
The State of the Southern Oxidants Study (SOS) Policy Relevant Findings in Ozone and $PM_{2.5}$ Pollution Research 1995-2003

Edited by:

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On Behalf of the **SOS Science Team**
(See Table 1.1. on page 6 and Appendix B of this report)

Disclaimer

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Table 1.1 on page 6 lists the 41 research universities and 42 government and private sector organizations that participated in SOS. Approximate total amounts of financial and in-kind support varied between about $15 and about $19 million per year during 1999-2003. The approximate distribution of support among SOS' principal sponsoring organizations is summarized on pages 23 and 24 of this report.

The principal institutions and investigators in SOS are listed in Appendix B.

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1. OVERVIEW OF SOS

During the 15 years since 1988, the Southern Oxidants Study (SOS) has become an important source of policy-relevant findings in ozone pollution and particulate matter research. Results achieved mainly during 1995-2003 include the following:

> 1. SOS OVERVIEW
>
> - SOS developed a new paradigm for cooperative research on oxidants, and evolved to include $PM_{2.5}$
> - SOS research elements include:
>   - Rural field measurement networks
>   - Intensive urban field measurement campaigns
>   - Several SOS and SOS-affiliated ozone and $PM_{2.5}$ characterization studies
> - SOS participants number nearly 500 individuals in more than 80 organizations
> - Total investments in SOS and SOS-related activities are about $15-19 million per year

1. Confirmed several of the reasons why the NRC (1991) report concluded that ozone management efforts in the United States "largely have failed:" need for more robust air quality standards, regionality of ozone and particulate matter pollution, importance of biogenic precursors of ozone and $PM_{2.5}$, inadequate NO_y measurement instruments, need for improved emissions inventories and air quality models, etc.
2. Further quantified the importance of biogenic and other natural emissions in the formation and accumulation of ozone and $PM_{2.5}$ in the SOS region – including isoprene from trees, ammonia from animal agriculture, and NO_x from well-fertilized soils and lightning as well as combustion of fossil fuels.
3. Improved current understanding of urban/rural exchange of ozone and $PM_{2.5}$ and their precursor chemical constituents.
4. Developed and used superior instruments to better characterize the pollution climate of the SOS region – both chemically and meteorologically – and used this knowledge to improve prognostic air-quality models for both ozone and $PM_{2.5}$.
5. Developed and used observation-based methods to evaluate and improve emissions inventories and improve the performance of emissions-based air-quality models.
6. Improved present understanding of vertical, horizontal, daytime, and nocturnal interactions among urban plumes, power plant and industrial plumes, and both natural and mobile sources of precursors in determining rural, urban, and regional ozone and $PM_{2.5}$ exposures under a wide variety of meteorological conditions and in regions with distinctive patterns of land use and industrial development including – both inland and coastal urban/regional environments.
7. Evaluated a wide variety of measurement instruments and approaches for characterizing $PM_{2.5}$ in both rural and urban areas throughout the SOS region and understanding some features of these exposures that are relevant to human health, agricultural and forest productivity, and global climate change.
8. Participation of SOS scientists in the ozone and $PM_{2.5}$ assessment activities of NARSTO. Nineteen SOS scientists served as senior authors or co-authors for nine of the Critical Review Papers in the NARSTO ozone assessment; 58 of 195 scientific papers cited were prepared by SOS scientists. Also, several SOS scientists contributed to the NARSTO PM assessment.

KEY CITATIONS:

See page 7

1.1. HISTORICAL BACKGROUND AND EVOLUTION OF SOS

Before SOS was initiated in 1988, one of the most poorly characterized regions of high tropospheric ozone, $PM_{2.5}$, and regional haze concentrations in North America was the ten-state area of the southeastern United States. This broad territory extends more than 2500 km west from the Atlantic Ocean and about 1000 km north from the Gulf of Mexico. It includes three physiographically distinct geographical areas: 1) the low-lying (0 to about 200 meters above sea level), relatively flat, 100-200 km wide Coastal Plain areas of North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas; 2) the hilly Piedmont regions (200-500 meters above sea level) within the states of North and South Carolina, Georgia, Alabama, Mississippi, Louisiana, Texas, Kentucky and Tennessee; and 3) the high-elevation Appalachian Mountain and Cumberland Plateau regions (500-2000 meters above sea level) within the states of North and South Carolina, Georgia, Alabama, Mississippi, Kentucky and Tennessee.

About 26% of the total US population (approximately 75 million people) live and work within the boundaries of the SOS measurement and modeling domain, which covers about 1.2 million km^2. The Coastal Plain and Piedmont portions of the SOS study region are sub-tropical in climate, with warm, humid summers, and extended periods of intense sunshine. The highest-elevation plateau and mountain portions of the SOS study domain are nearly boreal in general climate with cool summers and a high frequency of clouds. Rural parts of the SOS region are dominated by intensively managed commercial hardwood and pine forests and both crop and rapidly increasing animal agriculture.

Although still lagging economically behind some other parts of the United States and southeastern Canada, the SOS study region has been expanding very rapidly in both human population and manufacturing-based and service-based economic activity, especially during the past 35 years. This combination of rapid urban, suburban, industrial, commercial, transportation, and tourism growth, and further intensification of agricultural and forest operations, has resulted in substantial increases in and concern about ozone and $PM_{2.5}$ concentrations and precursor emissions in large parts of the SOS region (NC, SC, GA, FL, AL, MS, LA, TX, TN, KY).

1.1.1 Meteorology and Climate of the SOS Region

The SOS region has generally weak summertime winds compared with the northeastern and most of the midwestern parts of the US and southeastern Canada. In fact, the maximum frequency of air stagnation days for the North American continent is centered over the Great Smoky Mountain National Park on the border between North Carolina and Tennessee. This combination of weak winds and moderate mixing heights make the SOS region generally less well ventilated than most other parts of North America. As a result of these unique climatological, meteorological, geographical, biological, land-use, population-growth, industrial-development, and chemical-emissions factors, 31 of the 96 (32%) ozone non-attainment counties in the United States are located in the 10-state SOS study domain using the 1-hour standard and ~130-150 of the 453 (30%) counties using the 8-hour standard.

With the notable exception of the Houston/Galveston coastal areas of Texas, peak ozone concentrations in most of the SOS region are generally somewhat lower (125-175 ppb) than in the northeastern or midwestern United States (150-200 ppb); average summertime ozone concentrations are generally higher – 50-80 ppb compared to 40-70 ppb, respectively. Also, the SOS region tends to have higher rural/regional background concentrations of ozone than northeastern and midwestern parts of the US. In fact, peak ozone concentrations in the Gulf Coast region of Texas now are generally higher than in southern California, and both $PM_{2.5}$ and regional haze concentrations in western North Carolina and eastern Tennessee are among the highest in the nation as a whole (EPA, 2001). Also, the metropolitan areas of both Atlanta and Houston have among the highest per capita daily distances of vehicle traffic in the US.

1.1.2 Origin of SOS

These unique pollution climate characteristics of the SOS region led Dr. C. S. Kiang of Georgia Tech and others elsewhere to postulate in the early 1980s that air quality management approaches developed in other parts of the United States may not be appropriate for the southeastern part of the US. To address these concerns, a *Workshop on Atmospheric Photochemical Oxidants: A Southern Perspective* was held on the campus of Georgia Tech in June 1988. At the conclusion of this workshop, recommendations were formulated for a coordinated, long-term cooperative research program focusing on the formation, accumulation, and management of photochemical oxidants in the South (Rodgers and Chameides, 1988).

At about this same time, three other landmark publications altered conventional wisdom about the scientific underpinnings of ozone management in the United States: 1) Chameides et al.'s (1988) paper on "*The Role of Biogenic Hydrocarbons in Urban Photochemical Smog: Atlanta as a Case Study;*" Milton Russell's (1988) paper, "*Ozone Pollution: The Hard Choices*;" and 3) the National Research Council (1991) report, "*Rethinking the Ozone Problem in Regional and Urban Air Pollution*." The major conclusions from these publications were that the United States' ozone management approaches "largely have failed."

Stimulated and encouraged by these highly critical perspectives, nearly 200 of the nation's most able air-quality scientists and engineers and a few from abroad joined the SOS research program from more than a dozen universities and 35 industrial, state, federal, and public interest groups. They were convinced that "rethinking" the ozone problem was indeed essential, that a "new paradigm for air-quality research" was needed, and that the southern US should be used as a "natural laboratory" in which to "test essentially every assumption that has undergirded ozone management approaches since 1970." Thus, the SOS Science Team is systematically pursuing the 18 policy-relevant issues shown in Figure 1.1, especially as they pertain to ozone, but also to the public-health and regional-haze problems caused by high ambient concentrations of PM.

During 1995-1997, and especially after the transition from an ozone-only to an "ozone-and-$PM_{2.5}$" program in 1998 and the addition of the Southern Company's and EPRI's regionally focused Southeastern Aerosol Characterization study (SEARCH) and epidemiologically focused Aerosol Research Epidemiological Study (ARIES), and the Texas 2000 Air Quality Study (TexAQS 2000), the number of scientists, engineers, and graduate and postdoctoral students increased to almost 500 persons (see Appendix B) in more than 80 institutions and organizations (see Table 1.1).

With these 18 policy assumptions in mind, it soon became apparent that attempts to decrease ozone and $PM_{2.5}$ exposures and their effects on public health, ecosystems, and regional haze in various parts of the US are confounded by a number of critical factors, including:

1. Almost complete ignorance among public health scientists about what specific features of $PM_{2.5}$ and their physiological mechanisms of action determine their effects on the respiratory and cardiovascular systems of humans.

