IMPROVE Aerosol Monitoring Network

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IMPROVE Monitoring Program
The Interagency Monitoring of Protected Visual Environments

• Established in 1985 to aid the creation of Federal and State implementation plans for the protection of visibility in Class I areas - 1977 CAA amendments

• A cooperative measurement effort governed by representatives from Federal and regional-state organizations

• Objectives:
  – Establish current visibility and aerosol conditions in federal class I areas
  – Identify chemical species and emission sources responsible for existing man-made visibility impairment in FCIA
  – Document long-term trends for assessing progress towards the national visibility goal to FCIA
  – With the enactment of the Regional Haze Rule, to provided regional haze monitoring representing all visibility-protected FCIA

• Key participant in visibility-related research:
IMPROVE Monitoring

- Monitoring Began in March 1988
- **Aerosol** – particle sampling/analysis for six major species & trace constituents to aid in source attribution (24 hour samples twice weekly; every 3rd day starting in 2000)
- **Optical** – extinction by transmissometer &/or scattering by nephelometer (hourly) plus absorption on particle filters (24-hour)
- **Scene** – color **photography** to document scenic appearance (typically 3 photos/day)
  - photographic spectrums of a range of visibility conditions are generated from 5 years of photos
IMPROVE Aerosol Samplers

- Four independent sampling modules
- Prior to 2000, two 24 hour samples were collected twice a week, after 2000, samples collected every three days.

<table>
<thead>
<tr>
<th>Module</th>
<th>Filter</th>
<th>Size</th>
<th>Variable</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Teflon</td>
<td>PM2.5</td>
<td>mass</td>
<td>gravimetric</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Na-Mn</td>
<td>Proton Induced X-Ray Emission (PIXE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fe-Pb</td>
<td>X-ray Fluorescence (XRF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>total H</td>
<td>Proton Elastic Scattering</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>optical absorption</td>
<td>Hybrid Integrating Plate/Sphere (HIPS)</td>
</tr>
<tr>
<td>B</td>
<td>Nylon</td>
<td>PM2.5</td>
<td>sulfate, nitrate</td>
<td>Ion Chromatography</td>
</tr>
<tr>
<td>C</td>
<td>Quartz</td>
<td>PM2.5</td>
<td>OC, EC in 8 fractions</td>
<td>Thermal Optical Reflectance</td>
</tr>
<tr>
<td>D</td>
<td>Teflon</td>
<td>PM10</td>
<td>mass</td>
<td>gravimetric</td>
</tr>
</tbody>
</table>
Began with 20 sites in 1988, today 163 monitoring sites are in operation
116 monitoring sites collected some data in 2000
Data Quality Assurance

- IMPROVE data go through extensive QA/QC procedures by UC Davis, NPS/CIRA and users

- Begins at filter purchase
  - Acceptance tests

- Pre-weight measurement
  - Enters sample into log file for tracking

- Post-sample tests
  - Field and laboratory control filters
  - Log sheets
  - Flow rates

- Post-analysis tests
  - PIXE vs. XRF
  - Sulfur vs. sulfate
  - B_{abs} vs. LAC
  - OMC vs. OMH
  - PM_{2.5} mass vs. PM_{10} mass
  - Reconstructed mass vs. mass

Elemental S vs. Ionic Sulfate
IMPROVE aerosol data are used to estimate haze ($b_{\text{ext}}$) in class I areas (rural United States)

Reconstructed light extinction equation:

$$Light\ Extinction\ (b_{\text{ext}}) = 3\ f\ (RH)[Amm.\ sulfate] + 3\ f\ (RH)[Amm.\ nitrate] + 4[\text{Organic}] + 10[\text{Light Abs. Carbon}] + 1[\text{Soil}] + 10$$

The aerosol types are calculated from the speciated aerosol data, e.g. Amm Sulfate = 4.125 * Sulfur. The leading coefficient are extinction efficiencies [m$^2$/g] and the f(RH) factor accounts for water uptake by the sulfate and nitrate species.

