



# Meeting Report

## Tropospheric Aerosols: Science and Decisions in an International Community

*a technical symposium on aerosol science  
held October 23-26, 2000 in Quer taro Mexico*



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## n About NARSTO 2000

More than 185 scientists gathered in Quer taro, Mexico, in October 2000 to discuss recent research and policy related to atmospheric aerosols. The symposium was conducted under the auspices of the NARSTO cooperative, a public/private partnership whose membership spans government, industry, the utilities, and academia throughout North America. The Instituto Nacional de Ecología, directed by Adri n Fern ndez, hosted the group, which included approximately equal numbers of Canadian, U.S., and Mexican scientists. Over 40 students completed four half-day courses.

Addressed primarily to atmospheric science aspects of aerosols (including modeling and measurement), the sessions featured the implications of such research for national and international decision processes and the intersections with the policy and health-sciences communities.

For more information about NARSTO, please contact:  
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Pasco, WA 99301  
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## n NARSTO 2000 Local Arrangements Committee

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## n Editors of Meeting Report:

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## n NARSTO 2000 Financial Sponsors



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Desert Research Institute,  
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## Preliminary Conference Overview

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The conference consisted of 4 pre-conference short courses, 4 invited plenary speakers, 3 plenary sessions, 15 platform sessions containing 88 platform papers, 1 poster session containing 11 poster papers, 2 evening events, and 2 pre-conference sightseeing tours.

### n MONDAY, OCTOBER 23, 2000

7:00am	Check-in and registration
8:00am - 12:00n	Morning pre-conference training courses
12:00n - 1:00pm	Lunch
1:00pm - 5:00pm	Afternoon pre-conference training courses
8:00pm	Session Chairs meeting
8:00am - 6:00pm	Trip to Guanajuato
9:00am - 6:00pm	Trip to San Miguel de Allende

### n TUESDAY, OCTOBER 24, 2000

7:00am	Check-in and registration and breakfast
8:15am - 1:15pm	Opening plenary sessions
1:15pm - 2:30pm	Lunch
2:30pm - 6:00pm	Technical plenary sessions on science and policy
7:00pm - 9:00pm	Evening reception, poster viewing, and vendor exhibits

### n WEDNESDAY, OCTOBER 25, 2000

7:00am	Check-in and registration and breakfast
8:05am - 10:05am	Concurrent technical sessions 1, 2, and 3
10:05am - 11:00am	Break, poster viewing, vendor exhibits
11:00am - 1:00pm	Concurrent technical sessions 2, 3, and 4
1:00pm - 2:15pm	Lunch
2:15pm - 3:50pm	Concurrent technical sessions 5, 6, and 7
3:50pm - 4:30pm	Break, poster viewing, vendor exhibits
4:30pm - 6:30pm	Concurrent technical sessions 8, 9, and 10
7:00pm	Noche Mexicana

### n THURSDAY, OCTOBER 26, 2000

7:00am	Check-in and registration and breakfast
8:05am - 10:05am	Concurrent technical sessions 11, 12, and 13
10:05am - 11:00am	Break, poster viewing, vendor exhibits
11:00am - 1:30pm	Concurrent technical sessions 11, 12, 13, 14, and 15
1:30pm - 2:45pm	Lunch
2:45pm - 4:00pm	Closing plenary sessions
4:00pm	Conference adjourned

## Sessions at a Glance

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### Tuesday, October 24, 2000

#### ***Morning: Opening plenary session and keynote addresses***

Ignacio Loyola Vera, Gobernador Constitucional del Estado de Querétaro

Enrique Provencio, Instituto Nacional de Ecología

Mario Molina, Massachusetts Institute of Technology

Don McKay, Environment Canada

Peter Lunn, U.S. Department of Energy

Armando Rivera C., Secretario de Desarrollo Sustentable, Qro.

Rolando Garcia M., Presidente Municipal de Santiago de Qro.

Jake Hales, ENVAIR

Adrián Fernández Bremauntz, Instituto Nacional de Ecología

#### ***Afternoon: Technical plenary sessions on science and policy***

Jake Hales, ENVAIR

Michael King, National Aeronautics and Space Admin.

Joyce Penner, University of Michigan

Marjorie Shepherd, Environment Canada

Francisco Guzmán, Instituto Mexicano del Petróleo

#### ***Exhibit viewing and evening receptions***

### Wednesday, October 25, 2000

Session 1 – PM Exposure and Health

Session 2 – Air Quality Modeling

Session 3 – PM Measurement Methods, Part I

Session 4 – PM Health Effects

Session 5 – Science-Policy Linkages

Session 6 – Source Characterization

Session 7 – PM Measurement Methods, Part II

Session 8 – Transboundary Issues

Session 9 – Stationary Sources/Controls

Session 10 – Data Management/Quality

Poster and exhibit viewing during breaks

### Thursday, October 26, 2000

Session 11 – Aerosol Satellites

Session 12 – Particle Emission/Formation

Session 13 – Field Studies

Session 14 – Visibility Impact and Assessment

Session 15 – Motor Vehicle Emissions

Closing Plenary Session (session chairs' summaries)

Poster and exhibit viewing during breaks

## Pre-Conference Training Courses

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### **n 1 Aerosol Measurements**

The purpose of this training course was to share current knowledge of, and recent developments in, ambient monitoring methods for particulate matter; describe methods for aerosol sampling for exposure assessment; and discuss aspects of quality assurance and quality control in air quality studies.

#### Instructor

Dr. Judith Chow, a Research Professor at the Desert Research Institute, Reno, NV, will present the course. Dr. Chow has 24 years of experience in aerosol sampling and chemical analysis. She prepared USEPA's guidance for chemically speciated PM<sub>2.5</sub> measurements and was author of the 1995 A&WMA Critical Review of measurement methods for determining PM<sub>2.5</sub> and PM<sub>10</sub> compliance.

### **n 2 Integrated Air Quality Modeling**

This course provided an overview of the scientific concepts of oxidant and particulate matter (PM) formation in the atmosphere, a discussion of the fundamentals of air quality modeling, and a description of currently available computer simulation models for ozone and PM air quality.

#### Instructor

Dr. Christian Seigneur is Vice President of Atmospheric and Environmental Research, Inc. (AER) in San Ramon, CA. He has over 20 years of experience in air quality studies and in the development, evaluation, and application of air quality models.

### **n 3 Data Validation, Management, and Interpretation Methods**

This course described elements of database management, demonstrated methods for assembling and validating air quality measurements, and summarized descriptive and statistical methods for data

analysis. Preparation of data for input to different models was examined.

#### Instructor

Dr. John Watson is a Research Professor at the Desert Research Institute, USA. He has more than 25 years of experience in aerosol characterization studies, specializing in management of comprehensive databases. Dr. Watson is the primary developer of Chemical Mass Balance modeling software and is familiar with data requirements for many urban- and regional-scale air quality models applied in air quality studies.

### **n 4 Particle Risk Assessment**

This course provided an introduction to risk assessment. Topics covered included current approaches for both cancer and non-cancer risk assessment, the roles of epidemiology and toxicology assessment, uncertainties and approaches for characterizing these uncertainties, and the use of risk assessment in development of sound environmental health policy.

#### Instructor

Dr. John Evans of Harvard University is a Senior Lecturer and Co-Director of the Program in Environmental Science and Risk Management at the Harvard Center for Risk Analysis. Dr. Evans is now engaged in a study of the health risks from exposure to air pollution in Mexico City.

# **NARSTO 2000**

## **OPENING PLENARY SESSION AND KEYNOTE ADDRESSES**

**FINAL PROGRAM**

**OCTOBER 24, 2000**

- 8:00-8:10 AM** Presentation of the Air Monitoring Mobile Unit  
Government of Queretaro  
Lic. Armando Rivera Castillejos  
Secretar a de Desarrollo Sustentable
- 8:15-8:25 AM** Welcome to Quer taro  
Ing. Ignacio Loyola Vera  
Governador de Estado de Quer taro
- 8:25-8:40 AM** Conference Welcome  
Lic. Enrique Provencio  
Instituto Nacional de Ecolog a
- 8:25-8:35 AM** Conference Welcome  
Dr. Adri n Fern ndez Bremauntz  
Instituto Nacional de Ecolog a
- 8:40-9:10 AM** KEYNOTE ADDRESS  
Enrique Provencio  
Instituto Nacional de Ecolog a
- 9:10-9:40 AM** KEYNOTE ADDRESS  
Dr. Mario Molina  
Massachusetts Institute of Technology
- 9:40-11:00 AM** coffee break
- 11:00 - 12:15 AM** KEYNOTE ADDRESS  
Dr. Don McKay  
Environment Canada
- 12:15-1:15 PM** KEYNOTE ADDRESS  
Dr. Peter Lunn  
U.S. Department of Energy

## **Conference Welcome**

### **Elementos para la intervención del Presidente del INE, Enrique Provencio en la inauguración del Simposium técnico “Aerosoles Troposféricos: Ciencia y decisión en la Comunidad Internacional”**

**Enrique Provencio**

**Instituto Nacional de Ecología**

Es para mí un honor dirigirme a ustedes en ocasión de la inauguración del Primer Simposium Técnico sobre Aerosoles Troposféricos: Ciencia y Decisión en la Comunidad Internacional, dentro del contexto del Programa NARSTO. Quiero, a nombre de la Secretaria de Medio Ambiente, Recursos Naturales y Pesca, Julia Carabias y del Instituto Nacional de Ecología darles a ustedes la más cordial bienvenida a nuestro país, desearles que durante este encuentro se logren importantes intercambios de información y se estrechen los lazos de colaboración y de investigación en materia de contaminantes troposféricos en la región de América del Norte.