**SOS SYSTEMATICALLYPURSUES SCIENTIFIC ISSUES
RELATED TO OZONE and $PM_{2.5}$ POLICY ASSUMPTIONS**

Issues Related to Assumptions about Regulatory Strategies

1) Advantages and limitations of alternative forms of the primary (public health based) and secondary (public welfare based) National Ambient Air Quality Standards

2 Veracity of the twin concepts of State Implementation Plans and Attainment Counties and Non-Attainment Counties

3) Veracity of the concept of "attainment demonstrations" based on mathematical modeling of a limited number of "exceedance events" under extreme weather conditions

4) Needs for regionally focused as well as locally focused management strategies and tactics

5) Needs to distinguish among "NO_x-sensitive," "VOC-sensitive," and "transitional" regimes

Issues Related to Assumptions about the Adequacy of Emissions Inventories and Models

6) Importance of both natural and human sources of ozone and $PM_{2.5}$ precursors

7) Need for improvement of mathematical models for estimation of NO_x, VOC, CO, CH_4, SO_2 and NH_3 emissions from biogenic and other natural sources and from point, area, and mobile human sources

Issues Related to Assumptions about Traditional and Innovative Ways of Thinking about Ozone and $PM_{2.5}$

8) Need for careful thinking about long-term climatological trends and season-long exposures as well as short-term meteorological episodes and weekday and weekend day exposures

9) Need for stochastic as well as deterministic chemical and meteorological thinking

Issues Related to Assumptions about Air Quality Models

10) Complementarity of observation-based as well as emissions-based air-quality models

11) Needs for improvement of regional-scale and urban-scale air-quality models

12) Needs for both long-term (seasonal) as well as short-term (episodic) air-quality models

Issues Related to Assumptions about Implementation of Ozone Abatement and Mitigation Programs

13) Adequacy of commercially available instrumentation for monitoring of ozone, NO_x, speciation of NO_y, NH_3, and speciation of VOC (especially volatile aldehydes, alcohols, acids, esters, and hydrocarbons with more than 10 carbon atoms)

14) Adequacy of guidance for development of emissions inventories

15) Effectiveness of regulatory practices that distinguish "reactive" from "negligibly reactive" VOCs and then exclude "negligibly reactive" VOCs from ozone and $PM_{2.5}$ precursor inventory requirements

16) Adequacy of guidance for development of State Implementation Plans

17) Reliability of predictions for public health advisories for ozone, $PM_{2.5}$, and regional haze

18) Adequacy of planning for public education and both public and commercial acceptance and expected costs of alternative management strategies and mitigation options

Figure 1.1. SOS scientists and engineers have pursued a variety of policy-relevant scientific issues – by systematically questioning essentially every assumption that undergirds ozone- and PM-management approaches used in the US since the early 1970s.

Table 1.1. Organizations that participate in the Southern Oxidants Study (SOS).

Research Universities	Government and Private Sector Organizations
Baylor University	Aerodyne Research, Inc.
Boston College	Aerosol Dynamics, Inc.
Brigham Young University	Atmosphere Research and Analysis, Inc.
Clarkson University	Environ Corporation
Clemson University	Environment Canada
Colorado State University	EPRI
Duke University	Mantech Environmental Technology
Emory University	NARSTO
Georgia Institute of Technology	NASA Marshall Space Flight Center
Harvard University	NASA Goddard Space Flight Center
Mercer University	NASA Jet Propulsion Laboratory
North Carolina State University	National Center for Atmospheric Research
Ohio University	National Research Council of Canada
Oregon Graduate Institute	National Inst. for Environmental Studies
Pennsylvania State University	National Inst. of Standards and Technology
Purdue University	NOAA Aeronomy Laboratory
Rice University	NOAA Environmental Technology Lab.
South Dakota School Mines & Technology	NOAA Air Resources Laboratory
Texas A & M University	NOAA Forecast Systems Laboratory
Univ. of Agric. Sciences, Vienna, Austria	Netherlands Energy Research Center
University of Alabama in Huntsville	Research Triangle Institute
University of California at Berkeley	Southern Company
University of California at Los Angeles	State of North Carolina
University of California at Riverside	State of Georgia
University of California at San Diego	Tennessee Valley Authority
University of Colorado	Texas Hazardous Waste Center
University of Delaware	Texas Nat. Res. Conservation Commission
University of Denver	URS Corporation
Univ. of Heidelberg, Heidelberg, Germany	U.S. Department of Commerce
University of Houston-Clear Lake	USDOE Pacific Northwest National Lab.
University of Innsbruck, Innsbruck, Austria	USDOE Brookhaven National Laboratory
University of Maryland	USDOE Fed. Energy Technology Center
University of Miami	USDOE Lawrence Berkeley National Lab.
University of Michigan	USEPA National Exposure Research Lab.
University of Minnesota	USDOE Oak Ridge National Laboratory
University of Tennessee	USEPA Nat. Health & Env. Research Lab.
University of Texas at Austin	USEPA National Risk Man. Res. Lab.
University of Washington	USEPA National Center for Env. Research
Washington State University	USEPA Nat. Center for Env. Assessment
Western Michigan University	USEPA Off. Air Quality Plan. & Standards
York Univ. North York, Ontario, Canada	USEPA Region 4, Atlanta, Georgia
	USEPA Region 6, Dallas, Texas

2. Non-linearities and complexities in the photochemical reactions that lead to formation and accumulation of ozone and $PM_{2.5}$ and that can render ineffective some management strategies that are VOC-based, NO_x-based, SO_2-based, or NH_3-based unless these non-linearities and complexities, and their variations from location to location, are well understood.

3. Long-range transport of ozone and $PM_{2.5}$ and their respective precursor chemicals that can overwhelm local efforts to decrease emissions of ozone and $PM_{2.5}$ precursors.

4. The strong influence of seasonal and both day-time and night-time meteorological processes on the severity and frequency of ozone and PM pollution episodes, which can confound trend analyses and mask both local and regional pollution-management efforts and/or their apparent success or lack of effectiveness.

5. Large and continuing uncertainties associated with emissions inventories and lack of ambient exposure data documenting the actual impact that management efforts and regulations have on these emissions and the public health, regional haze, or other air-quality related values that are to be protected.

6. Lack of reliable methods and dependable instrumentation for routine measurements of: a) speciation of VOC and NO_y, b) concentrations of NO_x and NH_3, and c) such meteorological factors as mixing height, and wind speed and direction, at various altitudes.

7. Lack of seasonal air-quality models and exposure standards that will support or encourage management approaches designed to "avoid a bad summer" rather than "a bad few-day episode."

8. Lack of comprehensive chemical, meteorological, and climatological data sets with which to test both numerical and conceptual models of urban and regional scale ozone, $PM_{2.5}$, and regional haze formation and accumulation processes.

KEY CITATIONS:

Chameides, W.L., R.W. Lindsay, J. Richardson, and C.S. Kiang. 1988. The role of biogenic hydrocarbons in urban photochemical smog: Atlanta as a case study. *Science* 241:1473-1475.

EPA. 2001. Latest Findings on National Air Quality: 2001 Status and Trends. http://www.epa.gov/airtrends/.

NARSTO. 2000. An Assessment of Tropospheric Ozone Pollution: A North American Perspective. NARSTO Management Office (Envair), Pasco, WA. http://www.cgenv.com/Narsto.

NARSTO. 2003. Particulate Matter Science for Policy Makers: A NARSTO Assessment. NARSTO Management Office (Envair), Pasco, WA. http://www.cgenv.com/Narsto.

NRC (National Research Council). 1991. Rethinking the Ozone Problem in Regional and Urban Air Pollution. National Academy Press. 489 pp.

Rodgers, M.O. and W.L. Chameides. 1988. Atmospheric Photochemical Oxidants: A Southern Perspective. Workshop Report. Georgia Institute of Technology, School of Earth and Atmospheric Sciences, Atlanta, GA. 33 pp.

Russell, M. 1988. Ozone pollution: The hard choices. *Science* 241:1275-1276.

1.1.3 Development of the SOS Research Paradigm

With these and other critical uncertainties in mind, the SOS Science Team developed and has continued to evolve a "new paradigm for air-quality research." It follows many of the NRC (1991) recommendations for a long-term “coherent and focused study of tropospheric ozone and related aspects of air quality.”

Since its conception during the 1988 Workshop, SOS has developed and evolved as a ***long-term, cooperative, regionally focused***, air quality ***research and assessment program***. SOS is ***implemented through a unique voluntary alliance of research universities, federal research and regulatory agencies, private sector research organizations, and regional and state air-quality management organizations***. The program is guided by a philosophy that all ***stakeholders in the rural and urban tropospheric ozone and $PM_{2.5}$ issues*** are ***welcome to participate*** and contribute to the maximum extent of their interest and ability.

This unique, university-led, collaborative alliance of nearly 500 individual investigators (see Appendix B) has enjoyed 15 years of sustained financial and in-kind support from various parts of EPA, NOAA, DOE, TVA, EPRI, and the Southern Company. Periodic financial and in-kind contributions also have been provided by the 10 states of the SOS region – Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas – and by EPA Regions 4 and 6. In addition, matching funds have been provided by more than three dozen research universities. Federal, state, industrial, and university investments in SOS research totaled about $6 million per year from 1990-1995. As outlined more thoroughly in Section 1.7, however, since 1995, total investments in SOS and SOS-affiliated research have increased from a minimum of about $15 million to a maximum of nearly $19 million per year.

The SOS paradigm is based on the following major principles and associated research approaches.

1. Ozone, regional haze, and $PM_{2.5}$ involve many of the same photochemical formation and accumulation processes and many of the same chemical precursors – NO_x, VOC, CO, and CH_4 in the case of ozone and NO_x, VOC, CO, CH_4, SO_2, and NH_3 in the case of $PM_{2.5}$ and regional haze. Thus pollutant management approaches that consider these similarities and overlaps are likely to be more efficient and cost-effective in decreasing ozone and $PM_{2.5}$ exposures than approaches that consider only one pollutant at a time.
2. Ozone, regional haze, and some fractions of $PM_{2.5}$ all are secondary pollutants that are so fundamentally regional in sources of precursors and geographical scope that regional-scale measurements of all three pollutants and their several precursors are essential to understand both their causes and their cost-effective management.

