INTERAGENCY MONITORING OF PROTECTED VISUAL ENVIRONMENTS

IMPROVE

2nd Quarter 2012 | The IMPROVE Newsletter | Volume 21 / Number 2

Monitoring update

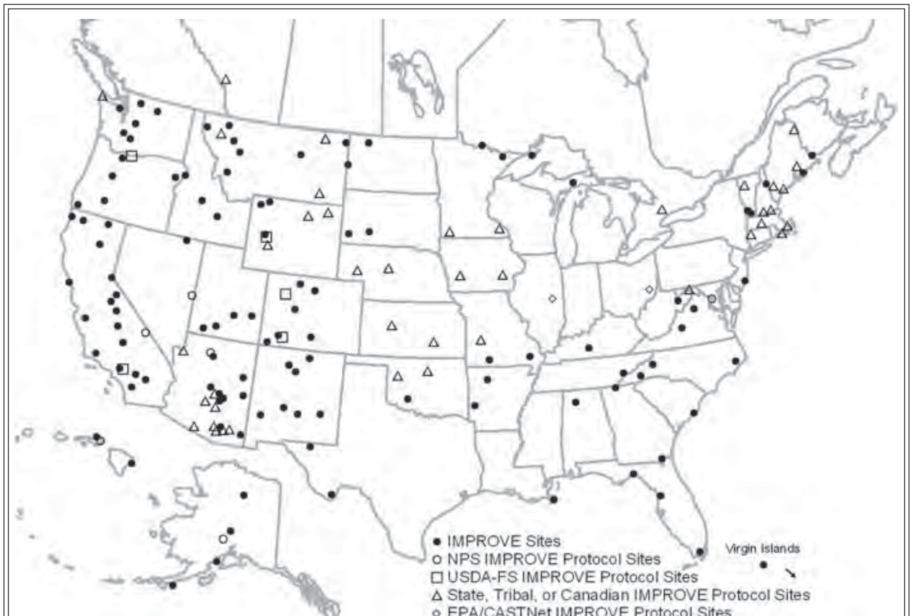
Feature Article: Trends in wintertime particulates in the Great Plains, Page 4

Network operation status

The IMPROVE (**I**nteragency **M**onitoring of **Pro**tected **V**isual **E**nvironments) Program consists of 110 aerosol visibility monitoring sites selected to provide regionally representative coverage and data for 155 Class I federally protected areas. Instrumentation that operates according to IMPROVE protocols in support of the program includes 53 additional aerosol samplers, and optical instrumentation (nephelometers and transmissometers), scene instrumentation (Webcamera systems), and interpretive displays.

IMPROVE Program participants are listed on page 8. Federal land management agencies, states, tribes, regional air partnerships, and other agencies operate supporting instrumentation at monitoring sites as presented in the map below. Preliminary data collection statistics for the 2nd Quarter 2012 (April, May, and June) are:

- Aerosol (channel A only) 95% collection
- Aerosol (all modules) 95% completeness
- Optical (nephelometer) 98% collection



IMPROVE and IMPROVE Protocol Sites
2nd Quarter 2012

Data availability status

Data and photographic spectrums are available on the:

- IMPROVE Web site
  http://vista.cira.colostate.edu/improve/Data/data.htm
- VIEWS Web site
  http://vista.cira.colostate.edu/views
- Federal Environmental Database (FED)
  http://views.cira.colostate.edu/fed/Default.aspx

Aerosol data are available through May 2011. Nephelometer and transmissometer data are available through February 2012 and December 2011, respectively.

Webcamera real-time images and associated air quality data are available on agency-supported Web sites:

- National Park Service
  http://www.nature.nps.gov/air/WebCams/index.htm
- U.S. Forest Service
  http://www.fsvisimages.com
- CAMNET (Northeast Camera Network)
  http://www.hazecam.net
- Midwest Haze Camera Network
  http://www.mwhazecam.net
- Wyoming Visibility Network
  http://www.wyvisnet.com
- Phoenix Visibility Network
  http://www.phoenixvis.net

The U.S. Environmental Protection Agency AIRNow Web site *http://airnow.gov* includes many of these same images, as well as additional visibility-related Webcameras from 33 states and the District of Columbia. Click on "Visibility Cameras" at the AIRNow home page.

***Monitoring update** continued on page 3....*

Visibility news

EPA proposes to revise air quality standards for particulate matter

In June 2012, the U.S. Environmental Protection Agency (EPA) proposed to strengthen the National Ambient Air Quality Standards (NAAQS) for fine particulate matter ($PM_{2.5}$) and retain the existing standards for coarse particles (PM_{10}). Both fine and coarse particles cause visibility reduction/haze and respiratory problems.

