INTERAGENCY MONITORING OF PROTECTED VISUAL ENVIRONMENTS

IMPROVE

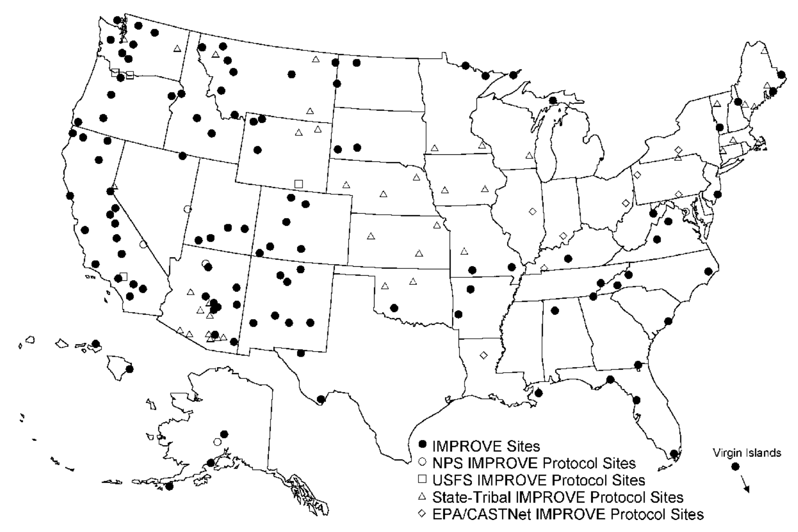
4th Quarter 2002 | The IMPROVE Newsletter | Volume 11 / Number 4

Monitoring update

Network operation status

The IMPROVE Program monitoring network consisted of 110 aerosol samplers, 17 transmissometers, 8 nephelometers, and 8 camera systems during 4th Quarter 2002 (October, November, and December). In addition, 52 aerosol samplers, 4 transmissometers, 24 nephelometers, and 9 cameras operated according to IMPROVE Protocols. Also supporting the program were 8 Web camera systems and 3 interpretive displays. Preliminary data collection statistics for the quarter are:

- Aerosol (channel A only) 96% collection
- Aerosol (all modules) 93% completeness
- Optical (transmissometer) 92% collection
- Optical (nephelometer) 99% collection
- Scene (photographic) 82% collection



IMPROVE and IMPROVE Protocol Sites
4th Quarter 2002

Web camera systems now operate at: Acadia NP, Big Bend NP, Grand Canyon NP, Great Smoky Mountains NP, Joshua Tree NP, Mammoth Cave NP, Sequoia-Kings Canyon NPs, and Theodore Roosevelt NP. Each system displays a real-time scenic image of the area along with visibility and meteorological parameters. Interpretive displays are operative in: Acadia NP, Big Bend NP, and Great Smoky Mountains NP. Each display is unique and is geared toward park visitor education.

Data availability status

Data are available on the IMPROVE Web site, at *http://vista.cira.colostate.edu/improve/Data/data.htm*. IMPROVE and other haze related data are also available on the VIEWS Web site, at *http://views.vista.cira.colostate.edu*. Aerosol data are available through August 2002. Transmissometer data are available through September 2001 and nephelometer data are available through September 2002.

Photographic slides and digital images are archived but are not routinely analyzed or reported. Complete photographic archives and slide spectrums (if completed) are available at Air Resource Specialists, Inc. Slide spectrums are also available on the IMPROVE Web site, under *Data*.

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

Visibility news

IMPROVE scene and optical monitoring

Since 1999, IMPROVE has expanded to over 150 monitoring sites. It has become the primary national speciated aerosol monitoring network, designed to meet specific requirements of the Regional Haze Regulations for tracking visual air quality in Class I areas. Unlike aerosol sampling, scene and optical monitoring:

1. Are high-time resolution methods that can be cost-effectively performed many times per day, and thus are able to see short-term (e.g., hourly) trends.
2. Allow for rapid turnaround times for reporting results in a real-time manner. Federal land managers or local air quality agencies can present the public with real-time visibility information, issue alerts, or implement timely control strategies.
3. Scene monitoring is the only cost-effective routine method that can detect elevated plumes or layered hazes.

***Scene and optical monitoring** continued on page 2....*

Visibility news continued from page 1 ....

Scene and optical monitoring continued from page 1....

