THE IMPROVE PROGRAM

Interagency Monitoring of Protected Visual Environments

Jenny Hand

CIRA, Colorado State University

Photo : Scott Copeland
Green River Lake, WY

Overview

- Purpose
- Management & Organization
- Routine Monitoring
- Logistics
- Documentation
- Data Download & Tools
- Data Analysis

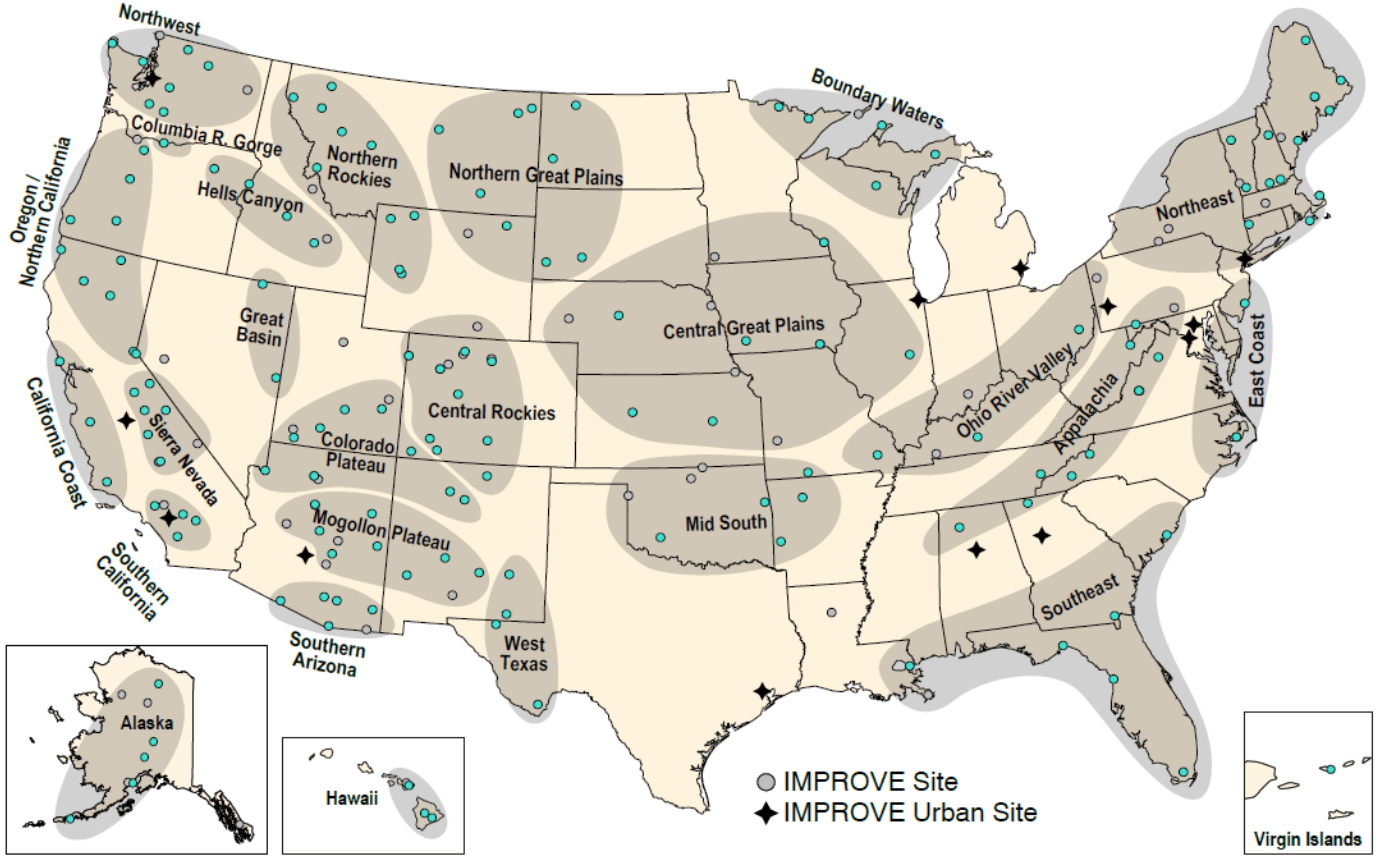
Capitol Reef, UT

Purpose

- The 1977 Clean Air Act Amendments
  - Congress established a national goal that calls for "***the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution***."
- The 1999 Regional Haze Rule (RHR) expanded this mandate.
  - ***Required state and federal agencies to work together to improve visibility in all 156 federal Class I national parks and wilderness areas***
  - Established a goal of no "man-made impairment" in Class I areas by 2064.
  - ***Required visibility monitoring*** in locations representative of the 156 visibility-protected federal Class I areas. ***IMPROVE*** was designated as the monitoring network to carry out this responsibility.

IMPROVE Visibility Monitoring

- The IMPROVE Program began in 1985.
- Long term monitoring began in 1988 with 20 monitoring sites.
- Currently 155 sites.



Purpose

The **IMPROVE program** is a cooperative measurement effort designed to

1. Establish **current visibility and aerosol conditions** in mandatory Class I areas (CIAs);
2. Identify **chemical species** and emission sources responsible for existing anthropogenic and natural visibility impairment;
3. Document **long-term trends** for assessing progress toward the national visibility goal;
4. Provide **regional haze monitoring** representing all visibility-protected federal CIAs where practical.

Big Bend, TX

156 Class I Areas

International parks, national wilderness areas, and national memorial parks that exceed 5000 acres in size and national parks that exceed 6000 acres in size that were in existence on the date of enactment of the 1977 Clean Air Act Amendments

Purpose

- **IMPROVE is an open and collaborative program** that involves stakeholders in all decisions, and where consensus among stakeholders is sought but not required. Input from other organizations involved in IMPROVE and data users are also sought and taken into consideration.
- The IMPROVE Steering Committee **provides guidance and recommendations to EPA** and the contracting agency on how to best meet the program's mission and objectives.
- IMPROVE is a regulatory network, **operated in support of the requirements of the Regional Haze Rule**. IMPROVE data also **support additional scientific and regulatory inquiries** and the program is operated to foster these additional endeavors.
- Recommendations for **changes in the monitoring program are based upon sound scientific justification** within resource constraints. Changes are implemented in a manner that **minimizes discontinuities in long term trends.**

Management and Organization

IMPROVE Steering Committee

- Guides the management and evolution of the monitoring network:
  - Oversees all program activities, develops guidance and procedures governing IMPROVE samples and data,
  - Makes recommendations to EPA and NPS related to funding, expansion/reduction of the network and all technical and non-technical issues,
  - Interacts directly with the laboratories,
  - Seeks input from the broader community.

Management and Organization

IMPROVE Steering Committee

- Chair, Vice Chair, Secretary
- Representatives from NPS, USFS, FWS, BLM, NOAA, state organizations (WESTAR, NESCAUM, MARAMA, NACAA)
- Associate members: State of Arizona, Environment and Climate Change Canada, Republic of Korea Ministry of Environment

Current Members

NPS: Bret Schichtel
EPA: Melinda Beaver
USFS: Scott Copeland (Chair)
FWS: Tim Allen (Vice Chair)
BLM: Bret Anderson
NOAA: Xinrong Ren
WESTAR: Jay Baker
NESCAUM: Heidi Hales
MARAMA: Charles Turner
NACAA: Farrah Fatemi

Secretary: ARS

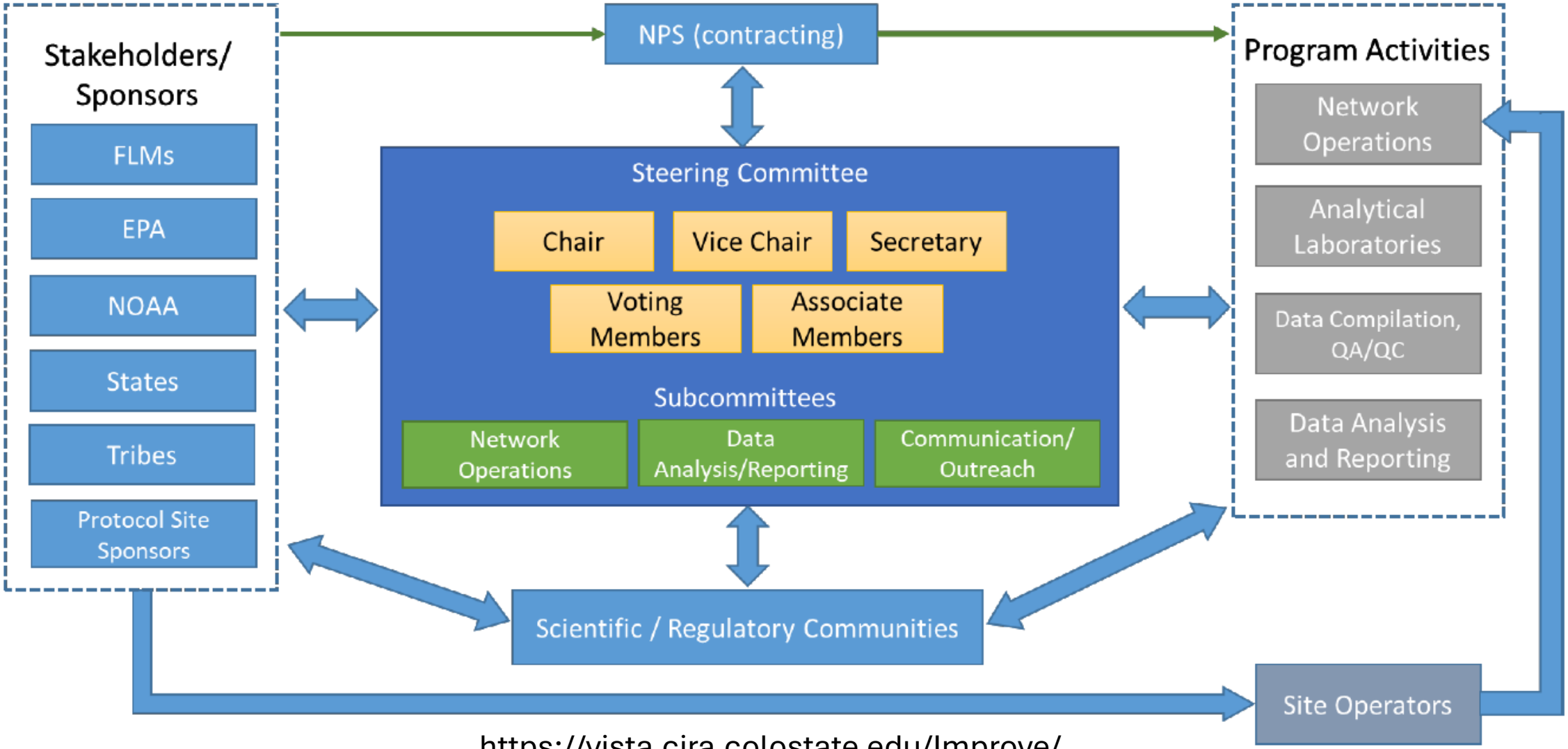
Management and Organization

The IMPROVE Program

- Is governed by a Charter.
- Hosts an annual fall meeting (hybrid) and virtual spring meeting to report on the state of the network.
- Code of Conduct (see Charter).

White River, CO

Management and Organization



https://vista.cira.colostate.edu/Improve/

Management and Organization

Program Activities

1. Network operations: filter handling and shipping, and site maintenance
2. Laboratory activities: filter analyses
3. Data Compilation and QA/QC
4. Data Analysis and Reporting: higher level QA, data synthesis and generation of RHR metrics.

The details of these activities are discussed in the IMPROVE quality management plan (QMP), quality assurance project plan (QAPP), and standard operating procedures (all available on the IMPROVE website).

Management and Organization

IMPROVE Subcommittees

- Network Operations (Melinda Beaver, EPA)
- Data Analysis & Reporting (Jenny Hand, CSU)
- Outreach/Communication (Jay Baker, WESTAR)

- Provide the technical guidance needed to evaluate and adapt the IMPROVE monitoring program to ensure it meets its mission and objectives.

- Ad-hoc workgroups may also be formed to work on timely issues related to the IMPROVE program.

