INTERAGENCY MONITORING OF PROTECTED VISUAL ENVIRONMENTS

IMPROVE

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IMPROVE MONITORING UPDATE

Preliminary data collection statistics for the Fall 1992 monitoring season (September - November 1992) are:

Data Type	Collection Percentage
Aerosol Data	95%
Optical (transmissometer) Data	92%
Scene (photographic) Data	85%

Figure 1 is a map of the current IMPROVE and IMPROVE Protocol sites. No major network changes occurred over the past three months; however, twelve Optec NGN-2 ambient nephelometers will be installed throughout the network during Spring 1993 at the following sites:

Boundary Waters	Lye Brook
Crater Lake	Mammouth Cave
Dolly Sods	Mount Rainier
Edwin B. Forsythe	Okefenokee
Great Smoky Mountains	Shenandoah
Jarbidge	Upper Buffalo

Aerosol data for the Spring 1992 season is complete and analysis of Summer and Fall 1992 data is underway.

Reprocessing of all transmissometer optical data from Spring 1991 through Fall 1992 is underway to incorporate final lamp drift correction factors. The final quality-assured data will be available for general distribution in February.

VISIBILITY NEWS.......

GRAND CANYON TRANSPORT COMMISSION NEWSLETTER

The Grand Canyon Transport Commission is publishing a newsletter entitled "Western Vistas." For additional information contact John Leary, Western Governors Association, at 303-623-9378.

NAS REPORT

The National Academy of Sciences, National Research Council has just completed a study entitled "Protecting Visibility in National Parks and Wildernesses." The report will be available soon and will be highlighted in the next issue of the IMPROVE Newsletter.

VISIBILITY NEWS *continued on Page 7*

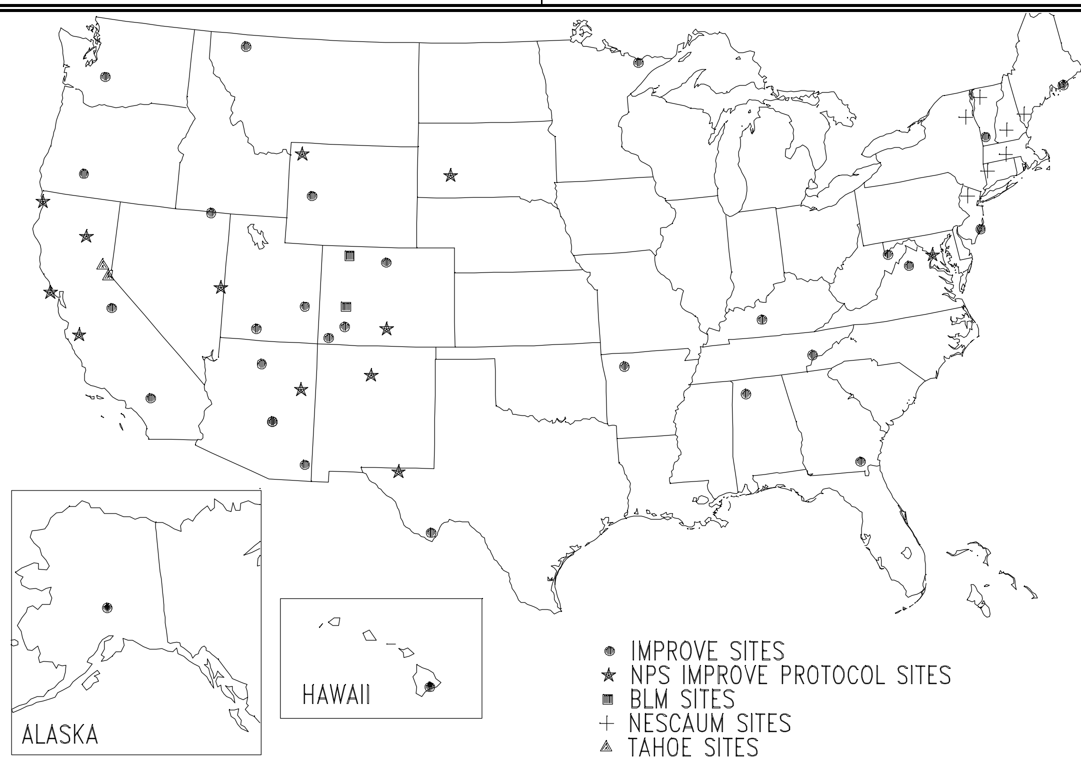

Figure 1. IMPROVE and IMPROVE Protocol Sites January 1993

Feature Article

IMPROVE, The First Three Years

INTRODUCTION

"Spatial and Temporal Patterns and the Chemical Composition of the Haze in the United States: An Analysis of Data from the IMPROVE Network, 1988 - 1991", a report summarizing extensive, comprehensive analyses of IMPROVE data, has been finalized and is ready for distribution. To receive a copy of the report, use the order form on page 6.