3. Biogenic and other natural sources of isoprene and oxygenated VOCs, NO_x from well-fertilized crop lands and lightning, and NH_3, especially from confined animal feeding operations, are so abundant in the SOS regions, and so reactive or important, that they must be quantified.
4. Observation-based strategies, tactics, and models are essential to efficient and cost-effective management of ozone, $PM_{2.5}$, and regional haze. This is true fundamentally because it is the chemical precursors *actually present* and the meteorological processes *actually occurring in the atmosphere* that lead to formation and accumulation of these pollutants. For this reason, to the maximum extent possible, decisions about efficient and cost-effective management tactics and strategies should be based on *direct measurements in the atmosphere*. Managers can no longer depend on estimates of amounts of precursors *believed to be present* on the basis of inadequate emissions inventories, or use of "typical summer day" representations of the chemistry and/or meteorology during any given pollutant episode or seasonal period of exposure.
5. Rural/urban and urban plume/point source plume interactions must be elucidated and must include not only nearby regional background sources (100-500 km) but also at least periodic/seasonal (500-1,000 km) sources such as industrial regions in the eastern or midwestern US, and at least occasional far distant (1,000-10,000 km) sources such as wild fires in the western US, Canada, and Mexico, and wind-blown dust from the Sahara in Africa.
6. Seasonal models, seasonal ambient air-quality standards, and direct measurement of public health, ecological impacts, and visibility impairment outcomes may help increase the efficiency and cost-effectiveness of air-quality management approaches.
7. Independent analytical approaches that support robust scientific conclusions and explicit analysis of air quality management implications of these scientific findings must be carefully formulated and communicated to users. For these purposes, many SOS scientists use the *Guidelines for Formulation of Statements of Scientific Findings to be Used for Policy Purposes* developed by the NAPAP Oversight Review Board (NAPAP, 1991). These Guidelines are reprinted on page 10 of this report.

KEY CITATIONS:

NRC (National Research Council). 1991. Rethinking the Ozone Problem in Regional and Urban Air Pollution. National Academy Press. 489 pp.

NAPAP (National Acid Precipitation Assessment Program). 1991. The Experience and Legacy of NAPAP. Report of the Oversight Review Board of the National Acid Precipitation Assessment Program. NAPAP, Washington, DC.

GUIDELINES FOR THE FORMULATION OF SCIENTIFIC FINDINGS TO BE USED FOR POLICY PURPOSES

The following guidelines in the form of checklist questions were developed by the NAPAP Oversight Review Board to assist scientists in formulating presentations of research results to be used in policy decision processes.

1) **IS THE STATEMENT SOUND?** Have the central issues been clearly identified? Does each statement contain the distilled essence of present scientific and technical understanding of the phenomenon or process to which it applies? Is the statement consistent with all relevant evidence-evidence developed either through NAPAP [or SOS] research or through analysis of research conducted outside of NAPAP [or SOS]? Is the statement contradicted by any important evidence developed through research inside or outside of NAPAP [or SOS]? Have apparent contradictions or interpretations of available evidence been considered in formulating the statement of principal findings?

2) **IS THE STATEMENT DIRECTIONAL AND, WHERE APPROPRIATE, QUANTITATIVE?** Does the statement correctly quantify both the direction and magnitude of trends and relationships in the phenomenon or process to which the statement is relevant? When possible, is a range of uncertainty given for each quantitative result? Have various sources of uncertainty been identified and quantified, for example, does the statement include or acknowledge errors in actual measurements, standard errors of estimate, possible biases in the availability of data, extrapolation of results beyond the mathematical, geographical, or temporal relevancy of available information, etc. In short, are there numbers in the statement? Are the numbers correct? Are the numbers relevant to the general meaning of the statement?

3) **IS THE DEGREE OF CERTAINTY OR UNCERTAINTY OF THE STATEMENT INDICATED CLEARLY?** Have appropriate statistical tests been applied to the data used in drawing the conclusion set forth in the statement? If the statement is based on a mathematical or novel conceptual model, has the model or concept been validated? Does the statement describe the model or concept on which it is based and the degree of validity of that model or concept?

4) **IS THE STATEMENT CORRECT WITHOUT QUALIFICATION?** Are there limitations of time, space, or other special circumstances in which the statement is true? If the statement is true only in some circumstances, are these limitations described adequately and briefly?

5) **IS THE STATEMENT CLEAR AND UNAMBIGUOUS?** Are the words and phrases used in the statement understandable by the decision makers of our society? Is the statement free of specialized jargon? Will too many people misunderstand its meaning?

6) **IS THE STATEMENT AS CONCISE AS IT CAN BE MADE WITHOUT RISK OF MISUNDERSTANDING?** Are there any excess words, phrases, or ideas in the statement that are not necessary to communicate the meaning of the statement? Are there so many caveats in the statement that the statement itself is trivial, confusing, or ambiguous?

7) **IS THE STATEMENT FREE OF SCIENTIFIC OR OTHER BIASES OR IMPLICATIONS OF SOCIETAL VALUE JUDGMENTS?** Is the statement free of influence by specific schools of scientific thought? Is the statement also free of words, phrases, or concepts that have political, economic, ideological, religious, moral, or other personal-, agency-, or organization-specific values, overtones, or implications? Does the choice of how the statement is expressed rather than its specific words suggest underlying biases or value judgments? Is the tone impartial and free of special pleading? If societal value judgments have been discussed, have these judgments been identified as such and described both clearly and objectively?

8) **HAVE SOCIETAL IMPLICATIONS BEEN DESCRIBED OBJECTIVELY?** Consideration of alternative courses of action and their consequences inherently involves judgments of their feasibility and the importance of effects. For this reason, it is important to ask if a reasonable range of alternative policies or courses of action have been evaluated? Have societal implications of alternative courses of action been stated in the following general form?:

   "If this [particular option] were adopted then that [particular outcome] would be expected."

9) **HAVE THE PROFESSIONAL BIASES OF AUTHORS AND REVIEWERS BEEN DESCRIBED OPENLY?** Acknowledgment of potential sources of bias is important so that readers can judge for themselves the credibility of reports and assessments.

1.1.4 Transition of SOS from an "Oxidants Only" to an "Oxidants and $PM_{2.5}$" Research and Assessment Program

During 1997, EPA promulgated two new National Ambient Air Quality Standards. The ozone standard was changed from a 1-hour standard of 120 ppb to an 8-hour standard of 80 ppb. Also, a new standard for $PM_{2.5}$ was added to the existing annual and 24-hour PM_{10} standards. During the spring of 1998, in part in response to EPA's promulgation of these two new standards, SOS began its transition from a policy-relevant research and assessment program concerned primarily with *ozone and other oxidants* into a similar program concerned with *fine particulate matter as well as ozone and other oxidants*. In making this transition, SOS retained its traditional focus on each of the several distinctive features shown in **bold type** on pages 7-8 of this report. SOS also sought to maintain its traditional preference to be "policy relevant" without becoming "policy driven." Our recent experience working with the critically severe air quality problems in the Houston/Galveston area of Texas through cooperative ties with both the Texas Natural Resource Conservation Commission (TNRCC) [recently renamed the Texas Commission on Environmental Quality (TCEQ)] and the Business Coalition on Clean Air (BCCA) in Houston – have made this traditional preference more difficult to maintain than during our earlier experiences working together with the air quality divisions of the States of Georgia and Tennessee and with EPRI and the Southern Company.

In making this transition, SOS was careful to retain its traditional focus on:

1. Regional and local sources of biogenic and anthropogenic precursor chemicals,
2. Observation-based methods for evaluation of emissions inventories,
3. Rigorous field testing of chemical and meteorological measurement methods,
4. Rural/urban exchange of both ozone and $PM_{2.5}$ and their several precursor chemicals,
5. Using a combination of aircraft-based and ground-based chemical and meteorological measurement platforms to explore urban, power plant, and industrial plumes in all of their temporal, spatial, and diurnal dimensions within the 10-state SOS region,
6. Complementary use of both observation-based and emissions-based air-quality models,
7. Retaining both a scientific and moral commitment to thorough analysis, interpretation, and publication of policy-relevant scientific findings, and, whenever possible,
8. Following up scientific publications with carefully crafted translations, packaging, and delivery of scientific findings [and policy implications of these findings] with information, graphic displays, and briefing forums that are designed to be of practical value to air-quality managers in industry, municipal, county, regional, state, and federal government organizations, and in public-interest and commercial-trade organizations.

1.1.5 SOS Participating Institutions, Investigators, and Major Stakeholders

As shown in Table 1.1 of this report, the scientists, engineers, graduate students, and postdocs who participate in SOS are drawn from more than 80 organizations and institutions across the United States. These include 41 research universities, 36 federal research or state regulatory organizations, and 6 private and industrial organizations. Appendix B lists the names and organizational affiliations of those who provide intellectual leadership and/or who accomplish the detailed research tasks of the SOS and SOS-affiliated research programs. Also included are representatives of some of the important stakeholder groups with which SOS scientists have interacted during 1995-2003.

1.1.6 Organization of the SOS Science Team and Executive Committee

Since SOS involves so many different investigators and institutions, coordination of research activities is essential. Early on, SOS's sponsors established a coordination entity – the SOS Office of the Director (SOS-OD). This headquarters office was led by C. S. Kiang of Georgia Tech from 1988-93 and Ellis Cowling of North Carolina State University since 1993. The SOS Science Team involves four specific **Taskgroups** and a six-member **Executive Committee**:

1. The **SOS Taskgroup on Measurements, Technology, and Standards (SOS-MTS)** is led by Eric Apel of the National Center for Atmospheric Research It ensures the reliability of measurement techniques and instrumentation before they are used in the field.
2. The **SOS Taskgroup on Chemical and Meteorological Measurements (SOS-CMM)** is led by James Meagher of NOAA, Peter Daum of Brookhaven National Laboratory, and Rodney Weber of Georgia Tech. It coordinates ground-based and aircraft-based chemical rural and urban meteorological measurement and monitoring activities.
3. The **SOS Taskgroup on Emissions and Effects (SOS-EE)** is led by Walter Heck and Cari Furiness of NC State University and Carlos Cardelino of Georgia Tech. Its *emissions* work focuses mainly on development of "research grade emissions inventories" for biogenic, mobile, and industrial sources. Its *effects* work focuses mainly on ecological effects, including recommendations for a secondary standard different in form from the primary standard and both ozone- and PM-effects on public health, regional haze, and global climate change.
4. The **SOS Task Group on Models and Model Evaluation (SOS-MME)** is led by Richard McNider of the University of Alabama in Huntsville. It evaluates and improves emissions-based and observation-based air-quality and emissions models. SOS-MME also pioneers development Season-Long Regional Air Quality Models such as (SMRAQ).
5. The **SOS Executive Committee (SOS-EC)** presently includes Ted Russell of Georgia Tech, James Meagher of NOAA's Aeronomy Laboratory, Peter Daum of Brookhaven National Laboratory, Richard McNider of the University of Alabama in Huntsville, David Allen of the

University of Texas, John Jansen of the Southern Company, and Ellis Cowling in the SOS Office of the Director at NC State University.