Me gustaría agradecer a NARSTO, a la Agencia de Protección Ambiental de Estados Unidos y de Canadá su colaboración para hacer posible este evento en México, también me gustaría hacer un especial reconocimiento al Comité Organizador, formado por el Pacific Northwest National Laboratory y el Desert Research Institute, que junto con personal del INE llevaron a cabo la organización del evento.

En México, hemos reconocido la necesidad de mejorar los conocimientos técnicos y científicos en cuestiones de contaminación atmosférica, e incorporarlos en la toma de decisiones. Esta actividad se ha intensificado durante la gestión de la Maestra Julia Carabias, y es por ello que se ha puesto un especial énfasis y apoyo a las tareas de capacitación dentro de la misma Secretaría, gobiernos estatales y locales, así como las instituciones académicas.

Muestra de estas tendencias, están representadas en el Centro Nacional de Investigación y Capacitación Ambiental (CENICA), el cual surge en un esfuerzo conjunto de la Agencia de Cooperación Internacional de Japón (JICA), la Universidad Autónoma Metropolitana y la SEMARNAP. El principal objetivo de este Centro es fortalecer la capacidad de gestión ambiental a todos los niveles de gobierno, así como en los sectores privados y sociales, mediante el desarrollo de programas de investigación aplicada y capacitación técnica en los campos de calidad del aire y manejo de residuos.

Desde el inicio de esta administración y en especial en estos últimos años, se han realizado un gran número de actividades de intercambio y capacitación a nivel internacional con Universidades de renombre, como son Harvard, el MIT y la Universidad de Berna. También, gracias a nuestros programas de cooperación con JICA, numerosos expertos han tenido la oportunidad de capacitarse en Japón a través de los programas de intercambio establecidos.

Las estrategias de la SEMARNAP para avanzar en este contexto, se realizan a través de ampliar su participación en foros internacionales, donde podemos destacar las actividades desarrolladas en foros como la Organización para la Cooperación y el Desarrollo Económico,



OCDE y la Comisión de Cooperación Ambiental, CCA. Además, de mencionar las continuas actividades bilaterales de cooperación y capacitación establecidas con Canadá y la Agencia de Protección al Ambiente de EUA.

Los logros han sido importantes, y muestra de ello es la realización de este tipo de eventos en nuestro país, demostrando que la SEMARNAP y el Instituto Nacional de Ecología trabajan intensamente para construir bases sólidas en el conocimiento científico.

Finalmente, espero que los temas tratados durante el evento establezcan criterios sólidos, y fortalezcan las relaciones entre nuestros países para continuar con el estudio y la investigación de las cuestiones ambientales relacionadas con la contaminación troposférica.

## **CONFERENCE OBJECTIVES**

### **Elementos para la intervención en la inauguración del Simposium técnico “Aerosoles Troposféricos: Ciencia y decisión en la Comunidad Internacional”**

**Adrián Fernández Bremauntz**

**Instituto Nacional de Ecología**

Buenos días, es para mí un honor darles la más cordial bienvenida a este Simposium Técnico relacionado con Aerosoles Troposféricos: Ciencia y Decisión en la Comunidad Internacional de NARSTO.

Esta conferencia se desprende del programa de *Estrategia de Investigación para Ozono Troposférico de América del Norte, NARSTO (North America Research Strategy for Tropospheric Ozone)*, el cual está conformado como una asociación pública - privada, cuyos miembros abarcan representantes del gobierno, industria, y academia en México, Estados Unidos y Canadá. Su misión principal es coordinar e intensificar las investigaciones y evaluaciones científicas relevantes para establecer políticas ambientales relacionadas con el comportamiento de la contaminación troposférica. Para lograr esta meta, NARSTO está a cargo de establecer y mantener canales efectivos de comunicación, entre sus esfuerzos científicos, la comunidad de tomadores de decisiones, planeación y analistas estratégicos.

Es importante recalcar que está, es la primera reunión sobre partículas que se realiza dentro del contexto de NARSTO, y por ello, nos enorgullece que hayan elegido a México como sede del evento. Me gustaría agradecer la presencia del Gobernador de Estado de Querétaro, Ing. Ignacio Loyola Vera, del Presidente del Instituto Nacional de Ecología, Enrique Provencio, del Premio Nobel de Química, Profesor Mario Molina y de los representantes de NARSTO, Jake Hales, Don Mackey de la Agencia de Medio Ambiente de Canadá y a Peter Lunn, del Departamento de Energía de EUA.

Actualmente, nos encontramos viviendo una época interesante y oportuna para realizar investigaciones científicas sobre aerosoles troposféricos, ya que aunque el conocimiento sobre el tema ha ido en aumento. Existen, aún tareas frente a nosotros que representan un gran desafío. Las áreas de investigación en el tema son extensas, ya que éstas no solo incluyen la química y física básica sobre la formación y dispersión de aerosoles, sino también los métodos de medición y análisis, la salud, el cambio climático y la contaminación transfronteriza.

Por ello, esta conferencia está dirigida a científicos, consultores, industria, expertos en calidad del aire y salud, y servidores públicos involucrados en el estudio y la investigación de asuntos relacionados con aerosoles troposféricos en la región de América del Norte, teniendo como principal objetivo lograr una mejor comprensión de dichos asuntos en ambientes urbanos y regionales, así como su intersección con la comunidad científica y de toma de decisiones.

La conferencia está conformada por 4 cursos pre-congreso, que fueron impartidos el día de ayer con temas sobre Monitoreo de Aerosoles, Modelos de Calidad del Aire, Evaluación de Riesgo, y Manejo y Validación de Datos; se realizarán en la Conferencia, 3 sesiones plenarias, 15 sesiones temáticas con 88 trabajos y 1 sesión para la presentación de 11 pósters, dando un total de casi 100 trabajos. Dentro de las sesiones se tratarán temas como Exposición a PM y

Salud, Monitoreo de PM, Relación entre Ciencia y Política, Asuntos transfronterizos, Emisión de Partículas, Emisiones Vehiculares, Modelos de Calidad del Aire, Formación de Partículas, etc. También se cuenta con una sala de exhibición con la participación de renombrados centros de investigación como: el Desert Reserch Institute, Pacific Northwest National laboratory y el CENICA. Asi mismo, se cuenta con la participación de importantes firmas comerciales de instrumentación y servicios ambientales representadas por Andersen, BGI Incorporated, RJ Lee Group y Rupprecht & Patashnick.

En las actividades sociales de la conferencia, se realizaron el día de ayer dos visitas guiadas, una a la ciudad de Guanajuato, y otra a San Miguel de Allende. El día de hoy tendrá lugar un brindis de bienvenida en la zona de la terraza y la exhibición, y para el día de mañana se realizara una Noche Mexicana.

Finalmente, me gustaría poner en relevancia los esfuerzos realizados por NARSTO desde sus inicios, para impulsar la colaboración entre los tres países de América del Norte en temas relevantes a contaminantes troposférico, y prueba de ellos es la gran participación que tenemos en la conferencia, ya que contamos con alrededor de 180 personas registradas, en su mayoría de la región de América del Norte, sin descartar algunos representantes Europeos y Japoneses.

## **KEYNOTE ADDRESSES**

### **An Overview of the Chemistry of Atmospheric Particulates in the Stratosphere and Troposphere**

**Mario J. Molina**

**Massachusetts Institute of Technology**

The temperature profile of the atmosphere determines the existence of the different atmospheric layers. In the lowest layer, the troposphere, temperature decreases with altitude, and mixing times are on the order of months. In the next layer, the stratosphere, the temperature does not decrease with altitude, and mixing times in the vertical direction are much longer—several years.

The chemistry of the two layers is also very different. Rain in the troposphere provides an efficient cleansing mechanism that removes water-soluble gases and particles. The hydroxyl radical (OH) efficiently oxidizes non-soluble gases to convert them to species that are more readily removed. In the stratosphere, the cleansing mechanisms are significantly less effective: there is no rain, because the clouds there are very thin and furthermore exist only at high latitudes (the so-called polar stratospheric clouds).

The chemistry of the stratosphere turns out to be relatively simple compared to the troposphere. It is the presence of ozone that causes the temperature to increase with altitude in the stratosphere; hence, ozone effectively determines the existence of the two lowest atmospheric layers. The chemistry of the stratosphere is driven by species that are stable enough to be transported there from the Earth's surface through the troposphere; such "source" species include  $\text{N}_2\text{O}$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_4$ , and chlorofluorocarbons (or CFCs, the industrial compounds used in refrigeration, air conditioning, etc.). These decompose in the stratosphere to produce free radicals (*e.g.*, NO,  $\text{NO}_2$ , OH,  $\text{HO}_2$ , Cl, ClO), which then end up as temporary "sinks" (*e.g.*,  $\text{HNO}_3$ , HCl and  $\text{H}_2\text{O}$ ). Numerous gas phase chemical and photochemical reactions inter-convert radicals and temporary sinks, and the rates of most of these reactions have been well characterized in the laboratory. Using these measured reaction rates, together with information about surface fluxes of source species and about atmospheric transport (meteorology), it is possible to understand the chemical behavior of the atmosphere by means of computer models, and hence, it is possible to predict the effects of the release of industrial compounds such as the CFCs on the stratospheric ozone layer. Such predictions have been largely corroborated in the last ten to fifteen years by atmospheric measurements of a wide variety of chemical species, including ozone itself.