The report was prepared by:

William C. Malm - NPS-AQD
James F. Sisler - CSU-CIRA
Dale Huffman - CSU-CIRA
Douglas A. Latimer - Latimer & Associates

This report is the first in a series of annual reports that will present the results of visibility related analyses based on IMPROVE monitoring data. The three primary objectives of the report are to:

1. Describe the spatial and temporal variation of visibility (as measured by the light extinction coefficient) and the chemical composition of the visibility-degrading aerosols for the first three years of network operation: Spring 1988 through Winter 1991.

2. Provide a first estimate of the apportionment of visibility impairment to the fundamental chemical species, such as sulfate, nitrate, organic and elemental carbon, and soil.

3. Compare measurements of light extinction to calculations of light extinction, reconstructed from the component chemical species.

Data were examined from a total of 36 sites, 20 IMPROVE and 16 NPS/IMPROVE Protocol sites. Figure 2 is a map of the site locations. Each site has aerosol monitoring equipment (a particle sampler designed specifically for the IMPROVE program) and scene monitoring equipment (automatic 35mm camera systems). 20 sites also have optical monitoring equipment (a transmissometer). On the basis of regional similarities (relative location, climatology, sulfate acidity, and similarities in aerosol concentrations and seasonal trends), the sites were grouped into 19 regions. Table 1 details the regional grouping of the sites and the monitoring configuration at each site.