At its inception in 1987 IMPROVE was specifically designed to address these issues and has considered scene and optical monitoring integral to the complete monitoring program. (See *IMPROVE Newsletter*, March 1992).

Scene monitoring: is the appearance of a scene viewed through the atmosphere. Scene characteristics, closer to the simple definition of visibility than aerosol or optical characteristics (observer visual range, scene contrast, color, texture, clarity, and other descriptive terms) can change with illumination and atmospheric composition. While aerosol and optical data provide measurements, scene monitoring allows one to see what the vista actually "looked" like at the time of the monitoring. Monitoring is done with digital cameras, or 35mm cameras using color slide film. Historic archives (which for some locations contain thousands of slides) have been carefully examined and "slide spectrum" images representing the range of visibility conditions captured at each location have been extracted. These spectrums are available on the IMPROVE Web site. (See *IMPROVE Newsletter*, Summer 1998, for a discussion on the creation and specific contents of slide spectrums).

Optical monitoring: is the physical properties of the atmosphere described by extinction, scattering, and absorption coefficients, plus an angular dependence of the scattering known as the normalized phase function. Optical characteristics integrate the effects of atmospheric aerosols and gases, using transmissometers to estimate the ambient extinction coefficient, and nephelometers to measure the ambient aerosol scattering coefficient. Both instruments yield hourly average data that provide detailed information about the temporal dynamics of visibility conditions where monitoring occurs.

Due to uncertainties in optical monitoring, the data have not been used historically for trend analysis, but as an adjunct data set to be used in an attempt to come to "closure" with aerosol and other optical measurements. This newsletter's feature article (see page 4) discusses the care that must be taken when using transmissometer data in trend analyses. Future newsletters will discuss the use of nephelometer scattering data and scene-specific visibility indices.

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.

Hawaii Volcanoes focus of particulate study

The IMPROVE Program and the National Park Service's Gaseous Pollutant Monitoring Program have teamed up to conduct a 5-month particulate study in Hawaii Volcanoes National Park. A $PM_{2.5}$ size-cut nephelometer (Optec NGN-3) was installed at the Visitor Center to monitor hourly average scattering during the period when volcanic smog (VOG) is most prevalent. Researchers will study the relationship among high SO_2 concentrations, particulate loading, and visibility during VOG events. These data will supplement the continuous SO_2, ozone, meteorological, and IMPROVE aerosol data taken routinely at this site. In addition, other particulate and atmospheric chemistry measurements may be taken by other research groups. The study began in mid-January and is expected to last through May 2003.

The park installed an SO_2 advisory system two years ago to alert park employees and visitors when SO_2 levels may be unsafe for human health. The park experiences SO_2 levels that exceed the national ambient air quality standard multiple times each year. Volcanic emissions are the major cause of sulfur dioxide in the park's air.

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

New MARAMA representative to IMPROVE

David Krask recently joined the IMPROVE Steering Committee as the representative from MARAMA, the Mid-Atlantic Regional Air Management Association. Mr. Krask fills the position vacated by Charles O. Davis III.

Mr. Krask is the chief of the Technical Services Branch of the District of Columbia Air Quality Division. As chief, he oversees operation of the district's air quality monitoring network (NAMS/SLAMS/PAMS/toxics) and the enhanced vehicle emissions inspection/maintenance quality assurance program, as well as general grant preparation and management.

Mr. Krask has been with the district for 14 years. Prior to coming to the district he worked as a consultant on a wide variety of source sampling and ambient air quality monitoring projects throughout the U.S. and abroad. He is a past chair of the MARAMA Monitoring Committee, and holds a master's degree in atmospheric chemistry from the University of Maryland.

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

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 operating the IMPROVE and IMPROVE Protocol networks. Sites that achieved 100% data collection for 4th Quarter 2002 are:

Aerosol

Acadia
Addison Pinnacle
Arendtsville
Badlands
Bandelier
Big Bend
Bondville
Boundary Waters
Breton Island
Brigantine
Brooklyn Lake
Cabinet Mountains
Cadiz
Caney Creek
Canyonlands
Cape Cod
Cape Romain
Capitol Reef
Chiricahua
Cohutta
Connecticut Hill
Craters of the Moon
Death Valley
Denali
Dolly Sods
Dome Land
El Dorado Springs
Everglades
Flathead
Fort Peck
Gila
Grand Canyon
Great Basin
Great Smoky Mountains
Hercules-Glades
Isle Royale
James River Face
Jarbidge
Lake Seguna
Linville Gorge
Livonia
Lostwood
Mammoth Cave
Medicine Lake
MK Goddard
Mohawk Mountain
Mount Baldy
Mount Hood
Mount Rainier
North Absaroka
North Cascades
Northern Cheyenne
Okefenokee
Olympic
Pasayten
Petrified Forest
Phoenix
Pinnacles
Presque Isle
Proctor Research Center
Puget Sound
Quabbin Reservoir
Quaker City
Rocky Mountain
Sac and Fox
Saguaro East
Saguaro West
Salt Creek
San Gabriel
San Gorgonio
San Rafael
Seney
Shenandoah
Snoqualmie Pass
Starkey
Sula Ranger District
Theodore Roosevelt
Three Sisters
Tonto
Trapper Creek-Denali
Voyageurs
Washington DC
Wheeler Peak
White Mountain
White River
Wichita Mountains

Transmissometer

-- none --

Nephelometer

Grand Canyon
Mammoth Cave
Mount Rainier

Photographic

Grand Canyon

Operators of distinction

Gates of the Mountains Wilderness, Montana, is one site where wintertime conditions pose challenges for its operators, Larry Cole, Dave Madden, and Keith Leatherman. Even so, these three Forest Service employees visit the site as scheduled to achieve excellent data collection.

"During winter, we often have to snowmobile out to the site, which is a six to eight hour commitment," said Cole. "We have safety measures that state at least two snowmobiles and two people are required to service the remote area. We also have go/no-go criteria, which means if a snowstorm is imminent, or if the temperature is 20 degrees below zero, we choose not to go. A lookout tower at the monitoring site is stocked with survival gear in case we get stranded by a blizzard." Summertime servicing is not much easier. The IMPROVE station takes at least three direct lightning hits each year. The operators must then diagnose and repair the instrumentation.

The three primary operators have other assigned responsibilities, and maintaining the IMPROVE site is one of those "other duties as assigned." Cole, a lands forester, currently handles land adjustments and special use duties in the Helena Ranger District. He also oversees the air quality program and has been with the district for over 20 years. Madden, a recreation technician, oversees visitor campgrounds and recreational facilities. He has been with the district for over 15 years. Leatherman, a culturist, currently handles reforestation, timber stand improvement, and other forest health issues. He has also been with the district for over 20 years.

When the aerosol sampler was installed in July 2000, its first three months showed skewed data due to wildfire activity in the area. As the fire season got on, two major fires burned within 15 miles from the monitoring site. A remote digital camera system was installed at the site the following spring.

Gates of the Mountains monitoring station in the Helena National Forest is located atop Hogback Mountain. The station is equipped with an IMPROVE aerosol sampler and a remote digital camera system.

Feature article

Warnings on the use of transmissometer data to analyze long-term visibility trends

Introduction

The IMPROVE monitoring network currently collects hourly estimates of light extinction with 17 transmissometers at 15 Class I areas. Most of the monitoring sites contain more than 10 years of data. It is tempting to use these data to examine the long term trends of haze, but data users should be aware that transmissometers are subject to varying biases that can obscure, or worse, create false trends.

In addition, the transmissometer data released on the IMPROVE Web site are at Level 1 of the quality control process and should be considered as preliminary data. These data should only be used after careful scrutiny and reconciliation with concurrent aerosol and nephelometer data. Due to the uncertainties in the transmissometer data, they have not been used historically for trend analysis, but as an important data set to be used in an attempt to come to "closure" with aerosol and other optical measurements.

This article discusses the main, but not all, issues related to the use of transmissometer data. Several misleading interpretations are illustrated concerning the trends of haze that these transmissometer data can cause, using data from Big Bend National Park.

Transmissometer data quality issues

The four data quality issues discussed herein must be considered before using transmissometer data.

1) *Transmissometers do not directly measure the atmospheric extinction coefficient.* A transmeter measures the irradiance (I_r) of a light some distance (r) from the source. The average extinction (b_{ext}) of the path is calculated as:

$$b_{ext} = \ln(I_o / I_r) / r$$

where: I_o is the estimated irradiance of the light source that would be measured at the distance (r) in the complete absence of any atmosphere (gases or aerosols).

Anything that modulates the measured irradiance (I_r) will affect the estimated extinction coefficient. Besides aerosols and absorbing gases along the path, this can include (but is not limited to): snow, rain, fog, clouds, airborne insect swarms, birds, fogged or dirty optical surfaces, misalignment of the detector or light source, optical blooming or turbulence, non-uniform light beam, or varying I_o.