Hoover, CA

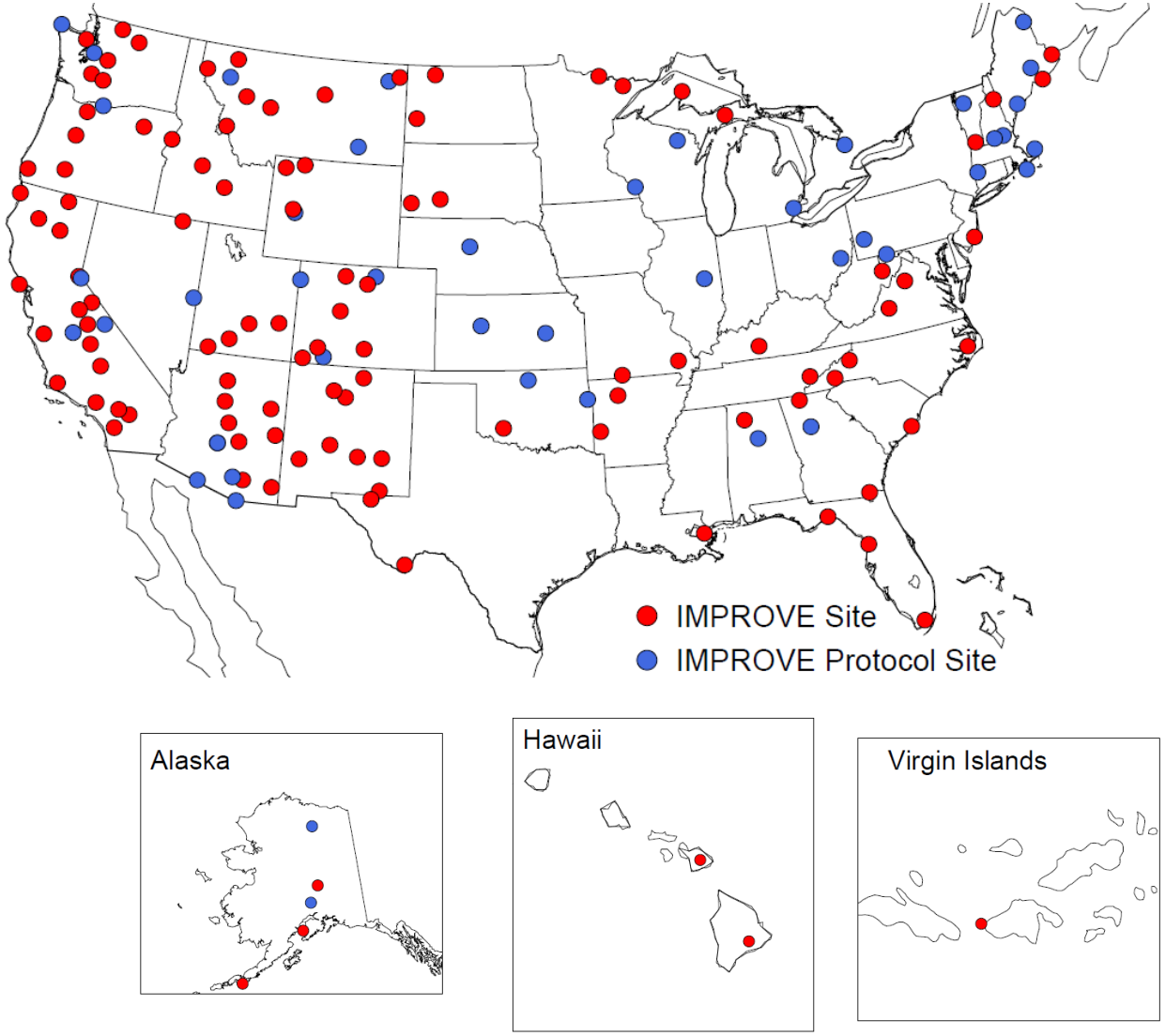
Management and Organization

Funding

EPA funds laboratory costs of the 110 IMPROVE sites on behalf of the states.

Protocol sites are funded by various state, regional, tribal, and federal organizations as well as international organizations. Protocol sites are operated similarly to network sites.

Protocol sites: 40k



Management and Organization

Laboratory Contracts

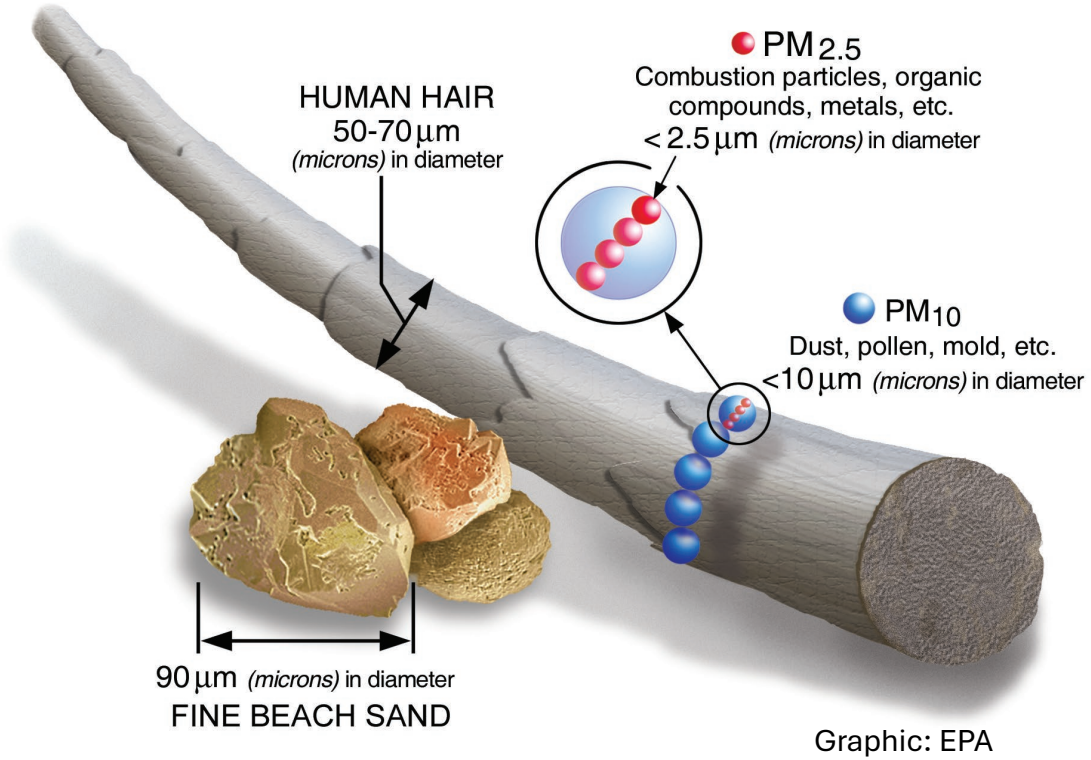
The NPS administers all IMPROVE contracts for routine IMPROVE operations:

- Network operations and analysis of PM samples collected on Teflon filters (XRF, gravimetric weighing, HIPS)- **UC Davis.**
- Carbon contract: analysis of samples collected on quartz fiber filters for carbonaceous content- **DRI.**
- Ion contract: analysis of the samples collected on nylon filters for ionic composition- **RTI.**

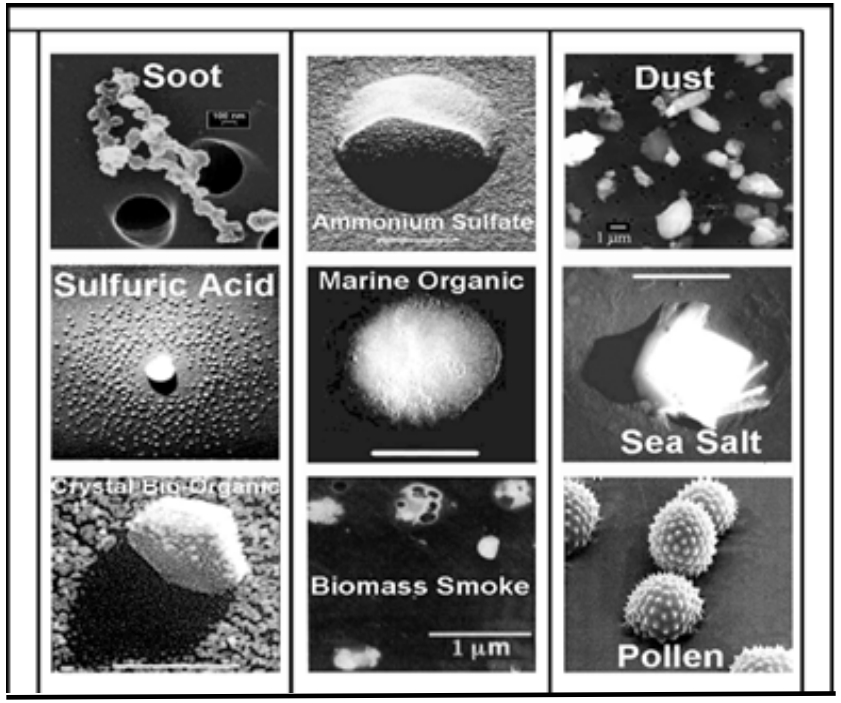
Great Sand Dunes, CO

Routine Monitoring

Atmospheric Aerosols



Graphic: EPA



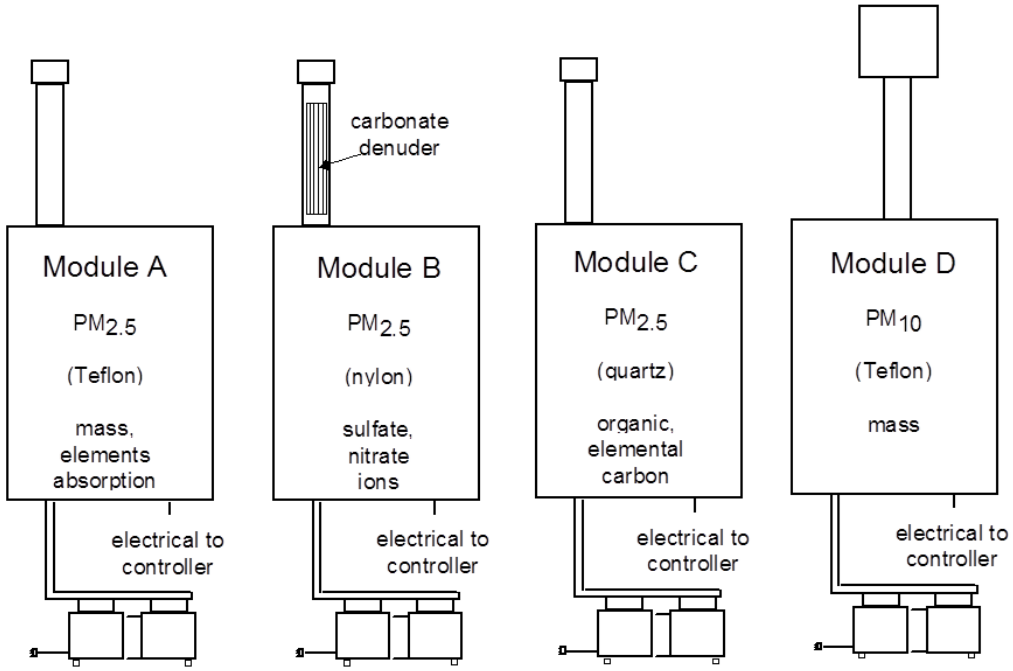
There are many different types of particles in the atmosphere.

$PM_{2.5}$ and PM_{10} are the tiny particles collected by the IMPROVE filters.

Routine Monitoring

- 24-hr samples collected every 3rd day
- Midnight-midnight local standard time

IMPROVE Samplers



Dome Lands, CA

A: $PM_{2.5}$ Gravimetric mass, elements, filter absorption

B: $PM_{2.5}$ Ions (SO_4^{2-}, NO_3^-, Cl^-, NO_2^-)

C: $PM_{2.5}$ Organic Carbon, Elemental Carbon

D: PM_{10} Gravimetric mass

IMPROVE Module A

Gravimetric Mass: Filter is weighed in a temperature and relative humidity-controlled chamber (T = 21.5 ºC and RH = 39%).

[$PM_{2.5}$ gravimetric mass]

Photo: UC Davis

Teflon filter

IMPROVE Module A

XRF Elemental Analysis: Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Zr, Pb

Calculate:

(old*) **[Fine Dust] = 2.20×[Al] + 2.49×[Si] +1.63×[Ca] + 2.42×[Fe] + 1.94×[Ti]**

(new) **[Fine Dust] = 2.53×[Al] + 2.86×[Si] +1.87×[Ca] + 2.78×[Fe] + 2.23×[Ti]**

Assumes all measured dust is the same at all locations.

Teflon filter

(*Used in FED)

IMPROVE Module A

Hybrid Integrating Plate/Sphere (HIPS): Measures the reflected and transmitted laser light through the Teflon filter (633 nm)

Light Absorption Coefficient [f_{abs}, Mm^{-1}]

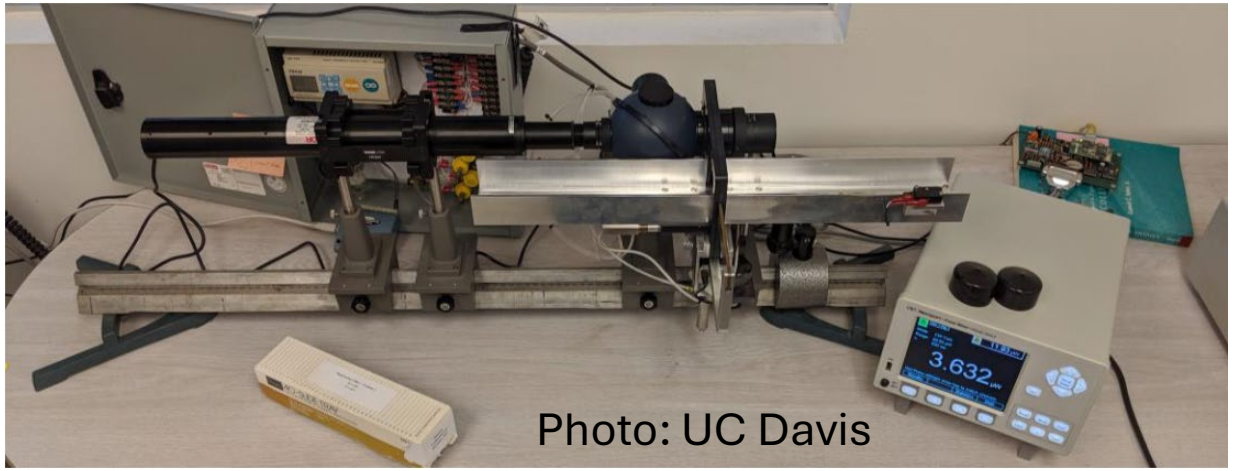


Photo: UC Davis

Teflon filter

IMPROVE Module B

Ions: sulfate [SO_4^{2-}], nitrate [NO_3^-], chloride [Cl^-], nitrite [NO_2^-]

Calculate:

[Ammonium Sulfate] = 1.375×[sulfate ion]

[Ammonium Nitrate] = 1.29×[nitrate ion]

[Sea Salt] = 1.8×[chloride ion]

Nylon filter

Photo: RTI

IMPROVE Module C

Carbon: [Organic Carbon], [Elemental Carbon]


Photo: DRI

For organics, we only measure organic carbon and estimate total particulate organic matter (organic mass by carbon, OMC).