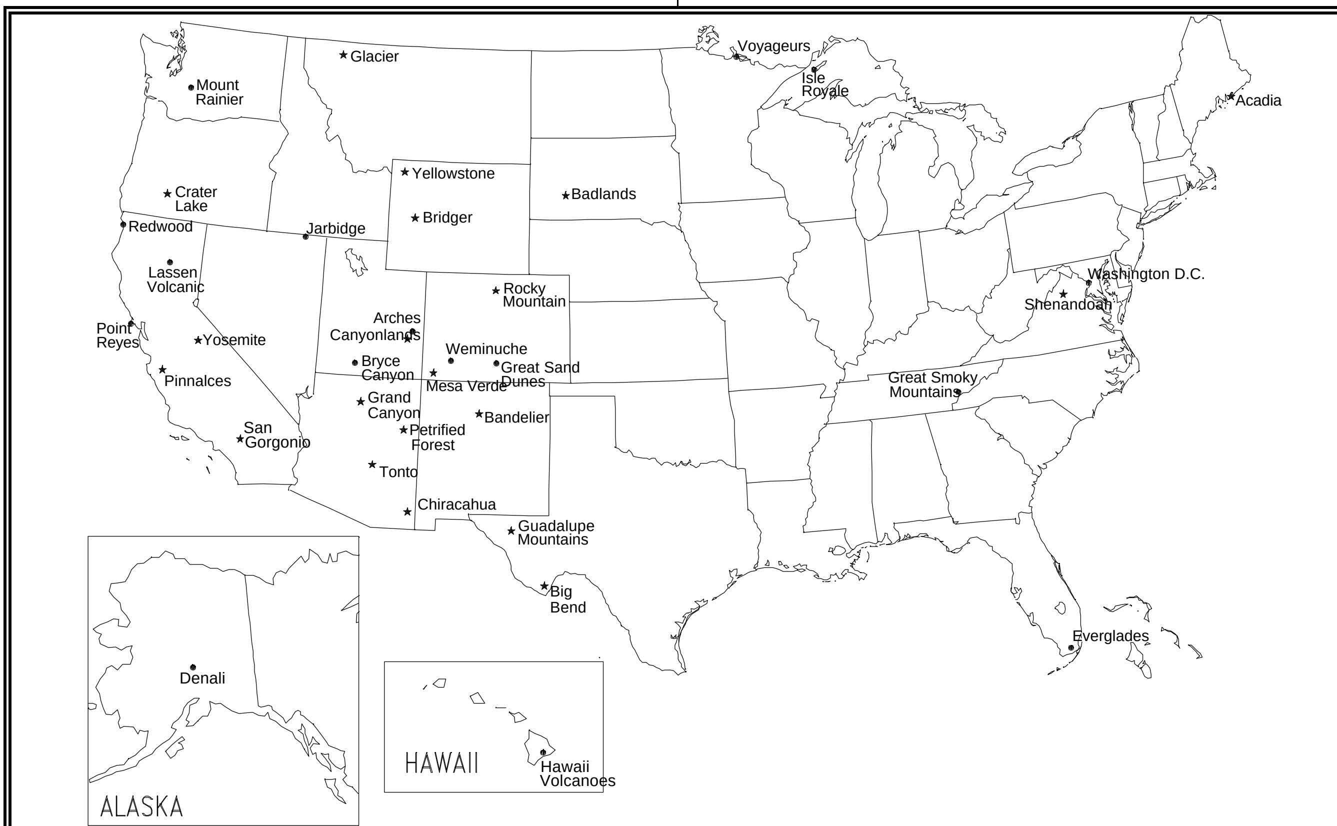

Figure 2. The 36 IMPROVE sites included in the report. Sites designated by a star have both aerosol and visibility monitoring.

In addition to meeting the primary objectives, the report includes:

- an overview of the IMPROVE Program and Monitoring Network;
- technical background regarding visibility impairment and aerosols;
- a summary of the methodologies, protocols, and uncertainties of aerosol and optical monitoring;
- the assumptions for determining the chemical compositions of the fine aerosol types and coarse particles and the adequacy and validity of the assumptions;
- the results of various cross-checks and comparisons for quality assurance and validation of the parameters derived from the aerosol measurements; and
- recommendations for future research.

Table 1
The Regional Groupings and Monitoring Configurations of the 36 IMPROVE Sites

Region	Site Name	Aerosol Sampler	Auto Camera	Transmis-someter
Alaska	Denali NP	X	X	
Appalachian Mountains	Great Smoky Mountains NP	X	X	
	Shenandoah NP	X	X	X
Boundary-Waters	Isle Royale NP	X	X	
	Voyageurs NP	X	X	
Cascade Mountains	Mount Rainier NP	X	X	
Central Rocky Mountains	Bridger Wilderness	X	X	X
	Great Sand Dunes NM	X	X	
	Rocky Mountain NP	X	X	X
	Weminuche Wilderness	X	X	
	Yellowstone NP	X	X	X
Coastal Mountains	Pinnacles NM	X	X	X
	Point Reyes NS	X	X	
	Redwood NP	X	X	
Colorado Plateau	Arches NP	X	X	
	Bandelier NP	X	X	X
	Bryce Canyon NP	X	X	
	Canyonlands NP	X	X	X
	Grand Canyon NP	X	X	X
	Mesa Verde NP	X	X	X
	Petrified Forest NP	X	X	X
Florida Everglades	Everglades NP	X	X	
Great Basin	Jarbidge Wilderness	X	X	
Hawaii	Hawaii Volcanoes	X	X	
Northeast	Acadia NP	X	X	X
Northern Great Plains	Badlands NP	X	X	X
Northern Rocky Mountains	Glacier NP	X	X	X
Sierra Nevada	Yosemite NP	X	X	X
Sierra-Humboldt	Crater Lake NP	X	X	X
	Lassen Volcanic NP	X	X	
Sonoran Desert	Chiricahua NM	X	X	X
	Tonto NM	X	X	X
Southern California	San Gorgonio Wilderness	X	X	X
Washington, D.C.	Washington, D.C.	X	X	
West Texas	Big Bend NP	X	X	X
	Guadalupe Mountains NM	X	X	X

This article presents highlights from three chapters of the report: Spatial and Seasonal Distribution of Aerosol Concentration and Chemical Composition, Spatial and Seasonal Distribution of Reconstructed Light Extinction and Species Contribution, and Measured Light Extinction.