The current primary standards (to protect health) for $PM_{2.5}$ are an annual standard of 15 µg/m^3 (micrograms per cubic meter) (set in 1997) and a 24-hour standard of 35 µg/m^3 (set in 2006). The proposed annual standard is within the range of 12 µg/m^3 to 13 µg/m^3 and the 24-hour standard is proposed to be retained. The current secondary standards (to protect against decreased visibility and damage to animals, crops, vegetation, and buildings) are also expected to be retained. These standards are identical to the primary standards. EPA is also proposing an entirely new $PM_{2.5}$ visibility standard for urban areas. The two options being proposed for this 24-hour standard are 30 deciviews (dv) or 28 dv.

The current primary and secondary standards for PM_{10} are expected to be retained. These 24-hour standards, set in 1987, are 150 µg/m^3.

EPA proposed the new standards after receiving advice from its independent science advisors, the Clean Air Scientific Advisory Committee (CASAC) and other agency experts. These experts brought evidence from over 300 new studies performed since 2006, showing adverse health and other effects being seen with the current standards.

EPA will issue final standards by December 14, 2012. They anticipate making attainment/nonattainment designations by December 2014 and states would have until 2020 to meet the new standards.

For more information, read the proposed standards and supplemental information at: http://www.epa.gov/airquality/particlepollution/actions.html.

IMPROVE contractors monitor smoke impacts from Colorado wildfires

A 2-acre wildfire started by a lightning strike the evening of June 8, 2012, in the mountains west of Fort Collins, CO, grew to almost 10,000 acres 24-hours later (Figure 1). Named the High Park Fire, this national news event eventually burned 80,000+ acres and destroyed 250+ homes.

At times, smoke lowered visibility in Fort Collins (15 km east of the fire), to less than 1 km. IMPROVE contractors [Air Resource Specialists (ARS), Colorado State University Atmospheric Science, and the Cooperative Institute for Research in the Atmosphere], the National Park Service, and the Colorado Department of Public Health and Environment (CDPHE) deployed optical, aerosol, and gaseous monitors in and around Fort Collins to monitor the smoke event. Fortunately, ARS operates a transmissometer and nephelometer in downtown Fort Collins for CDPHE, so continuous extinction (b_{ext}) and aerosol scattering (b_{sp}) were immediately available. Figure 2 plots hourly b_{ext}, b_{sp}, temperature, and relative humidity for June 1 - July 15, 2012.

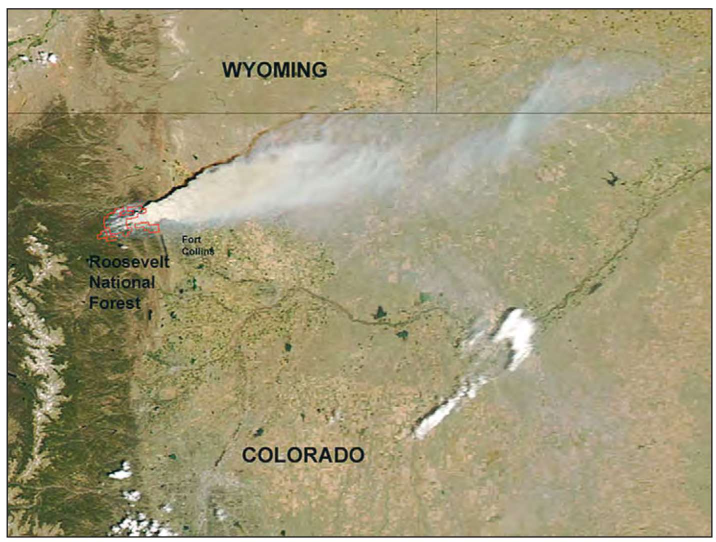


Figure 1. Satellite image of High Park Fire plume taken June 10, 2012.

Colorado wildfires continued on page 8....

PUBLISHED BY:

Air Resource Specialists, Inc.

1901 Sharp Point Drive,
Suite E
Fort Collins, CO 80525

The IMPROVE Newsletter is published electronically four times a year (February, May, August, and November) under National Park Service Contract P11PC70968. To submit an article, to receive the IMPROVE Newsletter, or for address corrections, contact:

Gloria S. Mercer, Editor
Telephone: 970/484-7941 ext.221
Fax: 970/484-3423
E-mail: Gmercer@air-resource.com

IMPROVE Newsletters are also available on the IMPROVE Web site at *http://vista.cira.colostate.edu/improve/Publications/news_letters.htm.*

EPA develops IMPROVE audit video

The Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards (OAQPS) produced and has made available a short video showing steps an auditor takes while performing an audit of an IMPROVE aerosol sampler. The nearly 17-minute educational video is intended for a general audience who may be interested in the procedures included in an audit. It does not replace the auditor certification procedures currently in place – rather, it provides the viewer with a general idea of how an audit is performed and what components are involved. The video is part of EPA's list of chemical speciation standard operating procedures for field operations.

