APPENDIX C. MONITORING DATA: AVAILABILITY, LIMITATIONS, AND NETWORK ISSUES

C.1. MONITORING PROGRAMS AND OBJECTIVES

PM data are currently available from a variety of monitoring programs and databases, which include

1. Global Atmosphere Watch (GAW) [global]
2. Interagency Monitoring of Protected Visual Environments (IMPROVE) [United States]
3. National Air Pollution Surveillance (NAPS) network [Canada]
4. Canadian Aerosol and Precipitation Monitoring Network (CAPMoN) [Canada]
5. Guelph Aerosol and Visibility Monitoring Network (GAViM) [Canada]
6. Federal Reference Method (FRM) fine particle monitoring network and U.S. National $PM_{2.5}$ speciation network [United States]
7. National PM Research Monitoring Network [United States]
8. Red Automatica de Monitoreo Atmosferico (RAMA) [Mexico City]
9. Clean Air Status and Trends Network (CASTNet) [United States]
10. U.S. National Park Service data [United States]
11. California Air Resources Board databases [United States]
12. U.S. EPA Aerometric Information Retrieval System (AIRS) databases [United States]
13. Special studies.

Different PM monitoring networks have been designed for different purposes. Any one or more of the following objectives may be of principal importance:

1. Determine PM levels
2. Monitor exposure to some size fraction of PM or to one or more components
3. Monitor visibility impairment
4. Ascertain compliance with regulatory standards
5. Develop estimates of source contributions
6. Evaluate how well control strategies are achieving goals
7. Provide information needed to advance scientific understanding.

In practice, monitoring networks are resource-limited and cost considerations typically limit their ability to address multiple objectives.

GAW sites are operated by individual investigators for scientific research purposes. Efforts are underway to establish an integrated archive of data.

The IMPROVE network was designed to monitor visibility impairment, with additional goals related to improving scientific understanding of the physical and chemical processes affecting visibility. Much of the nonurban data for the United States are from the IMPROVE network. IMPROVE fine-particle measurements are made in U.S. national parks and other locations that are typically representative of regional background PM concentrations. The IMPROVE network collected aerosol samples at ~30 sites since the mid-1980s, and was recently expanded to over 100 locations. Because of its focus on providing data related to visibility in Class I and other areas where visibility is protected, the IMPROVE network is concentrated in the western United States, but future measurements will provide broader geographical coverage.

The Canadian NAPS was designed to provide a large and geographically diverse database for characterizing PM. It presently covers all main urban areas of Canada and includes 15 urban and four rural locations. Sampling has been conducted using dichotomous samplers, and data collection commenced as early as the mid-1980s at some sites. Samples are normally collected over a 24-hour period once every six days. Both the coarse ($PM_{10-2.5}$) and fine ($PM_{2.5}$) fractions are analyzed for mass and over 50 elements.

The CAPMoN is a regional-scale air and precipitation monitoring network with multiple objectives. These objectives are to measure regional-scale spatial and temporal variations and long-term trends in the chemical composition of air and precipitation, to provide data for use in model development and testing, to provide data for process studies, and to provide a set of standard monitors across Canada. Sites are located outside urban areas and away from point or transportation emission sources and agricultural activities. The types of measurements made vary among sites, with, for example, 10 sites currently measuring SO_2 and 18 sites sampling precipitation chemistry. Data records extend back to the late 1970s for some sites. PM samples are collected daily. The size cutoff for particulate samples is not well defined, but is estimated to be about 8 µm (Nejedly et al., 1998).

The GAViM network is intended to improve scientific understanding of the physical and chemical processes affecting visibility in Canada. It has made speciated aerosol and optical measurements at five urban and rural locations across Canada twice per week, beginning in 1994. Measurements are made using IMPROVE-protocol samplers. Particle-size cutoffs are 2.5 and 10 µm.

The new U.S. fine-particulate FRM network is primarily a compliance-monitoring network, and numbers roughly 1000 sites nationwide. These sites are concentrated in urban areas. The U.S. National $PM_{2.5}$ Speciation Trends Network was designed to develop estimates of source contributions, monitor exposure to PM components, and track trends.

