gross Error | Norm Gross Error | N | Mean Obs | Raw Bias | Norm Bias | Raw Gross Error | Norm Gross Error | N | Raw Bias | Raw Gross Error | N | Raw Bias | Raw Gross Error |
| ***All Stations*** | | | | | | | | | | | | | | | | | | |
| 950705 | 381 | 57.46 | 15.08 | 33.25 | 18.78 | 37.95 | 372 | 49.94 | 17.61 | 44.84 | 19.89 | 47.79 | 1464 | 15.29 | 19.04 | 1493 | 19.52 | 23.95 |
| 950706 | 376 | 59.28 | 6.09 | 13.00 | 10.88 | 19.83 | 367 | 51.27 | 10.20 | 23.10 | 11.92 | 26.01 | 1430 | 12.40 | 14.24 | 1454 | 14.06 | 17.73 |
| 950707 | 377 | 55.39 | 11.19 | 29.87 | 15.32 | 35.87 | 374 | 47.97 | 14.70 | 47.80 | 16.94 | 51.34 | 1443 | 13.66 | 15.35 | 1465 | 16.09 | 18.35 |
| 950708 | 379 | 59.36 | 3.78 | 15.98 | 10.89 | 25.75 | 375 | 51.96 | 6.77 | 28.73 | 11.37 | 35.84 | 1507 | 12.58 | 15.22 | 1486 | 18.71 | 21.00 |
| 950709 | 379 | 53.50 | 2.26 | 12.81 | 13.79 | 30.62 | 378 | 46.73 | 6.02 | 22.76 | 12.94 | 35.04 | 1502 | 12.18 | 16.08 | 1488 | 17.89 | 20.43 |
| 950710 | 379 | 69.85 | 0.41 | 2.66 | 10.61 | 15.70 | 375 | 61.83 | 3.96 | 8.68 | 9.49 | 16.67 | 1464 | 12.90 | 15.78 | 1460 | 20.55 | 22.71 |
| 950711 | 377 | 73.32 | 1.23 | 3.57 | 12.89 | 17.83 | 373 | 64.68 | 5.65 | 11.20 | 12.65 | 20.75 | 1424 | 14.14 | 17.80 | 1456 | 18.23 | 23.06 |
| 950712 | 374 | 80.46 | 1.75 | 4.34 | 13.22 | 18.17 | 371 | 71.02 | 5.13 | 9.35 | 11.96 | 18.71 | 1432 | 16.46 | 19.88 | 1463 | 25.85 | 28.93 |
| 950713 | 374 | 96.34 | -6.67 | -4.74 | 18.08 | 18.95 | 370 | 86.01 | -2.28 | -0.48 | 14.89 | 18.05 | 1441 | 18.36 | 23.01 | 1453 | 26.31 | 29.87 |
| 950714 | 373 | 96.73 | 0.67 | 3.05 | 15.82 | 17.01 | 356 | 86.77 | 4.44 | 6.97 | 14.44 | 17.56 | 1420 | 15.55 | 21.21 | 1435 | 18.52 | 23.96 |
| 950715 | 360 | 88.98 | 0.92 | 6.66 | 16.99 | 21.15 | 350 | 76.73 | 6.49 | 13.38 | 15.55 | 23.12 | 1380 | 14.92 | 21.51 | 1378 | 22.56 | 28.47 |
| 950716 | 363 | 67.15 | 11.94 | 19.86 | 15.31 | 24.42 | 360 | 58.75 | 15.22 | 28.11 | 16.40 | 29.84 | 1410 | 17.24 | 20.52 | 1396 | 17.64 | 24.04 |
| 950717 | 367 | 62.88 | 8.31 | 22.45 | 14.95 | 29.83 | 361 | 53.00 | 13.66 | 36.06 | 16.60 | 39.93 | 1370 | 18.61 | 19.80 | 1387 | 19.90 | 21.74 |
| 950718 | 375 | 63.82 | 11.31 | 27.51 | 14.24 | 31.21 | 369 | 56.97 | 14.07 | 37.77 | 15.20 | 39.33 | 1378 | 20.34 | 21.38 | 1419 | 21.17 | 24.65 |