Solomon Ricks, Environmental Engineer for the OAQPS, narrates the video, which begins with a background and introduction to the IMPROVE aerosol program. It then discusses when an audit is performed and what documentation must be completed. The video then proceeds through the sample audit, including performing a temperature audit, sampler clock check, and leak and flow checks. It concludes with acknowledgement of those who produced the video.

"Audit Procedures for the IMPROVE Air Sampler" is available online at *http://www.epa.gov/ttn/amtic/spectraining.html*. This is the final video in a series, developed for the NCore monitoring network that became operational in January 2011. The focus of this training series illustrates how monitoring equipment should be installed, operated, and audited. OAQPS has also produced similar training videos for a variety of gaseous, particulate, and meteorological instrumentation; these videos are available at *http://www.epa.gov/ttn/amtic/training.html*.

For more information contact Geri Dorosz, Environmental Scientist for the OAQPS and Executive Producer of this video. Telephone: 919/541-5492. E-mail: dorosz.geri@epa.gov.

Monitoring update *continued from page 1 ....*

Operators of distinction

Ray Finan knows what he wants to do – then he does it. After being in the corporate world and moving 14 times in 21 years, Ray wanted to do something different. He is now a Visitor Services Information Assistant with the Green Mountain National Forest, VT, and is also the primary operator of the relocated IMPROVE Lye Brook station (Lye Brook Wilderness is contained within the Green Mountain National Forest). The new station on Mount Snow is concurrently running with the older station on Mount Equinox, which will be decommissioned in October.

The new Lye Brook station took on water last spring when melting ice and accumulated snow dripped through the station's roof and into the sampler's filters. Ray spent some time repairing the leaking roof and shortly thereafter began to obtain valid samples again. He performs site visits in the winter via chairlift and hiking up the mountain, and skiing back down. Summer site visits are a 1 1/2 hour round-trip drive with a 40-minute hike up the mountain to the site.

Most of Ray's time is spent assisting forest visitors with hiking and camping information, and occasionally assisting with campground maintenance, stocking of fish, or other such needs. He also recently completed wildland fire training and is hoping to be deployed to a wildfire later this month.

"I earned B.A. degrees in history and political science, then moved a lot," said Ray. He has lived mostly in the Northeast, in New York and New Jersey, but has also lived in Virginia and South Carolina, and most recently in Ohio. While visiting the Green Mountain National Forest, Ray casually inquired about a job, and the timing was just right. "After 25 years in business, I wanted to do more of what interested me in places I wanted to be," said Ray. He left his position as Director of Business Process Integration in the papermaking industry, and moved to Vermont with his wife. Vermont gives them the opportunity to be close to family and friends, and allows Ray to pursue his interests, namely skiing, hiking, and fly fishing. "I also spend a good amount of time each week making custom, fine furniture," said Ray. Ray's interests are varied, and he is fortunate enough to be able to do them all.

IMPROVE site operator Ray Finan helped install and maintains the new Lye Brook, VT site (LYEB1) on Mount Snow.

***Monitoring update** continued on page 7....*

Feature article

Increasing trends in wintertime particulate sulfate and nitrate ion concentrations in the Great Plains of the United States (2000-2010)

(by J.L. Hand[1], K.A. Gebhart[2], B.A. Schichtel[2], W.C. Malm[1])

Introduction

Particulate nitrate and sulfate are important secondary aerosols formed through chemical reactions in the atmosphere. Their precursors (i.e., NO_x and SO_2, respectively) originate primarily from combustion processes. Sulfate ion concentrations are highest in the eastern United States, up to 5-10 times the concentrations in the West, due to the proximity of significant SO_2 sources in the United States. Sulfate (interpreted as ammonium sulfate) contributes up to 60% to the fine mass budget in summer when concentrations are typically highest. Nitrate ion concentrations are highest in southern California and the Midwest due to high NO_x emissions and available ammonia, respectively. Nitrate ion concentrations are generally highest in winter and, when interpreted as ammonium nitrate, contribute up to 50% to the fine mass budget in the Midwest and southern California. Both sulfate and nitrate impact the atmosphere and environment through their contributions to visibility degradation, wet deposition to aquatic and terrestrial ecosystems, and cloud-condensation nuclei and cloud microphysical processes. In addition, they interact directly with incoming short-wave radiation, thereby contributing to global cooling, and are potentially harmful to human health.

From 2000 to 2010, NO_x emissions in the U.S. have decreased 63% and SO_2 emissions have decreased 55%, based on data from the U.S. Environmental Protection Agency. The reduction of these emissions has contributed to an annual decrease in particulate sulfate and nitrate concentrations at IMPROVE rural sites. In addition, earlier work demonstrated that decreases in annual particulate sulfate concentrations at rural sites in the U.S. and the state of New York were occurring at a similar rate to reductions in SO_2 emissions. The decrease of sulfate and nitrate particulates in the atmosphere also has led to their reduction in precipitation. It has been reported that annual sulfate in precipitation decreased almost everywhere in the U.S. from 1985 to 2009. Nitrate in precipitation also decreased but not as spatially consistent or to as large a degree. A handful of sites in Montana and Wyoming were associated with statistically insignificant increasing nitrate precipitation trends, and higher positive significant trends occurred at sites in the Southwest.