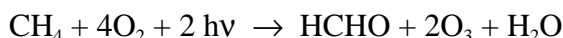
The disappearance of ozone over Antarctica in the spring months (the "Ozone Hole"), which began in the early 1980s, was first observed by a team from the British Antarctic Survey, who had been carrying out ground-based ozone measurements since 1957. The reasons for the disappearance were originally unknown. The decomposition products from the CFCs were suspect from the beginning, but the chemistry was not understood initially. Gas phase reactions could not explain the rapid disappearance of ozone, and it eventually became clear that important chemical reactions were taking place on the surface of polar stratospheric cloud particles (some of which consist of ice crystals). Laboratory studies indicated that certain important chemical processes occur very efficiently on the surface of ice crystals, namely HOCl (hypochlorous acid)

and ClONO<sub>2</sub> (chlorine nitrate) react with HCl to form Cl<sub>2</sub>; the reactants are the most important temporary chlorine reservoirs, and the product Cl<sub>2</sub> rapidly breaks down in the presence of visible and near ultraviolet radiation to generate Cl-atoms, which destroy ozone through a catalytic cycle involving also the species ClOOCl (chlorine peroxide). There is another important chemical reaction that takes place on the surface of ice particles: N<sub>2</sub>O<sub>5</sub> reacts with H<sub>2</sub>O to form HNO<sub>3</sub>, a product that remains largely incorporated in the cloud particles. The consequence is the removal of nitrogen oxides from the gas phase; these radicals tend to interfere with the catalytic chlorine chain reactions that destroy ozone, so that in their absence ozone is destroyed extremely efficiently by chlorine.

Observations show that more than 99% of the ozone in the Antarctic stratosphere is destroyed in the spring on a time scale of four to six weeks at those altitudes where polar stratospheric clouds are present (about 15 to 20 km altitude); in the summer the ozone levels recover their higher values by the mixing of polar air with ozone-rich air from lower latitudes. Ozone is also destroyed in the spring months in Arctic stratosphere, but not as dramatically as over the South Pole, because in the Northern hemisphere polar stratospheric air mixes more readily with lower-latitude air, and because the temperatures there are not as low as over Antarctica.

Satellite observations indicate that stratospheric ozone is also depleted significantly at lower latitudes. The chemistry is similar to that occurring over the poles, but less efficient in terms of ozone destruction; it involves reactions on sulfuric acid droplets, which are not as fast as those on ice crystals.

The chemistry of the troposphere is different and much more complicated. While nitrogen oxides (NO and NO<sub>2</sub>) destroy ozone in the stratosphere, they create ozone in the troposphere through a multi-step process involving the conversion of NO to NO<sub>2</sub> through reactions driven by hydrocarbon oxidation fragments, and the subsequent photolysis of NO<sub>2</sub>. For the oxidation of methane, the net reaction can be written as:



The oxidation of larger hydrocarbons, however, becomes much more complicated, involving many possible reaction pathways and intermediate species. Because of this complexity, it is not possible to use the reductionist approach of considering all the important individual reactions, as has been done for stratospheric chemistry. Instead, it is necessary to lump hydrocarbon species and reactions into different classes.

While our understanding of these gas phase reactions in the troposphere is improving and has a sound theoretical basis, much less is currently known about the reactions that take place on particles or that create particles. For example, reactions of OH with condensed-phase organic aerosols are thought to be important processes in converting hydrophobic aerosols to hydrophilic aerosols, which then may serve as cloud condensation nuclei. Current research in our laboratory includes studies of reactions of OH and HO<sub>2</sub> radicals with condensed organics, using flow tube techniques coupled to chemical ionization mass spectrometry.

The production of atmospheric particles and of ozone by nitrogen oxides and hydrocarbon oxidation fragments is particularly efficient in urban atmospheres. Mexico City is an important example where urban air pollution is severe, and it is particularly interesting because of the high concentrations of soot aerosols present. As is the case elsewhere in the world, the major concern over air pollution in Mexico City – and the major driver for policy

actions – is human health. Particulate air pollution is one of the most serious health risks in Mexico City and other megacities around the world.

We are currently conducting an integrated program involving the participation of an interdisciplinary and multidisciplinary group of researchers from MIT and Harvard and from various Mexican institutions. The main goal of the program is to provide objective and balanced assessments of the causes and possible solutions to local, regional, and global atmospheric pollution problems that are useful to decision makers. We are using an integrated assessment approach to facilitate the integration of health and atmospheric science with technological and policy analyses, as well as stakeholder input and knowledge dissemination. Mexico City will serve as the initial case study for the Project's research and educational activities. Additional information on the “Integrated Program on Urban, Regional and Global Air Pollution” is available at the following website: <http://eaps.mit.edu/megacities/>.

In addition to the growth in urban air pollution in megacities, biomass burning is also increasing in rural regions around the globe. Together, urban pollution and biomass burning are causing important changes in the chemistry of the lower atmosphere, even in remote regions, where concentrations of ozone and other pollutants have clearly increased. Air pollution is increasingly being viewed as a global problem, and there is interest in studying, for example, the effect of emissions in Asia on air pollutant concentrations in the U.S., as well as the effects of U.S. emissions on pollutant levels in Europe. Atmospheric chemistry also plays an important role in yet another problem, namely global climate change; increases in the background levels of ozone and particulates affect the thermal balance of our planet. In particular, the effect of changes in the concentrations of aerosols on cloud properties—the so-called “indirect effect”—is a key source of uncertainty in predictions of future climate. These uncertainties have begun to be addressed through field campaigns such as the INDOEX experiment, which measured pollutants thousands of kilometers off the coast of India. These pollutants include soot particles, which apparently shorten the lifetime of clouds by absorbing solar radiation; normally, aerosols are expected to increase that lifetime by inducing the formation of smaller cloud particles.

In conclusion, the problem of CFCs and stratospheric ozone loss provides a very good example showing that global environmental problems can be solved through international agreement. We are now faced with problems of climate change and global air pollution that are more difficult to solve. But we are optimistic that through cleaner technologies and international agreements, solutions to these problems can also be implemented.

# **PLENARY ADDRESSES**

## **Perspective on Tropospheric Aerosols**

**Peter Lunn**

**U.S. Department of Energy**

**Significance of Tropospheric Aerosols.** Tropospheric aerosols are significant not only to air quality and exposure and health, but also to global change and to energy policy. There is only one atmosphere and air tends to flow across boundaries. The science is very complex, and the urban and regional environments are diverse. There are diversity and mixture of sources and timing, and there is diversity of chemistry, geography, and meteorology.

**International Considerations.** We believe that no single country has all the needed assets and experience to resolve all the pertinent issues, and so we must necessarily work together and pool our talents and resources.

**Role of NARSTO.** NARSTO is a wonderful invention. It facilitates international cooperation. It brings governments together with academia and industry. It engages and facilitates field measurements campaigns, the sharing of data, and the performance of needed assessments. The recent NARSTO ozone assessment was very well received. And the PM assessment now underway will undoubtedly prove also to be very beneficial to all of us. In recent years NARSTO has facilitated a number of very productive field measurement campaigns, including the Eastern Canada Tropospheric Ozone Field Study (NARSTO-CE) and a comparable northeastern U.S. field study (NARSTO-NE). These studies were well coordinated between the U.S. and Canada. Also the Mexico City Air Quality Study is a great example of effective collaboration between the U.S. and Mexico. The bottom line is that the NARSTO partnership works, and that the U.S. and the Department of Energy are firmly committed to NARSTO.

**U.S. Activities.** There are numerous U.S. agencies and organizations involved in air quality and PM studies under the NARSTO umbrella, including state agencies such as the California Air Resources Board (CARB) and the Texas Natural Resources Conservation Commission (TNRCC), the various federal agencies, universities, and industry organizations like API and EPRI. The U.S. Subcommittee on Air Quality Research has published an inventory of federal PM research activities that includes the Department of Agriculture, the Department of Energy, the Department of Interior (National Park Service), the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and the Tennessee Valley Authority (TVA). These studies involve a wide range of research in atmospheric science and with regard to exposure and health.

**Department of Energy Activities.** DOE activities include the Environmental Science and Health Effects Program in the Office of Energy Efficiency and Renewable Energy, the Ambient Fine Particulate Matter Research Program in the Office of Fossil Energy (National Energy Technology Laboratory), and the Atmospheric Science Program in the Office of Science. The Atmospheric Science Program includes the Atmospheric Chemistry Program, the Environmental Meteorology Program, the Research Aircraft Facility, and the planned Tropospheric Aerosol Program.

**Conclusions.** We believe that tropospheric aerosols are highly significant to air quality,

with serious potential health consequences, serious visibility issues, serious challenges in meeting air quality standards, and potentially serious economic considerations. We also believe tropospheric aerosols are highly significant to climate change, in the sense of both direct and indirect aerosol radiative forcing. There are major uncertainties in the underlying science, relating both to atmospheric processes and to health and exposure considerations. And these are all issues of multi-national, multi-agency concern.



# **Remote Sensing of Tropospheric Aerosols from Space: Past, Present, and Future**

**Michael D. King**

**National Aeronautics And Space Administration**

Tropospheric aerosol particles originate from man-made sources such as urban/industrial activities, biomass burning associated with land use processes, wind-blown dust, and natural sources. Their interaction with sunlight and their effect on cloud microphysics form a major uncertainty in predicting climate change. Furthermore, the lifetime of only a few days causes high spatial variability in aerosol optical and radiative properties that requires global observations from space.

