A History of the A&WMA Visibility Specialty Conferences

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ABSTRACT

The enactment of the Clean Air Act of 1970 (1970 CAA) and the creation of the U.S. Environmental Protection Agency in the same year resulted in a major shift in the federal government air quality programs (https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act). Congress recognized that visibility is a resource to be valued and preserved and in the 1977 CAA amendments set forth a national goal that called 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." Class I areas are the 156 national parks and wilderness areas where visibility was deemed an important attribute. In addition, the CAA amendments established the Prevention of Significant Deterioration (PSD) rule, with the intent of preserving the air quality in Class I areas, and in 1999 the Regional Haze Rule (RHR) was created with the goal of reducing haze on the most-impaired days to natural conditions. The 1990 CAA amendments were designed to curb four major threats to both the environment and human health, which indirectly helped to improved visibility. The mandate to reduce the threat of acid rain resulted in significant reductions in SO_2 emissions from oil- and coal-fired power plants and subsequently a reduction in haze-causing particulate sulfate. To aid in the implementation of the visibility goals and PSD rule, the Interagency Monitoring of Protected Visual Environments (IMPROVE) program was established in 1985 and began speciated aerosol sampling in 1988; the program was significantly expanded beginning in 2000 to support the RHR. In response to the 1977 CAA amendments, the Air Pollution Control Association (now the Air & Waste Management Association—A&WMA) held its first visibility specialty conference in Denver, Colorado, in 1980. These conferences have been repeated since then about every three or four years. The relationships among the growth of the IMPROVE monitoring program, the development of the science, the introduction of the PSD rule, the introduction of the RHR, and these conferences are the subjects of this manuscript.

IMPLICATIONS

Since 1988 the IMPROVE monitoring program has provided the data needed to evaluate progress toward the attainment of our national goal of the prevention of any future, and the remedying of any existing, visibility impairment and to support the implementation of the RHR. The series of visibility conferences held by the A&WMA, beginning in 1980, has been a major source of information on the progress in these areas. The publication of this history of the visibility specialty conferences with accompanying supplemental material preserves this record.

Background

The Clean Air Act (CAA) of 1970 was the first of the major federal environmental laws. It launched an ambitious set of federal programs to establish air quality goals and impose pollution control technology requirements on new and existing stationary sources and on motor vehicles. Congress established the basic structure of the CAA in 1970. To protect public health and welfare nationwide, the CAA required the U.S. Environmental Protection Agency (EPA) to establish national ambient air quality standards (NAAQS) for certain common and widespread pollutants based on the latest science. The EPA has set air quality standards for six common "criteria pollutants": particulate matter (also known as particle pollution), ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead (https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act). A geographic area that does not meet one or more of the federal air quality standards is designated as a nonattainment area.

Major amendments (CAAAs) were added to the CAA in 1977 and 1990. The 1977 amendments primarily concerned provisions for the Prevention of Significant Deterioration (PSD) of air quality in areas attaining the NAAQS. They also contained requirements pertaining to sources in nonattainment areas for NAAQS and established major permit review requirements to ensure attainment and maintenance of the NAAQS. Our national parks and wilderness areas possess many stunning vistas and scenery that are diminished by uniform haze that causes discoloration and loss of texture and visual range. Layered hazes and plume blight also detract from the scene. Recognizing the importance of visual air quality, Congress included legislation in the 1977 CAAA to prevent future and remedy existing visibility impairment in Class I areas. Class I areas are the 156 national parks and wilderness areas, such as Grand Canyon and Great Smoky Mountains National Parks, where visibility was deemed an important attribute.

In the 1990 CAAA, a nationwide approach to reduce acid pollution was introduced. Included in the law was a plan designed to reduce acid rain and improve public health by dramatically reducing emissions of SO_2 and SO_4^{-2} (SO_x) and NO and NO_2 (NO_x) (https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary). Emissions of SO_2 and NO_x are precursors to haze-forming sulfate and nitrate aerosols, and as shown in Figure 1, the reduction of these emissions improved visibility, particularly in the eastern United States (Malm et al., 2002; Hand et al., 2020). See Bachman (2007) for a detailed history and critical review of the U.S. air quality legislation and national ambient air standards.

In 1999, the EPA announced a major effort to improve air quality in national parks and wilderness areas (Watson, 2002). The Regional Haze Rule (RHR) calls for state and federal agencies to work together to improve visibility in the 156 Class I areas. The rule requires the states, in coordination with the EPA, National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), U.S. Forest Service (USFS), and other interested parties, to develop and

implement air quality protection plans to reduce the pollution that causes visibility impairment. The first state plans for regional haze were due in December 2007. States, tribes, and five multi-jurisdictional regional planning organizations worked together to develop the technical basis for these plans. Comprehensive periodic revisions to these initial plans are currently due in 2021, 2028, and every 10 years thereafter (https://www.epa.gov/visibility).

To aid in the development and implementation of visibility legislation, the Interagency Monitoring of Protected Visual Environments (IMPROVE) program (Eldred et al., 1988; Malm et al., 1994) was initiated in 1985. This program implemented an extensive long-term monitoring program to establish the current visibility conditions, track changes in visibility, and determine causal mechanisms for the visibility impairment in many national parks and wilderness areas. With the establishment of the RHR, IMPROVE was tasked with providing regional haze monitoring representative of all visibility-protected Class I areas. IMPROVE is managed as a cooperative measurement effort through a steering committee that consists of representatives from the EPA, NPS, USFS, FWS, Bureau of Land Management (BLM), National Oceanic and Atmospheric Administration (NOAA), four organizations representing state air quality organizations, National Association of Clean Air Agencies (NACAA), Western States Air Resources Council (WESTAR), Northeast States for Coordinated Air Use Management (NESCAUM), and Mid-Atlantic Regional Air Management Association (MARAMA), and three associate members (Arizona Department of Environmental Quality—AZ DEQ, Environment Canada, and the South Korea Ministry of Environment (http://vista.cira.colostate.edu/Improve/).