We investigated the 2000-2010 annual, monthly, and seasonal mean trends in particulate sulfate and nitrate concentrations at rural IMPROVE sites across the U.S. On an annual basis, it appears that the expense and resources invested in emission reductions are resulting in measurable improvements in air quality; however, this is not the case for specific seasons and regions. In particular, we highlight significantly increasing trends in December monthly mean sulfate and nitrate concentrations in the Great Plains of the U.S. We speculate as to possible causes for these trends and comment on implications for increasing concentrations in this region.

Data and methods

The IMPROVE program currently operates 170 sites in mostly remote and rural locations around the U.S. for the purpose of establishing and tracking spatial and temporal trends in visibility and aerosol conditions. The 24-hour samples are collected every third day from midnight to midnight local time, and concentrations are reported at local conditions. The IMPROVE network is an excellent source of data for trend analyses in the U.S. because of its duration, spatial distribution of sites, and consistent sampling and analytical methodology for all sites in the network. We used $PM_{2.5}$ sulfate and nitrate ion data analyzed by ion chromatography and artifact-corrected. Precisions were 4% and 10% for sulfate and nitrate ions, respectively. Additional details regarding site location, sampling, and analysis methodology, including artifact corrections, are provided by Hand et al. (2011). All IMPROVE data and metadata, detailed descriptions of the network operations, and data analysis and visualization results are available from *http://views.cira.colostate.edu/fed/*.

Trends in data from 2000 to 2010 were computed for sites that met our completeness criteria, defined as 8 out of 11 (~70%) "complete" years, where a "complete" year corresponded to 50% or more valid data for a given year. Completeness criteria were met with 152 and 151 sites for sulfate and nitrate trends, respectively. A linear Theil regression was performed to determine the percent change in concentration over time. Trends (% yr^{-1}) were computed by dividing the slope derived from the Theil regression by the median concentration value over the time period of the trend, multiplied by 100%. We assumed that a trend was statistically significant at a 90% confidence level ($p \leq 0.10$) using Kendall tau statistics. We computed trends for 10^{th}, 50^{th}, and 90^{th} percentiles and annual, monthly, and seasonal means and medians.

Results

Isopleths of 2000-2010 December monthly mean trends for all "complete" IMPROVE sites are presented in Figures 1A and 1B for particulate sulfate and nitrate concentrations, respectively. The patterns shown in Figures 1A and 1B were observed only for December monthly mean trends. Increasing concentrations were associated with a swath of sites that extended from the northern Great Plains south into the central Great Plains. Many sites within this swath corresponded to trends of at least 5% yr^{-1} or higher, and the similarity between the spatial patterns in sulfate and nitrate trends is striking. The maximum sulfate trend within this swath was 17.5% yr^{-1} (p = 0.06) at Fort Peck, Montana, and the maximum nitrate trend of 11.1% yr^{-1} (p = 0.01) occurred at Wind Cave National Park, South Dakota. Trends corresponding to the December 10th, 50th, and 90th percentiles suggested that the increasing concentrations affected the entire distribution, not just the monthly mean value.

A regional trend corresponding to the swath of sites shown in Figures 1A and 1B was computed by grouping data from 17 complete sites in the region that had positive trends for both sulfate and nitrate concentrations. A Theil regression was performed on the regional December monthly mean data for all 17 sites. Timelines of regional mean data are shown in Figure 2. Nitrate concentrations ranged from 0.66 to 1.68 $\mu g/m^{-3}$ over the 11-year span; sulfate concentrations ranged from 0.48 to 1.17 $\mu g/m^{-3}$. The trends in regional sulfate and nitrate concentrations were similar, although nitrate trends were somewhat higher and statistically insignificant, with a value of 6.9% yr^{-1} (p = 0.18) compared to the statistically significant sulfate trend of 5.0% yr^{-1} (p = 0.02).