The major functions of the SOS Executive Committee are to:

a) Coordinate research approaches among SOS investigators;
b) Ensure efficient use of human, financial, and instrumentation resources – especially the "core funds" provided by EPA-NERL through its Cooperative and Interagency Agreements and additional funds provided through state and private-sector grants and contracts;
c) Encourage coordination between SOS and SOS-affiliated research and outreach activities, and
d) Facilitate contributions of SOS to NARSTO and other national and international conferences and reports.

1.1.7 Role of SOS Scientists in NARSTO and Other International Organizations and Conferences

SOS's role as a significant part of NARSTO began in 1991 shortly after publication of the National Research Council (NRC) report on *Rethinking the Ozone Problem in Regional and Urban Air Pollution*. NARSTO was created in response to the 10th and final recommendation in the "Rethinking" report. This recommendation called for creation of a "coherent and focused national program for the study of tropospheric ozone and related aspects of air quality" that "emphasizes high-quality science and is relevant to policy but not driven by policy considerations." In fact, SOS was mentioned specifically on page 11 of the Executive Summary of the "Rethinking" report as an example of the kind of regional research program that was needed on a national scale. From the beginning of the planning processes that led to signing the formal charter of NARSTO in February 1993, SOS scientists and engineers played prominent roles in the NARSTO working groups on modeling, measurements, emissions, and other topics.

During 1997-2002, NARSTO developed plans for two major Scientific Assessments – one on the tropospheric ozone problem and the other on the particulate matter issue. SOS scientists and engineers will continue in the years ahead to make important contributions to other NARSTO research-coordination, data archiving, and scientific-assessment activities.

Just as SOS found inspiration and guidance for much of its ozone-focused research in the National Research Council's 1991 "Rethinking" report, SOS also found similar inspiration and guidance for its $PM_{2.5}$ research in the National Research Council's recent reports on *Research Priorities for Airborne Particulate Matter* (NRC, 1998, 1999, 2001).

SOS scientists also participated in all six of the Joint Scientific Conferences on Air Quality Research and Policy organized under the US-Germany Environmental Agreement and several meetings of the similar US-Dutch Environmental Agreement. US participation and leadership for the US-Germany conferences is provided by Basil Dimitriades, EPA's long-standing Project Officer for SOS. These conferences are held every other year, with meetings alternating between the two countries. Meetings of the US-Dutch conferences are held similarly.

In 1999, SOS's Taskgroup Leader on Emissions and Effects, Walter Heck, organized an International Conference on *Future Directions in Air Quality Research, Policy, and Education*. Several SOS scientists and the SOS Office of the Director contributed to the planning, logistics, and editing and distribution of the conference proceedings which were published in the refereed journal *Environment International* (Heck et al., 2003).

In 1998-2003, at the request of the Dutch Ministry of the Environment, SOS's director, Ellis Cowling, joined with James Galloway of the University of Virginia in organizing the Second International Nitrogen Conference and publishing the Conference's major scientific findings and recommendations for future research on management of nitrogen in food and energy production and environmental protection. The SOS Office of the Director played a prominent role in organizing this conference and editing its major published outputs.

Many of the policy-relevant scientific findings and recommendations from these three international conferences confirm and augment those presented in this Third *State of the Southern Oxidants Report* – especially those that relate to shortcomings in emissions inventories, observation-based and emissions-based air quality modeling, and potentials for decreasing emissions of NH_x and NO_x from animal agriculture, power plants, and both industry and transportation sources (Cowling et al., 2001; Galloway et al., 2002).

KEY CITATIONS:

Cowling, E.B. et al. 2001. Summary Statement from the Second International Nitrogen Conference. Ecological Society of America, Washington, DC. 16 pp. (See also http://N2001.esa.org)

Galloway, J. et al. (eds.) 2002. Optimizing Nitrogen Management in Food and Energy Production and Environmental Change. *Ambio* 33:59-199.

Heck, W.W. et al. (eds.). 2003. Future Directions in Air Quality Research: Ecological, Atmospheric, Regulatory/Policy/Economic, and Educational Issues. *Environment International* 29(2-3):123-413.

NARSTO. 2000. An Assessment of Tropospheric Ozone Pollution: A North American Perspective. NARSTO Management Office (Envair), Pasco, WA. http://www.cgenv.com/Narsto.

NRC (National Research Council). 1998. Research Priorities for Airborne Particulate Matter. I. Immediate Priorities and a Long-Range Research Portfolio. National Academy Press, Washington, DC. 195p.

NRC (National Research Council). 1999. Research Priorities for Airborne Particulate Matter. II. Evaluating Research Progress and Updating the Portfolio. National Academy Press, Washington, DC. 111p.

NRC (National Research Council). 2001. Research Priorities for Airborne Particulate Matter. III. Early Research Progress. National Academy Press, Washington, DC. 168pp.

Schere, K.L. and G.M. Hidy (eds.). 2000. The NARSTO Ozone Assessment -- Critical Reviews. *Atmos. Environ.* 34(12-14):1853-2332.

1.2. SOS DATA, PUBLICATIONS, AND COMMUNICATIONS

1.2.1 SOS Data Archives

> 1.2. SOS Information, Data Distribution and Archiving
>
> - SOS data are maintained in publicly accessible data archives maintained by EPA and NARSTO
> - SOS publications are available from the Air-Quality Library at NCSU
> - Continuing evolution of the SOS web site
> - SOS has both data distribution and publication policies

Beginning in 1999, the SOS Science Team made the decision that data from all SOS field measurement campaigns and as many as possible of SOS-affiliated research efforts should be placed in the Permanent Data Archive established by NARSTO at the NASA Langley Research Center Distributed Active Archive Center (DAAC). These efforts are facilitated by Les Hook, Sigurd Christensen, Meng-Dawn Cheng, and Tammy Beaty of the *NARSTO Quality Systems Science Center* (QSSC) at the Oak Ridge National Laboratory (ORNL).

Data from the SOS 1995 Nashville/Middle Tennessee Ozone Study were originally archived in a database maintained by Ken Schere and Shawn Roselle at EPA's National Exposure Research Laboratory in Research Triangle Park, NC. By mutual agreement between the NARSTO QSSC and the SOS scientists who participated in both the SOS Nashville '95 Ozone and Nashville '99 Ozone and $PM_{2.5}$ Studies, several of these data sets are now accessible through the NARSTO ftp site and/or the NARSTO Permanent Data Archive at the Langley DAAC.

Data from the Atlanta Supersite Experiment were originally collected on a specialized project data system established at Georgia Tech for the convenience of all investigators involved. Thanks to the Herculean efforts of Carlos Cardelino at Georgia Tech, Jeff West and Jake Hales of NARSTO, and substantial cooperation by SOS individual investigators and personnel at the NARSTO QSSC, essentially all data from the Atlanta Supersite Experiment are now publicly available through the NARSTO Permanent Data Archive.

Data from some but not all of the myriad of investigators involved in the TexAQS 2000 study also have been placed in the NARSTO Permanent Data Archive.

Scientists and engineers in universities, and in state, county, municipal, regional, federal and industrial air-quality management organizations, can gain access to and use these publicly accessible archived SOS data sets. Please note below the SOS and SOS-related data sets that are currently available through the NARSTO QSSC and their web-accessible URLs:

SOS 1995 Nashville/Middle Tennessee Ozone Study

NARSTO QSSC FTP Site: ftp://narsto.esd.ornl.gov/pub/SOS/nash95/

SOS 1999 Nashville Ozone and PM Study

NARSTO QSSC FTP Site: ftp://narsto.esd.ornl.gov/pub/SOS/nash99/

SOS Atlanta Supersite Experiment (See EPA Supersites Atlanta)

NARSTO QSSC FTP Site: ftp://narsto.esd.ornl.gov/pub/EPA_Supersites/atlanta99

TexAQS 2000 Study (See EPA Supersites Houston)

NARSTO QSSC FTP Site: ftp://narsto.esd.ornl.gov/pub/EPA_Supersites/houston

South Carolina $PM_{2.5}$ Composition Data

NARSTO QSSC FTP Site: ftp://narsto.esd.ornl.gov/pub/SOS/sscu/

NARSTO Permanent Data Archive

http://eosweb.larc.nasa.gov/project/narsto/table_narsto.html

To assist users in deciding if a given set of archived SOS data is of interest, Guide information is provided with each data file. This separate Guide file includes SOS investigator contact information (name, phone number, E-mail address, institution affiliation, etc.) as well as statements of the purpose of the measurements made; descriptions of research project plans, measurement methods, and instruments used; quality assurance/quality control information; and (in some cases) links to publications by one or more of the investigators who provided the data set to the NARSTO QSSC. In addition, to be sure that a given data file will be of value to prospective users, documentation archived with all data files can be viewed on-line (without ordering the data) before directly downloading or ordering the data set.

Data files of interest to any user may be opened or downloaded directly from the NARSTO QSSC FTP Site. Data on the Permanent Data Archive at the Langley DAAC may be downloaded either by selecting the data set directly (using the appropriate URL) or by following links provided through the QSSC Search and Order Tool. After a simple registration step, the data may be ordered and it will be posted to an FTP site for downloading by users.

A detailed tabular report indicating the frequency of "hits" and actual downloading of SOS data by users is made each calendar year by the QSSC to the NARSTO Executive Committee. These annual reports enumerate user contacts with data files in both the NARSTO QSSC ftp sites and each data set in the NARSTO Permanent Data Archive in the Langley DAAC.

1.2.2 Accessing and Using the Archived Data

Most data files in the Permanent Data Archive are in the self-documenting NARSTO Data Exchange Standard (DES) format. These files follow a tabular layout and are stored as ASCII comma-separated values files (.csv); thus they can be readily opened in most spreadsheet programs (such as EXCEL or FoxPro) or read by SAS and FORTRAN programs. The DES format does not rely on row position to identify specific information. It uses a self-explanatory tag on each row of data to describe the information contained in the row (e.g., principal investigator's name, parameter name, units of measurement, or blank correction) as it applies to the actual measured values. A sample DES file template with detailed documentation is available on the QSSC web site, http://cdiac.esd.ornl.gov/programs/NARSTO.