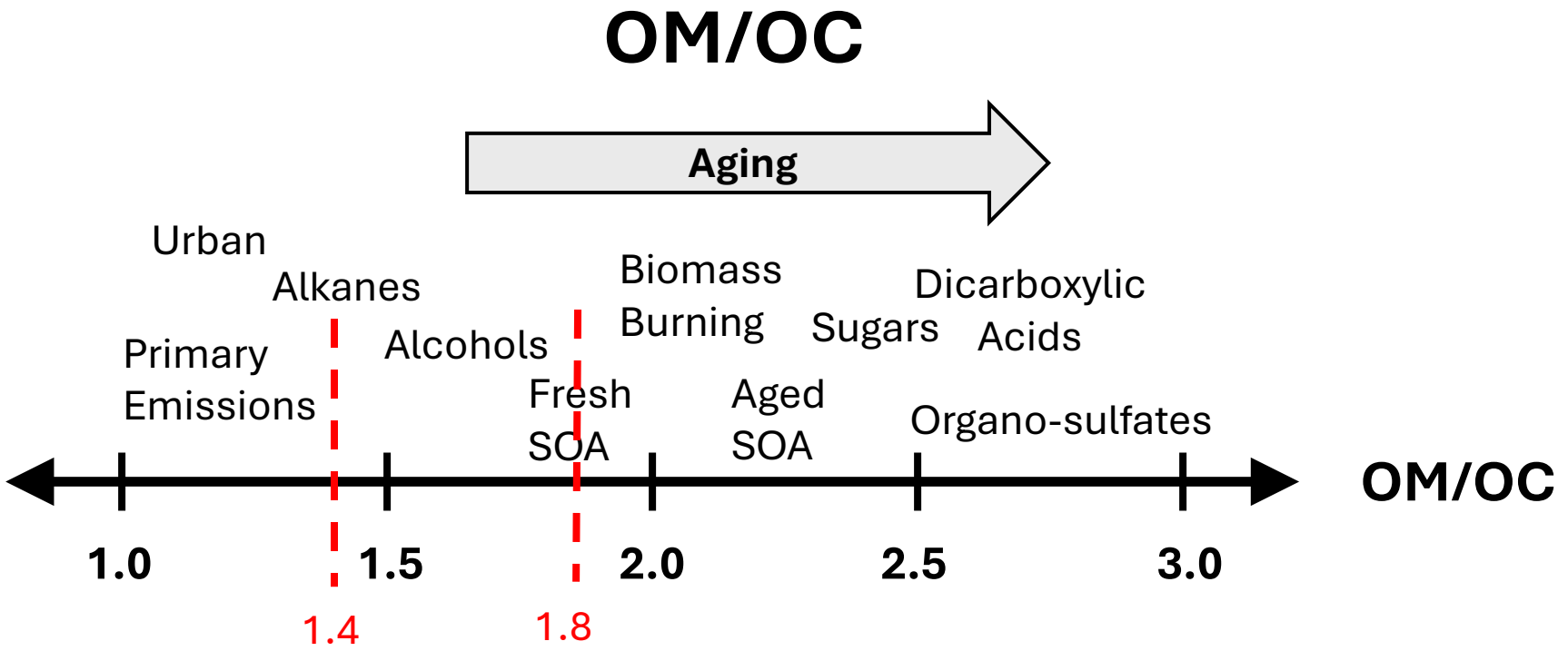
Calculate:

[Particulate Organic Matter] = (OM/OC)×[organic carbon]

Quartz filter

IMPROVE Module C

Carbon: [Organic Carbon], [Elemental Carbon]



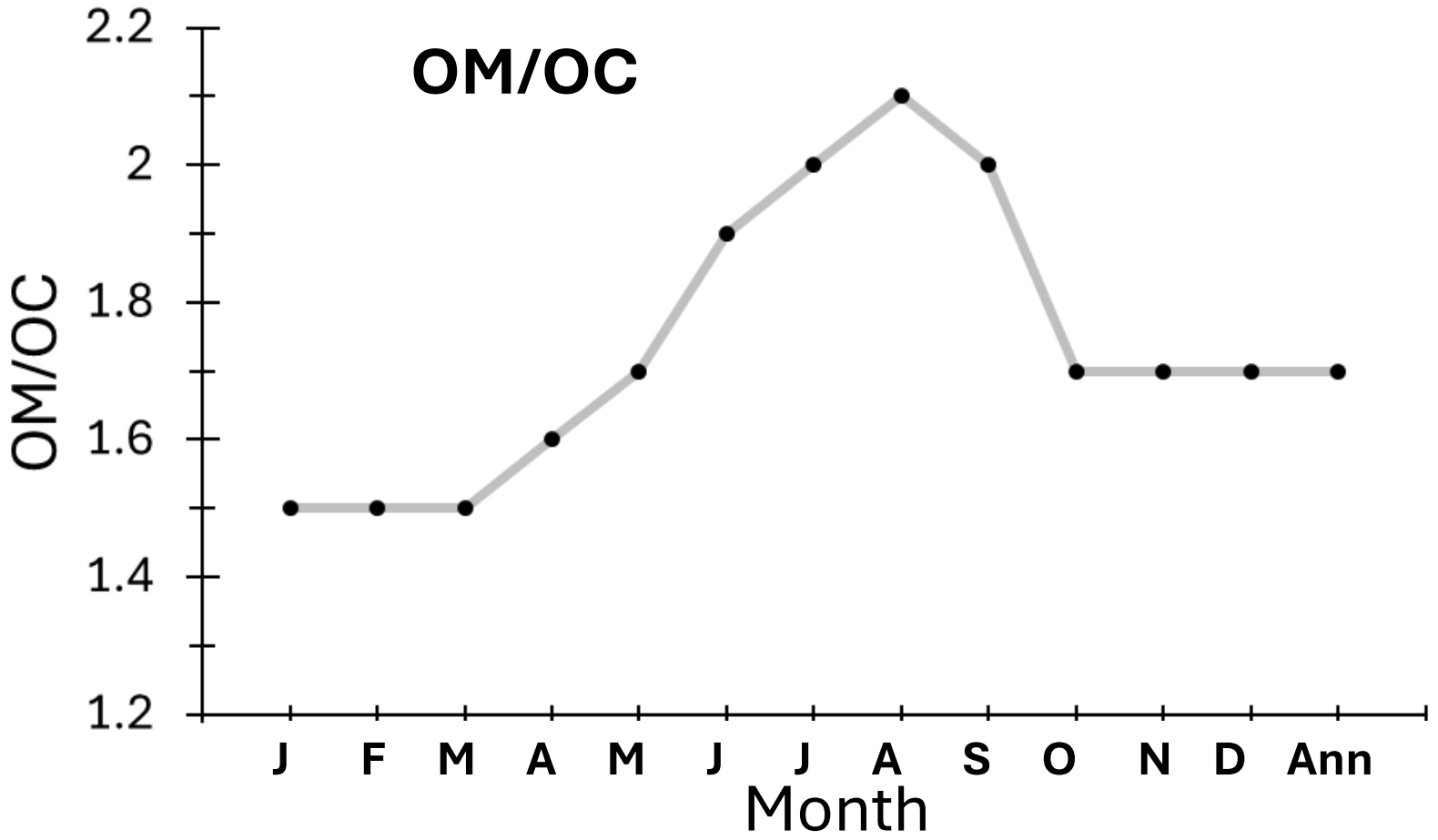
Previously, OM/OC = 1.4, and then 1.8*, but now we vary it monthly.

(*Used in FED)

IMPROVE Module C

Carbon: [Organic Carbon], [Elemental Carbon]

Monthly varying OM/OC (regionally constant)



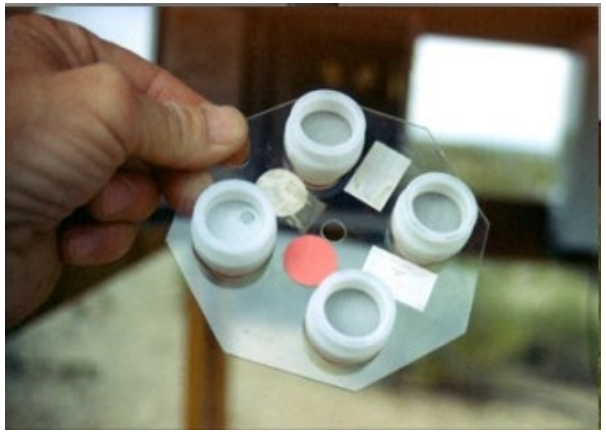
Annual mean: 1.7

Hand et al., 2023

IMPROVE Module D

Gravimetric Mass: Filter is weighed in a temperature and relative humidity-controlled chamber (T=21.5 ºC and RH=39%)

[PM_{10} gravimetric mass]



Calculate:

[Coarse Mass] = [PM_{10}] – [$PM_{2.5}$]

Teflon filter

Reconstructed Mass Algorithm

Ammonium sulfate (AS) = 1.375 × [sulfate ion]

Ammonium nitrate (AN) = 1.29 × [nitrate ion]

Particulate Organic Matter (POM) = (OM/OC) × [Organic Carbon]

Elemental Carbon (EC)

Fine Dust (FD) = 2.53 × [Al] + 2.86 × [Si] +1.87 × [Ca] + 2.78 × [Fe] + 2.23 × [Ti]

Sea Salt (SS) = 1.8 × [chloride ion]

Reconstructed Fine Mass (RCFM) = AS+AN+POM+EC+FD+SS

Coarse Mass (CM) = $PM_{10} - PM_{2.5}$

Logistics

Each IMPROVE site has a sponsoring agency

Sponsoring Agency:

- 110 RHR sites funded by the FLM whose CIA the site represents.
- Protocol sites are sponsored by the agency that funds them.
- Provides support (location, shelter, power, and a site operator).

Network contractor (UC Davis) supports the sites by providing samplers, internet connections, communications with site operators, sending filters to the sites, shipping costs, and routine maintenance once every two years.

North Absaroka, WY

Logistics

Site Operators

- Change filters once/week.
- Send filters to the network contractor (UC Davis).
- Serve as a point of contact for network contractor and auditors.
- Provide basic troubleshooting, with support from the network contractor.

Wheeler Peak, NM

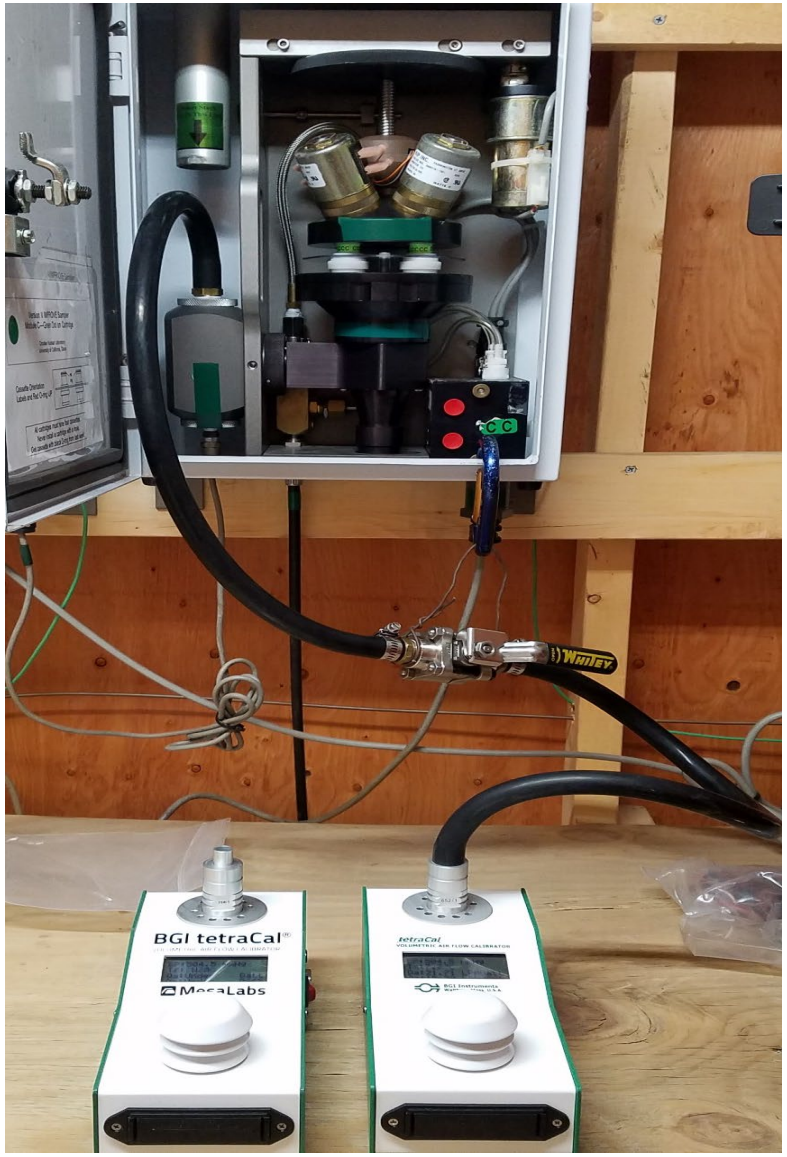
Technical System Audits (TSAs)

Assess whether a sampling site complies with IMPROVE QAPP.