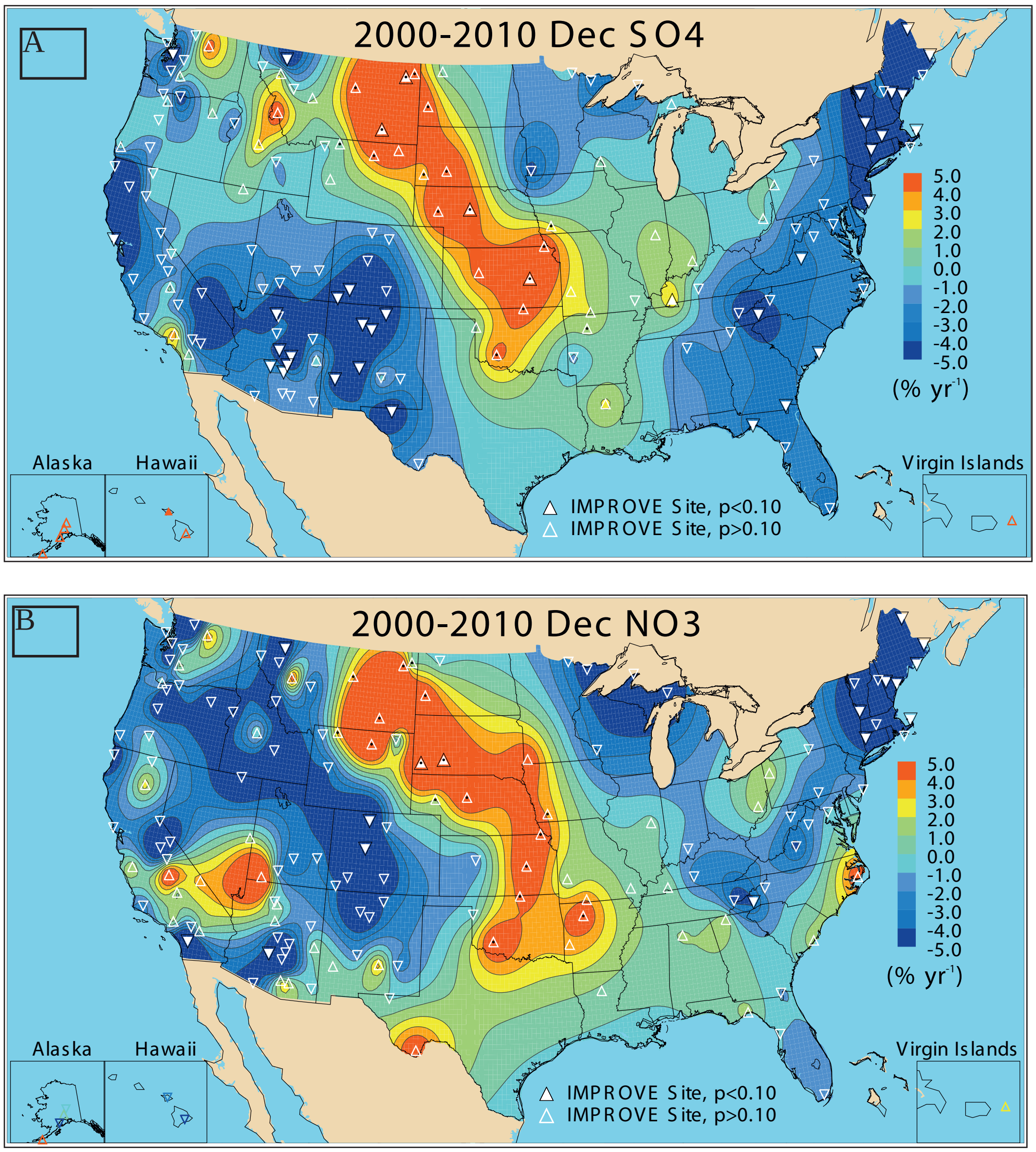


Figure 1. 2000-2010 December monthly mean trends in (A) particulate sulfate ion concentrations and (B) particulate nitrate ion concentrations. Upward and downward pointing filled triangles correspond to increasing and decreasing trends, respectively, that were significant at a 90% confidence level (*p* < 0.10) Unfilled triangles correspond to trends with significance levels of *p* > 0.10. Triangles with black dots indicate the 17 complete sites where data were used.

Implications

Both the location and timing of these trends have important implications. Ammonium nitrate formation is limited by the available ammonia beyond what is required to neutralize sulfate. Currently, the increases in both sulfate and nitrate concentrations suggest that the available ammonia is sufficient for neutralizing both sulfate and nitric acid, resulting in more particulates. However, if increasing concentrations of sulfate result in a competition for ammonium nitrate formation, perhaps remaining nitric acid would be available for other atmospheric reactions and deposition. The increase in nitrate and sulfate concentrations obviously intensifies their impacts to the environment, such as visibility degradation and acid precipitation. Nitrate is already a major contributor to fine mass at many sites in the

Trends continued on page 6....

Trends continued from page 5....