SPATIAL AND SEASONAL DISTRIBUTION OF AEROSOL CONCENTRATION

The spatial and temporal variations of IMPROVE aerosol data are presented. Seasonal fine and coarse mass concentrations and the constituents of the fine-particle mass in each region are discussed. Figure 3 shows the fine mass concentrations for each of the 19 regions. The major patterns observed are:

- Fine aerosol concentrations are highest in the eastern United States (the Appalachian Mountains and Washington, D.C.); concentrations are also relatively high in Southern California.
- The lowest concentrations occur in the Great Basin, the Colorado Plateau, and Alaska.
- Organic carbon was the largest single component of measured fine aerosol in nine regions (Alaska, Cascades, Colorado Plateau, Central Rockies, Coast Mountains, Great Basin, Northern Rockies, Sierra Nevada, and Sierra-Humboldt).
- Sulfate was the largest single component of fine aerosols in six regions, mainly in the East (Appalachian Mountains, Florida, Hawaii, Northeast, Northern Great Plains, and Washington, D.C.).
- The contributions of organic carbon and sulfate were approximately equal in three regions (Boundary Waters, Sonoran Desert, and West Texas).
- Nitrate was the largest component of fine aerosol only in Southern California.
- Average fine mass concentrations, as well as the sulfate, organic carbon, and light absorbing carbon components of fine mass, are highest in summer; soil concentrations are highest in spring or summer; nitrate concentrations are generally highest in winter or spring.

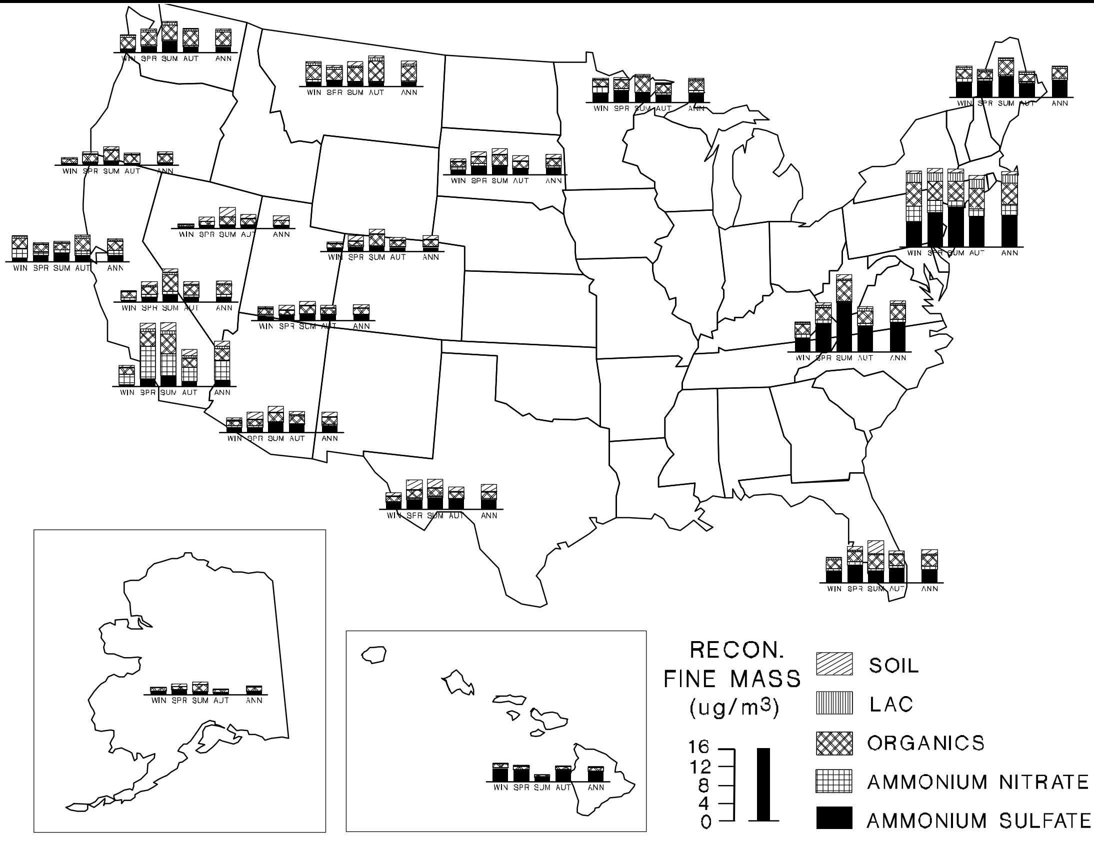

Figure 3. Seasonal and annual average concentrations of the fine particle mass and its components (in $\mu g/m^3$) in the United States for the three-year period, March 1988 through February 1991. For each of the 19 regions, the bars from left to right show the winter, spring, summer, autumn, and annual averages.