1. Site meets sampling criteria – collecting regionally representative aerosol sample.
2. Integrity/condition of sampling structure.
3. Measure flow rates, temperature, pressure using NIST certified audit device.
4. Observe operator technique (when possible) to assess issues of sample contamination.

Required: One audit every ten years

All but five sites have been audited in the last seven years, three of which will be audited this winter.

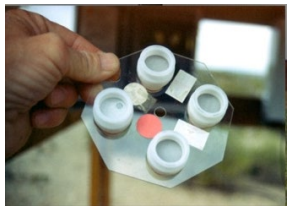


Quality Assurance/Quality Control

- Mass concentrations are blank corrected using field and laboratory blanks.
- All data undergo quality assurance evaluations.
  - QA reports
  - Standard Operating Procedures
  - Quality Management Plan (QMP) & Quality Assurance Project Plan (QAPP)

Hells Canyon, OR

Life Cycle of an IMPROVE Filter



UC Davis packs and ships filters to site

Samples collected

Filters sent back to UC Davis

UC Davis keeps Teflon filters and sends other filters to DRI and RTI

All labs do their own analysis and quality assurance checks (QA/QC)

All data sent to UC Davis

Data are combined and undergo more QA/QC

Problems? Filters are reanalyzed

Data are combined and undergo more QA/QC

Filters/extracts are stored at labs

Final data sent to FED/EPA AQS

Process: 6-9 months

Documentation

IMPROVE Website

Quality Assurance/Quality Control
Quality Management Plan (QMP)
Quality Assurance Project Plan (QAPP)
QA Reports by Labs
Standard Operating Procedures
Technical System Audits
Data Advisories
IMPROVE Reports
Data User Guide
Visibility Documents

Kalmiopsis, OR

https://vista.cira.colostate.edu/Improve/

IMPROVE Website

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Search ... Search

Home Overview Data RHR Data Resources Publications Meetings Special Studies

Interagency Monitoring of Protected Visual Environments

News & Updates

A new paper has been published characterizing trends in seasonal mean speciated aerosol composition from IMPROVE data.

Photos and Presentations from the 2023 IMPROVE Steering Committee Meeting have been posted.

The 2022 RHR files have been posted.

A revised IMPROVE Data User Guide has been posted

A draft of the 6th IMPROVE Report has been posted.

A new video featuring Bill Malm has been released by the NPS: National Parks in the History of Science: Visibility

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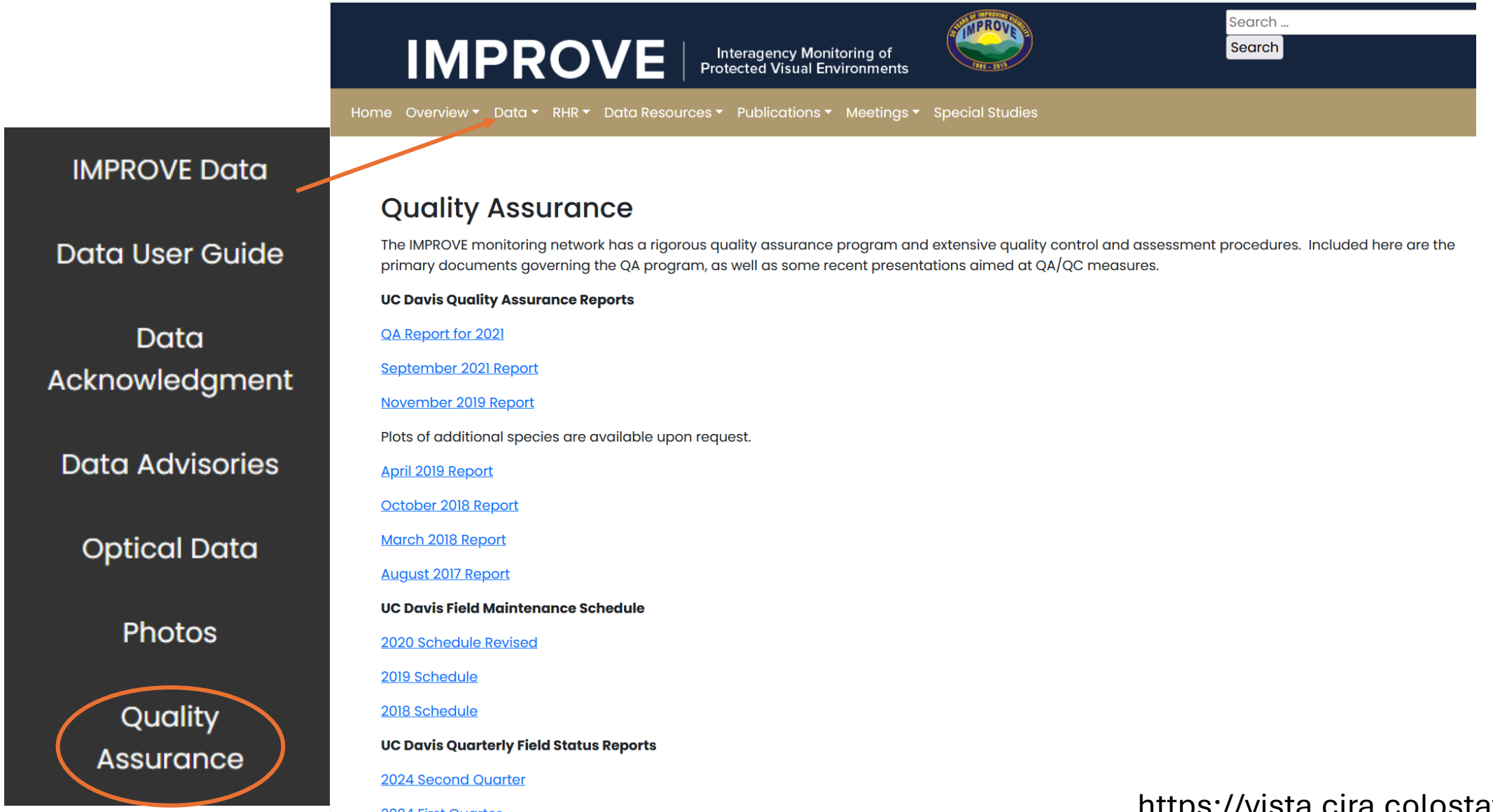
Quality Assurance/Quality Control



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Data Advisories

IMPROVE Data

Data User Guide

Data Acknowledgment

Data Advisories

Optical Data

Photos

Quality Assurance

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Home Overview Data RHR Data Resources Publications Meetings Special Studies

Data Advisories

This is an IMPROVE data user community supported page meant to document interesting findings from the IMPROVE database including data anomalies, potential problems, and new uses for the IMPROVE data. These advisories are not meant to be comprehensive or complete. In addition, unless explicitly stated the data advisories are not necessarily endorsed by the IMPROVE steering committee, National Park Service, CIRA or others.

Universal calibration constants for flow rate calculation	*Submitted by*: C. Wallis	*On*: 09/2019	*Doc #*: da0044
Sites: All, following installation of Version 4 controllers	*Time Period:* 2018-present	*Module/Species: All*	
Change in analytical protocol for XRF analysis	*Submitted by*: K. Trzepla	*On*: 06/2019	*Doc #*: da0043
Sites: All	*Time Period:* 10/2018-present	*Module/Species: A/All elements*	
Method change for calibrating flow rate transfer standards	*Submitted by*: C. Wallis	*On*: 05/2019	*Doc #*: da0042
Sites: All	*Time Period:* 1/2015-present	*Module/Species: All*	
Changes to HIPS System	*Submitted by*: K.Trzepla & J. Giacomo	*On*: 04/2019	*Doc #*: da0041
Sites: All	*Time Period:* 1/2017-present	*Module/Species: A/Fabs*	
Updated data for Carbon	*Submitted by*: B Schichtel	*On*: 04/2019	*Doc #*: da0040

Data User Guide

IMPROVE DATA USER GUIDE 2023 (VERSION 2)

J.L. Hand (24 October 2023)

Version 1.0 1995 User Guide can be found here.

TABLE OF CONTENTS

1.0 INTRODUCTION

The IMPROVE Data User Guide provides information for the general user on routine monitoring, aerosol sampling and analysis, accessing and downloading data, descriptions of methods for determining concentrations, minimum detection limits, uncertainties, calculated variables, mass and aerosol extinction reconstruction algorithms, and other applicable information for obtaining, analyzing and interpreting IMPROVE data. The guide will periodically be updated as new information is available or changes occur.

Information in this Guide is reproduced or summarized from several documents that provide additional details regarding the operation of the IMPROVE network and reporting of

Yosemite, CA

Standard Operating Procedures

- Intro to Visibility
- IMPROVE Reports
- Gray Literature
- Standard Operating Procedures
- IMPROVE Calendars
- Principal Visibility Documents
- Newsletters (discontinued)

Standard Operating Procedures

The IMPROVE network follows strict protocols that have been peer reviewed. In depth documentation of these protocols are provided in the Following SOPs.

Particulate Monitoring Network

The University of California, Davis is responsible for the installation and operation of the IMPROVE samplers. In addition UC Davis analyzes the Teflon filters from module A for fine mass and its elemental constituents. The PM10 mass is also obtained from the Teflon filter in module D. The following SOP's describe the site selection, installation and operating procedures of the IMPROVE samplers. The analysis of the filters for mass and elemental composition and QA/QC procedures are also described.

Carbon Analysis

The Desert Research Institute analyses the quartz filters from module C of the IMPROVE sampler for organic and elemental carbon using the DRI thermal/optical reflectance carbon analyzer. The following operating protocols provide the basic understand of the principle of the carbon analysis and carbon analyzer and detailed descriptions of the procedures for conducting the carbon analysis.

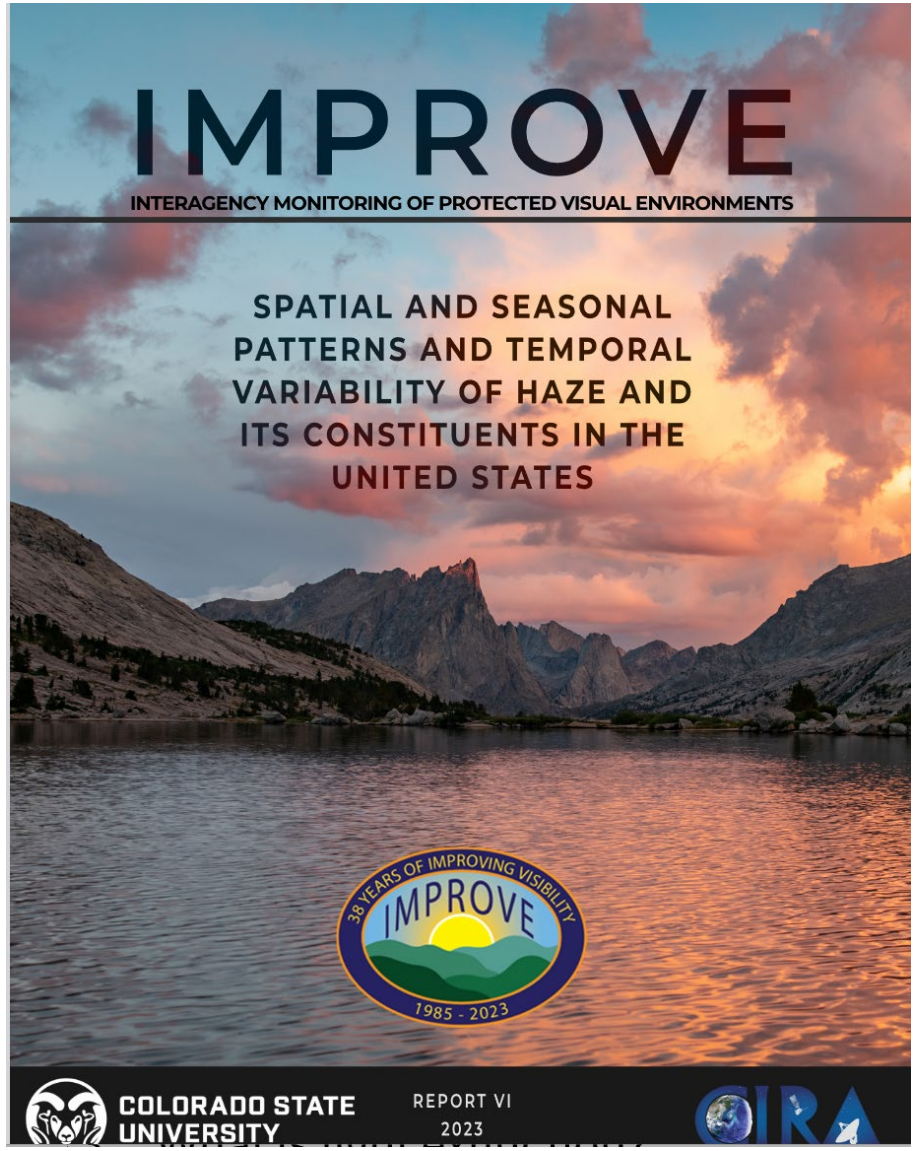
Ion Chromatography Analysis

The Research Triangle Institute analyzes the nylon filters from module B of the IMPROVE sampler for ions using ion chromatography (IC). The following SOP describes the procedures for analyzing the filters and QA/QC analyses conducted on the data.