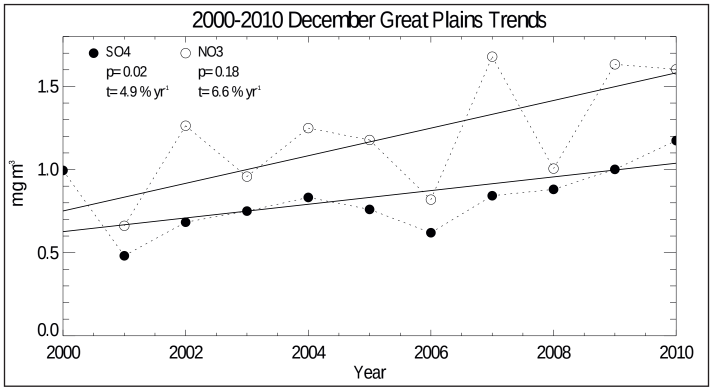


Figure 2. December monthly and regional mean concentrations (μg/m³) in particulate sulfate ion (filled circles) and particulate nitrate ion (open circles). Trends (t, % yr^{-1}) and significance levels (*p*) are provided.

northern and central Great Plains in winter. While sulfate concentrations historically have been highest in spring and summer in these regions, remarkably, the highest concentrations at sites within this swath shifted to winter and fall maxima in 2009 and 2010. In 2010 nearly every site in the swath of positive trends was associated with maximum sulfate concentrations during winter months.

The increasing December monthly mean trends are important because they counter the national annual declining trends in NO_x and SO_2 emissions based on controls of regulated sources such as power plants and mobile sources. In addition, 1995-2010 trends in December monthly SO_2 emissions from power plants decreased in every state associated with these sites, except for increasing trends in December in Nebraska (2.6% yr^{-1}, $p < 0.01$). The similarity in the magnitudes and spatial patterns in December sulfate and nitrate trends suggests a common cause.

Some possibilities can be speculated. Oil and gas development in several states located in the swath of positive trends has been significant and is projected to further increase. Oil and gas production and associated activities are sources of NO_x and to a lesser degree SO_2. SO_2 can be emitted from flaring of hydrogen sulfide gas (H_2S) in regions with sour gas basins, such as in northern Wyoming, northern North Dakota, and northeastern Oklahoma, and from diesel motor emissions and mobile sources associated with oil and gas production. Population has also increased in towns associated with oil and gas development. Trends based on census data suggested an increase in population (~0.4-1.2% yr^{-1} from 2000 to 2009) in states associated with increasing sulfate and nitrate trends.

Long-range transport is also a possible cause. Emissions of NO_x, SO_2, and reduced sulfur species from oil sand operations in Alberta, Canada, are significant. Concentrations in both NO_2 and reduced sulfur species have increased considerably from 2000 to 2010 at industry monitoring sites near the oil sands. Annual mean trends at all industry sites for NO_2 were 8.3% yr^{-1} (p = 0.01) and 9.9% yr^{-1} (p = 0.01) for reduced sulfur species, while trends in SO_2 were fairly flat and statistically insignificant (0.2% yr^{-1}, p = 0.58) based on data reported by the Wood Buffalo Environmental Association. Back trajectories for sites in the northern Great Plains, such as Fort Peck, Montana, implicate this area. However, back trajectory analyses do not pinpoint any individual source area as being responsible for increasing trends at all sites. They do suggest that a combination of local and long-range sources are likely responsible. Although changes in meteorological parameters could be contributing to the trends, investigations into trends in wind speeds, mixing layer heights, or ventilation (mixing layer height x wind speed) from back trajectory analyses were inconclusive. Increases in sulfate and nitrate concentrations are likely a combination of typical winter meteorological patterns that transport high concentrations into the region or trap increasing local concentrations during stagnation events.

The success of regulatory efforts in reducing annual pollutant concentrations in the U.S. apparently does not extend to winter concentrations in the historically clean Great Plains region, where concentrations were discovered to be significantly increasing, unlike during other times of the year. Additional analysis is necessary to understand the sources and causes of these increasing trends. If unregulated emission sources are responsible, it has important implications for our current air quality mitigation strategies.

References

Hand, J.L., Copeland, S.A., Day, D.E., Dillner, A.M., Idresand, H., Malm, W.C., McDade. C.E., Moore Jr., C.T., Pitchford, M.L., Schichtel, B.A., Watson, J.G., 2011. IMPROVE (Interagency Monitoring of Protected Visual Environments): Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report V. *http://vista.cira.colostate.edu/improve/Publications/Reports/2011/2011.htm.*

Complete reference citations can be found in this article, as published in Atmospheric Environment 55 (2012) 107-110.

Author affiliations

[1] Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO

[2] Air Resources Division, National Park Service, Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University, Fort Collins, CO

For more information contact Jenny Hand at CIRA. Telephone: 970/491-3699. Fax: 970/491-8598. E-mail: jlhand@colostate.edu.

Monitoring update

continued from page 3 ....