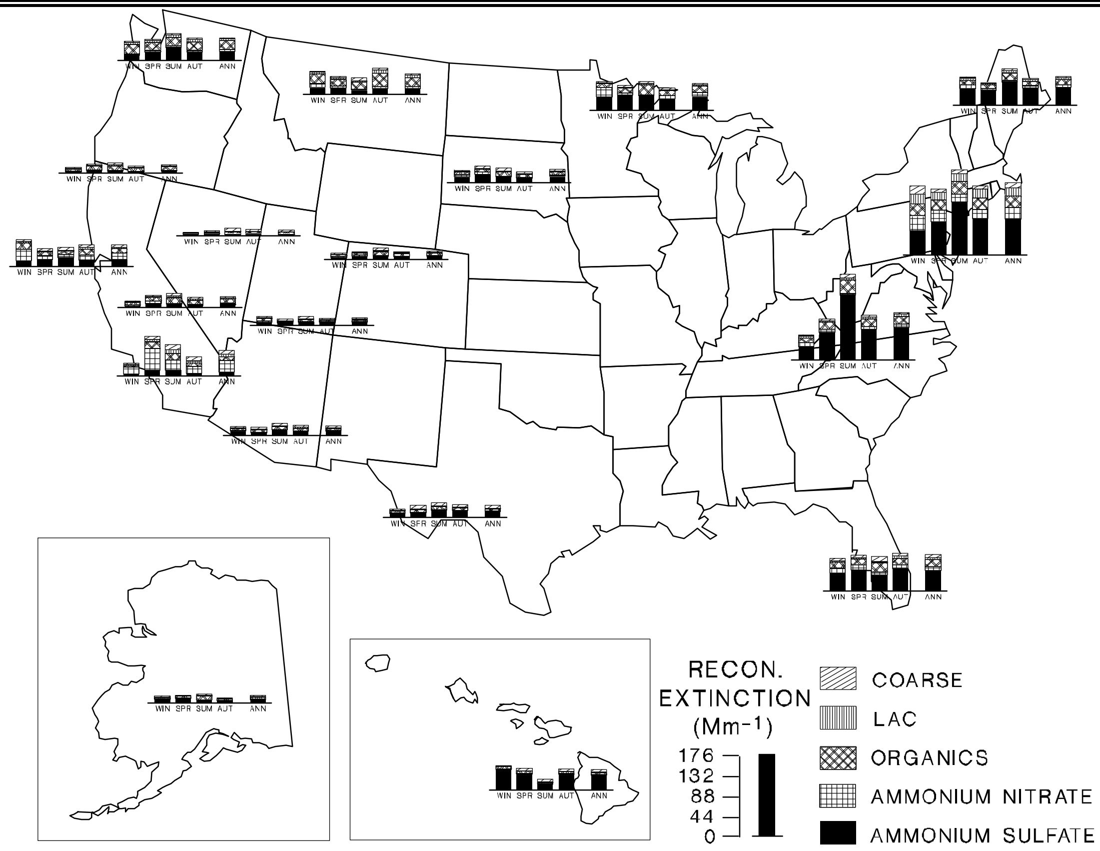

Figure 4. Spatial and seasonal distribution of reconstructed aerosol light extinction coefficient (Mm^{-1}) in the United States for the three-year period, March 1988 through February 1991. For each of the 19 regions, the bars show the contributions to aerosol light extinction of sulfate, nitrate, organic carbon, light absorbing carbon, and coarse particles and fine soil. From left to right the bars show winter, spring, summer, autumn, and annual averages.

SPATIAL AND SEASONAL DISTRIBUTION OF RECONSTRUCTED LIGHT EXTINCTION

Reconstructed light extinction coefficient data calculated from the three years of IMPROVE aerosol measurements are presented. In addition, the relative contribution of various aerosol components to total light extinction (the light extinction budget) was calculated for each region. The light extinction coefficient (b_{ext}) was calculated by multiplying the concentration of each measured aerosol species by its light extinction efficiency and totaling the effect of all species. The exact formula and assumptions for reconstructed light extinction, including how relative humidity effects extinction efficiencies, are discussed in the report.