The RAMA network consists of 32 stations in Mexico City and has operated since 1986. Types of measurements vary among sites, but typically include surface meteorological parameters, gas-phase species (ozone, CO, SO_2, and NO_x), and PM_{10} mass. A variety of special studies provides additional data for Mexico City over a 40-year period (Raga et al., 2000), but present measurements of PM composition are limited to a one-month period in 1997 (Edgerton et al., 1999).

The U.S. EPA CASTNet network was designed to provide estimates of dry-deposition rates of sulfur and nitrogen compounds, which are combined with precipitation-chemistry measurements to estimate total sulfur and nitrogen loading rates. The standard CASTNet sites do not select a specific PM size, and they collect samples over a one-week time period. CASTNet sites are concentrated in the eastern United States, where IMPROVE coverage is limited. Eight eastern CASTNet sites have been instrumented with samplers operated according to the IMPROVE protocols (U.S. EPA, 2000).

An important ongoing special study is the Southeastern Aerosol Research and Characterization (SEARCH) project (Hansen et al., 2003). It began operating four urban-nonurban site pairs in mid-1998 in the southeastern United States (with urban sites in Atlanta GA, Birmingham AL, Gulfport MS, and Pensacola FL). Primary goals of the SEARCH network include aerosol research, measurement evaluation, characterization of urban-rural contrasts, and improved understanding of atmospheric processes. Both PM and gas-phase species are measured, and PM sampling includes continuous as well as filter-based methods.

C.2 NETWORK DESIGN

Network design begins with specification of network objectives. Contemporary networks emphasize different objectives, leading to a variety of general design specifications (Table C.1). Some of the specific key dimensions of PM monitoring programs include:

1. Size fractions
2. Chemical species
3. Sampling duration
4. Sampling frequency
5. Number and location of monitors
6. Length of monitoring program

7. Instrumentation required to accomplish each of the above accurately and affordably.

Size fractions and species measured, sampling duration and frequency, site location, sampler design, and other variables are typically optimized for the purpose of each network, and these differences add to uncertainty in the use of the data when applied for different purposes. An ongoing need is to provide

Table C.1 General specifications for PM observation and monitoring networks.

Objective	Measurements	Spatial Resolution	Temporal Duration and Resolution	Design Procedure	Comments
What's there	FRM [a] or other prescribed methods; specialized instruments	Variable targets-ground and aloft	Variable; usually short term campaign	Subjective-targets of opportunity	Historical guidance and direction from air chemistry; later, regulatory motivation
Exposure/ Dose	FRM and speciation measures	Mainly urban population oriented	Long term-multiyear	Relies on existing compliance networks or special process studies	Only considered explicitly in a few recent short term studies; e.g., PTEAM (Riverside, CA) and ARIES (Atlanta)
Visibility Variation	Optical properties or surrogate for human optical response	Designated air quality related value for pristine areas [b]	Prescriptive: linked with daytime visual perception.	Subjective with constraints on visual range	Recently driven by need to document light extinction combined with PM mass concentration and composition.
Compliance	FRM or other prescribed methods	Mainly urban/some regional non-urban	Prescriptive: long-term and linked with PM standards	Subjective or prescriptive (e.g. population based) [c]	Driven by regulatory needs for reporting community conditions-mostly urban focus. [d]
Source-Receptor Model	Specialized ground PM/precursor instrumentation supplemented with compliance networks; intermittent measures aloft; coupled with meteorological data.	Urban/regional scales covered by ground network, included nested grid for multiple spatial scale study.	Variable depending on model character; ranges from daily events to annual average considerations.	Subjective but recent objective concepts developed	Design varies with model methods; two regional studies followed semi-objective design; formal objective design approach attempted in concept.
Trends	FRM or other prescribed methods	Mainly urban/some regional non-urban	Long term-multi-year	Subjective; guided in U.S. as part of NAMS	Tied to emissions change; generally relies on compliance observations.
Processes	Specialized PM-precursor	Variable targets/designs range in scales from <1km-100km; aloft	Variable; usually short term campaign	Subjective-process specified	Highly focused; hypothesis generated; attention to secondary PM

[a] U.S. Federal Reference Method for PM.
[b] See, for example, the IMPROVE network.
[c] e.g., U.S. guidelines.
[d] For example, the NAMS, SLAMs networks in the U.S., NAPS in Canada, the RAMA network in Mexico City, or the California-Mexico border study.

complete documentation on network methods and comparability of data across networks.