2) *Transmissometers cannot be directly calibrated.* Various methods have been used to indirectly estimate I_o, but they all include major uncertainties and are not always self-consistent. In addition to the uncertainties associated with the initial estimate of I_o, current transmissometers occasionally suffer from step changes in the initial I_o when lamps are replaced in the field and all experience an increase in I_o as the lamp ages. It must be noted that any percent change in I_o results in an absolute incremental offset in calculated b_{ext} that is independent of b_{ext}. For example, a transmissometer operating along a 5 km path that has an unaccounted for 5% change in I_o will have an absolute offset of 10 Mm^{-1} in calculated b_{ext} for all b_{ext}.

3) *Validity codes are assigned for every hourly b_{ext} measurement using standard defined criteria, in an initial systematic effort to identify possible "interferences" and apply standard corrections, to account for I_o drifts that may be biasing the data.* These criteria are applied globally and at best should be considered the first step in a series of increasingly more comprehensive data validation methodologies.

4) *Primarily due to the above concerns, relying on Level-1 transmissometer data without examining concurrent collocated nephelometer and/or speciated aerosol data is dangerous and often leads to misleading conclusions.* Each specific site must be critically examined using all concurrent nephelometer and aerosol data before confidence can be placed in the transmissometer data.

Example using analysis of Big Bend transmissometer data

Misleading conclusions that can result from not reconciling transmissometer and aerosol data are illustrated in Big Bend IMPROVE data. Figure 1 is a timeline of daily average b_{ext} from transmissometer measurements at the site for IMPROVE aerosol sampling days. The daily average is only plotted if a minimum of 12 hourly non-flagged transmissometer b_{ext} values are present. Examining this b_{ext} trend it appears that b_{ext} increased from 1989-1994 and has been decreasing since then. This trend is apparent when looking only at the transmissometer data, however, when they are compared to simultaneous speciated aerosol data, a different picture emerges.

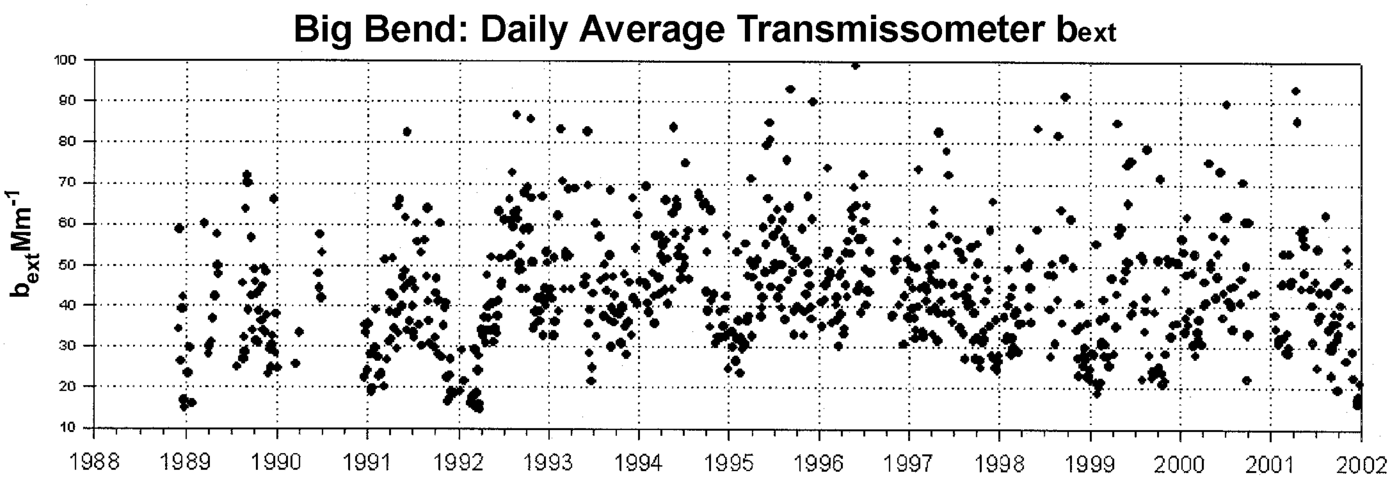


Figure 1. Daily average transmissometer b_{ext} timeline at Big Bend National Park 1988-2001 for IMPROVE aerosol sampling days. Daily average b_{ext} has a minimum of 12 hourly non-flagged transmissometer b_{ext} values.