| ***NE US Rutal/Regional*** | | | | | | | | | | | | | | | | | | |
| 950705 | 154 | 55.63 | 16.50 | 35.87 | 20.79 | 40.39 | 150 | 48.37 | 19.32 | 48.75 | 22.67 | 52.57 | 596 | 19.92 | 23.07 | 615 | 24.38 | 27.69 |
| 950706 | 151 | 56.64 | 6.59 | 13.64 | 9.76 | 18.49 | 147 | 49.50 | 10.22 | 23.88 | 11.68 | 26.45 | 571 | 14.12 | 16.04 | 590 | 16.25 | 20.17 |
| 950707 | 152 | 57.27 | 3.82 | 14.35 | 11.50 | 25.53 | 151 | 50.90 | 7.46 | 25.28 | 11.99 | 32.33 | 577 | 14.43 | 16.00 | 595 | 17.52 | 19.16 |
| 950708 | 152 | 54.99 | 1.02 | 6.32 | 7.54 | 16.50 | 150 | 48.42 | 4.32 | 16.24 | 8.49 | 23.57 | 606 | 8.86 | 11.60 | 606 | 16.09 | 18.05 |
| 950709 | 152 | 57.88 | -4.91 | -4.09 | 10.94 | 19.42 | 152 | 51.05 | -0.41 | 4.22 | 9.51 | 20.71 | 603 | 10.97 | 16.37 | 602 | 18.65 | 21.68 |
| 950710 | 153 | 69.39 | -4.00 | -3.99 | 9.46 | 13.33 | 151 | 62.46 | -0.57 | 0.66 | 7.43 | 12.14 | 593 | 10.87 | 15.12 | 598 | 20.08 | 22.42 |
| 950711 | 151 | 73.37 | -4.36 | -3.95 | 12.27 | 16.11 | 149 | 65.26 | 0.19 | 2.36 | 10.74 | 16.23 | 555 | 12.54 | 17.00 | 588 | 21.14 | 24.14 |
| 950712 | 149 | 80.74 | -4.83 | -5.40 | 11.48 | 14.48 | 149 | 72.52 | -0.75 | -0.66 | 9.67 | 13.73 | 576 | 16.83 | 21.60 | 590 | 28.51 | 31.64 |
| 950713 | 149 | 95.28 | -15.89 | -15.24 | 19.45 | 19.85 | 147 | 86.03 | -11.89 | -12.37 | 16.39 | 18.62 | 576 | 15.00 | 23.47 | 585 | 27.37 | 31.62 |
| 950714 | 147 | 91.45 | 1.31 | 2.74 | 12.92 | 15.30 | 141 | 83.11 | 4.10 | 5.41 | 12.16 | 15.14 | 560 | 21.44 | 24.89 | 571 | 19.92 | 25.49 |
| 950715 | 139 | 88.80 | -2.59 | 2.34 | 14.35 | 18.67 | 132 | 77.40 | 3.73 | 7.25 | 12.55 | 17.19 | 538 | 11.70 | 21.10 | 549 | 18.57 | 26.66 |
| 950716 | 144 | 69.90 | 7.39 | 11.78 | 12.45 | 18.66 | 143 | 61.04 | 12.06 | 20.73 | 13.54 | 23.12 | 562 | 22.93 | 23.52 | 559 | 27.00 | 27.80 |
| 950717 | 148 | 64.51 | 10.22 | 19.10 | 13.09 | 22.83 | 147 | 55.55 | 15.19 | 31.59 | 16.45 | 33.45 | 548 | 23.92 | 24.34 | 554 | 20.68 | 22.69 |
| 950718 | 149 | 60.92 | 6.29 | 13.79 | 8.55 | 16.99 | 146 | 55.99 | 8.10 | 17.00 | 8.76 | 18.14 | 551 | 18.53 | 19.14 | 573 | 24.26 | 25.00 |