The DES is a self-documenting format with three main sections: 1) The header contains information about the contents of the data file and the name of the investigator who made the measurements and/or submitted the data to the QSSC; 2) The middle section contains metadata tables that describe or define the measurement sites or platforms used, QA flags and calibration checks, and other codified fields; and 3) The final section is the main data table that contains key sampling and analysis information (file names of the parameters measured, units of measurement, volume standardization, etc.) and the sampling date, time, and the measured data values. Descriptions and tables of the standardized metadata are also available on the QSSC web site.

1.2.3 Acknowledgement by Users of NARSTO Archived Data

The "Guide" document accompanying each data file contains information on how to acknowledge the source of data sets that are used in publications or presentations of findings from analysis of SOS' data archived by the NARSTO QSSC. This professional courtesy is essential to ensure that SOS investigators receive appropriate credit for making the measurements in the first place, and that the archiving roles of the NARSTO QSSC and the Langley DAAC are recognized. The NARSTO Permanent Data Archive is maintained by the NASA Langley Research Center, Atmospheric Sciences Data Center in Hampton, VA, http://eosweb.larc.nasa.gov/.

1.2.4 SOS Website

During 1999-2003, Cari Furiness in the SOS Office of the Director made considerable progress in updating the SOS website. The SOS website – http://www.ncsu.edu/sos/ currently contains general SOS information, including newsletters and workshop announcements. It will contain:

1. Electronic linkages to the SOS data archives maintained by EPA/NERL and by the NARSTO Data Archive and *Quality Systems Science Center* of the Oak Ridge National Laboratory (ORNL);
2. Information about and links to SOS publications;
3. Information on the objectives, current status, and electronic linkages to SOS-affiliated research including:

- SOS' Southern Center for Integrated Assessment of Secondary Air Pollutants (SCISSAP),
- EPRI's and the Southern Company's regionally focused Southeastern Aerosol Research and Characterization (SEARCH) study,
- EPRI's and the Southern Company's epidemiologically-focused Aerosol Research Inhalation Epidemiological Study (ARIES),
- EPRI's and the Southern Company's urban-focused Assessment of Spatial Aerosol Composition in Atlanta (ASACA),
- The Fall Line Air Quality Study (FAQS) led by Georgia Tech,
- The TexAQS 2000 Study and the TexAQS II Study organized under the auspices of the Texas Commission on Environmental Quality.

1.2.5 SOS Publications Policy

In January 1992, the following policy on sharing, reviewing, and distribution of information from the Southern Oxidants Study was adopted by the SOS Coordinating Council.

THE SOUTHERN OXIDANTS STUDY POLICY ON SHARING, REVIEW AND DISTRIBUTION OF INFORMATION

SOS information is intended for the use and beneficial application by the participants, policy makers, and the general public to further advance the state of scientific and technical knowledge regarding the formation of ambient ozone [and particulate matter].

The policy set forth herein is designed to recognize all existing agreements between sponsor and investigator; foster free exchange of information among participants; avoid debilitating controversy within SOS; and provide all participants with opportunities to review and comment on relevant materials.

Information is defined as data, papers for publication, promotional materials, press releases, intellectual property, and all internal and external program reports and public outreach program communications.

Data

These would initially exist at two levels. Level I data are typically initial observations and data products that have not been officially checked and validated, but may be useful in providing preliminary consolidated data sets for interpretative and diagnostic analysis by participants. These data are generally not approved for public release. Level II data contain the official data and operational archives of SOS.

Distribution

Level I Data: may be distributed only within participant and co-investigator groups in response to a request or as part of an initial automatic distribution approved by a project oversight committee or the Coordinating Council. All data shall be made available to participants no later than 12 months after their collection. Recipients of these data are expected to proactively participate in the quality control of the data. They may make free use of these data in their work. However, prior to reporting any findings of fact, or opinion, based upon these data, the recipient must submit such reports to the data supplier for review and comment.
Level II Data: data contained in the SOS official data and operational archives have been approved for public release by the Coordinating Council. All data shall be finalized and approved as Level II data within 18 months of collection and submitted to the appropriate SOS archive. These data may be released upon request. Distribution will normally be effected through the SOS Management Center or appropriate Data Management Center.

Papers for Publication

The principal author of said papers shall have the responsibility for seeking comments of affected program participants with respect to proposed publication. Other participants shall be informed of the availability of proposed paper by the SOS Management Center and may comment directly to the author, if desired. Comments will be solicited concurrently with submission for publication.

Promotional Materials and Press Releases

Each participant is free to promote individual research efforts. However, when the work of another organization is entrained within that research, or when attribution is ascribed, or the name of another entity evoked; comment and approval must be solicited from these later entities prior to release or publication of the information.

Intellectual Property

The rights to intellectual property shall be governed by existing patent, copyright, contract and federal law and in accordance with any memoranda of agreement of understanding in force.

Internal and External Reports

Internal reports will be distributed only among participants. A copy will be kept on file at the SOS Management Center and made available upon request to program participants. External reports are those that summarize, integrate, and/or interpret SOS results and are meant for public distribution. Such reports will first be reviewed and approved for release by the appropriate Program or Executive Committee and the Coordinating Council.

Regulatory Agencies

Regulatory agencies operating air monitoring sites which provide data to SOS are not limited as to when hourly averaged criteria pollutant data can be released to the public or reported as required by regulation.

Approval

This policy statement has been thoroughly reviewed by the Coordinating Council and program participants. It is hereby accepted and approved as the Southern Oxidants Study official Policy on Sharing, Review, and Distribution of Information.

[Signed]

Robert H. Collom, Jr.
Chairman, Coordinating Council
January 1, 1992

In addition, SOS scientists are encouraged to use the following Guidelines for the Formulation of Scientific Findings to be used for Policy Purposes in creating statements that synthesize their research results:

1.2.6 SOS Traditions Regarding Publication of Scientific Findings and Communication with Stakeholders

As in other carefully focused scientific research programs, most "major scientific findings" from SOS and SOS-affiliated research develop gradually (often over months or even years of time) through many different stages of evolution:

1. Formulation of testable hypotheses and detailed research plans at SOS planning meetings.
2. "Initial impressions" derived from field observations that are first shared with colleagues during field measurement campaigns and later with colleagues in our own institutions.
3. "Emerging insights"(and sometimes major surprises!) shared with additional colleagues during SOS Data Analysis Workshops such as those held in October 1993 in Denver, CO, September 2000 in Research Triangle Park, NC, or the several TexAQS 2000 Data Analysis Workshops that were held in Houston or Austin, TX and in Boulder, CO. These Data Analysis Workshops were organized by the SOS Office of The Director or by one or another of the TexAQS 2000 sponsoring organizations.
4. Plans for joint authorship and submission of abstracts for verbal presentations or posters at open scientific meetings such as Special Sessions organized by the SOS Office of the Director at the 1999 and 2001 Fall meetings of the American Geophysical Union in San Francisco, CA, the annual meeting of the American Meteorological Society in Orlando, FL, the 2001 annual meeting of the American Association of Aerosol Research in St. Louis, MO, and in technical sessions at various annual and regional meetings of the Air and Waste Management Association and other scientific and professional meetings in this country, in NARSTO Workshops, or at international conferences and workshops of various sorts.
5. Further refinement of scientific insights in response to critical comments received at scientific and professional society meetings, and by comparisons with results of other investigations inside and outside of SOS.
6. Submission of manuscripts – usually to refereed journals – where "major scientific findings" that are "consistent with available scientific evidence and contradicted by no important evidence" are the raison d'être for acceptance by both the journal and the scientific community at large.
7. Revision of manuscripts in response to reviewer and editor comments and suggestions for improvement.
8. Acceptance and publication by the scientific journal – most often as individual papers – but sometimes in Special Sections of scientific journals where papers by various SOS scientists are published one-after-another in the same issue.
9. Publication of SOS Summary Reports of *Policy Relevant Findings from SOS Ozone and PM Research* and *SOS Compendium Volumes* of published papers for distribution to interested users and stakeholder groups.
10. Special Invitational briefings by carefully selected SOS scientists provided at the request of air quality leaders in industry and various state, regional, and federal government agencies.

A complete list of the SOS Summary Reports and SOS Compendium Volumes and SOS Contributions to NARSTO is provided below. Copies of most of these documents are available from the SOS Office of the Director and can be provided upon request, either electronically or in hard copy:

- SOS Data Analysis Workshop Report (Fehsenfeld et al., 1993)
- The State of the Southern Oxidants Study: Policy-Relevant Findings from Ozone Pollution Research – 1988-1994 (Chameides and Cowling, 1995)
- Comprehensive overview of scientific findings from major ozone field studies in North America and Europe (Solomon, Cowling, Hidy, and Furiness, 1998)
- SOS Special Sections of the Journal of Geophysical Research-Atmospheres and the journal of the American Association of Aerosol Research:
  - September 1998 – SOS 1995 Nashville/Middle Tennessee Ozone Study (Cowling et al. (eds.), 1998)
  - April 2000 – SOS 1995 Nashville/Middle Tennessee Ozone Study (Cowling, et al. (eds.), 2000)
  - September 2002 – Comparison of Instruments during the 1999 Atlanta Supersite Project (Solomon et al. (eds.), 2002)
  - October 2003 – Overview of the SOS 1999 Atlanta Supersite Project (Solomon et al. (eds.), 2003)
- First Compendium Volume of scientific papers from the SOS 1995 Nashville/Middle Tennessee Ozone Study (Cowling (ed.), 1999)
- Second Compendium Volume of scientific papers from the SOS 1994 Nashville/Middle Tennessee Ozone Study (Cowling (ed.), 2002)
- Comparison of scientific findings from major ozone field studies in North America and Europe (Solomon, Cowling, Hidy, and Furiness, 1998, 2000)
- The State of the Southern Oxidants Study: Policy-Relevant Findings from Ozone Pollution Research – 1994-2000 (Cowling and Furiness, 2001)
- The State of the Southern Oxidants Study: Policy-Relevant Findings from Ozone Pollution Research – 1995-2003 (Cowling and Furiness, 2004)

As shown in the 1995, 2001, and 2004 State of the Southern Oxidants Study reports, about 80 refereed journal papers were published by SOS authors prior to 1995, about 200 more between 1995 and 2000, and about 250 more between 2001 and 2004. In addition, nearly 300 abstracts, posters, and verbal presentations of SOS findings were made at scientific meetings in this country and abroad. Mainly during the past five years, several policy-focused briefings by SOS scientists and engineers were requested by various stakeholder groups including state, federal, industrial, university, and public interest groups concerned with air quality issues.