The relationship between the development of visibility related federal regulations; the visibility conference series documenting the regulatory and scientific developments and the implantation and expansion of the IMPROVE program, discussed above, is shown graphically in Figure 1.

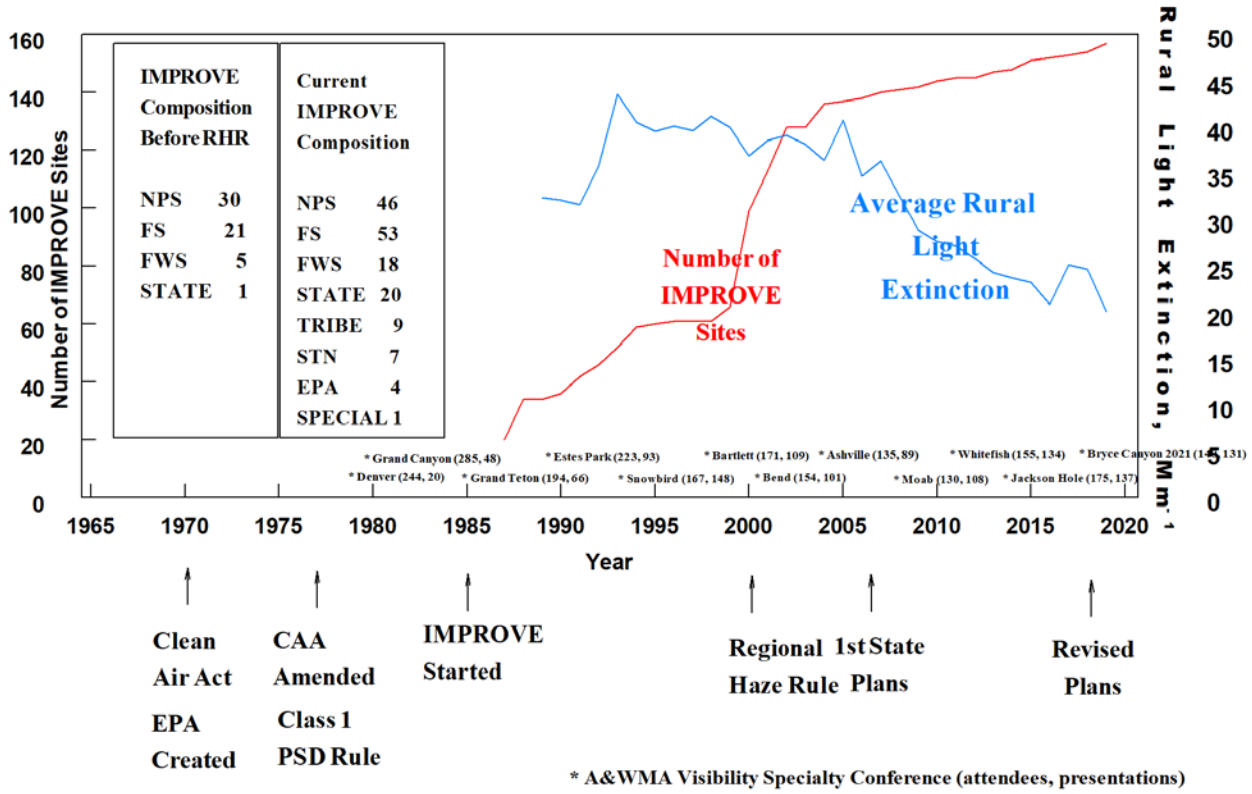

Figure 1. Number of IMPROVE sites as a function of year, EPA actions related to visibility, and occurrences of visibility conferences. Also plotted is the annual aerosol light extinction reconstructed from IMPROVE aerosol measurements. Data from all rural IMPROVE sites were used in each annual average.

Visibility Specialty Conferences

In 1979, just two years after the 1977 CAAA established the PSD rule for Class I visibility regions, the Air Pollution Control Association (APCA; Air & Waste Management Association—A&WMA—beginning in 1995) held a conference at the Brown Palace Hotel in Denver, Colorado, titled "A Specialty Conference on: View on Visibility – Regulatory and Scientific". In 1980 a second meeting was held at the Grand Canyon, followed by a meeting in 1986 at Grand Teton National Park. From then until the present, the visibility conferences were held every 3–5 years. The 2021 conference at Bryce Canyon, Utah, marked the twelfth conference in this series. It is interesting to note that the first two conferences included both the maximum number of attendees but the minimum number of presentations compared to later conferences in the series. There was a steady growth in the number of presentations until the 1994 conference at Snowbird, Utah, which had the maximum number of presentations of any of the conferences. Beginning with that conference, the number of presentations was closer to the number of attendees, as shown in Figure 2.

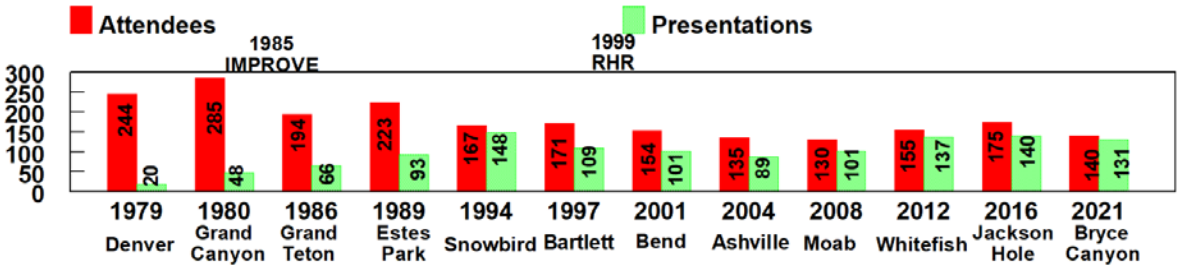

Figure 2. Attendance and number of presentations at visibility conferences with year and location noted.