Figure 2 plots the daily reconstructed aerosol b_{ext} calculated from the IMPROVE speciated aerosol data using the IMPROVE extinction equation:

$$b_{ext} = 3.0\ f(rh)\ [Sulfate] + 3.0\ f(rh)\ [Nitrate] + 4.0[OMC] + 1.0[Soil] + 0.6[Coarse\ Mass] + 10.0[LAC] + 10.0$$

The daily f(rh) employed is the average of all hourly f(rh) calculated from measured onsite hourly relative humidity data that corresponds to the b_{ext} hours used in the average b_{ext} calculation. The trend seen in the transmissometer b_{ext} plot is not apparent in the reconstructed aerosol b_{ext} plot.

Figure 3 plots the difference between concurrent daily average transmissometer b_{ext} and daily reconstructed b_{ext} from speciated aerosol data at Big Bend National Park for the period 1989 – 2001. Examination of the plot shows:

- There are significant, frequent, and varying in intensity, offsets in delta b_{ext} at the site.
- Trends at this site are also associated with offsets in the delta b_{ext} timeline.

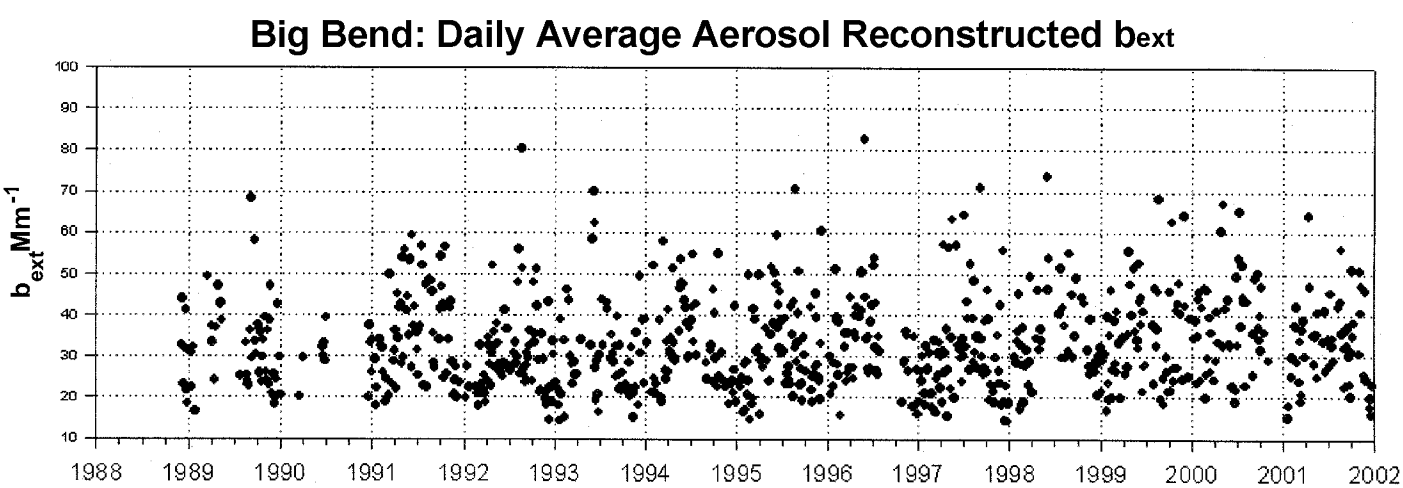


Figure 2. Daily average aerosol reconstructed b_{ext} timeline at Big Bend National Park 1988 – 2001. Aerosol b_{ext} is calculated using the IMPROVE algorithm. The daily f(rh) employed is the average of all hourly f(rh) calculated from measured onsite hourly relative humidity data that corresponds to the b_{ext} hours used in the average b_{ext} calculation.