1.2.7 SOS Publications Archive

An SOS Publications Archive is maintained in the Air Quality Library at North Carolina State University. It contains hard copies of reprints of most publications from the SOS research and assessment program. Copies of all the SOS Summary Reports listed above, an Internet-accessible list of refereed journal publications, titles, copies of abstracts or posters for presentations at scientific meetings, drafts of some manuscripts, and copies of some briefing documents prepared by SOS scientists and engineers for various stakeholder groups are posted on the SOS Website, http://www.ncsu.edu/sos/.

Full references for more than 400 refereed journal papers published since 1995 are listed in the Bibliography of SOS and SOS-Related Publications 1995-2003 within this third *State of the Southern Oxidants Study Report* (See Appendix A). Full references for SOS papers published in earlier years (1988-1994) are listed in Appendix A of the Second State of the Southern Oxidants Study Report (Cowling and Furiness, 2001).

1.2.8 Financial and In-Kind Support for SOS and SOS-related Research Programs

During each year between 1999 and 2003, the approximate total annual costs of SOS and SOS-related research, analysis, and assessment activities have been distributed among SOS' principal sponsoring organizations as follows:

- about $2 to $3 million per year in direct financial support and in-kind services from NOAA,
- about $1 to 1.5 million per year in direct financial support and in-kind services from DOE,
- about $500,000 per year in direct support and in-kind services from TVA,
- about $1 million per year in cost sharing contributions by the SOS cooperating universities,
- about $1 million per year in 1999-2001 in direct financial support for SOS' Southern Center for Integrated Study of Secondary Pollutants (SOS-SCISSAP) by EPA's competitive grants program (EPA/NCER),
- about $1.4 to $1.7 million per year in 1999-2003 from EPA's Office of Air Quality Planning and Standards for SOS' establishment of an "Initial Supersite" in Atlanta, Georgia, and for University of Texas' establishment of the Gulf Coast Aerosol Research and Characterization study (GC-ARCH) in Houston, Texas – one of 8 sites within EPA's PM Supersite Program,
- about $1.0-1.5 million per year in in-kind services by scientists in EPA's National Exposure Research Laboratory (EPA/NERL),
- about $800,000 per year in direct financial support from EPA/NERL through SOS' Cooperative and Interagency Agreements,
- about $200,000 per year in 1999-2001 in direct financial support over two years for SOS' Seasonal Model for Regional Air Quality (SOS-SMRAQ) from the eight states of the Southeastern Regional Air Resource Managers (SESARM),

– about $2 million per year in direct financial support and about $1 million in in-kind support from the state of Texas for the Texas Air Quality Study (TexAQS 2000) -- for a total of

about $12 to $14 million per year in support of SOS and SOS-related research activities.

In addition, in close cooperation with SOS, the Southern Company, other electric utilities, and EPRI have developed a series of SOS-related research efforts that have greatly complemented and enhanced SOS research efforts. These SOS-related studies include EPRI's regionally focused Southeastern Aerosol Research and Characterization study (SEARCH) (which is very closely coupled with SOS-SCION), its epidemiologically-focused Aerosol Research Inhalation Epidemiological Study (ARIES), its urban-focused Assessment of Spatial Aerosol Composition in Atlanta (ASACA), and cooperative studies within the Tennessee Valley $PM_{2.5}$ Partnership Network. Thus, through its Tailored Collaboration Group (matching funds) program, the utilities and EPRI are currently providing:

about $2 to $4 million per year for SOS-related research and assessment activities.

Also, during 1999-2003, in close cooperation with SOS scientists at Georgia Tech, the state of Georgia is investing in the Fall Line Air Quality Study (FAQS)

about $1 million per year for SOS-affiliated research and assessment activities.

Thus, the total investment by public-sector and private sector organizations for SOS and SOS-related research and assessment activities is about $15 to $19 million per year.

1.3. SOS RURAL FIELD MEASUREMENT NETWORKS

> 1.3. SOS Rural Field Measurements
>
> - Three-tiered SERON network included SON, SCION, SENIOR
> - SCION has evolved into O_3- and $PM_{2.5}$-focused SEARCH

To understand the long-distance transport of ozone, $PM_{2.5}$, and their respective precursor chemicals, and the regional background for physical and chemical exchange of ozone and its precursors between rural and urban areas, SOS deployed a three-tiered series of long-term rural and regional-scale monitoring networks within which its short-term urban intensive field measurement campaigns were embedded. These three regional networks – collectively called the Southeastern Regional Oxidant Networks (SERON) – were designed to achieve high spatial and temporal resolution as well as state-of-the-science characterization of atmospheric chemistry including air concentrations of O_3, NO, speciated NO_y, speciated VOC, PAN, CO, and a wide variety of meteorological parameters. As shown by the map in Figure 1.3, the SOS-SERON networks include the following.

- The Spatial Ozone Network (SOS-SON) of about 40 continuously monitoring ground-level rural ozone sites in 8 states.
- The Southeastern Consortium Intermediate Oxidant Network (SOS-SCION) for monitoring O_3, NO, NO_y, and speciated hydrocarbon concentrations at a smaller number of rural sites.
- The Southeastern Network for Intensive Oxidant Research (SOS-SENIOR) for characterizing detailed chemical and meteorological processes occurring at various rural sites using state-of-the-science instrumentation.

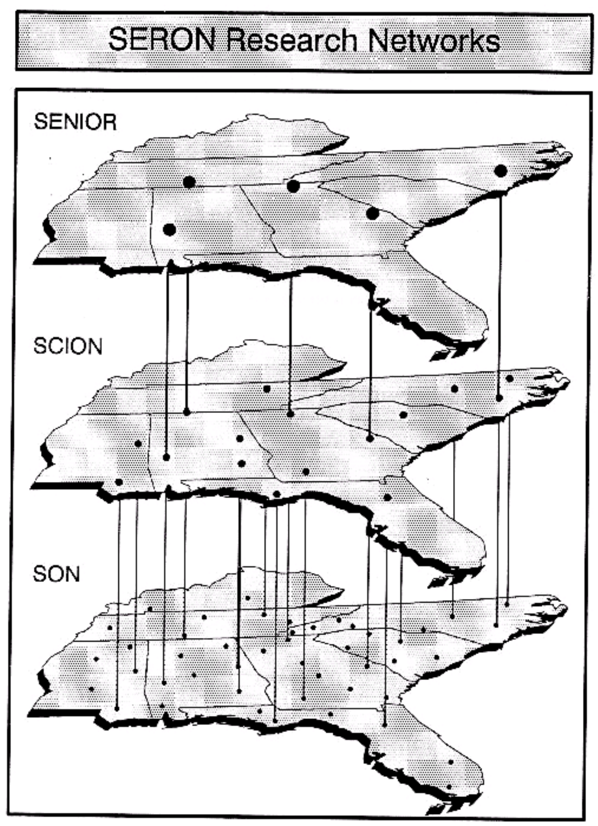

Figure 1.3. Schematic of SERON networks.

During 1996-2000, each of these rural-focused networks was transformed as described below. Funding limitations in SOS beginning in 1996 and some increases in ozone monitoring investments by the states and some industries in the SOS region led to gradual replacement of the formally recognized 40-station SOS-SON Network with a less formally recognized set of about 30 sites within the AIRS data base maintained by EPA and later also within the Tennessee Valley $PM_{2.5}$ Partnership Network.

Following EPA's promulgation of a National Ambient Air Quality Standard for $PM_{2.5}$ in 1997 and SOS' success in winning an EPA Competitive Grant titled *The Southeastern Center for Integrated Study of Secondary Air Pollutants (SOS-SCISSAP)*, beginning in 1998, the original 8-11 site SOS-SCION Network was transformed from an "ozone-focused network" into an "ozone- and $PM_{2.5}$-focused network" for measurement of ozone and $PM_{2.5}$, and their respective precursors. The research approach followed in this transformation of the SOS-SCION Network (paired sets of adjacent rural- and urban-focused $PM_{2.5}$ research characterization sites) was funded separately by the Southern Company and EPRI through EPRI's Tailored Collaboration Group matching-funds mechanism. Thus, the former SOS-SCION Network was changed significantly and is now known as the Southeastern Aerosol Research and Chacterization (SEARCH) study.

After its initial and highly successful intensive characterization of regional background ozone and precursor concentrations at ground level in 1990-1994, the SOS-SENIOR Network was replaced in 1995 and subsequent years by equally intensive rural ozone and precursor measurements using highly instrumented aircraft.

SEARCH is one of a series of six "SOS-affiliated" or "SOS-derived" research activities that are funded separately but are maintained in close cooperation with SOS. These studies involve many of the same SOS investigators who found professional and personal satisfaction through SOS – by learning to "reason together carefully" in debating research priorities, deciding what goals and objectives to pursue, and then voluntarily agreeing to "work together harmoniously" to fulfill those mutually agreed goals and objectives with whatever financial and in-kind support they can persuade their own institutions and other cooperating organizations to provide.

1.4. SOS URBAN/REGIONAL FIELD MEASUREMENT CAMPAIGNS

> 1.4. SOS Urban Field Measurement Campaigns
>
> - SOS completed 2 major O_3-focused and 3 major O_3-and-$PM_{2.5}$-focused campaigns in four urban non-attainment areas

Embedded within the three-tiered SOS-SERON Networks, SOS mounted five major summertime-only, urban-focused, intensive field measurement and modeling campaigns – the first two were focused on ozone and its precursors, the last three on ozone, $PM_{2.5}$, and their respective precursors. Table 2.2 displays the distinctive features of each of the urban areas chosen as sites for the SOS field campaigns. Items 1 – 5 below describe each specific SOS urban study.

Table 2.2. Characteristics/Distinctive Features of Four Major Urban Non-Attainment Areas Studied by SOS.