Remote sensing of tropospheric aerosol properties from space is reviewed both for present and planned national and international satellite sensors. Techniques that are being used to enhance our ability to characterize the global distribution of aerosol properties include well-calibrated multispectral radiometers, multispectral polarimeters, and multiangle spectroradiometers. Although most of these sensor systems rely primarily on visible to near-infrared spectral channels, the availability of thermal channels to aid in cloud screening is an important additional piece of information that is not always incorporated into the sensor design. There are various satellite sensor systems being developed by Europe, Japan, and the United States, with various advantages and disadvantages for aerosol applications. An important underlying theme is that the remote sensing of aerosol properties, especially aerosol size distribution and single scattering albedo, is exceedingly difficult. As a consequence, no one sensor system is capable of providing totally unambiguous information, and hence a careful intercomparison of derived products from different sensors, together with a comprehensive network of ground-based sunphotometer and sky radiometer systems, is required to advance our quantitative understanding of global aerosol characteristics.

# Comparison Of Models And Satellite-Retrieved Optical Depths

Joyce Penner

University Of Michigan

Comparisons of models with observations for sulfate aerosols and other sulfur compounds are particularly relevant for assessing model capabilities because the emissions of sulfur-bearing compounds are better known than the emissions of other aerosol compounds. Thus, comparison can focus on the capabilities of the models to treat transport and oxidation processes. Recent field studies, however, have pointed out the importance of organic aerosol compounds, dust aerosols, and sea salt aerosols. Also, soot is important because it decreases the reflection and increases the absorption of solar radiation. Furthermore, the magnitude of the indirect effect is sensitive to the abundance of natural aerosols. Therefore, an examination of model capability to represent this entire suite of aerosol components was undertaken as part of the IPCC report.

For dust, the model-observation comparison showed a better agreement with surface observations in the Northern than in the Southern Hemisphere. It appears that dust mobilization estimates may be too high, particularly those for Australia and South America. The paucity of dust from these regions relative to other arid dust source areas has been noted previously and may reflect the relative tectonic stability, low weathering rates, duration of land surface exposure, and low human impacts in this area.

Interpreting the comparison of observed and model-predicted concentrations for both organic carbon and black carbon is more difficult because of both inaccuracies in the observations and the fact that most measured concentrations are only available on a campaign basis. In addition, the source strength and atmospheric removal processes of carbonaceous aerosols are poorly known. Most models were able to reproduce the observed concentrations of BC to within a factor of 10 and some models were consistently better than this. Both modeled and observed concentrations varied by a factor of about 1000 between different sites, so agreement to within a factor of 10 demonstrates predictive capability. However, there are still large uncertainties remaining in modeling carbonaceous 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 needed for the other aerosol species. The large differences in predicted atmospheric aerosol burden, which is the relevant parameter in determining the forcing, impede an accurate estimate of the aerosol climate effect. Improvement of the assessment of aerosol burden requires more measurements within the free troposphere.

Modeled optical depths north of 30°N are sometimes higher and sometimes lower than those of the retrieved AVHRR optical depths. Modeled aerosol optical depths near 10°N are dominated by dust with some contribution from organic carbon and sulfate (especially in January and April). They are systematically lower (by, on average, 0.08) than the average retrieved optical depth. The discrepancy between modeled and retrieved optical depths in this region, however, would be reduced if the sea salt fluxes derived from SSM/I winds and larger DMS fluxes had been used.

The modeled aerosol optical depths from 10°S to 30°S are due to a combination of different aerosol types. They are systematically lower than the average of the retrieved optical

depths by an average of 0.06 with biases ranging from -0.14 to 0.01 in January, from -0.12 to -0.02 in April, from -0.13 to 0.07 in July and from -0.11 to 0.06 in October. As shown by the sensitivity study, much of the difference between the modeled and retrieved zonal average optical depths could be removed by using higher sea salt and DMS fluxes. However, the spatial character of the differences reveals that the cause of the discrepancies probably cannot be attributed to any single source. Modeled aerosol optical depths near 60°S are dominated by sea salt. This component appears to be reasonably well represented by the models, especially for the optical depth predicted using the SSM/I sea salt fluxes.

In summary, analysis of the AVHRR comparisons indicates that significant uncertainties remain in both our ability to retrieve aerosol optical thickness from satellites and in our ability to model aerosol effects on the radiation budget. The global average difference between the average optical depth from the models and the average optical depth from the satellite retrieval is of the same magnitude, namely -0.04. In the region 10° S to 30° S, the analysis indicates that modeled optical depths are consistently too low. Such a model underestimate might indicate that the retrieved optical depth from satellites is too high, for example, because the cloud screening algorithm is not adequate in this region. Alternatively, there may be a need for a larger source of aerosols in this region or for smaller modeled removal rates.

# **The NARSTO Particulate Matter Assessment**

**Marjorie Shepherd**

**Environment Canada**

The NARSTO Particulate Matter Assessment is coordinated by three co-chairs: P. McMurry of University of Minnesota, J. Vickery of US EPA and M. Shepherd of Environment Canada. This assessment will be the second major assessment of NARSTO following the Ozone Assessment released in October 2000.

In the field of air quality, assessments tend to focus on the ambient-receptor relationship to support air quality standard setting, or on the source-ambient relationship to support implementation of the standards. The focus of this PM Assessment is firmly on the latter—providing a current description of PM formation and transport with an evaluation of the science tools to support implementation.

We have recognized that the questions that arise in managing environmental issues are similar in most jurisdictions. For PM, atmospheric science has information that is useful in answering the questions of the policy community. Generally speaking these questions are:

- n Do we have a problem?
- n Is it getting better or worse?
- n What and where are the major sources?
- n How much do they have to change?
- n Is it possible/feasible to influence those sources?
- n Was the management approach successful?
- n Where is the greatest risk, the greatest uncertainty? Where can science inform these?

It is the intent of this assessment to be broadly applicable, and provide useful information outside of the regulatory framework of any one country. The decision issues are similar in every jurisdiction, and the responses need to be transferable to the regulatory framework of each country, state or province. The primary audience of this assessment is the air quality policy community and decision-makers. Thus the focus on making the information regarding the science tools for managing PM both useful and relevant.

PM standards exist in all jurisdictions. Implementation plans are being developed and monitoring being put in place to assess the extent of the problem, and in the future, the success of the implementation plans. However there is also a great deal of research activity right now expecting to deliver results in the next two to three years. So why are we doing an assessment now, in a relatively short amount of time? This assessment is being done in recognition that the scientific understanding is evolving, but to date there has not yet been a concise and useful presentation of the state of knowledge to support implementation of current standards. Doing the assessment now and quickly is a balance between meeting the decision-makers' information needs and communicating what we do know about PM formation and transport. We anticipate this to be the first in a series of NARSTO assessments with subsequent ones taking advantage of the research now underway.

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 Standards and will support implementation of that standard. In the U.S. 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 their 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 PM Assessment will occur in three phases. Phase I is the definition of assessment objectives and the information needs of the policy community (Spring 2000 – Spring 2001). To date there have been 39 briefings and interviews of federal, state, provincial and industry policy makers to fine-tune and confirm the objectives and direction of this assessment. Phase II is the synthesis of the information and critique of the knowledge in the context of the air quality policy communities' information needs (Autumn 2000 – Autumn 2001). Phase III is the integration of the knowledge and summary of key issues relevant to development of effective air quality management strategies to address health and environmental impacts (Spring 2001 – December 2002). Phase III includes a peer review of the science and policy relevance jointly coordinated by the U.S. National Research Council and the Royal Society of Canada. The final milestone is publication and release of the assessment in December 2002.

There will be new information in this assessment. Key scientific messages relevant to implementation will be developed emphasizing the latest knowledge. This will be presented in useful forms for policy makers. There will be a review of current capability to apply the available science tools (models) to support implementation. Where and when new science will answer the questions we cannot answer now will be explored. Also, our capability to track progress and a discussion of appropriate metrics to do so will be included. Lastly, efforts will be made to present uncertainties in a relevant and understandable manner for the policy community.

When providing information that is to be relevant to the policy community there is concern about how far science should go. This assessment will guide policy, not recommend policy. It will provide discussion of implications of current policy directions (e.g., NH<sub>3</sub> / NO<sub>x</sub> disbenefits, potential to increase ultrafine PM concentrations) and describe the breadth of uncertainty in tracking trends or predicting ambient responses to forecast emissions. Starting with what we do know and being as relevant to implementation as possible, all conclusions and recommendations will be the agreed upon understanding of the scientific participants. Lastly, effort will be made to provide this information that does not limit policy options, recognizing that science sits at the decision table with economic, technological and social issues.

Although we are focusing on providing useful and relevant information for policy makers, there are other objectives that can be met by exploring the development of conceptual framework for PM. The objectives are briefly to:

- n Gain an understanding from **decision-makers** of information needs.
- n Provide a comprehensive conceptual model of aerosol formation and particulate matter distribution for **science-policy analysts and air quality decision makers**.
- n Provide a plain language conceptual description of particulate matter air quality for the **public**.
- n Recommend atmospheric science and related emissions **research**.
- n Provide a framework for **atmospheric scientists** which relates their work to standards; implementation and air quality management; and health, exposure and environmental impact research for standard setting.
- n Provide a context for **researchers in related fields** to link their work to that of the atmospheric science community.

An overarching goal of the assessment is to provide an understanding as a conceptual framework that identifies the processes that affect spatial and temporal distribution of particles. These processes are common to all source environments and meteorological conditions, but the degree to which different precursors and processes limit or enhance particle formation is described by a conceptual model specific to a given region or source mix for given seasonal or meteorological conditions. The framework can be used to ensure that the relevant research is in place to support achievement of PM standards, and that the key measurements are made to track and evaluate success of the implementation plans.