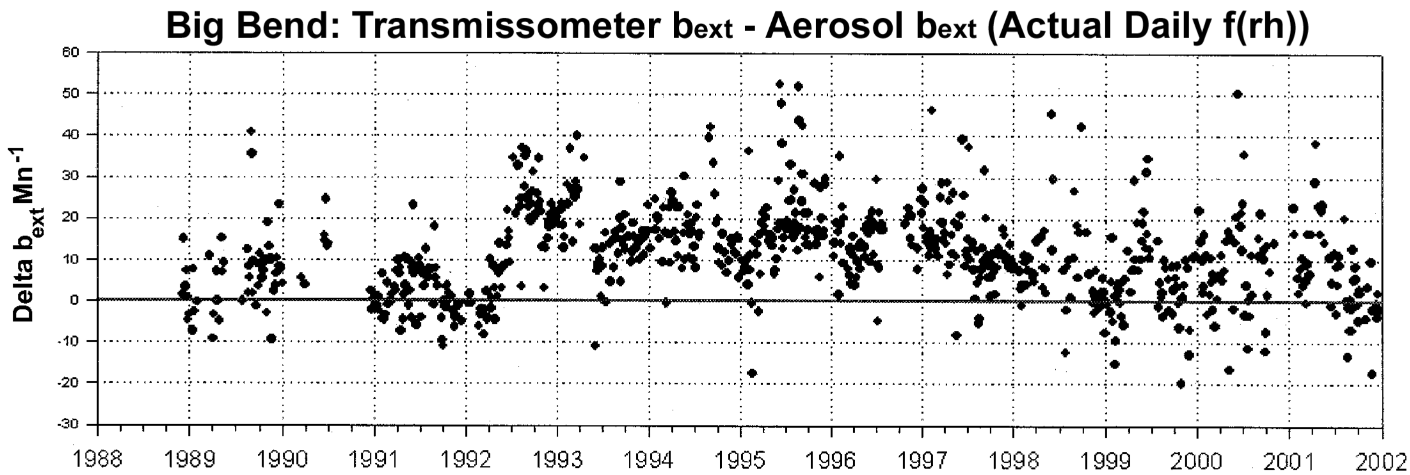


Figure 3. Daily delta b_{ext} (transmissometer b_{ext} – aerosol b_{ext}) timeline at Big Bend National Park 1988 – 2001. Daily average b_{ext} has a minimum of 12 hourly non-flagged transmissometer b_{ext} values. Aerosol b_{ext} is calculated using the IMPROVE algorithm. The daily f(rh) employed is the average of all hourly f(rh) calculated from hourly relative humidity data that corresponds to the b_{ext} hours used in the average b_{ext} calculation.

Two possibilities that would describe the timelines presented in Figures 1-3 are: (1) the transmissometer data are correct and some mechanism is causing multiple rapidly varying incremental changes in the speciated aerosol data, or (2) the speciated aerosol data are reasonably consistent and errors in estimates of I_o are causing these step functions.