Characteristic or Feature	Atlanta, GA	Nashville, TN	Dallas-Fort Worth, TX	Houston-Galveston, TX
Population	2.9 million	1.0 million	4.0 million	4.0 million
Area of Non-Attainment Counties	3991 mi^2	2790 mi^2	4266 mi^2	7767 mi^2
Inland vs. Coastal	Inland city	Inland city	Inland city	Coastal city
Elevation	330 meters	600 meters	800 meters	0-80 meters
Physiographic Region	Piedmont	Piedmont	Piedmont	Coastal Plain
Dominant Rural Land Use Nearby	60% mixed forest 40% cropland	70% hardwood forest 30% cropland	70% scrub oak 30% rangeland	60% scrub oak 40% crop/range
Latitude	33° 83 min N	36° 18 min N	32° 75 min N	29° 75 min N
Longitude	84° 36 min W	86° 76 min W	96° 77 min W	95° 33 min W
Emissions in Non-Attainment Counties (tons):				
NO_x-power plants	58,000	14,000	21,000	79,000
NO_x-fuel combustion	11,000	12,000	9,000	126,000
NO_x-other industrial	22,000	11,000	21,000	29,000
NO_x-motor vehicles	142,000	41,000	132,000	116,000
NO_x-off-highway	54,000	21,000	83,000	205,000
Total NO_x	291,000	100,000	270,000	557,000
VOC-industrial sources	102,000	58,000	73,000	158,000
VOC-mobile+off-highway	152,000	39,000	138,000	123,000
VOC-biogenic sources	163,000	47,000	92,000	247,000
Total VOC	421,000	144,000	307,000	530,000
Carbon Monoxide	1,611,000	415,000	1,272,000	1.249,000
Ozone Designation	Serious	Marginal	Serious	Severe
Ozone, 2nd max, 1-hr	157 ppbv	120 ppbv	118 ppbv	203 ppbv
Ozone, 4th max, 8-hr	126 ppbv	91 ppbv	94 ppbv	121 ppbv
PM_{10}, 24-hr	3.1 $\mu m\ m^{-3}$	5.6 $\mu m\ m^{-3}$	4.4 $\mu m\ m^{-3}$	5.2 $\mu m\ m^{-3}$

Counties within these four ozone non-attainment areas include:

Atlanta – Cherokee, Clayton, Cobb, Coweeta, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, Rockdale.

Nashville -- Davidson, Rutherford, Sumner, Williamson, Wilson.

Dallas-Fort Worth -- Collin, Dallas, Denton, Tarrant.

Houston-Galveston -- Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller.

1) SOS Field Intensives in the Atlanta, GA Metropolitan Area. These ozone-focused studies consisted of short-term exploratory studies during the summers of 1990 and 1991 followed by a major six-week-long field measurement campaign from July 15 to August 31, 1992. This study involved about 77 ground-based chemical and meteorological measurements sites and a series of tower-based and tethered-balloon-based measurements of ozone, its precursors, and meteorology. Since scientific findings from this first SOS Urban Intensive in Atlanta were thoroughly discussed in the first State of SOS Document (Chameides and Cowling, 1995), they will not be discussed further in this document.

2) SOS 1995 Nashville/Middle Tennessee Ozone Study. This ozone-focused field study was carried out in the 11-state region surrounding Nashville/Middle Tennessee. It began with a 3-week exploratory study during the summer of 1994 and culminated in a six-week-long major field measurement campaign from June 19 to July 28, 1995. Leadership for the study was provided by Jim Meagher of TVA who coordinated measurements at 116 ground-based and tall-building and tower-based chemical and meteorological measurement sites and a series of six airborne chemical measurement platforms including both fixed-wing NOAA, NASA, and DOE aircraft and a TVA helicopter. This study included a three-tiered hierarchy of progressively more sophisticated surface air quality measurements including: a) 108 "Level I" surface ozone monitors; b) six "Level II" sites providing continuous high sensitivity measurements of ozone, SO_2, NO, NO_y, and CO, canister sampling for speciated VOC measurements, wind speed and direction, temperature, relative humidity, and solar radiation; and c) two "Level III" sites that provided detailed research-grade photochemistry and meteorology measurements using rawinsonde and ozonesonde releases and a radar profiler/radar acoustic sounding system. Research-grade, day-specific, emissions inventories were produced for the six-week intensive period. They included biogenic, point source, and mobile sources based on daily activity logs, traffic counters, vehicle mix, tunnel studies, and a subregional domain inventory.

A very significant feature of the 1994-95 Nashville/Middle Tennessee Ozone Studies were the coordinated series of 40+ aircraft studies that had the following five general objectives and guiding "mentors":

a) Measurements of ozone formation in the Nashville urban plume under free-flow and stagnation conditions – Peter Daum and Larry Kleinman of Brookhaven National Laboratory.

b) Measurements of ozone formation and destruction in power plant plumes – Noor Gillani of TVA.

c) Detailed subregional characterization of atmospheric chemistry and meteorology to evaluate urban-rural exchange and provide observational data sets for model evaluations – Robin Dennis of EPA.

d) Regional characterization flights to provide context and contrast for air quality measurements in Nashville. They extended north to the Great Lakes, south to the Gulf of Mexico, west to Missouri and Arkansas, and east to the Appalachian Mountains – Michael Trainer of NOAA.

e) Side-by-side intercomparisons of aircraft measurements for the in situ sampling aircraft and overflights for the remote sensing aircraft – Gerd Hübler and James Meagher of NOAA.

3) SOS Nashville 1999 Ozone and $PM_{2.5}$ Study. This follow-up to the SOS 1995 Nashville/Middle Tennessee Ozone Study consisted of a four-week-long field measurement campaign during July 1999 with a similar array of ground-based measurement sites and four aircraft-mounted chemical measurement platforms. The Nashville '99 field measurement campaign was designed to answer the following scientific questions:

a) By what specific aerosol measurement methods can SOS achieve maximally beneficial characterization of aerosols in both urban and rural areas of the SOS region?

b) What are the linkages (similarities and differences) between the chemical, biological, and meteorological processes that govern formation and accumulation of ozone and fine particulate matter?

c) What is the relative efficiency of production of ozone and fine particulate matter in urban plumes compared to that in power-plant plumes?

d) In what ways are the rates and efficiencies of ozone and fine particulate matter production and accumulation different in large urban areas compared to small urban areas – especially in cases where an air mass spends an extended period traversing a very large urban area?

e) How do nighttime meteorological and chemical processes influence the rates, efficiencies, and areal extent of ozone and fine particulate matter formation and accumulation?

f) What meteorological and chemical factors determine the regionality and/or locality of ozone and fine particulate matter accumulation events? In particular:

  i) How do the processes that govern ozone accumulation in isolated urban areas surrounded by high-isoprene-emitting forests differ from those in urban areas in which urban plumes overlap from one urban or non-forested area to another?

  ii) How important are urban heat-island phenomena in determining the regionality and or locality of ozone and fine particulate matter formation and accumulation processes?

4) SOS Initial Supersite in Atlanta, GA. This study was one of two "Initial Supersites" established at the request of EPA's PM-Supersite program in EPA's Office of Air Quality Planning and Standards. The other "Initial Supersite" was in Fresno-Bakerfield, California. Both initial sites were part of EPA's effort to increase the nation's capacity to monitor $PM_{2.5}$ in a reliable way in various parts of the country. Under the leadership of SOS' Chief Scientist, Bill Chameides, SOS brought together in Atlanta during August 1999, the most comprehensive array of particulate-matter measurement instruments ever assembled in the US. The measurement site was located in a mixed commercial and industrial area about 8 km west of the center of Atlanta where routine $PM_{2.5}$ characterization measurements had been made as a part of the SEARCH and ARIES programs for more than a year. This major instrument-intercomparison and $PM_{2.5}$-characterization study included a wide variety of instruments for determining the mass, particle size distribution, chemical composition of individual particles, and chemical composition of hourly-collected filter samples collected on all days of the week, and simultaneous gas and particle measurements (See Section 2.5. and Section 2.6.).

5) Texas Air Quality Study (TexAQS 2000). Peter Daum and Larry Kleinman of Brookhaven National Laboratory provided leadership for this major urban field measurement campaign in the eastern half of Texas. The study was headquartered in Houston, TX where EPA established one of its operational PM Supersites under the leadership of David Allen of the University of Texas at Austin and Matt Fraser of Rice University. The six-week intensive field measurement campaign began on August 1 and extended to September 15, 2000. It involved nearly 100 ground-based chemical and meteorological measurement sites, and six airborne measurement platforms including aircraft from NOAA, NASA, DOE, and Baylor University. Two "Super-Chemistry" sites were set up to measure a wide array of trace gas and aerosol species – one at LaPorte Airport in the heart of the petrochemical industry surrounding the Houston Ship Channel, and the other at the top of a 30-story Williams Tower building on the west side of downtown Houston. More than 250 scientists were involved with the field measurements. Most have remained involved in the analysis, interpretation, and publication phases of this study.

TexAQS 2000 was designed to compare and contrast ozone and aerosol formation processes in and around two huge sprawling petrochemical-dominated metropolitan areas in the eastern half of Texas – Dallas-Fort Worth, an inland, somewhat more northerly metropolitan area with large emissions of VOC and NO_x, and Houston-Galveston, a more southerly and coastal urban-industrial complex with its heavily industrialized Ship Channel and land-sea breeze-reversal processes which often give a "double dose" of VOC, NO_x, SO_2, and Cl pollutants (see Table 2.2). Although these metropolitan areas are similar in size and population, the emissions mix and meteorological conditions are very different, affording an opportunity to study the effect of differences in industrial and biogenic emissions on ozone/aerosol formation. Also, ambient VOC/ NO_x ratios for parts of Houston are much larger than those in any other US city.

Five major research themes were pursued through the TexAQS 2000 Study:

- Atmospheric dynamics and transport – especially with reference to 1) land/sea breeze influences on transport and dispersion of ozone and $PM_{2.5}$, 2) height and intensity of mixing within the planetary boundary layer (PBL), and 3) processes of entrainment and detrainment from the PBL.
- Ozone formation and distribution – by 1) quantifying the relative contributions and reactivities of anthropogenic and biogenic VOCs, and 2) determining instantaneous rates and efficiencies of ozone formation as a function of time, location, and precursor concentrations.
- Particle formation and distribution – by measuring 1) large-scale spatial distributions of $PM_{2.5}$ and PM_{10}, 2) evolution of aerosols downwind from point sources and urban areas, 3) identifying conditions under which new particles are formed, and 4) determining if aerosols are a sink for NO_y.
- Emission inventories – by making a wide variety of ambient measurements and calculations designed to identify and quantify sources of error in estimates of anthropogenic and biogenic emissions including unscheduled and as yet undocumented releases of VOCs in the Houston Ship Channel.
- Modeling improvements – by developing 1) "ground truth" tests of the skill of models to simulate both horizontal transport and vertical dispersion processes, 2) comprehensive data bases against which model performance can be evaluated, and 3) data and information by which to judge the adequacy of the meteorological and chemical representations used in these models.