## TECHNICAL SESSIONS

Session 1: PM Exposure and Health  
Chairs: Edward Edney  
Ron Wyzga

Session 2: Air Quality Modeling  
Chairs: Mike Moran  
Elizabeth Vega

Session 3: PM Measurement I  
Chairs: Margarita Castillejos  
George Hidy

Session 4 : PM Health Effects  
Chairs: Mauricio Hernandez

Session 5: Science-Policy Linkages  
Chairs: Marjorie Shepherd  
Carlos Santos Burgoa

Session 6: Source Characterization  
Chairs: Hector Riveros  
Bruce Thomson

Session 7: PM Measurement II  
Chairs: Ray Hoff  
Irma Rosas

Session 8: Transboundary Issues  
Chairs: Maris Lulis  
Adrian Vazquez

Session 9: Stationary Sources  
Chairs: Howard Feldman  
Enrique Tolivia

Session 10: Data Management  
Chairs: Les Hook  
Gabriel de Icaza

Session 11: Aerosol Satellites  
Chairs: David Winker  
Javier Miranda

Session 12: Particle Emission/Form.  
Chairs: Francisca Aldape  
Peter McMurray,

Session 13: Field Studies  
Chairs: Marc Pitchford  
Graciela Raga

Session 14: Visibility  
Chair: Jim Meagher

Session 15: Mobile Source Emission  
Chairs: Steve Cadle  
Marisa Ruiz

Poster Session  
Chairs: Pablo Cicero-Fernandez  
Delbert Eatough  
Luis Sanchez-Catano

# **SESSION SUMMARIES**

## **SESSION 1: PM Exposure and Health**

Edward Edney US EPA

Ronald Wyzga EPRI

The papers presented at this session focused on exposure measurements of gases and PM in Chile and Mexico. The data generated in these studies provide scientists an important opportunity to assess the impacts of high exposure levels.

The first study involved investigating exposure of PM and gases to children in Chile. In the study a strong association was found between ambient, indoor, and personal PM<sub>2.5</sub> levels. On the other hand the indoor and personal exposure levels for the coarse fraction of PM were found to be strongly affected by indoor sources arising likely from the activities of children. In the second paper presented, modeling interpolation techniques were employed to estimate PM concentrations throughout the Mexico City area using measurements from a network of air quality stations. These data were used to estimate exposure levels. The estimates were then used, in a follow-on study also reported during this session, to estimate health consequences of PM in the Mexico City area. This exercise involved estimating dose-response relationships from existing studies, including those carried out in the Mexico City area. In another study, ambient concentrations as well as concentrations in a number of micro-environments were reported for a wide range of volatile organic compounds, including the secondary organic aerosol precursors toluene and xylene. In the final paper very high levels of PM were reported at several locations in a university library in Mexico City. Carpeting appeared to be a significant contributor to the indoor concentrations.

These results as well as many others published in the literature strongly suggest that ambient concentration data from centrally located monitoring stations may not alone be sufficient to understand PM-induced health effects. Concentrations in micro-environments, personal exposure data and time activity patterns are also likely required. Such issues need to be addressed in the NARSTO PM program.



## Session 2: Air Quality Modeling

Michael Moran, Environment Canada

Elizabeth Vega, Instituto Mexicano del Petroleo

Ten papers were presented in this wide-ranging session, which covered eight different air quality models and applications from the urban to the global scale. The first paper, by Christian Seigneur (AER Inc., USA), provided a valuable comparative review of the three-dimensional air quality models that are currently available for simulating size-distributed tropospheric PM. One process whose representation differs substantially among current PM models is secondary organic aerosol (SOA) formation, and none of the models include all SOA formation pathways. One open issue that was identified is how best to use existing PM air quality models, most of which are detailed episodic models, to predict annual PM concentration fields. The need for suitable regional PM observational data sets for PM model evaluation was also raised. In discussion after the presentation, suggestions made for the required characteristics of such data sets included the following: hourly resolution; six consecutive weeks or more in length; sampling of different seasons; measurements aloft as well as at surface; PM composition and size distribution measurements; simultaneous, co-located gas-phase measurements; and some "supersite" measurement sets for more detailed diagnostic comparisons.

Three papers dealt with the U.S. EPA's Comprehensive Multi-scale Air Quality model, CMAQ. Shawn Roselle (U.S. EPA, USA) gave an overview of CMAQ and presented some results for the eastern United States for a July 1995 episode, including predicted PM chemical composition. Weimin Jiang (National Research Council of Canada, Canada) discussed both the steps required to implement a new SOA formation parameterization in CMAQ within the Models-3 framework and the additional steps required to apply CMAQ to a non-U.S. modeling domain. The latter task requires a significant effort to extend or create emissions-processing input files for the non-U.S. jurisdictions in order to be able to use the Models-3 emissions processor to create CMAQ emissions input files for the domain of interest. Robin Dennis (U.S. EPA, USA) reported on the use of CMAQ to examine the impact of SO<sub>2</sub> emission reductions in the eastern U.S. between 1990 and 1995 on ambient PM sulfate concentrations and to investigate the cause of the observed sub-proportional response: preliminary analyses suggest that the spatial non-uniformity of the spatial reductions, chemistry, and meteorology may all play a role. He also described the application of the EPA's Extended Regional Acid Deposition Model (RADM) to explore the links between NO<sub>x</sub> emissions reductions from large stationary sources and fine particle sulfate production; the RADM results suggest a NO<sub>x</sub> disbenefit in that expected NO<sub>x</sub> emission reductions under the EPA's NO<sub>x</sub> State Implementation Plan lead to modest increases in particulate sulfate (0.1-0.2 ug/m<sup>3</sup>) in urban areas.

Michael Moran (Environment Canada, Canada) described the structure and characteristics of a new sectional regional PM model called AURAMS (A Unified Regional Air-quality Modelling System) and presented some results from an evaluation of predictions from a one-week August 1988 simulation made with a "dry" AURAMS prototype vs. both observations from the EMEFS field program for that period and predictions from a simulation for the same period made with an acid deposition model, the Acid Deposition and Oxidant Model. The evaluation suggested that the neglect of aqueous-phase chemistry in the "dry" AURAMS prototype resulted in an underprediction of SO<sub>2</sub>-to-SO<sub>4</sub> conversion even for this low-precipitation summertime anticyclonic case. In the presentation that followed, Sunling Gong (Environment Canada, Canada) provided more information about the Canadian Aerosol Module (CAM), the multi-component, sectional aerosol module that has been used in

AURAMS, and also described CAM's use in a global climate model to represent aerosol effects on radiation and clouds.

Sarath Guttikunda (University of Iowa, USA) presented results of PM simulations made with the STEM-III model for both east Asia (a 1993 Gobi dust-storm case) and the southwestern U.S. centered on Phoenix, Arizona (May 1998 Department of Energy Phoenix field study). The latter case included transport of smoke plumes to Phoenix from fires burning in Mexico. S.T. Rao (State University of New York at Albany, USA) discussed the important subject of the choice of grid resolution for grid-based photochemical models and its possible influence on the directionality or preference for emission control options. He showed a comparison of RAMS/UAM-V results for two nested simulations with finest grid spacings of 12 and 4 km, respectively. While predicted peak surface ozone levels at individual grid cells differed by as much as 40 ppb for the two simulations, traditional statistical measures of surface ozone predictions and predictions aloft were comparable.

Finally, two presentations dealt with the applications of simpler box models to the PM problem. Hector Jorquera (Pontificia Universidad Catolica, Chile) used a box model and measurements from the ambient air quality network in Santiago, Chile, to evaluate co-benefits from greenhouse-gas mitigation strategies on PM fine and coarse levels in Santiago. His analysis suggested that fine-particle levels would be affected more by combustion-related controls than would coarse-particle levels, whose primary source is the transportation sector. Hampden Kuhns (Desert Research Institute, USA) described the use of the SCAPE2 chemical equilibrium model in conjunction with a box model incorporating the RACM gas-phase chemistry mechanism to analyze and interpret the SO<sub>4</sub>/NO<sub>3</sub>/NH<sub>4</sub> equilibrium system in measurements of wintertime PM stagnation episodes in and near Boise, Idaho last winter. The measurements show that ammonium nitrate was the major aerosol component during observed episodes. The models suggest that the formation of ammonium nitrate aerosol is limited by nitric acid availability, focusing possible control strategies on NO<sub>x</sub> emissions from mobile sources and on VOC emissions (due to the role of hydrocarbons in forming hydroxyl radicals).

## Session 3 – PM Measurements

Margarita Castillejos, UAM-Xochimilco

George Hidy, Envair/Aerochem

This session contained 9 papers that can be sub-divided into three groups: (a) intercomparison of PM mass measurement, (b) chemical characterization, and (c) remote sensing of particles. Each of them represents an important topic of current interest in tropospheric aerosol particle research.

The first category concerns efforts to find a less labor intensive way to determine particle mass concentration that is consistent with the “reference” gravimetric method. Two papers were given that describe the performance of the continuous TEOM analyzer compared with 24-hour average filter based gravimetric observations. The first paper dealt with the significance of thermodynamic factors, particularly water (humidity) and temperature that will produce differences between the TEOM & FRM results. The second paper was on PM<sub>10</sub> TEOM observations with gravimetric filter monitoring in the Mexico City RAMA network. This comparison was disappointing in that the continuous TEOM measurements varied greatly by station and year when compared with the “6-day volume filter monitors.” The reasons for the large discrepancies are not known, as yet.

The second category covered the characterization of the carbon component of PM, the inorganic component by individual particle, and the determination of particulate mercury in the presence of mercury.

