Overview and Description of IMPROVE

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IMPROVE

• Interagency Monitoring of Protected Visual Environments
• Cooperative effort started in 1988 with ~30 sites
  – Expanded to ~165 sites ca. 2000
The IMPROVE network maintains ~165 sites.
Most samplers are located in National Parks & other remote areas
A few samplers are collocated with urban network samplers.
Current List of Sponsors

• U.S. National Park Service
• U.S. Forest Service
• U.S. Fish & Wildlife Service
• U.S. Environmental Protection Agency
• Various State Governments & Tribes
• Environment Canada
• South Korea Ministry of Environment
IMPROVE Measurements
Samples are collected every 3rd day, 24 hours, midnight to midnight
The IMPROVE sampler is designed for sampling clean air

- High flow rate – 23 liters per minute
- Small filter – 25 millimeter diameter filter concentrates the sample in a small area
- The result is better detection of small amounts of particulate matter
IMPROVE Sampler:

- 4 modules to collect different aerosol components

- Controller
  - Starts/stops pumps
  - Electronically records operating information
    - Solenoid positions
    - Flow rate readings
Sampling Module Design

- Inlet Stack
- Cyclone
- Solenoid Valves
- Filter Cassettes
Filters are shipped in cassettes
A local operator visits each site every Tuesday
UC Davis staff visit each site every 1 to 2 years for maintenance.
Collocated sampling measures precision
Data Validation at UC Davis

• UC-Davis validates data from entire network, providing consistent data quality assessment across the network
• Expected relationships are evaluated, for example sulfur compared to sulfate
• Research and advanced data analysis complement routine validation
IMPROVE data are available from AQS and at http://views.cira.colostate.edu/fed/
The Regional Haze Rule
The Goal – Natural Visibility Conditions by 2064

5 year baseline, 2000-2004
IMPROVE Supports the Regional Haze Rule (RHR)

- Establishes baseline conditions for visibility-protected areas such as National Parks
- IMPROVE designed to support the RHR
  - Many sites to characterize haze near each protected area
  - Multi-year data to evaluate long-term trends
  - Samplers designed to measure clean environments
  - PM$_{2.5}$ and PM$_{10}$ measurements to characterize the particles important to visibility impairment
Goals are set for reaching natural conditions
Technology has evolved since the beginning of IMPROVE

- Continuous recording of flow data initiated in 1999
- Switched to cleaner nylon filters in 2004
- Recent improvements
  - New XRF instruments in 2011
  - New balances in 2011
  - Ability to prepare our own XRF standards in 2011
- Improvements under development
  - New sampler controllers with remote communications
  - Add multiple wavelengths to light absorption measurement
  - IR absorption to estimate organic mass on each filter
IMPROVE Research & Data Analysis

Investigations can lead to better understanding and improvements of the measurements
Exploratory Data Analysis Can Uncover Unanticipated Problems

- Contamination from copper brushes on adjacent Hi-vol pumps on 1-in-6 day schedule
**Posting type**  Advisory  
**Subject**  S interference in XRF determination of Si  
**Module/Species**  A/ Si  
**Sites**  entire network  
**Period**  starting 12/1/01  
**Recommendation**  Distrust reported Si concentrations when [S] >> [Si], and disregard reported uncertainties and MDLs  
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**Supporting information**  
The primary XRF peak for sulfur has a shoulder that overlaps the primary XRF peak for silicon, as illustrated in Figure 1.

**Figure 1.** XRF spectra for two samples with differing S/Si ratios.
Creating XRF Calibration Reference Filters

- Reference filters prepared using IMPROVE or Partisol® sampler
- Provides reference filters at relevant concentrations
- XRF benchmark independent of commercially available standards
- Reference filters for S, Na, Cl, and K are used in current UC-Davis XRF calibrations
- Pb standards have been prepared to support EPA health effects measurements
Aerosol generation system

- Atomizer
- Particle Dryer
- Mixing Chamber
- IMPROVE PM2.5 Module
- Dilution Air
- RH Monitor
- Analyte Solution
- Dilution Air Dryer
Sulfur Reference Filters over IMPROVE range

Ammonium sulfate RMs linear regression:
\[ y = 0.51 \pm 0.01 x + 0.16 \pm 0.33 \]
\[ R^2 = 0.998 \]
Multi-year sample reanalysis to assess measurement influence on trends

Reanalysis of Archived IMPROVE PM$_{2.5}$ Samples Previously Analyzed over a 15-Year Period

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**ABSTRACT:** The IMPROVE (Interagency Monitoring of Protected Visual Environments) network has collected airborne particulate matter (PM) samples at locations throughout the United States since 1988. These samples have been analyzed for elemental content using analytical methods that evolved over the years. Changes in analytical methods sometimes introduced shifts in reported concentrations that are evident in the historical record. We sought to illuminate the effects of methodological changes by reanalyzing archived samples with current methods. To test the feasibility of this approach, the 15-year archive of PM samples from Great Smoky Mountains National Park was selected for reanalysis as a single analytical batch using a standardized protocol.
Reanalysis of 15 years of Archived Filters

• Great Smoky Mountains, Mount Rainier, Point Reyes
• Reanalysis under stable conditions and calibration
• Long-term uncertainties not reflected in our precision or collocated measurements
Developing a new carbon measurement: Fourier Transform Infrared (FT-IR) Spectroscopy

- **Non-destructive** analysis of Teflon® filters
- IR absorbances correspond to organic functional groups
- Sum of functional groups = OM
- Obtain OM/OC per sample

- Aliphatic C-H
- Carbonyl (C=O)
- Acid O-H
- Alcohol O-H
- Organonitrites
- Amines
- Organosulfate
FT-IR Spectra – each functional group has a characteristic absorbance.
OM/OC varies by sample

- OM/OC – annual
  - Median = 1.67
  - IMPROVE uses 1.8
  - 25th percentile = 1.53
  - 75th percentile = 1.86

- OM/OC – site
  - Mesa Verde NP, CO and Olympic NP, WA highest at ~1.8
  - Phoenix, AZ lowest at 1.55

- OM/OC – season
  - Winter (1.6) lower than other seasons (~1.7)

Samples for eight IMPROVE sites in 2011
IMPROVE: Our legacy is clear skies