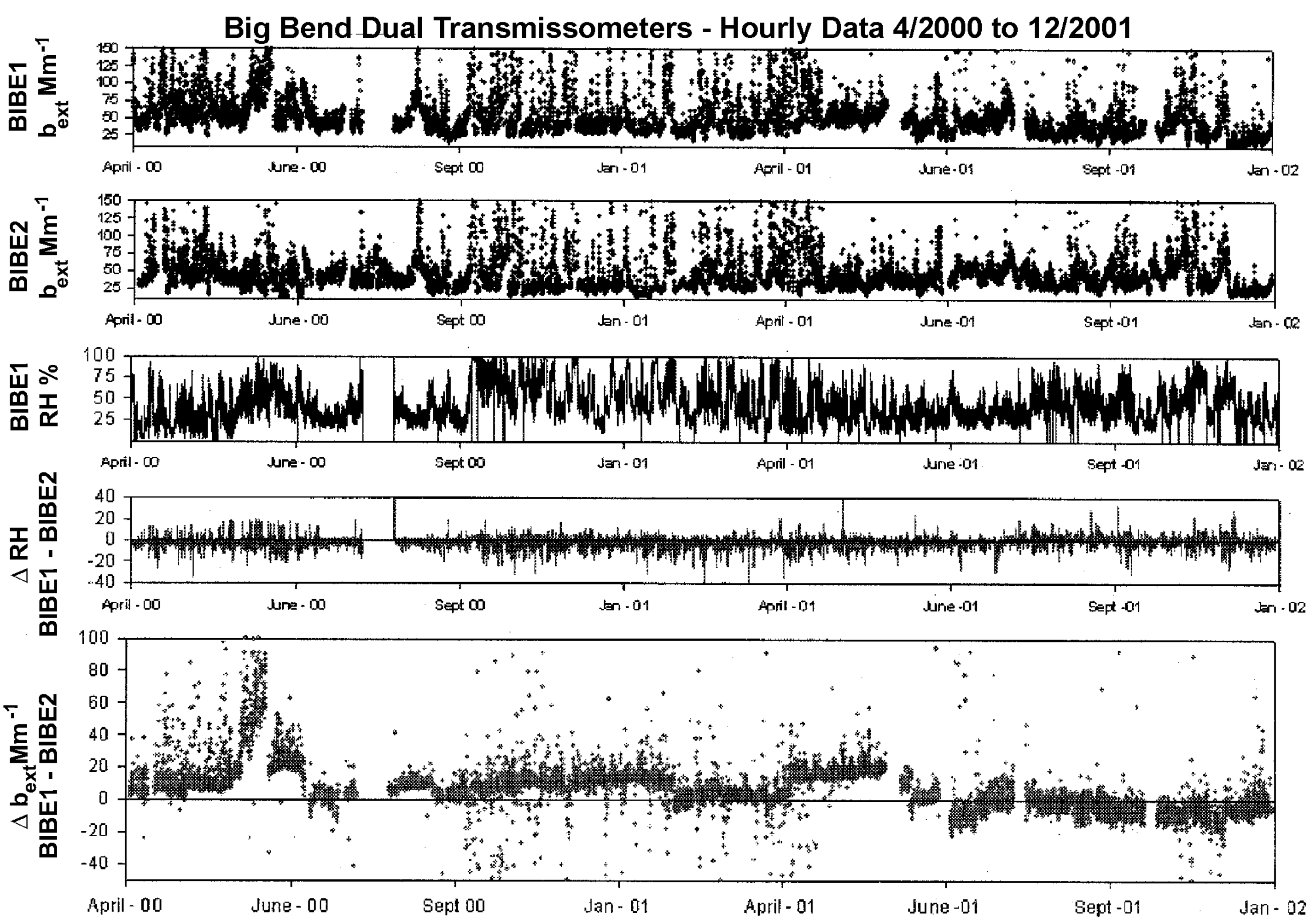


Figure 4. Hourly transmissometer b_{ext} data for Big Bend National Park dual transmissometer experiment. BIBE1 is the original system. BIBE2 operates along the same path length only about 30 m higher above the surface.

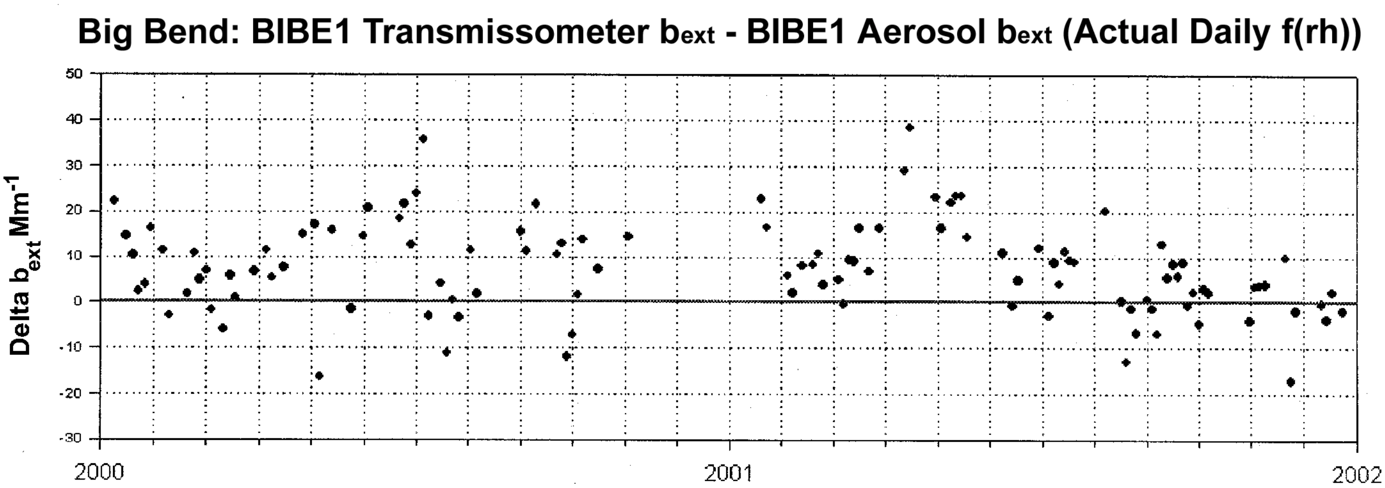
To investigate this issue a second transmissometer was installed at Big Bend in 2000 to operate along the same path as the existing system, but about 30 m higher above the surface. Figure 4 (previous page) plots various analyses of the dual Big Bend transmissometers. The same rapid, varying in intensity offsets are seen in the delta b_{ext} between the two transmissometers as seen in the transmissometer-aerosol delta b_{ext} in Figure 3. Even over this limited period of time, one or the other instrument appears to suffer some degree of offset.