## Table 4. Regulatory Statistics for CAMx, 36-km Grid

| | Normalized Bias (%) | | | Raw Bias (ppb) | | | Normalized Gross Error (%) | | | Raw Gross Error (ppb) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | O3 > 20 ppb | O3 > 40 ppb | O3 > 60 ppb | O3 > 20 ppb | O3 > 40 ppb | O3 > 60 ppb | O3 > 20 ppb | O3 > 40 ppb | O3 > 60 ppb | O3 > 20 ppb | O3 > 40 ppb | O3 > 60 ppb |
| ***All Stations*** | | | | | | | | | | | | |
| 950707 | -2.6 | -11.8 | -17.2 | -2.7 | -6.7 | -11.7 | 25.6 | 19.2 | 19.4 | 9.9 | 10.3 | 13.1 |
| 950708 | -4.9 | -14.4 | -19.0 | -4.0 | -9.1 | -14.1 | 29.9 | 22.9 | 22.6 | 12.0 | 13.6 | 16.6 |
| 950709 | 0.3 | -15.5 | -24.4 | -2.6 | -9.5 | -17.7 | 33.3 | 23.6 | 26.3 | 12.4 | 13.5 | 18.9 |
| 950710 | -7.6 | -9.0 | -9.2 | -4.4 | -5.6 | -7.1 | 31.2 | 27.2 | 22.8 | 14.6 | 15.8 | 16.4 |
| 950711 | -11.1 | -11.7 | -7.5 | -5.8 | -6.9 | -6.0 | 34.1 | 28.3 | 24.0 | 15.9 | 16.9 | 17.7 |
| 950712 | -8.0 | -11.9 | -13.2 | -5.8 | -8.0 | -10.3 | 32.1 | 26.6 | 21.7 | 15.9 | 16.4 | 16.5 |
| 950713 | -19.1 | -20.0 | -18.5 | -12.5 | -14.4 | -15.5 | 34.0 | 30.0 | 25.3 | 19.3 | 20.6 | 20.6 |
| 950714 | -11.4 | -12.2 | -7.9 | -6.9 | -7.9 | -6.6 | 37.5 | 31.8 | 25.3 | 20.4 | 21.2 | 20.5 |
| 950715 | -4.3 | -7.1 | -7.8 | -3.9 | -5.3 | -6.8 | 34.3 | 29.8 | 25.0 | 18.7 | 19.7 | 20.3 |
| ***NE US Regional/Rural*** | | | | | | | | | | | | |
| 950707 | -3.8 | -15.5 | -22.5 | -3.7 | -8.7 | -15.1 | 25.2 | 20.0 | 23.5 | 10.2 | 10.9 | 15.8 |
| 950708 | -2.1 | -15.3 | -17.6 | -2.8 | -8.5 | -12.2 | 26.8 | 19.9 | 21.5 | 10.0 | 10.9 | 15.0 |
| 950709 | -9.5 | -16.4 | -22.7 | -5.3 | -9.5 | -15.6 | 29.6 | 22.7 | 25.4 | 11.7 | 12.9 | 17.4 |
| 950710 | -10.8 | -10.9 | -11.3 | -5.7 | -6.6 | -8.4 | 28.1 | 23.2 | 19.0 | 12.9 | 13.4 | 13.7 |
| 950711 | -12.9 | -14.6 | -14.4 | -7.4 | -9.2 | -11.2 | 30.2 | 25.8 | 23.4 | 14.6 | 15.6 | 17.4 |
| 950712 | -15.4 | -19.4 | -19.6 | -10.3 | -12.9 | -15.1 | 30.3 | 26.6 | 23.2 | 16.0 | 16.8 | 17.6 |
| 950713 | -21.5 | -23.7 | -22.6 | -14.7 | -17.1 | -18.5 | 34.8 | 31.1 | 27.2 | 20.4 | 21.5 | 21.9 |
| 950714 | -3.4 | -8.7 | -5.4 | -3.4 | -5.3 | -4.1 | 37.9 | 32.4 | 26.1 | 20.6 | 21.3 | 20.5 |
| 950715 | -9.0 | -14.9 | -17.7 | -8.4 | -11.5 | -15.0 | 33.1 | 29.1 | 26.6 | 19.2 | 20.1 | 21.9 |

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