Optical Monitoring

Air Resource Specialist operate the optical monitors, transmissometer, nephelometer and camera, at the IMPROVE and IMPROVE protocol monitoring sites. This SOP describes the operating procedures for all three instrument from site selection to data archiving.

IMPROVE Report



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Regional Haze Rule

RHR Summary Data

Impairment Overview

Data Patching

RHR Guidance Documents

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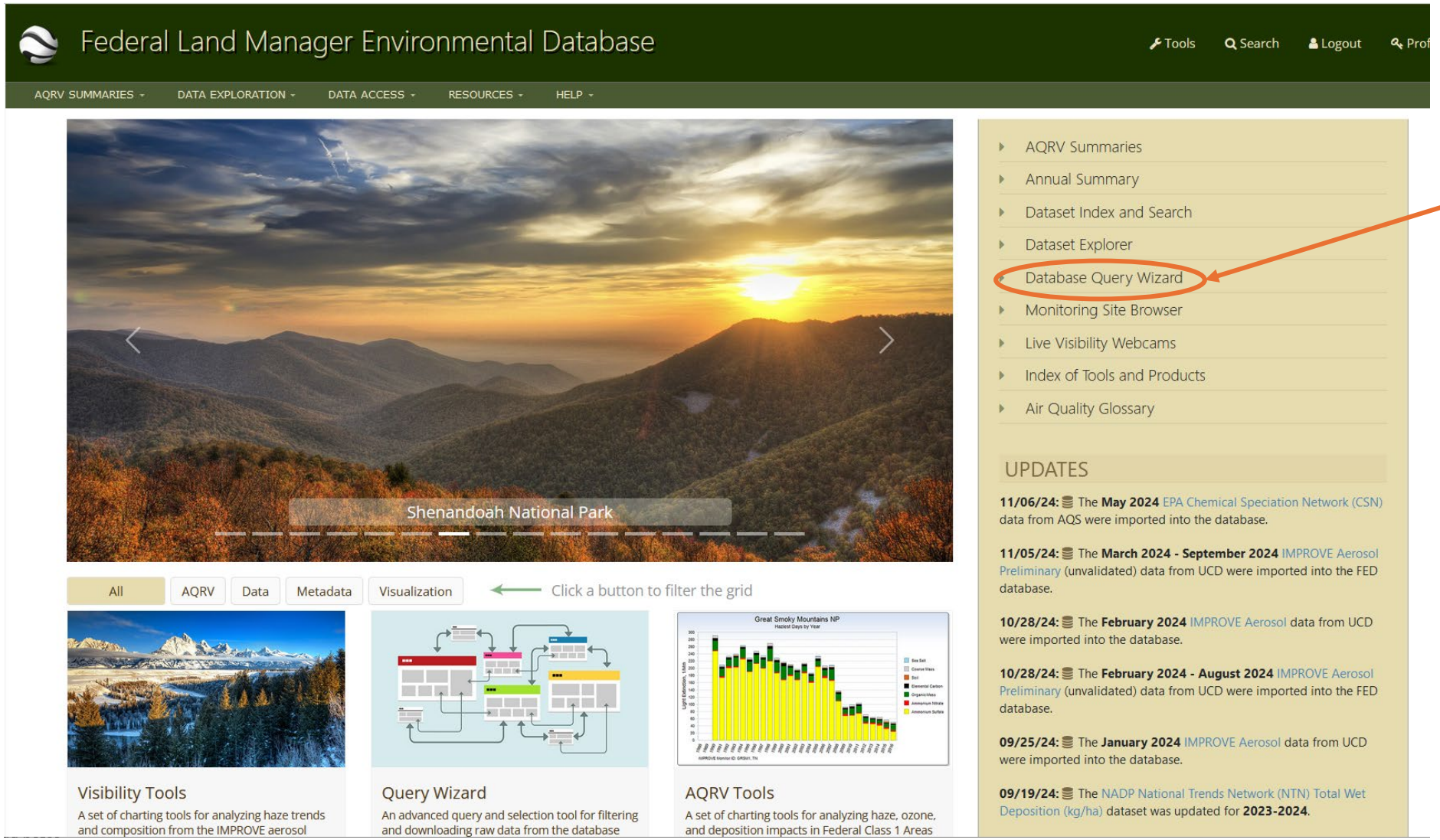
Data Download and Analysis Tools

"FED"

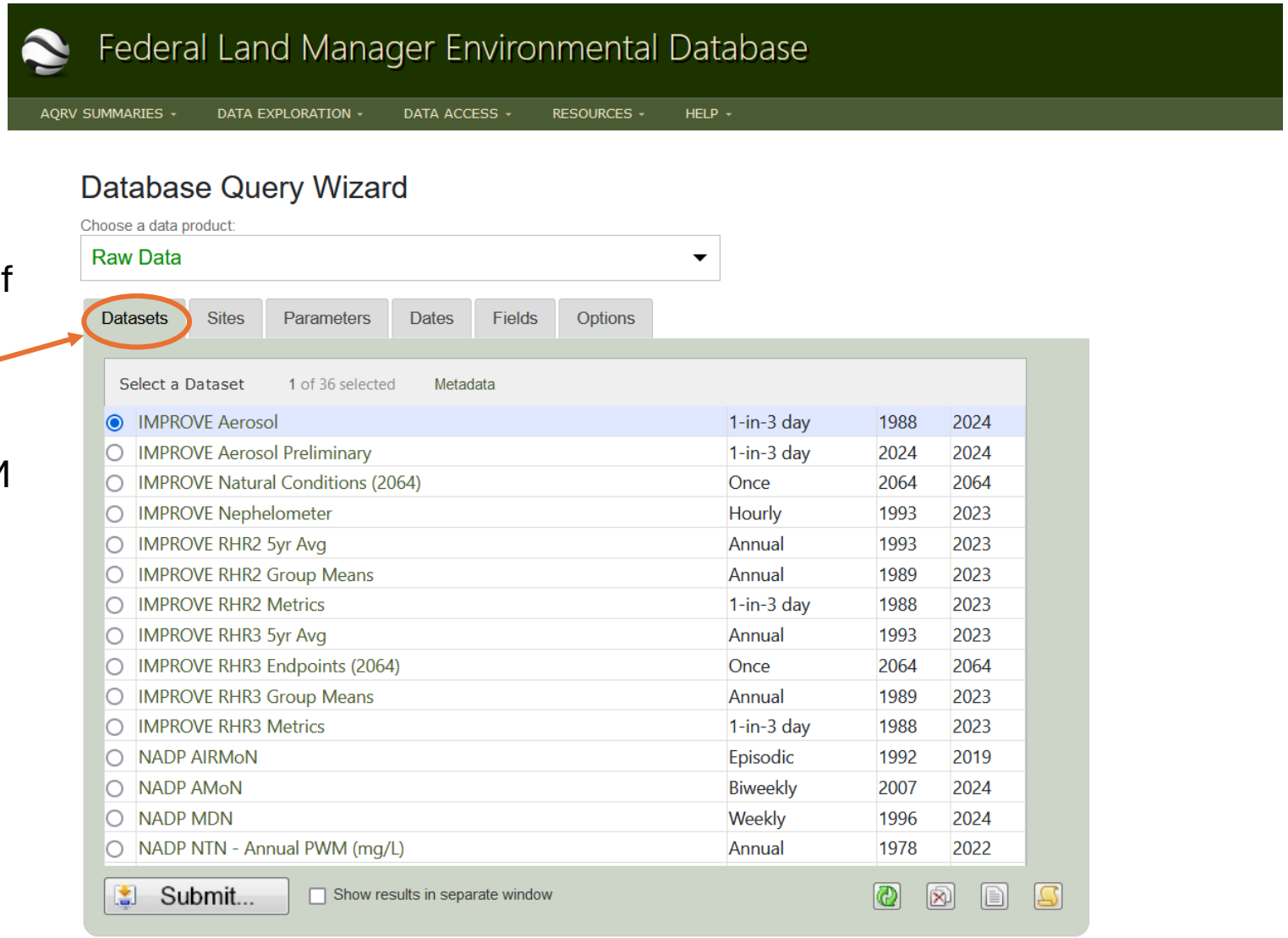


Data Download Tool

https://views.cira.colostate.edu/fed/

FED

Choose from a variety of datasets:
IMPROVE aerosol
IMPROVE b_{ext}
EPA $PM_{2.5}$ and PM_{10} FRM
EPA CSN
NADP
Ozone
CASTNET

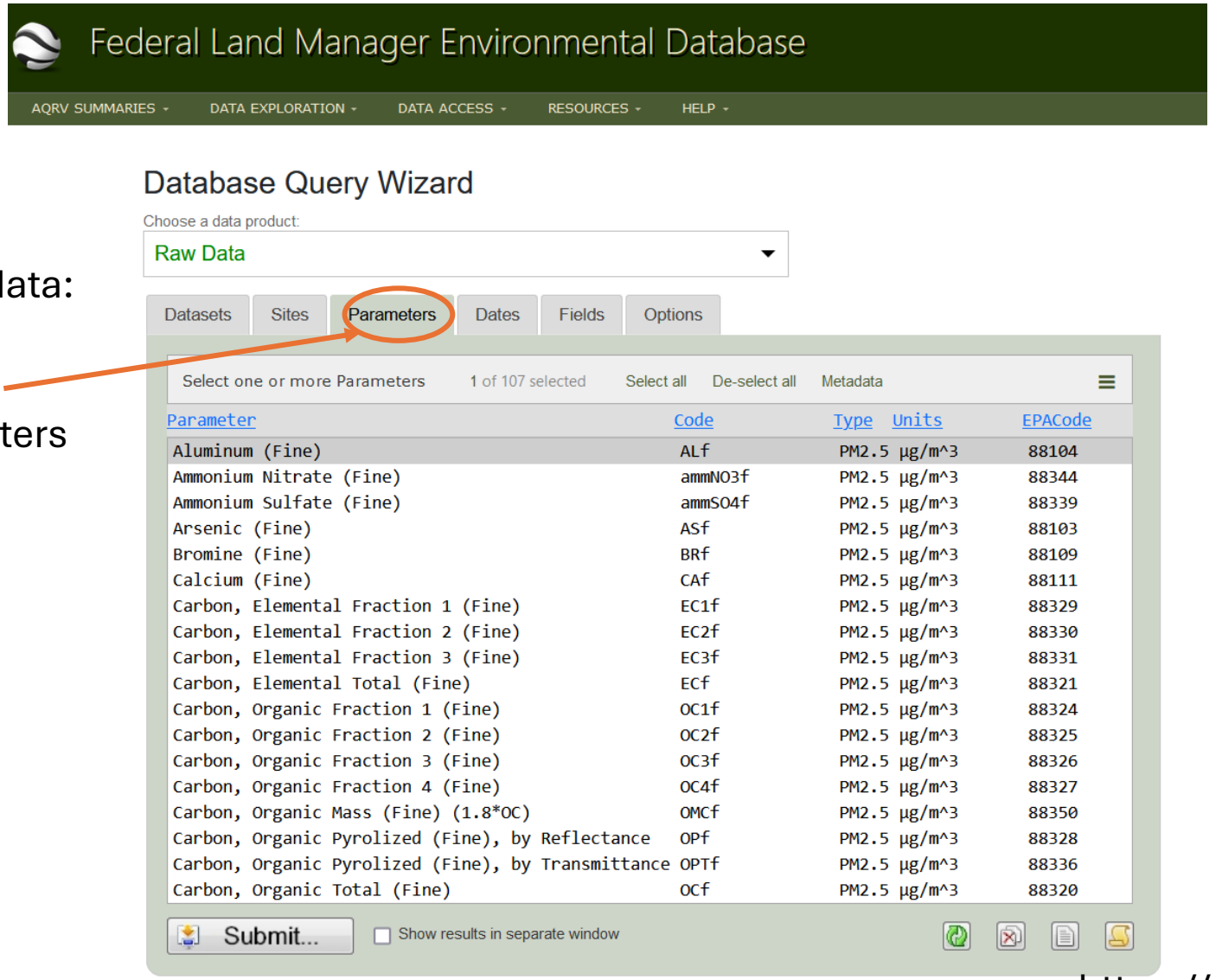


https://views.cira.colostate.edu/fed/

FED

IMPROVE aerosol data:

Measured and calculated parameters



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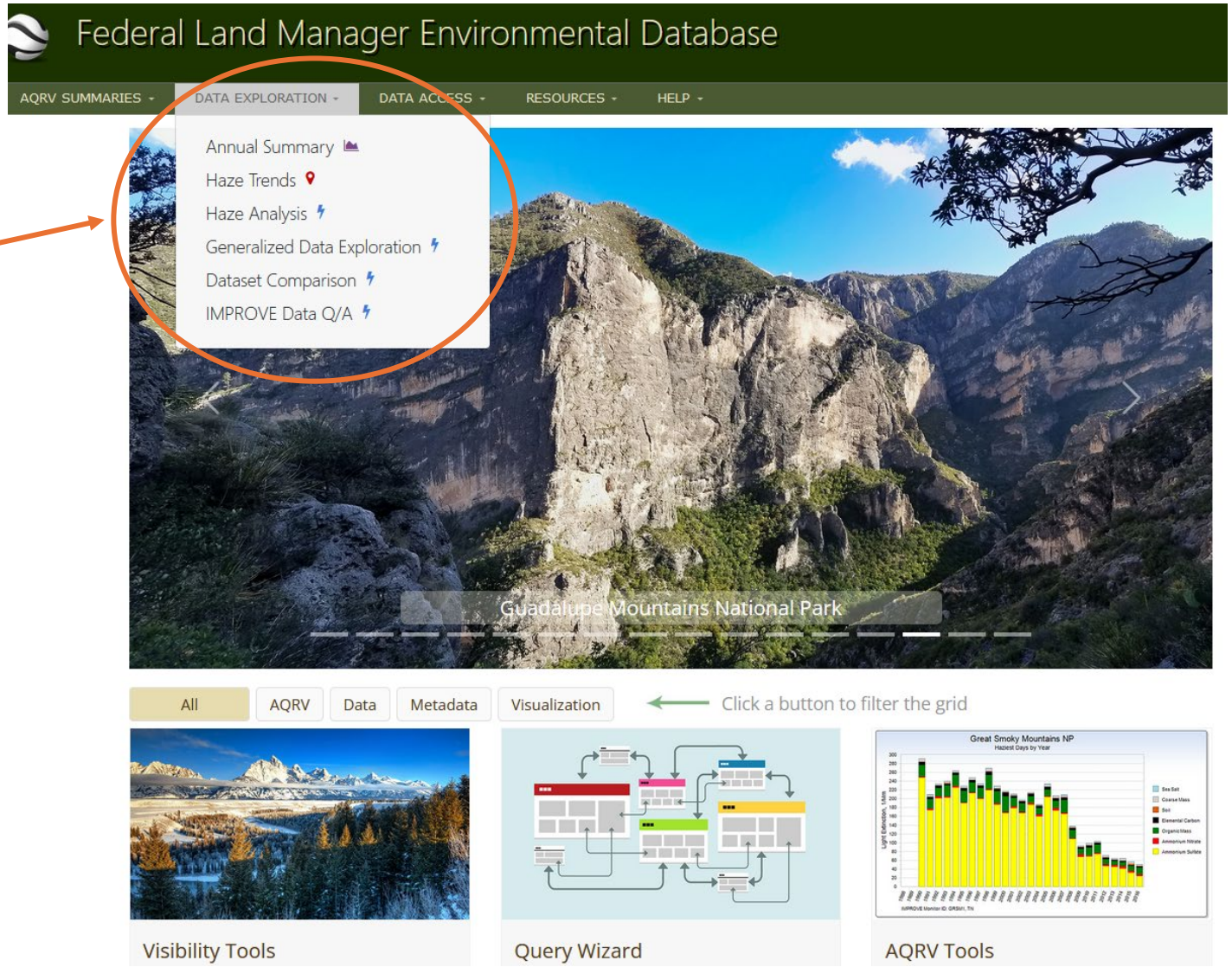
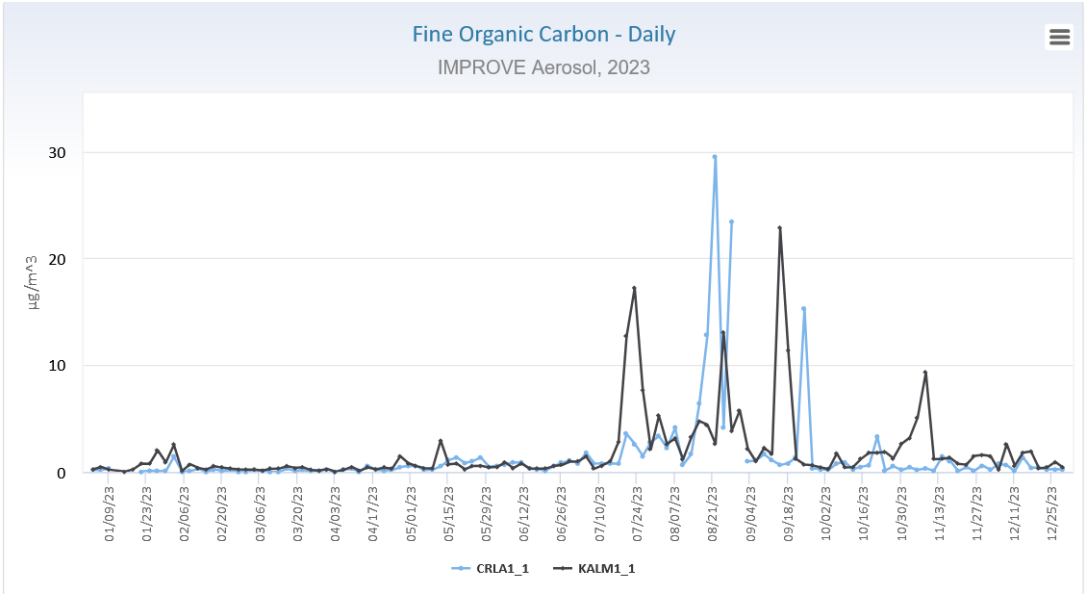
FED

Data exploration tools



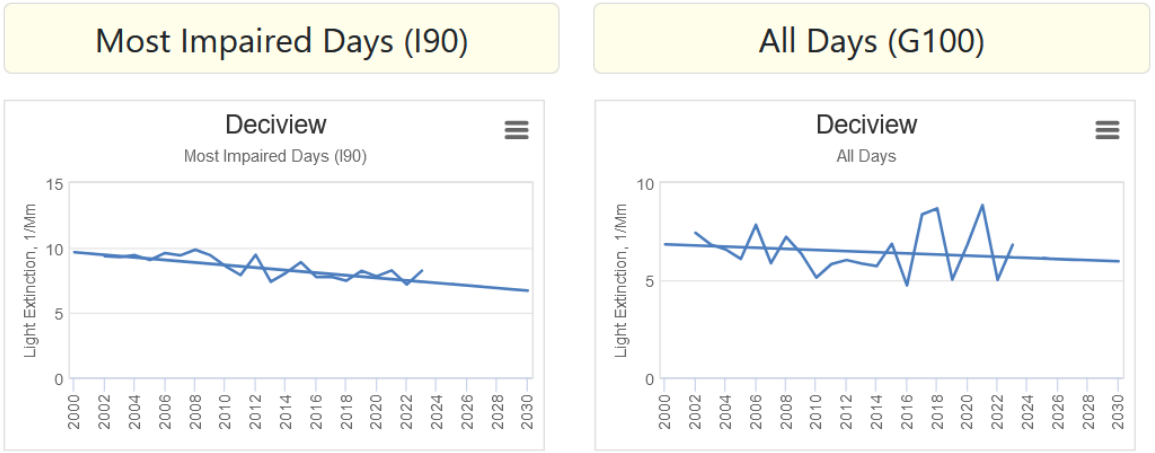
https://views.cira.colostate.edu/fed/

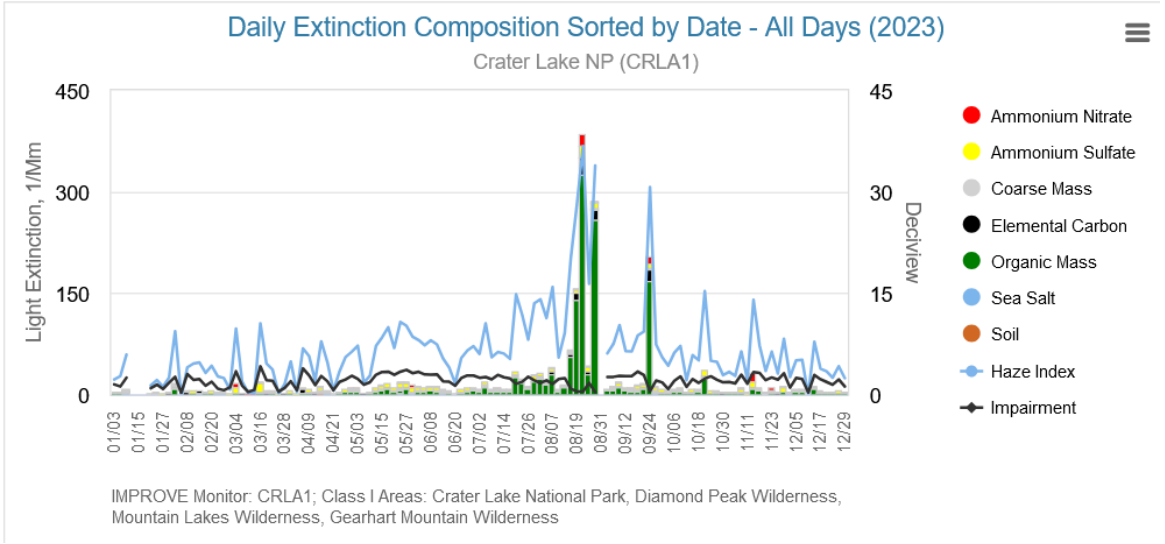
FED Analysis Tools



Species Trends: Most Impaired Days, All Days, and (

Crater Lake NP (CRLA1), 2000 - 2030





WRAP Technical Support System v2

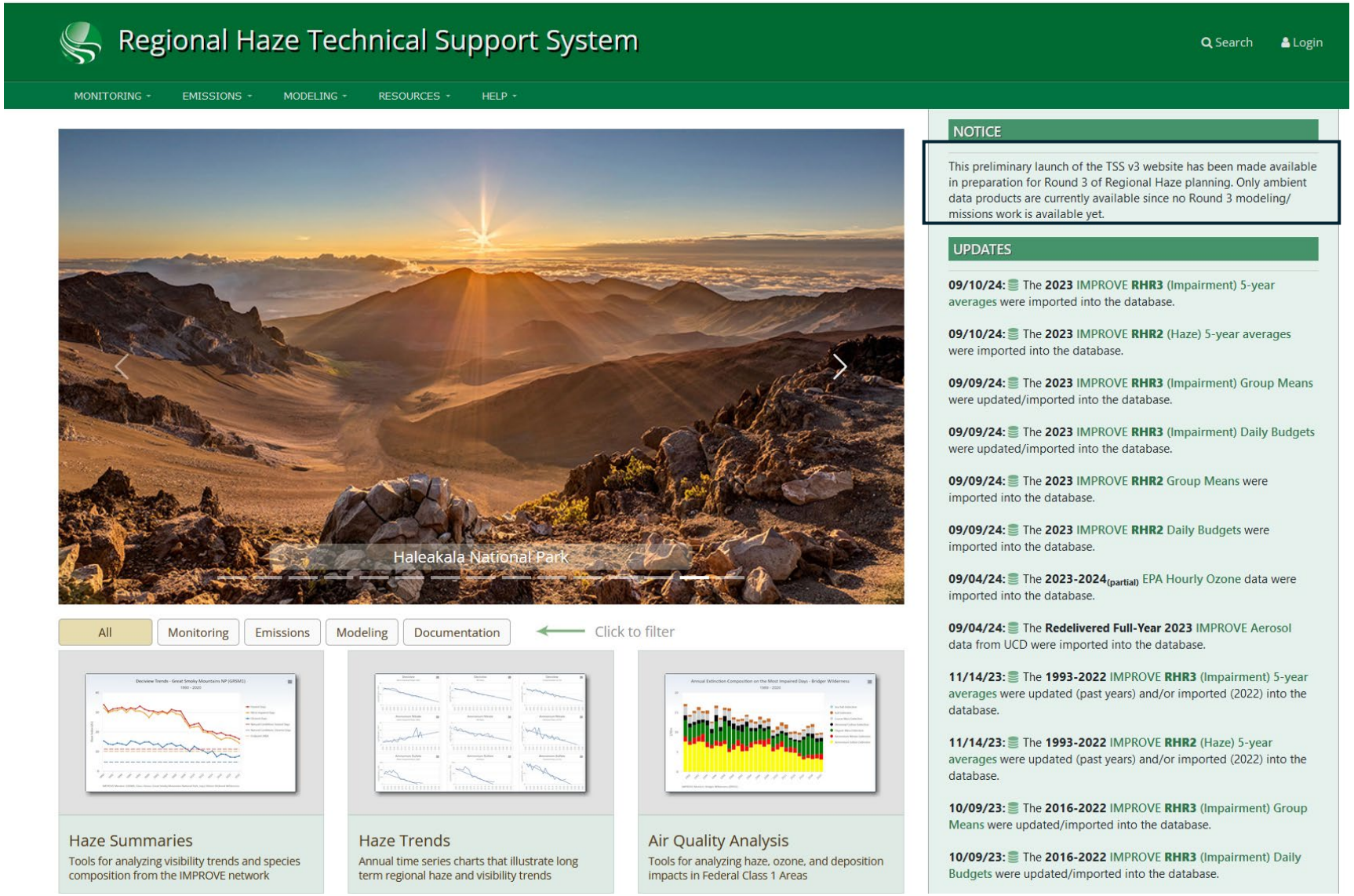
TSS: additional exploration tools, including emissions and modeling data