Monitoring networks fill a variety of needs including the measurement of long-term trends, the measurement of baseline pollutant levels, the assessment of impacts, and the acquisition of data for model validation. The data set required typically varies with its application, and an effort should be made to ensure that existing monitoring networks meet diverse needs with maximum efficiency. Furthermore, North American networks should be harmonized to the extent possible to facilitate the sharing of data among Canada, the United States, and Mexico.

Objectives, measurements, and design criteria for existing national air-quality networks in Canada and the United States, including those that monitor PM, are summarized by Demerjian (2000). The Demerjian (2000) review also identifies the types of data reports produced by each network as well as the additional types of data analyses of interest from the standpoints of science or of air-quality management, delineates data-analysis techniques of use for the analyses of interest, and characterizes data limitations. A key conclusion of the Demerjian (2000) review is that the differences between the types of monitoring information needed for scientific purposes compared with air-quality management become critical for secondary pollutants. In the case of secondary pollutants, understanding the relative effectiveness of emission-control strategies requires analyses of data that are capable of revealing the relations between the production of secondary species and their precursor concentrations.

The U.S. EPA has been an active participant in various attempts to apply network-design methods to deposition-monitoring networks, including the National Atmospheric Deposition Program/National Trends Network (e.g., Seilkop and Finkelstein, 1987; Seilkop, 1987, Haas, 1990; Oehlert, 1993), the Environmental Monitoring and Assessment Program (Bromberg et al., 1989; U.S. EPA, 1989), the CASTNet, and, most recently, the networks included within the National Ambient Air Monitoring Strategy (National Monitoring Strategy Committee, 2001; U.S. EPA, 2002). However, past efforts to establish scientific bases for network configuration have not always yielded results that were implemented or that affected network designs in significant ways.

The new National Air Monitoring Strategy offers the prospect of integrating current, single-pollutant monitoring approaches to better address the management of linked, multi-pollutant air-quality issues (U.S. EPA, 2002). This monitoring strategy is specifically focused on the National Air Monitoring Stations (NAMS), the State and Local Air Monitoring Stations (SLAMS), Photochemical Air Monitoring Stations (PAMS), and IMPROVE. The National Air Monitoring Strategy is an initial step, and continuing efforts are needed to expand the focus of scientific network design and coordination to include air toxics and deposition networks. To date, analyses of ozone data from monitors nationwide have shown how to identify monitors that are effectively measuring the same ambient concentrations within local areas. This information will be used to redistribute monitors to use resources more efficiently. Completion of these types of analyses requires the availability of an existing database. In addition, the National Air Monitoring Strategy outlines a plan for developing a national core network of up to just under one hundred locations where a number of air pollutants would be monitored in a coordinated manner.

In California, the results of ozone and PM field studies and modeling have been used to design enhancements to the routine monitoring network, which could reduce future reliance on major field programs (Sweet et al, 2002). A critical component of this design effort was the use of twenty years of air-quality studies to identify the numbers of monitoring locations and types of measurements needed for providing ongoing data that will characterize mesoscale meteorological features of importance to air quality. Examples of such features include onshore and offshore coastal flows, mixing depths, upslope and downslope flows, and eddies and jets. A network capable of resolving such features could routinely provide the data needed for operating and evaluating three-dimensional Eulerian air-quality models for any set of days. This capability would then permit assessment of pollutant transport, emission-control measures, and other questions of importance for air-quality management for all days of interest, thus addressing continuing concerns about the representativeness of special field-study periods.

The problem of characterizing the spatial field, or the spatial-temporal field, of one or more measurements has in fact attracted a great deal of attention over the years in several areas of study. Much of this attention has focused on network design, specifically on the placement of monitoring sites. Examples from the study of precipitation amount (rainfall) include Rodriguez-Iturbe and Mejia (1974) and Bras and Rodriguez-Iturbe (1976). Such network-design techniques yield the number and configuration of monitoring stations that minimize an objective function of estimation error and cost. A significant body of literature on the design of air-quality networks exists and dates back many years (e.g., Seinfeld, 1972; Noll et al, 1977; Nakamori and Sawaragi, 1984; Liu et al, 1986; Langstaff et al., 1987).