The first group described an important new step towards developing filter based reference standards for calibrating carbon in urban aerosol particles. The second paper proposed a simple method for at least qualitatively estimating soot concentrations based on ambient CO – PM carbon correlatives. The third paper described progress in developing a simple, robust impregnated filter method for collecting volatile and semi-volatile carbon material while sampling PM. The fourth paper illustrated progress in applying carbon isotope analysis to determine the “modern” carbon fraction in PM samples.

The last paper described recent ground-based remote sensing of plasmas using a scanning lidar system. Observations were made for summer and winter on a large power plume and a smelter plume in eastern Canada. The results provide qualitative information about plume evolution and interaction with boundary layer dynamics; these results may be useful for air quality modeling on different spatial and temporal scales.

## **Session 4: PM Health Effects**

Mauricio Hernandez, Instituto Nacional de Salud Publica

William Russo, U.S. EPA

This session was representative of NARSTO efforts to continue to improve coordination among atmospheric sciences, health and exposure research communities. Five presentations were included in the Session. Reported results are briefly summarized below.

Ronald Wyzga provided an overview of results from ARIES epidemiology studies in Atlanta GA linking air pollution and human health. The ARIES study has 18 months of data and is at the point where statistical significance can be identified. Thus far preliminary analyses have evaluated single pollutants and have identified statistically significant associations for CO (COPD and CVD patients) and the carbon component (elemental and organic) of PM (dysrhythmia for all cardiovascular patients).

David Chock presented modeling results that highlighted confounding effects in PM statistical associations, including the use of seasonal vs non-seasonal models and the variability in hospital admissions across days of the week, separating for respiratory from cardiac hospital admissions, and the use of single vs multi-pollutant models.

Marie O'Neil presented four particle metrics and their relationship with mortality in Mexico City. The metrics compared were the TEOM, Anderson HiVolume, Harvard impactor, and values predicted with visibility to fill in data gaps for the HiVol method. Time series analyses of mortality and PM10 using the metrics were conducted. The HiVol, TEOM and estimated PM10 differed little in their associations, but the magnitude of the effects were much lower than when using the impactor metric.

Art Fernandez's presentation was about the re-suspension of combustion generated fine particulates for inhalation health effects from coal ash and a coal ash/dry sewage sludge mixture. The paper describes a cross-disciplinary effort between combustion engineers and inhalation toxicologists to help identify relationships between specific combustion processes, their fine PM emissions and potential inhalation health effects. Results highlighted the higher concentration of zinc in the mixture combustion products, and that particles from the mixture resulted in significantly more lung damage.

Marjorie Shepard presented for Jeff Brook recent findings from health effects studies in Canada. The presentation provided an overview of results from animal toxicology, human clinical research, and epidemiology studies. Selected highlights included CO impacts in Toronto; the importance of particle composition (zinc in toxicology studies); the importance of pollutant interactions, such as those from mechanism work that showed pre-existing ozone damage greatly enhances lung damage from particles; and the strongest association to hospital admissions of the coefficient of haze (work to identify what the coefficient of haze is will be published over the next two years).

## Session 5 – Science-Policy Linkages

Marjorie Shepherd, Environment Canada

The science and policy linkages are becoming more numerous and more effective as each new issue is addressed and air quality management plans are developed. Both the atmospheric science and policy communities agree that in nearly every case the link needs to be strengthened. There is a need for scientific input at each stage and policy makers need to accommodate the following: problem identification, policy development policy adoption, and policy implementation.

For effective communication of the science to the policy community several points need to be kept in mind.

- n the level of trust the policy community and public have in the scientific community (currently for air quality the level is relatively high)
- n science's responsibility to point out what is known and those aspects for which science cannot at present provide guidance
- n effective risk communication as key to policy adoption and implementation (currently non-existent for most organizations involved in science assessment and implementation)
- n on a broad scale the need for science assessment/advice and policy development/ adoption/implementation timelines to intersect at frequent and appropriate levels
- n the varying usefulness of different science models for providing input to policy, e.g., science bank, reactive or feeder, and interactive

The NARSTO structure, being cross-country, cross-agency and cross-sectoral, is an effective one for facilitating the science and policy interactions. The impromptu discussion following the presentations recognized several interesting points.

There is broad recognition in both the scientific and policy communities of the value of assessments that are the result of the collective scientific community. In general scientists expressed a willingness to support the policy community but often need a better understanding of how policy is developed and where their input can be effective and appropriate. Keeping the science at the decision-making table along with social, economic and technological inputs is important and is often done by science advisors who need the back-up and support provided by the scientific communities assessments.

## Session 6: Source Characterization

Dr. Hector Riveros, UNAM-Instituto de Fisica

Bruce Thomson, Environment Canada

Strategies to control aerosols require identification of their sources. Reviewed in the session were several methods: trace elements, stable isotopes, and natural radioactivity, along with inductively coupled plasma/mass spectrometer methods and X-ray techniques at the Advanced Photon Source (APS) to characterize size-fractionated samples. We need to examine bioavailability issues when we develop new methods for characterization.

Emissions-based models (EMBs) have been the primary tool used to determine how source controls would affect air quality. A new modeling approach that combines EMB and classic receptor models has been applied in the Southern Appalachian Mountain Initiative (SAMI). The method is based on linking formal direct sensitivity analysis of size and chemically resolved aerosol model with ridge regression. The sensitivity coefficients effectively acts as a source fingerprint that provide information on how each source emissions strength should be altered to reconcile measurements and model predictions, and the adjustments account for the meteorology, chemistry and emissions.

In the boreal forest, high-intensity crown fires account for an overwhelming proportion of the area burned yearly. Quantifying the amount of black carbon (BC) from boreal crown fires is essential for assessing the effect on regional climate from natural wildfire aerosol emissions vs. that from anthropogenic activities. The BC and organic carbon (OC) compositions of aerosols produced during the flaming and smoldering stages of burning, were measured by the thermo-optical (absorbance) method. Particles were collected on quartz-fiber filters by helicopter with a hi-vol sampler and at ground level with a dichot sampler to separate the fine and coarse fractions. Analyses of the dichot back-up filters and properties from the thermo-optical method were used to correct for sampling artifacts.

The city of Colima, in Western Mexico, has been subjected to the emissions of the nearby Volcán del Fuego for over 20 years. However, their influence on the atmospheric aerosols present in the urban area has not been studied. A study of the inorganic components in particulate matter with mean aerodynamic diameter below 15  $\mu$ m was carried out, using Particle Induced X-ray Emission (PIXE). Elements found in the samples included Si, S, K, Ca, Ti, Mn, Fe, Cu, Zn. The results obtained allow an identification of the contribution of the volcanic emissions, other natural sources and anthropogenic fractions.

George Allen of Harvard University presented Lara Gundel's results from the Continuous Ambient Mass Monitor (CAMM) for PM<sub>2.5</sub>. CAMM was exhibited at NARSTO-2000 by Andersen Instruments. Again, CAMM detected more mass than a TEOM at 50C, showing that this pressure-drop virtual impactor system may provide more representative mass measurements.

## Session 7: PM Measurements II

R.M. Hoff, JTEC/UMBC

I. Rosas, PUMA

Like PM Measurements I, the papers in this session were divided between improved techniques to measure mass and to measure composition of aerosol. Of the four papers in this session, two focused on an artifact-free (or more artifact-free) method to obtain  $PM_{2.5}/PM_{10}$  masses. In Utah, Delbert Eatough will be conducting the Environmental Monitoring Program and Community Tracking (EMPACT) study. Dr. Eatough presented data showing the behavior of the RAMS and TEOM samplers in reference to their proprietary PC-BOSS system. The PC-BOSS was designed to study volatilization from filters and understand the volatile fraction of the particulate mass. In order of their ability to detect volatiles and semi-volatiles, BOSS>RAMS>FRM>TEOM.

George Allen of Harvard University presented Lara Gundel's results from the Continuous Aerosol Monitoring Method (CAMM). CAMM was exhibited at NARSTO-2000 by Andersen Instruments. Again, CAMM detected more mass than TEOM, showing that this pressure-drop virtual impactor system may provide more representative mass measurements.

The remaining two talks in the session focused on the speciation of the aerosols that make up  $PM_{2.5}/PM_{10}$ . Ann Middlebrook of NOAA studied over 500,000 particles in the Atlanta, Georgia, area. The method she used was Particle Analysis by Laser Mass Spectrometry (PALMS). Her finding showed that 70-99% of the particles had some organic fragments in them and over 90% contained sulfate fragments. 40-60% of the particles had small amounts of lead in them, which was an unusual result. 40% of the particles had organic acid peaks. Soot was clearly identified in 1% of the particles, and less than 1% of the particles were comprised of mainly metals.

Maria Theresa Limon Sanchez of UNAM examined acetic and formic acid concentrations in the Mexico City area. Findings showed that the nighttime acetic and formic acids were found predominantly in the particle phase. Data suggest that at the Merced site, vehicular traffic was most important.

## Session 9: Transboundary Issues

Maris Lulis, Environment Canada

Although during the course of this symposium there were several spectacular demonstrations of the long-range transport of PM, especially in some of the satellite images presented, the importance of the long-range transport of particles on regional and even inter-continental spatial scales has been appreciated at least since the 1970s. In North America, the Sulfate Regional Experiment (SURE), for example, in the late 1970s investigated the regional transport of sulfur oxides, and the meteorological conditions associated with elevated sulfate concentrations, and demonstrated that transport of PM and its precursors can occur over distances beyond 300-600 km. Even in the supposedly "background" northernmost North American observatory for the systematic measurement of atmospheric constituents at Alert, only 800 km from the North Pole, Environment Canada scientists have observed wintertime average sulfate levels comparable to those in industrialized southern Ontario, due to the incursion of polluted air masses from Siberia. So in a certain sense, there is a "transboundary" component in almost all of the papers and data analyses presented at this conference.