This section outlines the events of each visibility conference; those following the Denver meeting also relate those events to the changes in the federal programs and the development of the science. While we have details on presentations made at each conference, either as proceedings of the conference or the conference program, in most cases we do not have the abstracts of all presentations to provide the depth of the science discussed at each meeting. In some cases, special journal issues were published containing papers from a small subset of the presentations. The special journal issue for the 1980 meeting at the Grand Canyon was unique in that it included publications based on all of the conference presentations. We therefore rely on our own memory of the conferences. We have attempted to relate changes in the nature of the presentations over the years to the growth of the IMPROVE program, the passage of new federal regulations related to visibility, and the development of the science.

1979 Denver: A Specialty Conference on: View on Visibility – Regulatory and Scientific

This meeting was held at the Brown Palace Hotel in Denver, Colorado, with technical program chair Terry L. Theon of the EPA. The meeting was sponsored by the APCA technical committee on visibility (TE-5), chaired by Ben Linsky and the Rocky Mountain States section of the APCA. The November 25–27 three-day meeting had seven sessions with 20 presentations and 244 attendees. It is interesting to note that one of the presenters, William C. Malm, has presented at every subsequent A&WMA visibility conference. This first visibility conference focused on regulatory and scientific visibility issues, including measurement, modeling, and human perception as summarized in Table 1. The complete list of presenters and their topics is included in Appendix A.

The high attendance indicates the great interest in the topic as a result of the PSD rule. The program focused on what we knew about the relationships among measurements, visibility impairment, and human perception.

Table 1. Topic areas for the Denver visibility conference.

Topic Area	**Number of Presentations**	**Notes**
Keynote Address	1	William H. Lewis, Jr., National Commission on Air Quality (included in the conference proceedings in Appendix A)
Visibility Regulations	1	
Visibility Perception	3	
Visibility Field Programs	3	

Topic Area	Number of Presentations	Notes
Visibility Modeling	3	
Visibility Monitoring	3	
Intercomparison of Measurement Methods	4	
Implications of Visibility Impacts	3	

1980 Grand Canyon National Park: Visibility and Air Pollution, Measurements, and Model Components

Warren H. White, Washington University in St. Louis, chaired the meeting. We do not have either the conference program or proceedings for this conference. However, a conference overview and 48 journal articles based on conference presentations were published in *Atmospheric Environment* (1981) Volume 15. The overview and abstract for each publication, grouped according to topic areas in Table 2, are given in Appendix B.

Table 2. Topic areas for the Grand Canyon conference.

Topic Area	Number of Presentations	Associated Studies
Atmospheric and Plume Chemistry	13	MISTT (1), STATE (1)
Particulate Composition	2	
Human Perception of Visibility	5	
Optical Properties	3	
Plume Chemistry Modeling	4	
Visibility Modeling	5	VISTTA (2), VIEW (1)
Visibility Monitoring	8	VISTTA (3)
Visibility and Regional Transport	7	VISTTA (1), STATE (1)
Wildfires	1	

The Grand Canyon meeting, expanded upon the Denver meeting topics and included plume chemistry measurements, the determination of plume conversion kinetics and modeling, and particulate composition. It was known that sulfate was a major contributor to aerosols and haze. However, the sulfur emissions from large sources, e.g., coal-fired power plants, and their fate were poorly understood. This was critical information for implementation of the PSD rule and NAAQS. Several large programs were initiated in the 1970s to measure and model power plant emissions and the conversion of SO_2 to sulfate. These included the MISTT (Midwest Interstate Sulfur Transport and Transformation) study conducted in the St. Louis region that sampled urban plumes in July and August 1975 and collected data in the Labadie power plant plume in July 1976; STATE (Sulfur Transport and Transformation Experiment), a Tennessee Valley Authority (TVA) airborne study of the Cumberland and Johnsonville power plants in 1978; and VISTTA (Visibility Impairment due to Sulfur Transport and Transformation in the Atmosphere), an EPA program conducted at the Navajo generating station in Page, Arizona, in June, July, and

December 1979). The data collected in these studies were obtained through a coordinated set of gaseous, particulate, and meteorological measurements through specific power plant and urban plumes by aircraft. See Appendix B.

One presentation of note, by William C. Malm, was the first in the visibility modeling topic area that described the joint field program by the EPA and NPS, Visibility Investigative Experiment in the West (VIEW). In VIEW, a network of experimental teleradiometers and standardized photography instruments was deployed at 13 national parks and monuments in the Southwest. Analysis of the summer 1978 through spring 1979 data showed that winter had the highest standard visual range and spring the lowest. Capitol Reef National Park had the best visibility, while Wupatki National Monument had the worst. This program would be replaced by the IMPROVE program to measure both visibility and particulate composition with the monitoring beginning in March of 1988. Another highlight of the conference was the confirmation that the formation of NO_2 was responsible for the brown coloration of an elevated plume (see Appendix B).

1986 Grand Teton National Park: Visibility Protection: Research and Policy Aspects

This conference was sponsored by the APCA's visibility and particulate committees. The meeting was held at the Jackson Lake Lodge at Grand Teton National Park, and there were 194 attendees and 66 presentations in a plenary session and 14 technical sessions. The conference technical chairman was Prem S. Bhardwaja, Salt River Project, and the general conference chairman was Sara Head, AeroVironment Inc.

A summary of the presentations is given in Table 3. Details for each session are given in Appendix C.