C.3 NETWORK NEEDS

Specific instrumentation requirements are discussed in Chapter 5. Specification of instrumentation should ensure that the key measurements are made with necessary accuracy and time resolution. Recent developments in semi-continuous monitoring for mass and chemical PM components should be pursued so these methods become usable routinely in air monitoring and research programs.

The variety of types of measurement techniques currently in use raises questions about the accuracy and comparability of data obtained from different networks. These questions can be addressed only if adequate funding is devoted to comparisons (for comparisons of U.S. and Canadian data, see, e.g., Brook et al., 1997, Brook and Dann, 1999, Nejedly et al., 1998). Comparison of data from IMPROVE and nearby CASTNet sites indicate that the IMPROVE and CASTNet $SO_4^=$ measurements are comparable, but NO_3^- measurements are not (Malm, 2000). The differences in NO_3^- concentrations stem from the presence of coarse-particle NO_3^- and NO_3^- volatilization in the CASTNet samples. It has also been shown that the dichotomous samplers used in the Canadian NAPS experience losses of particulate NO_3^- (Brook and Dann, 1999). The U.S. EPA Federal Reference Method suffers from loss of NH_4NO_3 and semivolatile organic compounds. Losses can be significant and at times may represent over half the collected mass (Hering and Cass, 2000).

Measurements that are representative of both the mass and composition of particles in the ambient air are difficult to obtain with either filter-based or semi-continuous methods. Much of the fine PM mass is composed of secondary species (those formed in the air or condensed from the gas phase onto existing particles). Such species often have significant vapor pressures, and thus exist in both the gas and particle phases in quasi-equilibrium. Depending on the filter material used, collection of PM by filters is plagued by both positive and negative sampling artifacts that are exacerbated by the need to transport, store, and analyze the filter some time after collection. Since PM composition varies with location, season, and time of day, it is difficult to quantify the sampling artifacts. Denuders and reactive filters can be successfully used to obtain NO_3^- and NH_4^+ with minimal bias. These data can be used to correct the collected mass, but significant uncertainty still exists in the mass value. Organic species are even more difficult to collect and no method to date exists for collecting a relatively bias-free organic sample (see Chapter 5). Recent results from the 1999 Atlanta Supersite Project suggest lower interferences from sampling artifacts are observed with semi-continuous methods than with filter-based integrated methods.

Many networks measure a suite of PM components, including $SO_4^=$, NO_3^-, NH_4^+, OC, BC, and a variety of elements that represent crustal contributions. However, apart from limited special studies, virtually no speciated carbon measurements exist. Measurement of a variety of PM carbon compounds at emission sources and receptor locations holds the potential for substantially improving current knowledge of source contributions to ambient OC and BC concentrations. Similarly, gas-phase measurements are usually not included within most PM networks, yet they are necessary for fully understanding the behavior of semivolatile compounds (e.g., NH_4NO_3 and semivolatile organics). Because many networks make the same types of measurements, it is likely that duplication of effort exists in some specific locales. With appropriate harmonization of operating schedules and methods, more data could be shared across networks, freeing resources for measurements that are not now made by any network. *It is unlikely that techniques will be available in the near future to provide complete chemical characterizations of carbonaceous aerosols with the frequency that would be required for air-quality studies, so improved techniques for OC/BC measurements are needed for the near term. There is a need to learn more about the properties of organic compounds found in the gas and particulate phases. Moreover, an understanding of the behavior, lifetime, and effects of organic PM will require a better understanding of its tendency to absorb water.*

Continuing interaction with the health-effects and visibility research communities is needed to ensure appropriate specification of PM size fractions and species of interest. In the case of health-effects research, this interaction needs to be ongoing and iterative. Health-effects studies require monitoring information to conduct future epidemiological analyses, the conclusions from which may more fully identify the measurements of most importance. In contrast, the measurements needed for monitoring visibility impairment are generally well known as a result of past visibility studies.

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