Figure 4 shows the magnitude of total reconstructed aerosol light extinction (non-Rayleigh) coefficient for each of the 19 regions. A comparison of Figures 2 and 3 shows that variations in reconstructed light extinction and aerosol concentrations are correlated. However, relative humidity (and hence the light scattering efficiency of sulfate, nitrate, and some organics) is higher in the East than in the West. Therefore, the difference between eastern and western light extinction is even more pronounced than the difference in aerosol concentrations. The major patterns observed are:

- Largest light extinction occurs in the Eastern United States and in Southern California.
- Smallest extinction values occur in the non-urban West (e.g., the Great Basin and the Colorado Plateau) and in Alaska.
- Reconstructed light extinction was generally highest in summer and lowest in winter; significant seasonal variations occur especially in the Appalachian Mountains and in Southern California.

Fine aerosols are the most effective in scattering light and are the major contributors to light extinction. In most cases, the sulfate component of fine aerosol is the largest single contributor to light extinction; sulfate generally has a higher light extinction efficiency than other species because of liquid water associated with the hygroscopic species. This is especially true in the eastern United States where relative humidity is high:

- In the Appalachian Mountains, sulfate accounted for two-thirds of aerosol light extinction throughout the year and three-quarters in summer.
- Sulfate was the largest single contributor to light extinction in 12 regions and was tied for first