Table 3. Plenary and technical sessions for the Grand Teton National Park conference.

Title of Session	**Number of Presentations**	**Notes and Associated Studies**
Plenary Speaker, Scott M. Matheson, Governor of Utah	1	Remarks are included in Appendix C
Plenary Speaker, J. Craig Potter, Assistant Administrator for Air and Radiation, U.S.EPA	1	Remarks are included in Appendix C
Regulatory Issues	5	
Major Observational Studies	4	Included plans for IMPROVE SCENES (1), RESOLVE (1) PANORAMAS (1)
Economics/Benefits	5	
Radiative Transfer	4	
Perception	6	
Aerosols	6	
Urban Visibility	2	
Atmospheric Optics	6	
Visibility Modeling	6	
Particulate Monitoring	4	
Meteorology and Long-Range Transport	5	

Title of Session	Number of Presentations	Notes and Associated Studies
Optical Monitoring	3	
Source Attribution	7	PANORAMAS (1) RESOLVE (1)
Instrument Development and Demonstrations	1	

The Grand Canyon meeting was focused on visibility issues with, similar to the 1980 conference, significant input on plume chemistry measurements, the determination of plume conversion kinetics and modeling, and particulate composition. New topics addressed included regulatory issues, economics/benefits, and urban visibility. The results of several large field programs were presented with emphasis on understanding visibility monitoring, visibility modeling, and transport.

One field study, SCENES (Subregional Cooperative Electric Utility, Department of Defense, NPS, and EPA Study), was in response to the need for developing better monitoring techniques to address the reasonable attribution question. Its overall goal was to understand the origins of recurring uniform and layered hazes, both local and regional in extent, that affect visual air quality under certain meteorological conditions in the desert Southwest. The SCENES program consisted of 11 monitoring sites on and around the Colorado Plateau with a focus on Canyonlands, Mesa Verde, and the Grand Canyon. While improvements in comprehensive aerosol and visibility measurements were being made in the SCENES program, this study was not intended to advance our understanding of specific source–receptor relationships.

This long-term experiment was supplemented by several short-term intensive experiments in which special air quality and visibility measurements were made to begin to address the issues of source attribution. These studies included PANORAMAS (Pacific Norwest Regional Aerosol Mass Apportionment Study) and RESOLVE (Research on Operations Limiting Visual Extinction), which developed a model for the attribution of extinction to particulate components. Plans for the upcoming study, the Winter Haze Intensive Tracer Experiment (WHITEX) in January and February 1987, were also presented. Results from WHITEX were shared at the 1989 meeting at Estes Park (next section).

As noted in Figure 1, the IMPROVE program was approved in 1985, but the first IMPROVE sites would not become operational until the year after the conference. David B. Joseph gave a presentation titled “Plans for IMPROVE, a federal program to monitor visibility in Class I areas” in the session on major observational studies. The presentation included a description of the IMPROVE monitor, which consisted of a suite of modules to collect 24-hour samples of particulate mass with aerodynamic diameters less than 2.5 microns ($PM_{2.5}$) and 10 microns (PM_{10}) for the determination of $PM_{2.5}$ mass and composition and PM_{10} mass, respectively (Figure 3). This insured that data from all sites and as a function of time are comparable, allowing the development of meaningful trend analyses.

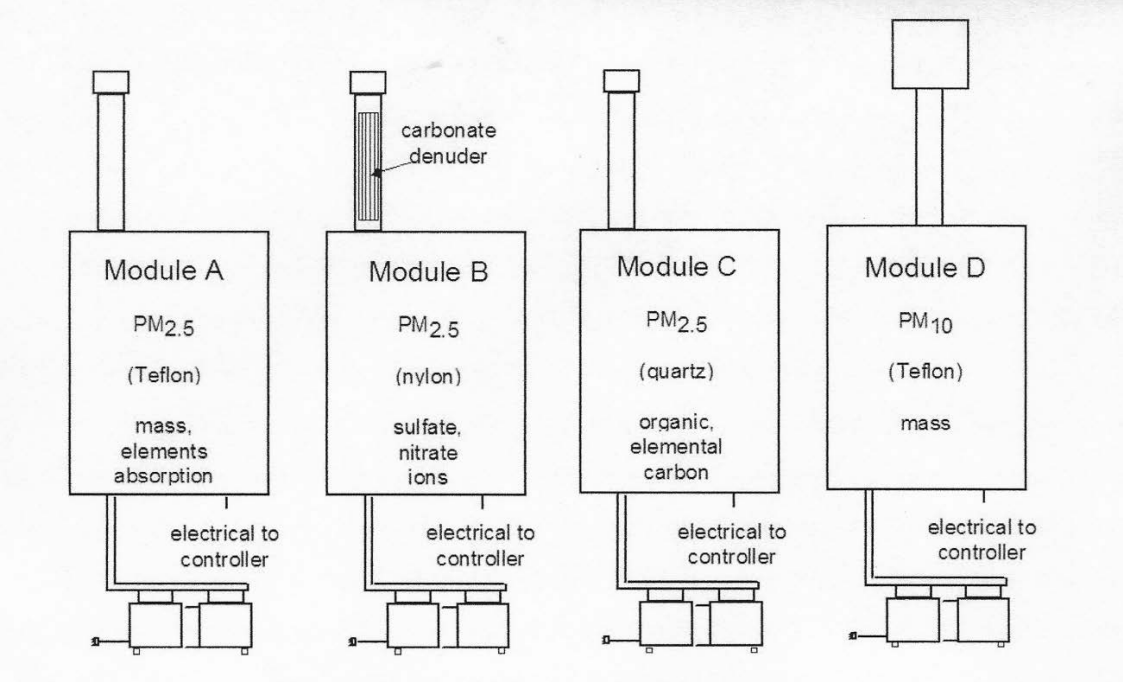

Figure 3. Schematic of the IMPROVE sampler showing the four modules with separate inlets and pumps. Filter substrates and analyses performed on each filter are also shown (see http://vista.cira.colostate.edu/Improve/).