Figure 5 presents the difference between concurrent daily average transmissometer b_{ext} and daily reconstructed b_{ext} from speciated aerosol data for the dual Big Bend transmissometers (same analysis as Figure 3). For 2000 and the first half of 2001 the new BIBE2 system agrees better with reconstructed aerosol b_{ext} than the original BIBE1 system. After mid-2001, the agreement is reversed. The aerosol reconstructed extinction should not be susceptible to the same types of uncertainties as with the transmissometer-derived extinction. Monitoring visibility using transmissometers allows for testing and verifying the calculations and equations used in aerosol reconstruction.

Conclusion

This brief example emphasizes the extreme care that must be taken when using transmissometer data independently in long-term trend analyses. It is clear that relying only on transmissometer data without examining concurrent collocated nephelometer and/or speciated aerosol data is dangerous and often will lead to misleading conclusions. Each specific site must be critically examined using all concurrent transmissometer, nephelometer, and aerosol data before confidence can be placed in the analyses results.

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.



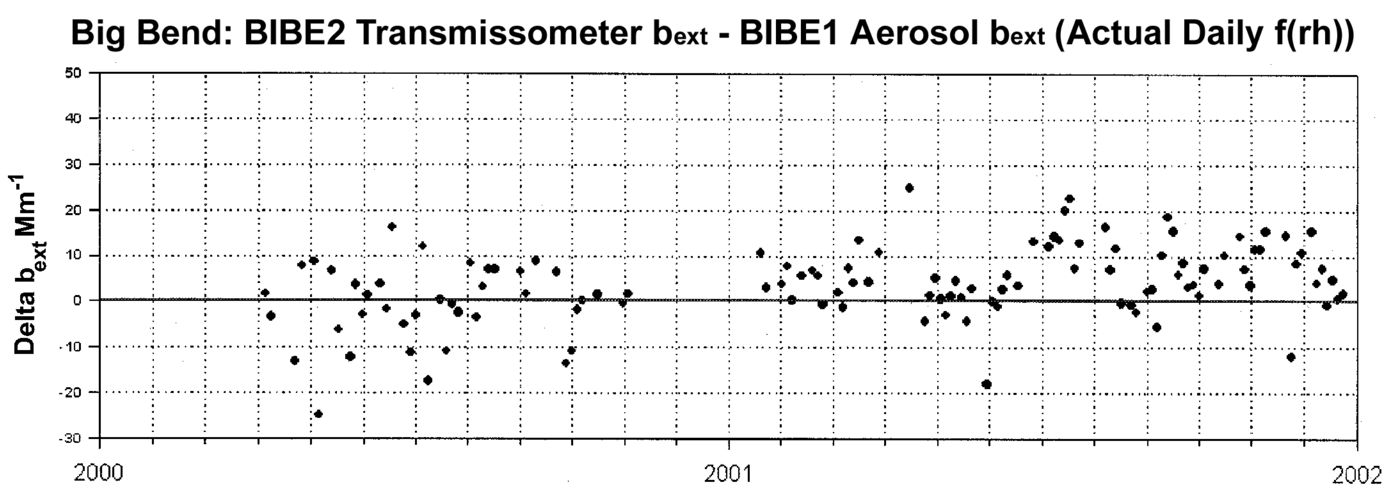


Figure 5. Daily delta b_{ext} (transmissometer b_{ext} – aerosol b_{ext}) timeline at Big Bend National Park 2000 – 2001 for the dual transmissometers (BIBE1 and BIBE2). Daily average b_{ext} has a minimum of 12 hourly non-flagged transmissometer b_{ext} values. Aerosol b_{ext} is calculated using the IMPROVE algorithm. The daily f(rh) employed is the average of all hourly f(rh) calculated from measured onsite hourly relative humidity data that corresponds to the b_{ext} hours used in the average b_{ext} calculation.

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