In the session on Transboundary Issues, five papers were presented on modeling, measurement and data analysis activities related to transboundary transport. Several of these were studies "in progress." The paper reporting on the Big Bend Regional Aerosol and Visibility Observational Study (BRAVO) has employed various techniques including trajectory climatology, distance- and frequency-weighted analysis of sulfur dioxide emissions, use of tracers, intensive sampling of meteorology and atmospheric constituents, and mathematical modeling to assess sources on both sides of the U.S./Mexico border contributing to visibility impairment in the park.

On a larger spatial scale, the feasibility of integrating ground-based data and spaceborne images was explored in another paper. This was found to be a possible and useful approach—if not yet quantitative—due to better satellite data now available and an increase in collaborative work among investigators due to the arrival of the internet. The use of a model to examine the contribution of Canadian and U.S. sources to the deposition of lead to the Great Lakes was explored by one presenter. It was found that U.S. sources are the major contributor to lead deposition to Lakes Erie, Michigan and Superior, while Canadian sources are the major contributor to Ontario and Huron.

In the final set of papers, detailed analysis of PM measurements on a smaller scale—i.e., an example of transboundary transport in the Paso/Juarez airshed—was used to explore the contribution of various sources. So, while these papers were on different aspects of transboundary transport, and described the phenomenon on different spatial scales, they all illustrated various approaches that can be deployed for analysis of transboundary transport problems.



## **Session 10: Data Management/Quality**

Les Hook, Oak Ridge National Laboratory

Victor Gutiérrez Avedoy, INE/CENICA

Les Hook, Director NARSTO Quality Systems Science Center, started out by presenting information on the NARSTO Data and Information Sharing Tool (DIST). DIST has two main purposes. First, it facilitates the flow of data and metadata from NARSTO projects to the NARSTO Permanent Data Archive, and, second, it enables sharing of data within a project by investigators and sponsors or among projects/sites within larger programs. This can be a very efficient process using web technology, consistent metadata throughout and documented data formats.

Alan Hansen, EPRI, brought us up to date on the SEARCH program of PM monitoring sites in the Southeastern United States. Levels are very near the NAAQS standard—compliance may depend on blank corrections. With a year's worth of data now available, differences in chemical composition are emerging between rural and urban paired sites, and inland and coastal sites. There appears to be a good correlation of SO<sub>4</sub> concentration across sites separated by several hundred kilometers. SEARCH will continue monitoring activities and add some additional capabilities. The Atlanta site is also an AIRES health study site and Alan hopes to coordinate summer measurements with the EPA Supersites Program.

Maris Lusic, Environment Canada, provided an excellent summary of the NATCHEM PM Database. The team has compiled data from 18 Canadian and United States PM monitoring networks into a SAS database with consistent metadata and formats. Attention has been paid to documenting the differences among networks, for example, sampling frequency, blank correction, and size cuts. Data are available by request from their website. NATCHEM and NARSTO data management staff have been leveraging our resources to the benefit of both programs. Both NATCHEM and NARSTO use the same Data Exchange Standard format for submission of data. Consistency of metadata is also maintained.

Hampden Kuhns, Desert Research Institute, described his current work at developing a relational database for a recent PM assessment study in Idaho. He has gained valuable experience in compiling data from numerous sources into a common structure and format.

Ernesto Alemon, National Institute for Nuclear Research, Mexico, described his recent research into using neutron activation analysis (NAA) to analyze air filter samples from sites in Mexico City. He started with a concise and thorough review of the principles of NAA and his development of sample counting equipment. His results showed he was able to achieve low detection limits for many metals of environmental interest. This technique may be particularly applicable to analyzing filters samples from ambient background sites with very low metal concentrations.

## Session 11: Aerosol Satellites

David Winker, NASA

The session on aerosol satellites contained four talks that highlighted new capabilities to observe aerosols from space using instruments that have been either recently launched or are under development. Two additional talks focused on the importance of observations from ground-based networks and fusion of data from multiple satellites with surface observations. From these new instruments and new techniques, the first three-dimensional view of the global aerosol will be derived over the next few years.

A 20-year climatology of aerosols over the oceans has been produced using one or two spectral channels of the AVHRR instrument. Two instruments providing improved aerosol measurements were launched in December 1999 on the NASA Terra satellite. The MODIS instrument will use 7 spectral channels for aerosol observations. The MISR instrument has 4 spectral channels at each of 9 different view angles. Both instruments are calibrated much more accurately than previous satellites used for aerosol observations. The improved measurement capabilities of these two instruments provides a capability to measure aerosol optical depth over land—except over bright surfaces such as snow and deserts—and to derive information on aerosol size. The multi-angle data from MISR allows classification of aerosol absorption and sphericity as well as size.

Lidar has a number of unique capabilities, including the capability to observe the vertical distribution of aerosol and to observing aerosol over all surface types, beneath thin clouds, and at night. The LITE experiment flew on the space shuttle in 1994 and demonstrated the feasibility of space lidar. The PICASSO-CENA satellite includes a three-channel lidar as well as visible and infrared imagers. PICASSO-CENA will fly in a polar orbit in formation with the NASA Aqua satellite and is planned for a three-year mission beginning in 2003. The three channels of the PICASSO-CENA lidar allow a vertically resolved classification of aerosol size and identification of non-spherical aerosol particles. One talk used LITE data to illustrate that data from satellite lidar can be used to estimate sulfate source strength. One feature of all the satellite instruments was the ability to observe aerosol transport on regional to global scales.

One talk focused on the need for surface observations, but this was a theme common to all the talks. Measurements from surface instruments are necessary for validation of satellite observations as well as to provide information that cannot be remotely sensed, such as chemical speciation. Existing sites operated by the WMO Global Atmospheric Watch program and by the Aeronet program provide some of these measurements, but there is a need for more sites and additional measurements at each site. Finally, one talk focused on the benefits to be gained by merging data from different satellites and merging satellite observations with ground observations. This will be necessary to gain the full benefit of the existing observations, but will require the development of new analysis techniques, including the development of 4D assimilation techniques for regional and global chemical transport models.

## Session 12: Particle Emission/Formation

Francisca Aldape, Instituto Nacional Investigaciones Nucleares

Jeff Gaffney, Argonne National Laboratory

The particle production from OH radical reactions with toluene was studied in an 8 cubic meter teflon chamber. Production of new particles was observed, followed by particle growth. Using the size distributions of the particles formed, the yield was examined. The yield was found to depend on mass and particle number, where the dependence on total particle mass was consistent with current partitioning theory. The vapor pressure of the condensibles was estimated to be  $10^{-8}$  –  $10^{-9}$  atm.

A new instrument for particle chemical analysis has been recently developed as a part of a research program focusing on studies of the chemistry of gas-to-particle conversion. The operation of this instrument, called thermal desorption particle beam mass spectrometer (TDPBMS), was described. Results from recent applications for real-time TDPBMS and TPTD to studies of the chemistry of secondary aerosol formation were presented. The results provided new insights into the products and mechanisms of secondary organic aerosol formation and in some cases results differed dramatically from those obtained using traditional GCMS techniques for organic aerosol analysis.

Smog chamber studies were conducted to identify the OH oxidation products of naphthalenes in a controlled atmosphere. The compounds (nitro and hydroxynitro) found in the gas phase and on the filters suggested that there is significant gas-to-particle conversion occurring during the chamber reaction. The novel methods used to study the reactions in the smog chamber were described, the results of the experiments to determine the identity of the products of the reactions were presented, and the partitioning of the products between gaseous and particulate phases was discussed.

The effects of the SO<sub>2</sub> emissions reductions on plume gas and particle species were assessed by comparing the results of plume measurements in 1978 with those of 1998 and 1999, in the TVA CUMBERLAND power plant in central Tennessee. The upper limits for the rate of the SO<sub>2</sub> oxidation in the 1978, 1998 and 1999 plumes were estimated using the particle size distribution. The results suggested that particle formation was more rapid near the outer edge than in the center of the plume. Also, the SO<sub>2</sub> oxidation rates before and after the SO<sub>2</sub> emission reduction were similar.

A Mexico City Metropolitan Zone ammonia emissions inventory was estimated with an uncertainty of 59%, very similar to the uncertainty obtained in the United Kingdom. It was estimated that human activities together with associated domestic animals accounted for 75% of ammonia emissions. The contribution of these and some additional sources, which had been ignored in most countries, were presented.

Sulfur compounds have shown anomalies that have drawn the authors' attention. Investigation of CASTNET data revealed that the relationship between airborne SO<sub>2</sub> and aerosol sulphate is non-linear. Examples were presented to illustrate the difficulties involved in developing spatial maps of trends in acid deposition rates in the presence of both natural variability and temporal/spatial inhomogeneities in the concentration rates. Of concern is the fact that while the atmospheric sulfur cycle is well understood, further investigation is needed before credible control strategies can be developed.

Emission inventories for  $PM_{10}$  and  $PM_{2.5}$  were constructed for Ontario for 1995. These inventories represent a significant advance over preliminary inventories developed for 1990, but substantial uncertainty was still attached to estimate for some source types. Total  $PM_{10}$  and  $PM_{2.5}$  emissions are comparable to those from neighboring American States.

## Session 13: Field Studies

Marc Pitchford, NOAA

From Mexico City we moved north to Corpus Christi, Texas, and heard about PM mass and chemistry as well as ozone from data collected at an urban site in 1998 and 1999. Values tend to be rather low for PM and O<sub>3</sub> except for May 1998 and to a lesser degree May 1999 when fire impacts from Mexico and elsewhere increased PM<sub>2.5</sub> to >100NG/M<sup>3</sup>. Ozone also increased at the leading edge of the plume.