Module A is used to determine $PM_{2.5}$ mass gravimetrically, elements by particle-induced X-ray emission (PIXE) analyses (conducted at the University of California, Davis), and light absorption. Module B collects fine particulate material on a nylon filter after a carbonate denuder. The denuder removes gas-phase nitric acid before sample collection, and the nylon filter retains any nitrate from ammonium nitrate on the filter. The sample is analyzed by ion chromatography. The possible loss of some ammonium nitrate from the module A Teflon filter was discussed by Ashbaugh and Eldred (2004). Module C contains a quartz filter that is analyzed for organic and elemental carbon by thermal optical reflection at the Desert Research Institute (Chow et al., 2007).

1989 Estes Park: Visibility and Fine Particles

This conference was sponsored by the A&WMA and EPA. The meeting was held in October at the YMCA of the Rockies, just outside Estes Park, Colorado, and adjacent to Rocky Mountain National Park. There were 223 attendees and 93 presentations. This conference included 18 sessions, including the keynote speech by Bruce C. Jordan and a poster session. The general conference chair was Scott F. Archer, Bureau of Land Management, Denver, and the conference technical chair was C.V. Mathai, Arizona Public Service. One event of note: the YMCA rooms did not have TV sets, and during the conference, a massive earthquake hit the Bay Area of California, including bringing down sections of a freeway in Oakland. The TV in the foyer was closely watched by anxious attendees.

At the time of this conference, the IMPROVE monitoring had been up and running for about 1.5 years and had a total of about 40 stations in operation. Though only one paper from the

IMPROVE program was presented at this conference, the establishment of the program had an impact on many related studies. This undoubtedly in part accounted for the increase from 68 presentations in 1986 to 93 presentations in 1989 and a subsequent increase to 148 in 1994. A summary of the presentations is given in Table 4. Details for each session are given in Appendix D.

Table 4. Plenary and technical sessions for the Estes Park conference.

Title of Session	**Number of Presenters**	**Notes and Associated Studies**
Keynote: Bruce C. Jordan, Chief, Ambient Standards Branch, OAQOS, EPA	1	Remarks are included in Appendix D
Policy and Regulatory Issues	9	WHITEX (1)
Visibility Measurements in Non-urban Areas. A. Fine Particle Measurements	15	WHITEX (1), IMPROVE (1) SCENES (2)
B. Optical Measurements	10	
Visibility Measurements in Urban Areas	10	Denver Brown Cloud (6)
Meteorological Factors Influencing Visibility	8	SCENES (2)
Human Perception of Visibility	6	
Economics of Visibility	5	
Visibility and Fine Particle Modeling	10	
Source Attribution of Visibility Impairment	12	WHITEX (7) Denver Brown Cloud (1)
Discussion	2	WHITEX (2)
Future Research Directions, Report from a Panel Discussion	5	WHITEX (1), SCENES (1)

As shown in Table 4, there were 12 presentations on the WHITEX study, representing a significant part of the program. At the time, WHITEX was at the forefront of relating emissions from sources to visibility impacts.

As described in the WHITEX final report (http://vista.cira.colostate.edu/Improve/final-report-whitex/),

> "This study was designed to evaluate the feasibility of attributing single point source emissions to visibility impairment in Grand Canyon National Park. WHITEX was conducted during a six-week period in January and February 1987. During this time, an artificial tracer, deuterated methane (CD_4), was released from the Navajo Generating Station at Page, AZ near the eastern end of the Grand Canyon. Aerosol, optical, tracer, and other properties were measured at Hopi Point (on the south rim of the Grand Canyon) and other locations. Using the tracer, 70% to 80% of the sulfate at Hopi Point under certain meteorological conditions in the winter was attributed to the NGS (Malm et al., 1989b). Some controversy arose from this attribution since the ratio of the CD_4 emissions rate to power plant load was not maintained at a stable value (Markowski, 1992).

> In addition, while the measurement of CD_4 concentrations is quite precise, the analytical costs are high. As a result, only a fraction of the samples collected were ever analyzed. WHITEX demonstrated the potential of tracer techniques for single source attribution. The study also showed that maintaining a stable tracer/power load emission ratio and using a low-cost tracer analytical technique could improve the quality of the source attribution."

In addition to the extensive contribution of WHITEX results to the conference program, observations from the SCENES program were also presented.

Three WHITEX- and SCENES-related studies were also reported by Brigham Young University (BYU) researchers in cooperation with the NPS, Salt River Project, and Southern California Edison. In the first study, spherical aluminosilicate particles (SAS), unique to coal-fired power plants, total fluoride (gas- and particle-phase), as well as SO_2 and sulfate were measured at Page, Arizona, and Bryce Canyon, Utah, during the WHITEX study (Winiwarter et al., 1990). At Page the two potential indicators of coal-fired power plants were correlated with IMPROVE data. Results at Bryce Canyon indicated there were at least two different sources of SAS, fluoride, and total SO_x, with the lowest ratios of SAS to SO_x being associated with transport from Page. The second study involved comparison of filter pack and denuder measurements of HNO_3 (g), HNO_2(g), SO_2(g), NH_3(g), and particulate-phase nitrate, nitrite, sulfate, and ammonium ion at both Page and the Bryce Canyon IMPROVE site (Lewis et al., 1990). The last study involved the collection of particulate organic compounds with diffusion denuder and filter pack sampling systems at Hopi Point in the Grand Canyon during the SCENES program in September 1985 and August 1988. These studies focused on understanding both the positive artifact from the absorption of gas-phase compounds onto a quartz filter and a negative artifact from the loss of semivolatile organic compounds from the particles during sampling (Eatough et al., 1990). The negative artifact was over an order of magnitude larger than the positive artifact. However, while this artifact will result in an underestimation of organic material in particles from the IMPROVE data, it will not affect the mass balance calculations from the IMPROVE data, since the negative artifact is present for both module A and module C of the IMPROVE system shown in Figure 3.