Outstanding sites

Data collection begins with those who operate, service, and maintain monitoring instrumentation. IMPROVE managers and contractors thank all site operators for their efforts in caring for IMPROVE and IMPROVE Protocol networks. Sites that achieved 100% data collection for 2nd Quarter 2012 are:

Aerosol (Channel A) - 53% of all sites

Acadia	Fresno	Presque Isle
Bandelier	Frostburg Reservoir	Proctor Research Cntr.
Big Bend	Glacier	Puget Sound
Bliss	Grand Canyon	Quaker City
Blue Mounds	Great Basin	Queen Valley
Bondville	Great Sand Dunes	Saguaro West
Boundary Waters	Great Smoky Mtns.	Seney
Bridger	Guadalupe Mtns.	Sequoia
Brigantine	Hawaii Volcanoes	Shamrock Mines
Cabinet Mountains	Hercules-Glades	Shining Rock
Caney Creek	Isle Royale	Snoqualmie Pass
Cape Romain	Joshua Tree	St. Marks
Capitol Reef	Kaiser	Starkey
Casco Bay	Kalmiopsis	Stilwell
Cedar Bluff	Lake Sugema	Tall Grass
Chassahowitzka	Lava Beds	Theodore Roosevelt
Cloud Peak	Londonderry	Three Sisters
Columbia Gorge East	Mammoth Cave	Tonto
Crater Lake	Meadview	Trapper Creek-Denali
Craters of the Moon	Medicine Lake	Tuxedni
Death Valley	Mesa Verde	Viking Lake
Denali	Moosehorn	Virgin Islands
Dolly Sods	Mount Zirkel	Weminuche
Dome Land	Okefenokee	White River
Egbert	Olympic	Wichita Mountain
El Dorado Springs	Pack Monadnock	Wind Cave
Everglades	Petrified Forest	Wrightwood
Flat Tops	Pinnacles	Yellowstone
Flat Head	Point Reyes	Yosemite

Nephelometer - 65% of all sites

Acadia	Glacier	Rocky Mountain
Big Bend	Great Basin	Shenandoah
Dysart	Indian Gardens	Vehicle Emissions
Estrella	Mount Rainier	

Sites that achieved at least 95% data collection for 2nd Quarter 2012 are:

Aerosol (Channel A) - 16% of all sites

Boulder Lake	Jarbidge	Quabbin Reservoir
Breton	Linville Gorge	Rocky Mountain
Bryce Canyon	Lostwood	Salt Creek
Crescent Lake	Mount Baldy	San Rafael
Douglas	North Cascades	Shenandoah
Gates of the Arctic	Northern Cheyenne	Simeonof
Great Gulf	Pasayten	Washington DC
Great River Bluffs	Penobscot	Zion Canyon
Hells Canyon	Phoenix	

Nephelometer - 29% of all sites

Grand Teton	Mammoth Cave	South Pass
	National Capital	

Transmissometer - 100% of all sites

Bridger

Sites that achieved at least 90% data collection for 2nd Quarter 2012 are:

Aerosol (Channel A) - 19% of all sites

Badlands	James River	Organ Pipe
Birmingham	Lassen Volcanic	Redwood
Bridgton	Lye Brook	San Gabriel
Canyonlands	Makah	San Gorgonio
Cape Cod	Martha's Vineyard	Sipsey
Cohutta	Mohawk Mountain	Sula
Fort Peck	Monture	Sycamore Canyon
Gates of the Mtns.	Mount Hood	UL Bend
Hoover	Mount Rainier	Upper Buffalo
Ike's Backbone	North Absaroka	White Pass
Indian Gardens		

Nephelometer - 6% of all sites

Cape Romain

Monitoring Site Assistance:

Aerosol sites: contact University of California-Davis telephone: 530/752-1123 (Pacific time)

Optical/Scene sites: contact Air Resource Specialists, Inc. telephone: 970/484-7941 (Mountain time)

Colorado wildfires *continued from page 2....*

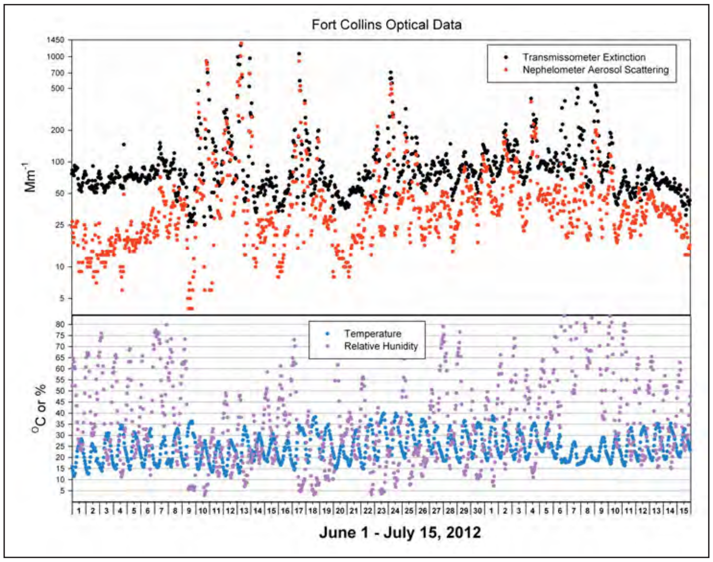


Figure 2. Fort Collins hourly optical data during Colorado fire events (note log scale for b_{ext} and b_{sp}).