The IMPROVE reconstructed $b_{\text{ext}}$ contains a number of assumption, however, overall it seems to work.
Aerosol Spatial Patterns 1996-1998

Fine Mass

Ammonium Sulfate

Organics

Fine Soil
Reconstructed $B_{ext}$ Spatial Patterns 1996-98
Sulfate Trends on the Worst 20% Days

Malm and Ames 2001
IMPROVE Derived AOD Compared to Measured Values from 1995–1997 (Corbin et al., 2002)

- AOD 670 nm – measured optical depth from the Aerosol Robotic Network (AERONET) instrument at Goddard Space Flight Center
- AOD$_I$ - IMPROVE derived AOD at Washington, D.C. calculated by multiplying the reconstructed $b_{ext}$ by the boundary layer dept at for the years 1995–1997.
- The data were screened for clouds.
- The correlation of the ranks is 0.55
Data Availability - IMPROVE Web Site

Purpose:
Describe, document, and delivery IMPROVE aerosol and optical data and data analysis products relevant to regional haze

http://vista.cira.colostate.edu/improve/
Visibility Information Exchange Web System

National (United States) aerosol and optical data integration, analysis and delivery system supporting the better understanding and analysis of haze and the implementation of the U.S. Regional Haze Regulation

Designed to acquire, manage, and provide access to data and metadata from multiple monitoring networks in a uniform format.

http://vista.cira.colostate.edu/VIEWS/
### Data Sets currently available from VIEWS:

<table>
<thead>
<tr>
<th>Network</th>
<th>Parameters</th>
<th>Location (sites)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARS</td>
<td>Light Scattering and extinction</td>
<td>United States (17)</td>
<td>1988 – present</td>
</tr>
<tr>
<td>CASTNET</td>
<td>Speciation aerosol data</td>
<td>United States: (120)</td>
<td>1987 – present</td>
</tr>
<tr>
<td>EPA AIRS FRM</td>
<td>Fine mass (&lt;2.5 microns)</td>
<td>United States: (1500)</td>
<td>1999 – present</td>
</tr>
<tr>
<td>EPA AIRS Speciation</td>
<td>Speciation aerosol data</td>
<td>United States: (200)</td>
<td>1999 – present</td>
</tr>
<tr>
<td>IMPROVE</td>
<td>Speciation aerosol data, Light Scattering and extinction</td>
<td>United States: (160)</td>
<td>1988 – present</td>
</tr>
<tr>
<td>MOHAVE</td>
<td>Speciation aerosol data, Light Scattering and extinction</td>
<td>Southwestern US. (40)</td>
<td>1992</td>
</tr>
<tr>
<td>PREVENT</td>
<td>Speciation aerosol data</td>
<td>Northwestern US: (30)</td>
<td>1990</td>
</tr>
<tr>
<td>REVEAL</td>
<td>Speciation aerosol data</td>
<td>British Columbia, CA (2)</td>
<td>1994-5</td>
</tr>
<tr>
<td>SEAVS</td>
<td>Speciation aerosol data, Light Scattering and extinction</td>
<td>Southeastern US: (1)</td>
<td>1995</td>
</tr>
</tbody>
</table>

### Data Sets soon to be added to VIEWS:

<table>
<thead>
<tr>
<th>Network</th>
<th>Parameters</th>
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<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Park Service Stack Filter Units (SFU)</td>
<td>Speciation aerosol data</td>
<td>United States</td>
<td>1976-1988</td>
</tr>
<tr>
<td>NESCAUM</td>
<td>Speciation aerosol data</td>
<td>Northeastern US</td>
<td>1988-1993</td>
</tr>
<tr>
<td>BRAVO</td>
<td>Speciation aerosol, light scattering and extinction</td>
<td>Texas</td>
<td>Summer 1999</td>
</tr>
<tr>
<td>SEARCH</td>
<td>speciated aerosol, gaseous, surface met</td>
<td>Southeastern US</td>
<td>1998-present</td>
</tr>
<tr>
<td>National Park Service Gas</td>
<td>Gaseous species</td>
<td>United States</td>
<td>19?? - present</td>
</tr>
<tr>
<td>GAViM</td>
<td>PM2.5, speciated aerosol</td>
<td>Canada</td>
<td>1994 - present</td>
</tr>
</tbody>
</table>
Guide to Resources

• to query the aerosol database:
  http://vista.cira.colostate.edu/improve/Data/DataQuery/IMP_Aer_Data_Acc

• to download predefined aerosol ASCII files:
  http://vista.cira.colostate.edu/improve/Data/IMPROVE/IMPLocTable_Data.asp

• to download nephelometer and transmissometer ASCII files at:
  http://vista.cira.colostate.edu/improve/Data/IMPROVE/Data_IMPOptical.asp

• to get a full description of all of the IMPROVE sites:
  http://vista.cira.colostate.edu/improve/Data/GraphicViewer/metadata.asp

• new “VIEWS” website at (aerosol/haze integration effort):
  http://vista.cira.colostate.edu/views/

• to get speciated data from IMPROVE, CASTNet EPA, AIRS …
  http://vista.cira.colostate.edu/views/Data/DataQuery/IMP_Aer_Data_Acces

• to see the metadata at:
  http://vista.cira.colostate.edu/views/Data/GraphicViewer/metadata.asp