A significant portion of the program involved visibility measurements in urban areas as shown in Table 4, with a large part of the session reporting on the results of the 1987–1988 Denver Brown Cloud study. This 3-month field study addressed Denver's severe winter brown cloud episodes and included the application of a receptor-oriented chemical mass balance modeling method to apportion light extinction to primary emissions.

The 1989 Estes Park conference thus highlighted many advances in visibility science. The past and future of the science was at a crossroads. As expressed in the keynote address by Bruce C. Jordan,

> "Let me briefly say why I believe the WHITEX and the President's acid rain bill will set the stage for the future. First, with the WHITEX study we are now in a position to assess the local impacts on visibility by sources far from the receptors of concern. Secondly, the WHITEX study and EPA's actions subsequent to it puts increased emphasis on the importance of visibility and on the law to protect it.

Thirdly, there are numerous other WHITEX type problems just waiting to surface. Thus, if WHITEX leads to regulatory action, we are going to have to deal with other such problems, many of which will occur in the West.

Secondly, the President's proposed Clean Air Act Amendments (the 1990 Amendments) if enacted, will become a primary mechanism for reducing regional haze in the East over the next 10 years. The provisions in Title V of the amendments would reduce sulfur oxide emissions by some 10 million tons primarily in the East. In addition to achieving our deposition goals reductions of this magnitude will also have an impact on regional visibility.

Thus, I see the WHITEX effort getting us focused on the local visibility problems in the West and the acid rain bill carrying us forward in addressing the regional haze problem in the East. However, there still remains the regional problem in the West, which neither of these actions will adequately address, and we should not overlook this.

There is another major program I am involved with that will also benefit visibility protection and it is the program for attaining the ozone national ambient air quality standard. We know from our visibility monitoring that organic fine particles are a part of the pollutant mix that causes visibility impairment. Since virtually every major urban area is not attaining the ozone standard, EPA will be seeking reductions in pollutant emissions that directly contribute to formation of organic fine particles."

1994 Snowbird: Aerosols and Atmospheric Optics: Radiative Balance and Visual Air Quality

The 1994 conference was sponsored by the A&WMA and the American Geophysical Union. The meeting was held September 26–30 at the Snowbird Ski Resort in Little Cottonwood Canyon just east of Salt Lake City, Utah, and adjacent to the Lone Peak Wilderness Area. The conference technical chairs were William C. Malm and Peter K. Mueller. The general conference chair was Delbert J. Eatough, and the exhibition chair was Joseph A. Martone. There were 167 attendees and 148 presentations. This conference included 20 sessions including two plenary sessions and a poster session. The presentations included 91 platform and 57 poster presentations. This was the largest conference in terms of presentations in the history of the visibility conference (Figure 2).

One afternoon, the conference attendees were taken from the conference hotel (8,100 ft) to the top of Hidden Mountain (11,000 ft) by the Snowbird tram. There, they were adjacent to the Twin Peaks Wilderness (11,300 ft) and enjoyed a walk back to the conference accompanied by trail guides. This afternoon event began a tradition that continued in subsequent conferences.

This was also the first conference to have an equipment exhibit. Exhibitors were Air Resource Specialists, Inc., Fort Collins, Colorado, URG Corporation, Carrboro, North Carolina, ENSR Consulting & Engineering, Camarillo, California, Rupprecht & Patashnick Co, Inc., Albany, New York, and TSI Incorporated, Particle Instrument Division, St. Paul, Minnesota. Air Resource Specialists and URG have exhibited at this and every subsequent visibility conference.

A summary of the presentations is given in Table 5. Details for each session are given in Appendix E.

Table 5. Plenary and technical sessions for the Snowbird conference.

Title of Session	**Number of Presentations**	**Notes and Associated Studies**
Plenary Session, State of the Science Overview Issues in aerosol measurements for optics assessment, Peter H. McMurry Recommendations for monitoring the effects of air quality on visibility, L. Willard Richards Response, John V. Molenar	3	Denver Brown Cloud (1) Project MOHAVE (1)
Reviews of Sampling Methodologies and Programs	5	SCENES (1) CASTNet (1)
Regional and Spatial Patterns	10	IMPROVE (2)
Determination of Optical Depth or Albedo	8	
Climate and Aerosols	3	
Visibility and Extinction	7	IMPROVE (3)
Radiative Transfer	7	
Plenary Session, State of the Science Overview The Whitehorse Effect: Shortwave Radiative Forcing by Anthropogenic Aerosols, Stephen. Schwartz	1	
Hygroscopic Aerosols	5	
Sulfate Aerosols	5	Project MOHAVE (1)
Organic Aerosols	2	Project MOHAVE (1)
Chemistry and Physics of Single particles	6	
Aerosol–Cloud Interactions	4	
Source–Receptor Relationships	5	Project MOHAVE (2)
Roles of Emissions, Transport, and Transformation on Visibility in the Southwest	9	Denver Brown Cloud (1) Project MOHAVE (2)
Air Quality Visibility Models	7	Denver Brown Cloud (1)
Atmospheric Science as Applied to Societal Issues	4	