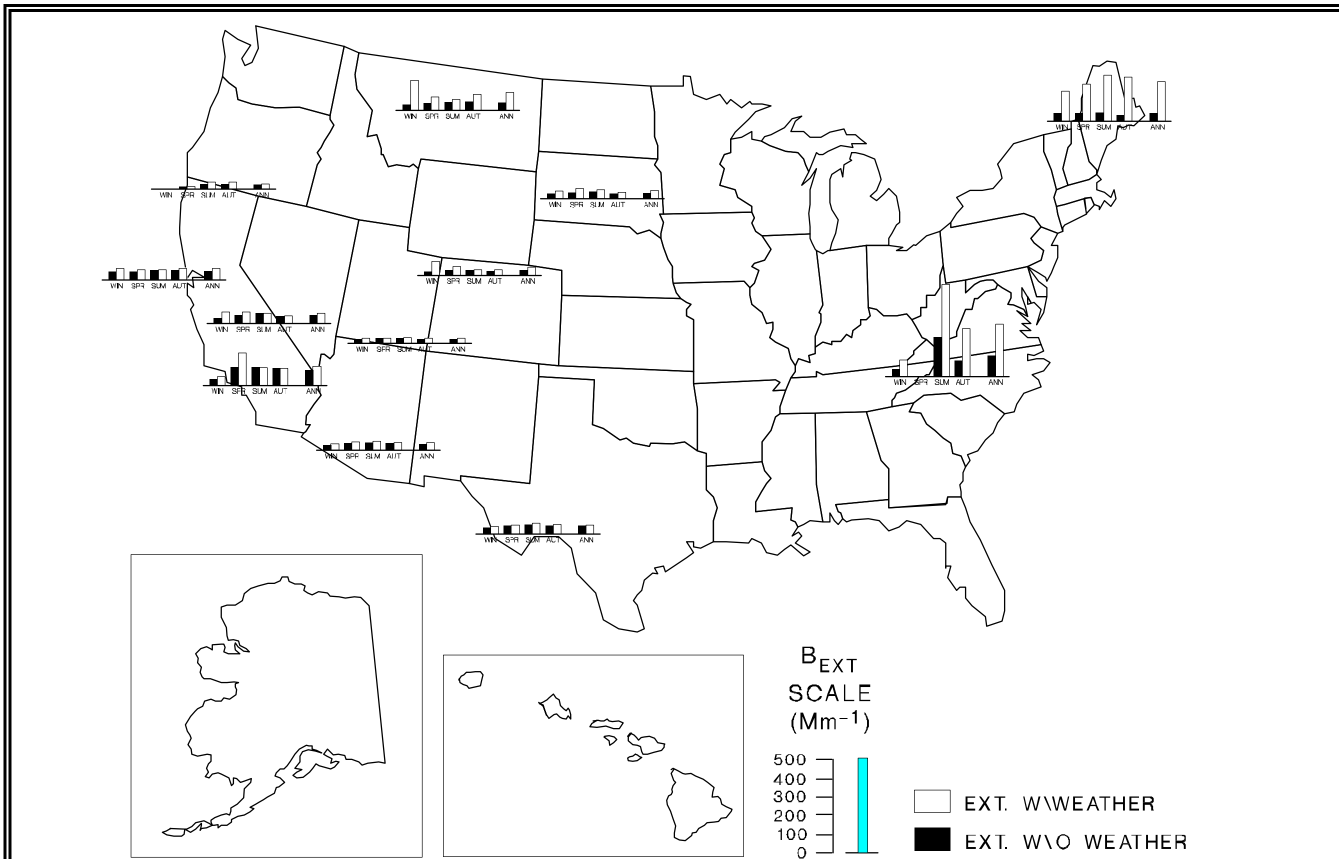

Figure 5. Spatial and seasonal variation of measured light extinction coefficient (Mm^{-1}) in the United States for the three-year period, March 1988 through February 1991. From left to right, the bars show for winter, spring, summer, autumn, and annual averages. Open bars include all time periods; dark bars exclude periods with fog, precipitation and low clouds.

place (with organics) in two additional regions (Cascades and Central Rockies).

- Organic carbon was the largest single contributor to light extinction in only four regions (Great Basin, Northern Rockies, Sierra Nevada, and Sierra-Humboldt).
- Nitrate was the single largest contributor to light extinction only in Southern California.

After the significant contributions of sulfate and organic carbon to light extinction, smaller contributions resulted from windblown dust (coarse particles and fine soil) and nitrate. Light absorbing carbon was generally the smallest contributor.

MEASURED LIGHT EXTINCTION

Light extinction data from the 20 IMPROVE sites with transmissometers are presented. The average seasonal and annual extinction, both excluding and including weather-affected values, is presented by region in Figure 5. The measured extinction data can be classified into three broad-based categories:

1) Western

16 of the 20 sites are in this category; all are located west of the Mississippi River. The weather algorithm identifies only 10%-20% of the data as weather affected and has little effect on the mean extinctions.

2) Eastern

Ambient RH levels are much higher at Acadia and Shenandoah National Parks. The weather algorithm flags more data at these sites (up to 70% at Acadia, 80% at Shenandoah).

3) Sites Influenced by Diurnal Hazes

Extinction data collected at San Gorgonio Wilderness and Yosemite National Park exhibit a strong diurnal pattern due to daily inclusions of severe hazes from areas of high pollution west of the Sierra Nevadas. Large fluctuations in measured extinction are caused by these hazes. Therefore, the rate of change test in the weather algorithm is not used at these sites; only the humidity and maximum extinction flags are used.

Comparisons between measured light extinction and reconstructed light extinction show:

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I	Measured extinction, standard visual range, and RH; ARS data summaries for all sites.
J	Stacked time lines of measured extinction (km^{-1}) for all sites by region.

ORDER FORM

Send me a copy of "Spatial and Temporal Patterns and the Chemical Composition of the Haze in the United States."

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- good agreement (within 10%) between measured and reconstructed extinction for the Appalachian Mountains, Central Rockies, Colorado Plateau, Northeast, Northern Great Plains, and Northern Rockies.
- reconstructed extinction about 80% of measured extinction in the Appalachian Mountains during summer and in the Pacific Coast, Southern California, Sonoran Desert, and West Texas regions. The summertime Appalachian Mountains reconstructed extinction may have been too low because of the assumption that the sulfate was fully neutralized (ammonium sulfate). It is likely that the elevated sulfate concentrations in the Appalachian Mountains are acidic; acidic sulfates have higher light scattering efficiencies than ammonium sulfate. It is not clear why the reconstructed light extinction is less than measured light extinction in the other regions.
- Considerable differences between measured and reconstructed extinction were noted at Yosemite. This inconsistency is being investigated thoroughly and will include a reanalysis and reevaluation of data and reconstruction assumptions.

Note that reconstructed light extinction was based on a 24-hour average of point aerosol measurements while measured extinction is based on hourly values of sight path measurements.