From Texas we moved to Fresno, California, to hear an overview of the PM Super Site monitoring that started there last year. High time-, space-, size- and composition resolution monitoring is the hallmark of this program. The objective is to evaluate advanced methods, gather sophisticated data for use in health studies and to better understand atmospheric processes.

Then we moved further north to Ontario where we heard about PM<sub>2.5</sub> and PM<sub>10</sub> mass and concentration from about 20 sites throughout the province. Highest PM levels were at Windsor and Hamilton, which exceed the 50 NG/M<sup>3</sup> level fairly often for PM<sub>10</sub> and the 30 NG/M<sup>3</sup> level for PM<sub>2.5</sub>. Transport from the U.S. probably caused Windsor's values while at Hamilton it was local.

Then we were taken on a quick tour of Oxidant and PM measurements by DOE at a number of cities. This included Mexico City, Phoenix, and Houston. We heard about a new study being planned for Puerto Rico in about 2 years.

Finally we were taken to Philadelphia to hear about the extensive measurements by an impressive array of organizations as part of the NARSTO Northeast Oxidant & Particle Study. This ongoing study made measurements in August 1998 and during the summer of 1999. This summer they took a break from Measurements to work on data. Measurements included aircraft, tethered balloon, remote sensing and ground based monitoring of particles and gases. Lidar measurements allowed boundary layer profiles of particle scattering in 3 wavelengths as well as ozone and water vapor.

## Session 13: Field Studies – Part II

Graciela Raga, UNAM

Five papers were presented that described the results obtained during a 1-month field campaign carried out from 23/02 to 22/03 1997 in the Mexico City basin. The main objective of this joint Mexico-US project was the characterization of all aspects of particulate matter in Mexico City, including size composition and transport and evolution. The first two papers (Vega et al, Chow et al) covered the spatial and temporal characterization of  $PM_{10}$  and  $PM_{2.5}$ . The main conclusions can be summarized as follows:

- n Most sites presented the highest PM concentrations between 6am and noon.
- n  $PM_{2.5}$  constitutes between 45 and 60% of  $PM_{10}$ .
- n  $PM_{10}$  composition is dominated (70-80%) by crustal components. The 12% organic components are also crustal-ased.
- n  $PM_{2.5}$  composition is remarkably uniform throughout the city, with 25-30% of the  $PM_{2.5}$  mass composed of sulfate+nitrate and 40-50% of organic and black carbon.
- n Nitrate losses during sampling can be up to 20% for 24-hr measurements.

The paper by Watson and Chow described a methodology to estimate local, neighborhood and urban-scales effects from aethalometer-derived black carbon. The results suggest that 10% of the BC can be attributed to local sources, 30% to neighborhood scale and the rest to urban-wide sources.

The paper by Zhong and Barchet presented the results of the large meteorological component of the field project, which included 4 wind profilers. They also presented results from the modeling carried out to understand the complex basin circulations. The main results showed the prevalence of “gap” winds that cool the lower levels of the atmosphere. Re-circulation of pollutants during the day is a possibility from lagrangian model results, while multi-day accumulation is not significant in Mexico City.

The last paper (Sosa et al) discussed the chemical composition of particles to determine the sensitivity of  $PM_{2.5}$  to different species. Results suggest that reducing ammonia would not lead to substantial reduction of  $PM_{2.5}$  mass.

## Session 14 – Visibility

Jim Meagher, NOAA

Bill Malm, NPS

Bill Malm provided an update on spatial and temporal trends of visibility in the United States using data from the IMPROVE network.

- Spatial sulfates and organics are highest in the East and make up about 65% and 20-30% of PM respectively.
- Inner Mt West has lowest fine mass loadings and carbon is the largest fraction of fine mass (40-50%).
- Nitrates are 30-40% of PM in Southern California.

### Trends

- Sulfates are decreasing in most of the U.S. except New Mexico, Texas, and Southern Colorado and the Great Smokies.
- Large decrease in nitrates in coastal areas of California, Oregon and Washington.
- Nitrates are up in the same areas as sulfates.
- Organic decrease in all areas of U.S. except inner mountain regions of the West, where they are increasing (smoke).

Sylvia Eidels-Dubovoi described the results of a visibility study conducted in the Mexico City basin during February/March of 1997. Dr. Eidels-Dubovoi compared high absorption and scattering measurement at two sites: one located within the Mexico City metro area and one in the suburbs. On average, the more rural site (Pedregal) experienced higher visibility with a higher concentration of total extinction for aerosol absorption relative to the urban site (Merced). The diurnal pattern in light extinction was often characterized by an early morning peak associated with primary black carbon emissions and a later peak that was attributed to secondary aerosols.

Mark Green from DRI shared some preliminary aerosol characterization and modeling results from the Bravo study. This study was centered in the Big Bend area of Texas and designed to help understand the transport of visibility-reducing particles in the region and their sources. The study included a number of highly instrumented monitoring sites, wind profiles, and tracer releases from sources in Texas and the Eagle Pass area near two large coal-fired power plants in Northern Mexico. Mark shared results from Hysplit trajectory analyses and dispersion modeling for seven episodes during the summer and fall of 1999. Future plans call for MM-5 and full MODELS3 simulation of the same episodes.

Dr. J. Husar from Washington University discussed regional aerosol patterns over southern North America and Central America. Dr. Husar used a combination of satellite and ground-based observations to characterize spatial and temporal trends in aerosol extinction and offered the following observations.

### **Aerosol levels in North America are low compared to the rest of the World.**

Aerosol levels in the eastern U.S. are highest in the summer and have been declining since 1980. Central America exhibits a consistent spring peak in aerosol levels. Forest fires and biomass burning are significant contributors to aerosol levels in Central America and the smoke from these fires can be transported long distances such as in 1998 when smoke from Central American fires was seen to be transported across Mexico, the U.S. and Canada.

## Session 15 – Motor Vehicle Emissions

Steve Cadle, GM

Marisa Ruiz, IMP

Several studies have been conducted on in-use, light-duty gasoline and diesel on-road vehicles in the United States. These studies have shown that modern gasoline vehicles emit approximately 1 mg/mi exhaust PM. On the other hand, there still exists a small population of gasoline vehicles that emit visible smoke. These vehicles have average PM emission rates of 500 mg/mi. When a broad spectrum of on-road vehicles was tested, it was found that the current light-duty fleet average PM emission rate is approximately 30 mg/mi. This is much higher than the 13 mg/mi predicted by PART5, the U.S. mobile source PM emission factor model. In addition, it is found that most of the PM is carbonaceous matter, whereas PART5 predicts that a significant amount of the mass is due to sulfuric acid and the associated water. PM chemical composition data collected during these studies has been used to create source profiles. Recently, a study was also conducted on light-duty automotive brake wear PM emissions using a dynamometer. Engineering estimates of vehicle brake wear emission rates were similar to the PART5 PM<sub>10</sub> emission rate of 13 mg/mi.

Very stringent PM and NO<sub>x</sub> emission regulations have been promulgated in the United States and Europe for both on-road heavy-duty and light-duty diesel vehicles. It will not be possible to meet these regulations without the development of exhaust aftertreatment devices. Currently, research is ongoing in four areas: PM traps (which frequently are catalyzed), diesel oxidation catalysts, NO<sub>x</sub> absorber traps, and selective catalytic reduction (SCR) (which involves the injection of urea into the exhaust). The first three approaches are impacted by fuel sulfur content. Recently, the DECSE (Diesel Emission Control–Sulfur Effects) program examined the impact of fuel sulfur on these technologies. It was found that fuel sulfur has two effects. First, it lowers the efficiency of devices such as catalyzed particle traps and NO<sub>x</sub> absorbers. Second, the active catalysts necessary in these devices oxidize some of the fuel sulfur to sulfuric acid, resulting in increased PM emission. In some cases the PM emissions can exceed those from the engine without any aftertreatment. Overall, it was concluded that a diesel fuel sulfur content of not more than 30 ppm will be required to enable these devices.

Measuring PM exhaust emissions is a deceptively difficult task, especially at the very low levels for current gasoline engines and future diesel engines. This is due, in part, to the semi-volatile nature of the organic carbon, which can be a significant fraction of the PM mass. With semi-volatile material present, the formation of particles in the diluted exhaust stream can be very sensitive to factors such as dilution ratio, dilution rate, and temperature. Confounding the measurement further is the fact that some of the semi-volatiles are deposited in sample transfer lines and the dilution tunnel under one set of conditions, and then released under other conditions. These processes are most troublesome when making particle number measurements. The result has been considerable uncertainty over the issue of nanoparticle emissions from vehicles. A study has recently been done in which particle number emission rates were determined for a limited set of vehicles using the standard dilution tunnel method, a tailpipe ejector diluter, and by monitoring the impact of the vehicle on the ambient PM concentration in a wind tunnel. While the traditional dilution tunnel methods showed significant nanoparticle emissions, they were not present with the other two techniques, leading to the conclusion that properly functioning, newer vehicles don't have significant nanoparticle emissions.



The possibility of modifying gasoline and diesel fuel properties by adding very small quantities of high molecular weight polymers was discussed. It was noted that polymer addition can have a dramatic effect on particle size from a fuel injector and can affect the way those droplets evaporate. Data was presented that showed that polymer addition can reduce both in-cylinder and exhaust temperatures, thereby reducing emission rates and enhancing performance, at least during steady-state operation. Very high fuel economy gains were also determined for two vehicles operated repeatedly on the road over a set course.

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