Title of Session	Number of Presentations	Notes and Associated Studies
Poster Session		
Instrumentation (gas; gas and particle)	3	Project MOHAVE (1)
Instrumentation (particles)	4	CASTNet (1)
Instrumentation (optical properties)	4	
Measurement Summaries	5	Project MOHAVE (1)
Climate and Aerosols	3	
Visibility and Extinction	5	
Radiative Transfer	1	
Hygroscopic Aerosols	5	
Sulfate Aerosols	1	
Organic Aerosols	3	Project MOHAVE (1)
Chemistry and Physics of Single Particles	3	
Aerosol–Cloud Interactions	3	
Source–Receptor Relationships	7	Project MOHAVE (2)
Roles of Emissions, Transport, and Transformation on Visibility on the Southwest	4	Project MOHAVE (2)
Air Quality Visibility Models	2	
Atmospheric Science as Applied to Societal Issues	4	

As noted in the previous section, the WHITEX program tested and validated the use of inert tracers for the study of source–receptor relationships and impacts. This science was further advanced in reports given at the Snowbird conference in connection with early results of Project MOHAVE, as noted by the 19 presentations related to that program.

Project MOHAVE (Pitchford et al., 1999) was an extensive monitoring, modeling, and data assessment project designed to estimate the contributions of the Mohave Power Plant (MPP), a 1580 megawatt electric coal-fired power plant located in Laughlin, Nevada, to haze at Grand Canyon National Park. The power plant is about 90 miles southwest of Meadview at the western edge of the park and 200 miles south-southwest of Hopi Point in the park. The field study component of the project was conducted in 1992 and contained two intensive monitoring periods (~30 days in the winter and ~50 days in the summer). This study built upon the pioneering use of inert tracers in the WHITEX program to track power plant plume emissions by continuously releasing unique and inert perfluorocarbon tracer (PFT) materials from the MPP stack during the two intensive periods. Tracer concentrations, ambient particulate composition, and SO_2 concentrations were measured at about 30 locations in a four-state region. Two of these monitoring sites, Hopi Point near the main visitor center at the south rim of the canyon and Meadview near the far western end of the national park, were used as key receptor sites representative of Grand Canyon National Park. In all, 13 federal, state, university, industry, and private organizations contributed to the field campaign, making MOHAVE the most extensive field study outside of the IMPROVE program to attempt to attribute visibility impairment to a

source. Project MOHAVE made significant contributions to aerosol and visibility characterization, identification of potential source profiles, and the development of source attribution analyses.

By this conference, there was a good understanding of the formation of sulfate in plumes, and there were only a couple of presentations on this topic. BYU reported on two studies, one on the formation of sulfate at the Grand Canyon during Project MOHAVE (Caka et al., 1993) and another on the formation of sulfate in winter fogs at Cache Valley, Utah (Mangelson et al., 1995). These studies provided insights into the factors that affect the conversion of SO_2 to sulfate but provided no information on conversion rates or mechanisms. A summary manuscript on the formation of sulfate in the atmosphere was also published by BYU (Eatough et al., 1994). This essentially completed research efforts on the formation of sulfate in plumes. However, this was the first conference with input on the role of water in visibility, with three presentations being concerned with particle hygroscopicity, six with cloud condensation nuclei (CCN) measurements, four with model development, one with measurements, and two with field studies, for a total of 16 presentations.

Another significant advance for this conference was the joint sponsorship of the conference by the A&WMA and the American Geophysical Union. This was the first attempt to engage both the visibility and the radiative balance communities in the conference.

Thirty-three peer-reviewed manuscripts resulting from presentations at the Snowbird conference were published in Volume 47, Issue 2 (1997) and Volume 47, Issue 3 (1997) of the *Journal of the Air & Waste Management Association*.

1997 Bartlett: Visual Air Quality: Aerosol and Global Radiation Balance

The 1997 conference was the second conference jointly sponsored by the A&WMA and the American Geophysical Union. The meeting was held September 9–12 at the Attitash Mountain Resort in Bartlett, New Hampshire, in the heart of the White Mountains. The conference technical chair was Ivar Tombach, with co-chairs L. Willard Richards, Philip Russel, and Pradeep Saxena. The exhibition chair was John Maker. There were 171 attendees and 109 presentations. This conference had 12 sessions, including one plenary session and a poster session. The presentations included 78 platform and 31 poster presentations. Exhibitors at the conference included Air Resource Specialists, Inc., Kipp & Zonen, MEI, Inc., Rupprecht & Pataschnick Co., Inc., Yankee Environmental Systems, and URG Corp.

The agenda of the conference is included in Appendix F. However, the manuscripts published in the proceedings are not available.

Table 6. Plenary and technical sessions for the Bartlett conference.

Title of Session	Number of Presenters	Notes and Associated Studies
Plenary Session Aerosol characterization and process studies – Improving the calculated climate forcing by aerosol particles, Timothy S. Bates Review of three-dimensional air quality models for particulate matter, Christian Seigneur Measuring and simulating particulate organics in the atmosphere: problems and prospects, Barbara J. Turpin	3	
Field Programs	11	Project MOHAVE (1), SCENES (1), IMPROVE (3)
Regional Transport	9	Project MOHAVE (2), IMPROVE (1)
Aerosol Measurement Techniques	9	Project MOHAVE (1), IMPROVE (2), SEAVS (1)
Atmospheric & Aerosol Optics	8	IMPROVE (1)
Numerical Modeling of Aerosols and Visibility	6	Project MOHAVE (1), IMPROVE (1)
Atmospheric Aerosols – Theory & Experiments	9	SEAVS (3)
Environmental Management & the Human Interface	5	IMPROVE (1), SEAVS (1)
Field Studies	8	Project MOHAVE (2), IMPROVE (4)
Source–Receptor Relationships	9	Project MOHAVE (2), GGVTC (2)
Aerosol Effects on Radiative Budgets	10	
Poster Session		
Radiative Transfer & Visibility Effects	6	SEAVS (1)
Aerosol & Optical Measurement Techniques	7	IMPROVE (1), SEAVS (1)
Aerosol Optics, Physical & Chemical Properties	9	IMPROVE (4), SEAVS (3)
Aerosol Processes	3	
Air Quality & Source–Receptor Relationships	6	Project MOHAVE (2), IMPROVE (1), SEAVS (1)

The Southeastern Aerosol Visibility Study (SEAVS) (http://vista.cira.colostate.edu/Improve/southeastern-aerosol-and-visibility-study-seavs/), which played a noticeable part in the Bartlett conference (11 presentations), was a special study conducted from July 25 through August 25, 1995, in the Great Smoky Mountains National Park, two years before the Bartlett conference. The study was a collaborative effort between several universities, consulting firms, the Electric Power Research Institute, and the NPS.