Shawn McClure, CIRA

https://views.cira.colostate.edu/tssv2/

Technical Support System v3

TSS: additional exploration tools, including emissions and modeling data



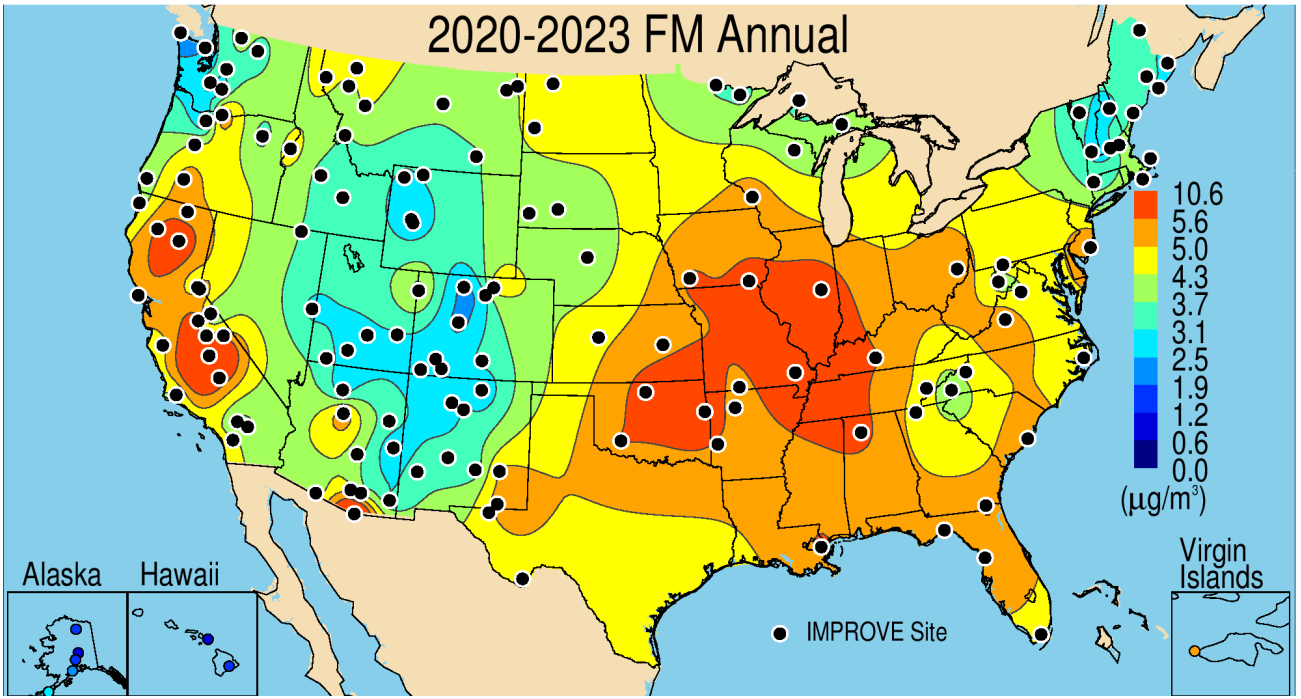
(preliminary)