6) Plans for the Second Texas Air Quality Study (TexAQS II) in 2005-2006. Under the leadership of Jim Thomas, Jim Price, David Allen, Fred Fehsenfeld, Jim Meagher, Peter Daum, Harvey Jeffries and many other SOS and SOS-Affiliated research leaders inside and outside of Texas, both general and specific plans are being formulated for a major follow-up urban/regional air quality field measurement campaign centered over Houston/Galveston metropolitan area and other coastal locations in Texas during 2005-2006.

The following detailed description of these plans was provided recently by Jim Thomas:

Foreword: Researchers from universities, state and federal agencies, private industry, and local governments are joining forces to conduct a major field study to address air quality issues in the eastern half of Texas in 2005-2006. Anticipated participants will include the Texas Commission on Environmental Quality (TCEQ), a consortium of Texas universities, national labs and universities from around the world, and other regional stakeholders. Leadership will be provided by key participants from the University of Texas-Austin, the University of Houston, Texas A&M, Rice University, Lamar University, the Texas Commission on Environmental Quality, the Texas Environmental Research Consortium, the Texas Air Research Center, the National Oceanic and Atmospheric Administration, the Department of Energy, and members of the Southern Oxidants Study. TexAQS II is planned for a period extending from April 2005 through October 2006. It will examine $PM_{2.5}$ formation, regional ozone formation, transport of ozone and ozone precursors, meteorological and chemical modeling, and issues related to ozone formation by highly reactive emissions in Texas. It is anticipated that scientific information from the study will be used for developing State Implementation Plans (SIPs) for ozone (with concentrations averaged over 8 hours), regional haze, and, if necessary, for fine particulate matter ($PM_{2.5}$). With the exception of El Paso County in west Texas, all violations of the National Ambient Air Quality Standards in Texas are currently for ozone and are located in the eastern half of the state. This same area is home to the majority of the state's business activity and population. Cleaning the air and bringing the state back into compliance with the ozone standard is one of the most important policy issues facing regulators and elected officials.

Introduction**:** Economic and population growth in Texas over the past fifteen years has been very rapid. The excellent climate and the abundance of employment opportunities have resulted in many people relocating to the State. The US Census Bureau estimates that by the end of 2002, the State's population was 23,000,000 as compared to a 1990 population of approximately 17,000,000. While the economic has growth rate has slowed to some degree, the eastern half of the state is still experiencing rapid growth. Collin and Denton counties, for example, had some of the highest net population gains in the United States in 2002.

Even with significant economic and population growth over the past several decades, air quality in the eastern half of the state had shown substantial improvement, as illustrated by the 1-hour design values for the Houston-Galveston and Dallas-Fort Worth areas. This improvement in the 1-hour design value trend has tapered off and the trend of improving air quality flattened over the last ten years. Design values for the 8-hour standard over this same period have, however, remained relatively constant.

The challenges facing near non-attainment areas coping with the 8-hour ozone standard will center on the issue of regional and longer range transport of ozone and ozone precursors. In many areas the contributions to monitored readings by transport can be as high as 65-70 ppb of the 85 ppb standard. Successfully dealing with this new standard will require a thorough and complete understanding of contributions from transport.

Texas and the nation will be moving away from the 1-hour ozone standard to the more stringent 8-hour ozone standard. At the same time, the state must be prepared to deal with challenges associated with the $PM_{2.5}$ and regional haze regulations. As the focus on the ozone standard changes, it is important to understand if the key factors contributing to exceedances of the 1-hour ozone standard are the same or significantly different from those affecting 8-hour ozone concentrations, fine particles ($PM_{2.5}$), and regional haze. Transport of ozone and $PM_{2.5}$ from other states as well as within Texas needs to be defined more quantitatively in order to develop successful control strategies for the 8-hour ozone standard.

With rapid population and economic growth trends expected to continue, it is vitally important that steps are taken to insure that the air quality of the state continues to improve and that areas currently not meeting the Nation Ambient Air Quality Standards for ozone are brought into compliance with the ozone standard. It is equally important to maintain compliance with the $PM_{2.5}$ standard and develop information to facilitate dealing with regional haze. In order to accomplish these objectives, it is extremely important that the scientific information used to formulate control strategies is sound and that the development of effective controls to improve the air quality will, to the greatest extent possible, allow continued business growth within the state and the mobility desired by Texans. Therefore, the importance of sound and timely scientific information as a basis for making the critical decision facing regulators and elected officials cannot be over emphasized.

***Scientific Objectives of TexAQS II*:** Previous experience has demonstrated that measurements done for regulatory compliance are not sufficient to guide the development of sound air quality management plans. Further, because emissions, atmospheric chemistry, and meteorology often interact in unexpected ways, collecting sound scientific data requires a comprehensive and coordinated measurement program. Therefore, periodic, major air quality field studies are needed in Texas. The study proposed for 2005 and 2006 will examine ozone and fine particulate matter formation, regional ozone formation, long-range ozone transport, meteorological and chemical modeling, and issues related to ozone formation by highly reactive emissions. Specifically, the study will:

Assess the extent of ozone and fine particle matter transport into and within Texas. Previous air quality studies have revealed that intercity transport of ozone is substantial in eastern Texas. In addition, measurements indicate that, under some meteorological conditions, a substantial fraction of the ozone and fine particulate matter in eastern Texas is the result of transport of continental air masses into the state. To better differentiate regional and local contributions to fine particulate matter and ozone, an expanded sampling network suitable for characterizing intercity and interstate transport of ozone and fine particulate matter will be deployed.

Refine and evaluate inventories of emissions that lead to ozone and fine particulate matter formation. Findings from previous air quality studies indicate that some segments of the emission inventories critical to understanding regional ozone and fine particulate matter formation are significantly underestimated or poorly understood. A variety of focused measurements of emission sources will decrease these uncertainties.

Characterize air pollution meteorology in all seasons. Previous air quality studies have been conducted during months with the greatest frequency of air pollution episodes – August and September. But elevated air pollution concentrations can occur in all seasons, and the meteorology leading to episodes will vary significantly from season to season. Therefore TexAQS II measurements of air pollutant concentrations and meteorology will be conducted over an 18-month period.

Develop and improve modeling tools to simulate regional ozone and fine particulate matter accumulation. The TexAQS II field program will improve our ability to quantify regional transport of pollutants and specific chemical and physical processes important in understanding air pollutant formation in Texas, such as the chemistry of process flares, the mixing and dispersion of pollutants emitted by complex, multi-source industrial facilities, the extent of atomic chlorine precursor emissions, and the transport and chemistry of emissions from fires.

***Specific Implementation Plans*:** Science teams will guide pre-study preparation of specific implementation plans, including early deployment of scientific instruments needed to optimize final objectives for the field program in 2005 and 2006. Science teams will also guide development of plans for ground, ship, and aircraft measurements and logistical support requirements.

A study implementation plan, capable of meeting the study plan objectives (characterizing transport of air pollutants, quantifying emissions, characterization of meteorology in all seasons, improving air quality models) will be developed after completion of the study plan, which is currently being drafted, and after the first major science team meeting. The study implementation plan will identify financial and human resources requirements and constraints to implement each element of the plan.

Study Budget: Multiple sources of funding are available to support the air quality program. This presents both opportunities and challenges. The challenge is to coordinate the diverse goals of multiple sponsors, while the opportunity is the leveraging of resources, enabling a far more thorough study to be undertaken than any single sponsor could accomplish in isolation. Some funding has been specifically dedicated to support the study, while other sources have funding that may be applied to the study if it meets the sponsor's objectives. It will extremely important to identify and dedicate funding to TexAQS II at the earliest possible date. The following list identifies sources with both dedicated and potential funding:

Texas Commission on Environmental Quality
- Dedicated to Study for FY04/FY05 $1,000,000.00
- Potential funding from research budget, which totals $1.5 mil FY04/FY05

Environmental Protection Agency
- Dedicated via federal appropriation FY04 (not yet final) $500,000

Texas Environmental Research Consortium (TERC)
- Potential funding from research budget, which totals $6 mil FY04/FY05

Texas Air Research Center (TARC)
- Potential funding from Research budget, which totals $1.2 mil FY04/FY05

Near-Non-attainment areas
- Potential funding from budgets which total $5 mil. FY04/FY05

Industry Contributions
- Dedicated to study for FY04/FY05 $TBD

Timeline - A five-year effort: Detailed planning for the study began late in 2003 and will continue until measurements begin in April 2005. The scientific planning team will coordinate with stakeholder groups and the Texas Commission on Environmental Quality (TCEQ) in refining study objectives. Measurements will be made over an 18-month time period, beginning in April 2005 and concluding in October 2006. This measurement period is longer than the period used in previous studies; the longer measurement period is necessary for two reasons.

First, the air quality standards that are of concern in Texas are based on annual average or seasonal concentrations, so a limited duration study will not provide sufficient data and information to guide policy development. Second, a variety of different types of meteorological conditions are associated with high ozone concentrations and high particulate matter concentrations in eastern Texas. The full range of meteorological conditions is unlikely to occur during a relatively short, late summer sampling period. While the extended sampling period will create some logistical challenges, the enhanced scientific understanding justifies the effort.

Constraints in equipment availability, costs, and logistics dictate that only the most essential measurements can be made during the entire 18-month study period. The focus in the full 18-month period will be on collecting meteorological data, and developing predictive ozone and fine particulate matter modeling capabilities interfaced with a regional monitoring network. During the summer of 2005 and the summer of 2006, additional measurements will augment the core measurement and modeling activities. During the summer of 2005, the focus will be on experiments that further refine our understanding of meteorological processes and experiments that characterize emissions and determine the quality and completeness of emission inventories. During the summer of 2006, the focus will be on improved understanding of atmospheric chemical and physical processes that influence pollutant formation.

Analysis and interpretation of results from measurements made during this study will be completed as soon as possible. The first year of this effort will be concurrent with data collection. This is possible because many measurements will provide data in real time. Concurrent measurement and analysis is desirable because it will allow scientific hypotheses and experiment designs to be modified as the study progresses and because it will accelerate the incorporation of scientific findings into policy development. It is anticipated that many of the most significant findings from TexAQS II will become known by late 2007.