Hourly aerosol concentrations were estimated from b_{ext} by assuming a range of extinction/mass ratios of 3 and 5 m^2/g (Figure 3).

Preliminary analysis indicates estimated aerosol concentrations approached 400 $\mu g/m^3$. The researchers also deployed TEOMs, Dustraks, additional nephelometers, E-Bams, aerosol, and gaseous samplers. Data from these instruments, regional meteorological information, and satellite imagery are currently being analyzed with results to be presented in future reports and papers.

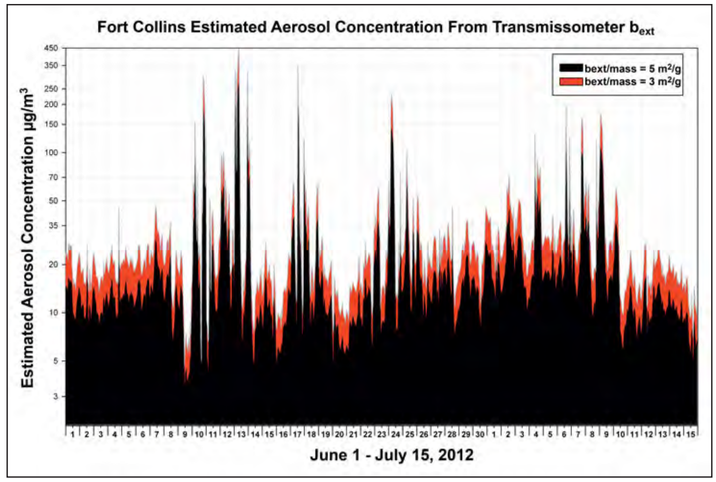


Figure 3. Aerosol concentration estimated from b_{ext} measurements.

For more information contact John Molenar at Air Resource Specialists, Inc. Telephone: 970/484-7941. Fax: 970/484-3423. E-mail: jmolenar@air-resource.com.

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.

U.S. EPA
Neil Frank
US EPA MD-14
Emissions, Monitoring and Analysis Div.
Research Triangle Park, NC 27711
Telephone: 919/541-5560
Fax: 919/541-3613
E-mail: frank.neil@epa.gov

NPS
Bret Schichtel
Colorado State University
CIRA - Foothills Campus
Fort Collins, CO 80523
Telephone: 970/491-8581
Fax: 970/491-8598
E-mail: schichtel@cira.colostate.edu

USFS
Scott Copeland *
USDA-Forest Service
Washakie Ranger Stn / 333 E. Main St
Lander, WY 82520
Telephone: 307/332-9737
Fax: 307/332-0264
E-mail: scott.copeland@colostate.edu
* Steering Committee Chair

USFWS
Sandra Silva
US Fish and Wildlife Service
7333 W. Jefferson Avenue
Suite 375
Lakewood, CO 80235
Telephone: 303/914-3801
Fax: 303/969-5444
E-mail: sandra_v_silva@fws.gov

BLM
David Maxwell
USDI BLM National Operations Center
Resource Services - Mail Stop OC-520
Denver Federal Center - Building 50
PO Box 25047, 205ST
Denver, CO 80225-0047
Telephone: 303/236-0489
Fax: 303/236-3508
E-mail: david_maxwell@blm.gov

MARAMA
David Krask
Maryland Dept. of the Environment
MARAMA/Air Quality Planning and Monitoring
1800 Washington Blvd.
Baltimore, MD 21230-1720
Telephone: 410/537-3756
Fax: 410/537-4243
E-mail: dkrask@mde.state.md.us

NESCAUM
Rich Poirot
VT Agency of Natural Resources
103 South Main Street
Building 3 South
Waterbury, VT 05676
Telephone: 802/241-3807
Fax: 802/244-5141
E-mail: rich.poirot@state.vt.us

WESTAR
Robert Lebens
715 SW Morrison
Suite 503
Portland, OR 97205
Telephone: 503/478-4956
Fax: 503/478-4961
E-mail: blebens@westar.org

NACAA
Gordon Andersson
State of Minnesota
Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155
Telephone: 651/757-2197
E-mail: gordon.andersson@state.mn.us

NOAA
Rick D. Saylor
NOAA/ARL/Atmospheric Turbulence & Diffusion Division
456 South Illinois Ave.
Oak Ridge, TN 37830
Telephone: 865/576-0116
E-mail: rick.saylor@noaa.gov

ASSOCIATE MEMBERS
Associate Membership in the IMPROVE Steering Committee requires operation of at least one IMPROVE protocol site, openly share data, and participate in technical review and oversight of the IMPROVE Program. Associate and International Associate Member representatives are:

STATE OF ARIZONA

ENVIRONMENT CANADA

REPUBLIC OF KOREA MINISTRY OF ENVIRONMENT