Shawn McClure, CIRA

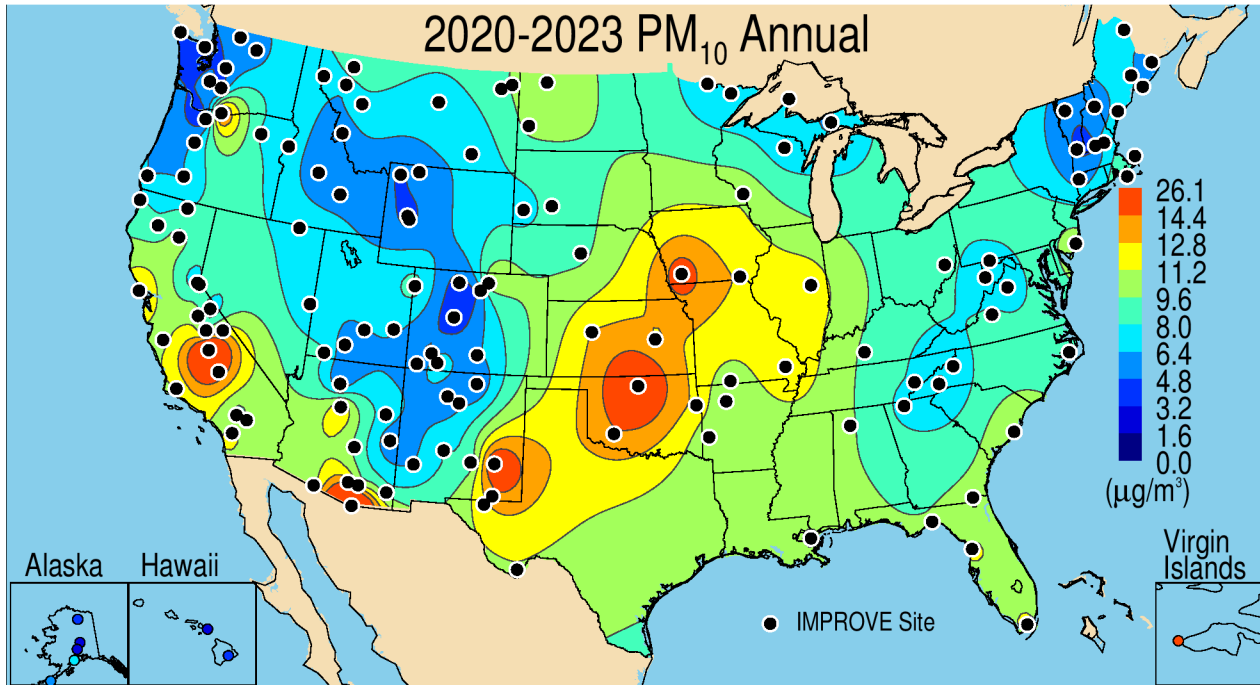
https://views.cira.colostate.edu/tssv3/

Data Analysis

$PM_{2.5}$

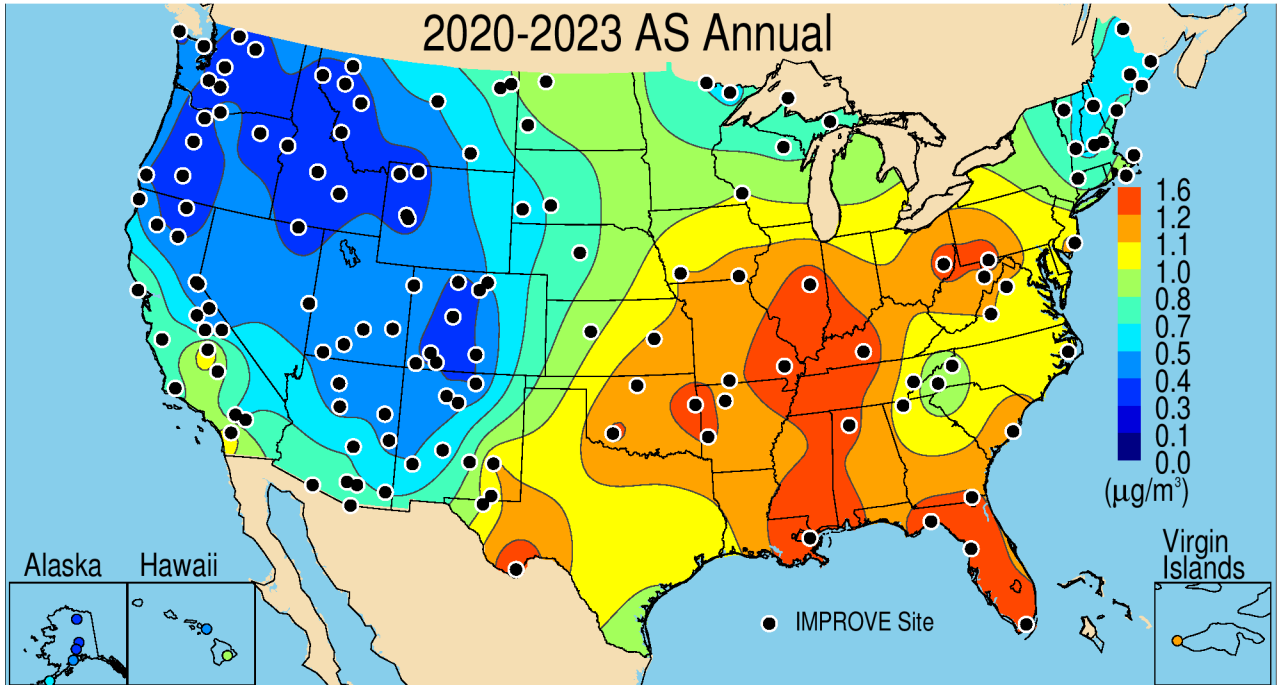


PM_{10}

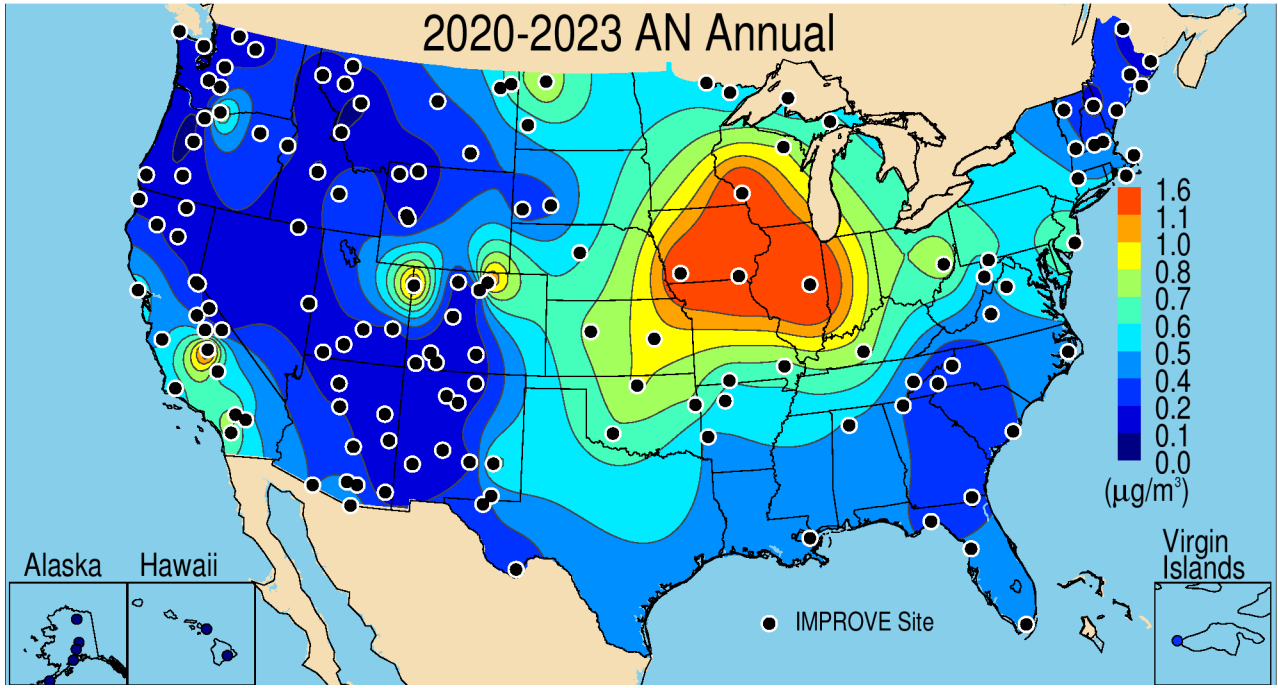


Data Analysis

Ammonium Sulfate

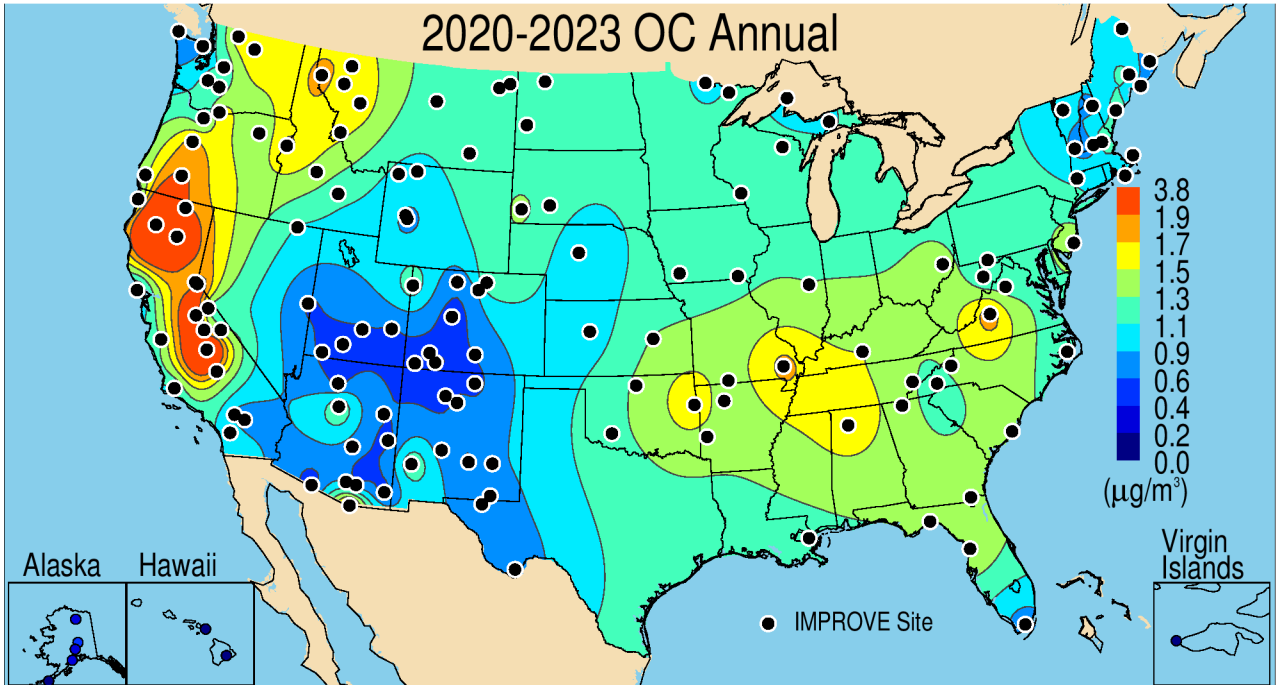


Ammonium Nitrate

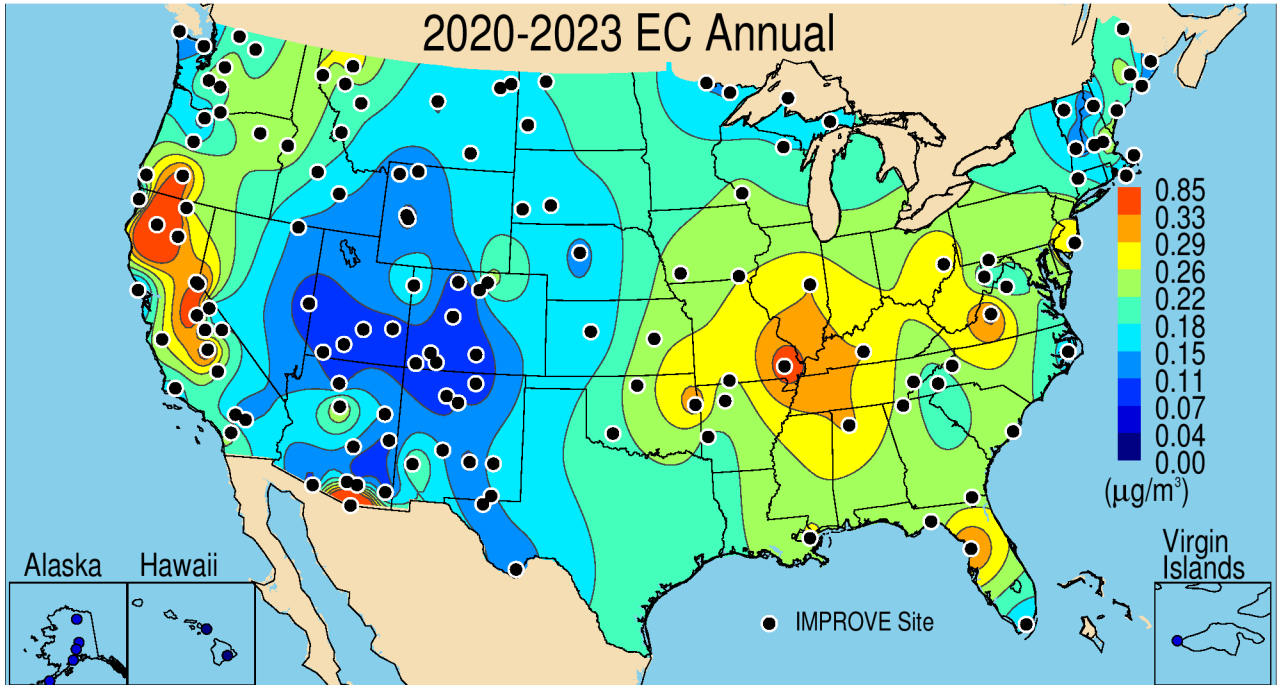


Data Analysis

Organic Carbon

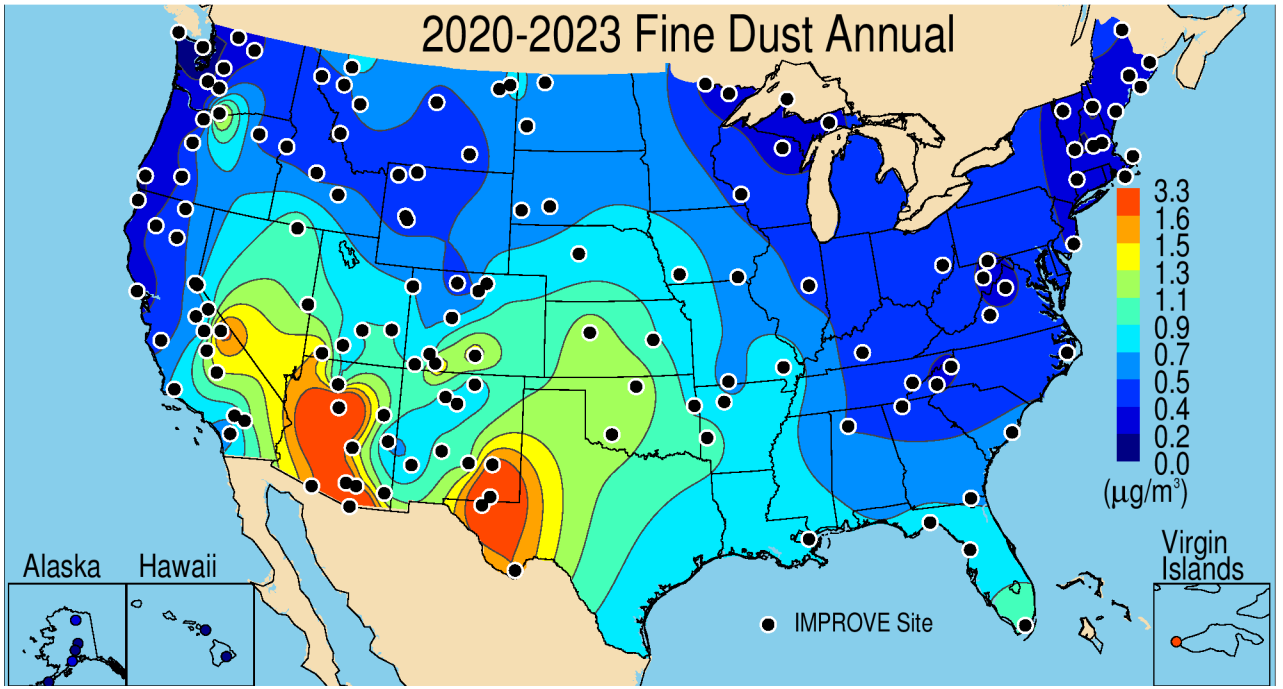


Elemental Carbon

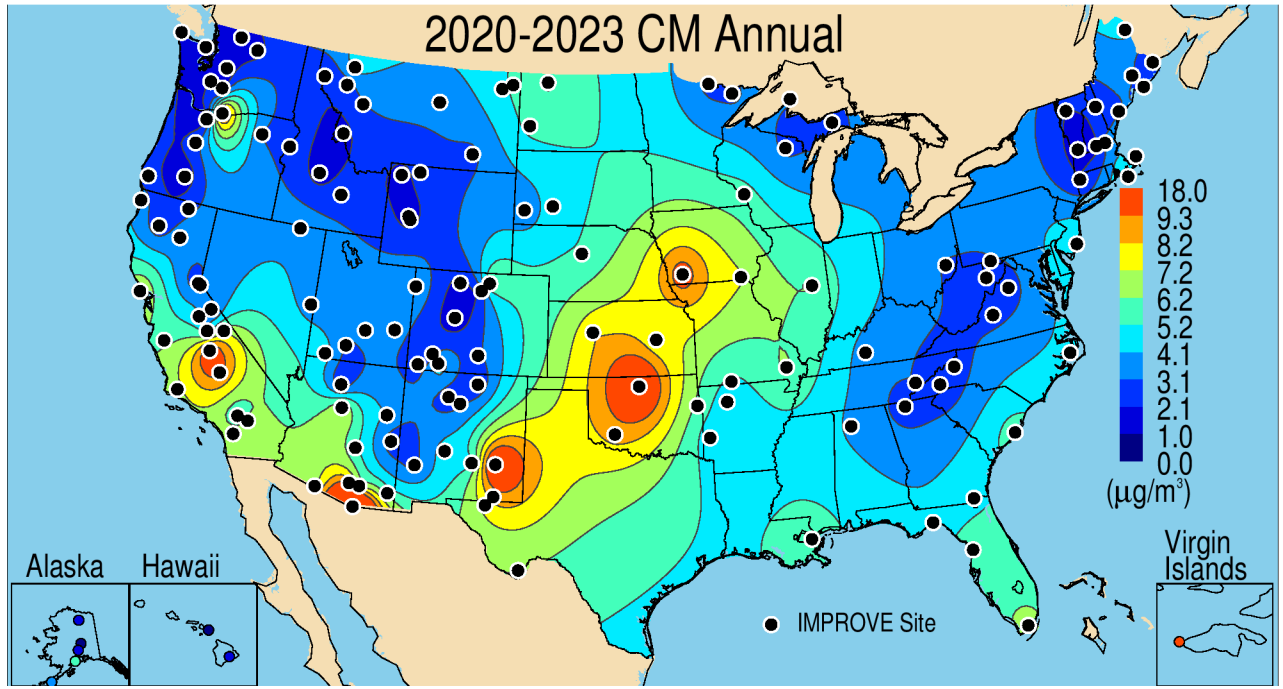


Data Analysis

Fine Dust



Coarse Mass



Thanks!

Bosque del Apache, NM

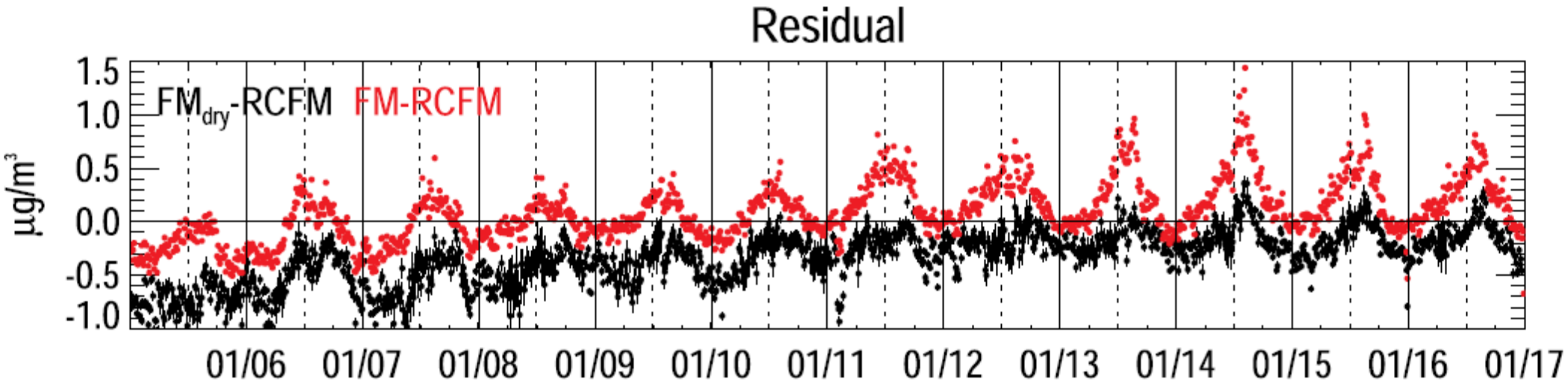


Fig. 4. IMPROVE daily network median dry residual (FM_{dry} − RCFM, µg m^{-3}) in black and original FM residual (FM − RCFM) in red. Measurement uncertainties are shown only for the dry residual.