FUTURE RESEARCH

Throughout this report, specific recommendations for future research are noted and discussed including:

- organic aerosol measurements;
- light absorbing carbon measurements;
- hygroscopicity of aerosols;
- comparison of measured and reconstructed light extinction;
- aerosol acidity;
- trajectory analyses; and
- spatial/temporal pattern analyses of clean and dirty episodes.

VISIBILITY NEWS....... *(continued from page 1)*

DECIVIEW INDEX

At the International Conference on Visibility and Fine Particles in Vienna, Drs. Marc Pitchford and William Malm presented a paper entitled: "Development and Application of a Standard Visual Index." This paper proposes a standard visual index called deciview (*dv*) appropriate for characterizing visibility through uniform hazes. The index is designed to be linear with respect to perceived visual air quality changes over its entire range in a way that is analogous to the decibel index for sound. The *dv* scale is zero for pristine (Rayleigh) conditions and increases as visibility degrades. Every one *dv* change represents a perceptible scenic change (approximately a 10% change in the extinction coefficient). For example, annual average visibility in the relatively clean Colorado Plateau would have a *dv* value of approximately 10, and average visibility in the eastern U.S. would have a *dv* value of approximately 24.

The paper is currently being prepared for publication in Atmospheric Environment. For more information on the deciview concept, contact Marc Pitchford, or look for the next issue of the *IMPROVE Newsletter*.

Conference Announcement

PROTECTING VISIBILITY IN WESTERN CANADA

Dates: Sunday, March 14 through Wednesday, March 17th, 1993

Location: The Harrison Hot Springs Hotel, Harrison Hot Springs, British Columbia

Co-Sponsors:

The Pacific Northwest International Section of the AWMA

The Greater Vancouver Regional District

The British Columbia Ministry of Environment, Lands & Parks

Environment Canada (Atmospheric Environment Service)

For more information contact:

Ken Stubbs, GVRD, at 604-436-6747

IMPROVE STEERING COMMITTEE

IMPROVE Steering Committee members represent their respective agencies and meet periodically to establish and evaluate program goals and actions. IMPROVE-related questions within agencies should be directed to the agency's Steering Committee representative. Steering Committee representatives are:

U.S. EPA
Marc Pitchford
Environmental Monitoring Systems Lab
P.O. Box 93478
Las Vegas, NV 89193-3478
702/895-0432 (Phone)
702/895-0496 (Fax)

U.S. EPA
Joe Elkins
MD-14
OAQPS
Research Triangle Park, NC 27711
919/541-5653 (Phone)
919/541-2357 (Fax)

NPS
William Malm
NPS-AIR
Colorado State University
CIRA - Foothills Campus

Fort Collins, CO 80523
303/491-8292 (Phone)

BLM
Scott Archer
Colorado State Office
2850 Youngfield
Lakewood, CO 80215
303/239-3726 (Phone)
303/239-3933 (Fax)

USFS
Rich Fisher
Air Specialist, Wash. Office
Rocky Mtn. Experiment Sta.
240 W. Prospect
Fort Collins, CO 80526
303/498-1232 (Phone)
303/323-1010 (Fax)

FWS
Sandra Silva
Fish and Wildlife Service
P.O. Box 25287
Denver, CO 80225
303/969-2814 (Phone)
303/969-2822 (Fax)

NESCAUM
Rich Poirot
VT Agency of Nat. Res.
103 South Main Street
Building 3 South
Waterbury, VT 05676
802/244-8731 (Phone)
802/244-5141 (Fax)

STAPPA
Dan Ely
Colorado Dept. of Health
Air Pollution Control Div.
4300 Cherry Creek Drive S.
Denver, CO 80222-1530
303/692-3228 (Phone)
303/692-5493 (Fax)

WESTAR
John Core
Executive Director
1001 S.W. 5th Ave.,
Suite 1000
Portland, OR 97204
503/220-1660 (Phone)
503/220-1651 (Fax)

PREVIEW OF UPCOMING ISSUE . . .

The next IMPROVE Newsletter will be published in April 1993, and will include:

- Network Status for the Winter 1993 Season
- **FEATURE ARTICLE:** Highlights from the NAS report, "Protecting Visibility in National Parks and Wildernesses."

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