The overall objective of this research effort was to

- better understand the physical, chemical, and overall optical characteristics of ambient aerosols under the humid conditions observed in the southeastern United States during the summer months and how these characteristics related to visibility issues.

Specific technical objectives were to

- document the intensity of haze and estimate the contributions of scattering and absorption components to the total light extinction;
- compare the chemical composition data from the IMPROVE sampler with data from other sampling systems;
- document the chemical composition of aerosols and identify each component's contribution to fine mass;
- document aerosol size distribution, how the distribution changes in time, and how these changes impact scattering efficiencies; and
- measure the hygroscopic properties of ambient aerosols and compare measured water uptake to theoretical model predictions.

Further details are available in the final report (http://vista.cira.colostate.edu/improve/wp-content/uploads/2016/10/SEAVSReport.pdf).

This conference program represented the overall shift in visibility science to a better understanding of the relationship between visibility impairment, aerosol composition, and the role of water along with an improvement in understanding of source–receptor relationships. This shift was also represented in the IMPROVE-related presentations. As noted in Table 6, 18 presentations were associated with the IMPROVE program. With 16 years of data now available, many of the presentations were related to measurement evaluation, trends analysis, and source–receptor relationships.

BYU presented a light extinction budget for Meadview during Project MOHAVE (Eatough et al., 1997), which included an assessment of the importance of fine particulate, semivolatile organic compounds (SVOC) not measured by filter-based sampling techniques, which indicated that 37% of the extinction was due to organic material and half of that was due to the SVOC lost during filter sampling. Ammonium sulfate was responsible for 28% of the extinction.

Three papers were presented that originated from the efforts of the Grand Canyon Visibility Transport Commission (GCVTC). The 1990 CAAA focused on the issue of acid rain. It also mandated the creation of the commission. The GCVTC's purpose was to advise the EPA on how to achieve "reasonable progress" toward the national visibility goal. This commission was created by Congress on June 10, 1996. The papers presented at the Bartlett meeting based on the early reports of the commission were

- "Alternatives to the nested grid model estimates as input to regional visibility," Prasad Pai, Mark C. Green, Prakash Karamchandani, and Ivan Tombach; and
- "Models: Lessons from the GCVTC assessment," Prasad Pai, Robert J. Farber, Prakash Karamchandani, and Ivar Tombach;
- "Evaluation of wind fields used in Grand Canyon Visibility Transport Commission analyses," Mark C. Green, Prasad Pai, Lowell L. Ashbaugh, and Robert J. Farber.

The efforts of the GCVTC contributed to the formation of the Regional Haze Rule (RHR) in 1999, which was promulgated between the Bartlett and the Bend meetings. As indicated in Figure 1, the creation of the RHR would have a major impact on the IMPROVE program.

Publications in proceedings not available.

2001 Bend: Regional Haze and Global Radiation Balance – Aerosol Measurements and Models: Closure Reconciliation and Evaluation

The 2001 conference is the first for which we have a copy of the final program. This is included in Appendix G. Also included is a preface to the proceedings by Scott Archer with his outline of the preceding conferences.

The 2001 conference was the third conference jointly sponsored by the A&WMA and the American Geophysical Union. The meeting was held October 2–5 at Inn of the Seventh Mountain, seven miles west of Bend, Oregon, and located in the Deschutes National Forest, just west of the Cascade Range and the Cascade Volcanic Arch. The conference technical chair was Scott F. Archer, with co-chairs Joseph M. Prospero and John Core. The general conference chair was Kirk Stopenhagen. There were 164 attendees and 101 presentations. This conference had 12 sessions, including one plenary session and two poster sessions. The presentation session included 84 platform and 17 poster presentations.

This conference was preceded by two half-day short courses related to major topics of the conference. Dr. Kevin J. Noone, Professor of Atmospheric Physics, Department of Meteorology, Stockholm University, taught a course on "Aerosols, Clouds and Climate Change." Dr. William C. Malm, Research Physicist, NPS, taught a course on "Introduction to Visibility Concepts."

On Wednesday afternoon, the conference enjoyed two luncheon speakers from the USFS on the "Geological features of the high desert region of Oregon," followed by field tours in the Deschutes National Forest. That evening there was a visit to the Pine Mountain Observatory for a presentation on astronomy followed by a night sky program.

Exhibitors at the conference included Air Resource Specialists, Met One Instruments, Inc., Rupprecht & Pataschnick Co., Inc., Thermo MIE, Inc., and URG Corp.

Details for each session in Table 7 are given in Appendix G.

Table 7. Plenary and technical sessions for the Bend conference.

Session Title	Number of Presentations	Notes and Associated Studies
Welcome and Conference History	1	Scott F. Archer

Session Title	Number of Presentations	Notes and Associated Studies
Plenary Session Keynote Address: Aerosol-induced modulation of climate, Dr. V. Ramaswamy, Senior Scientist, NOAA – Geophysical Fluid Dynamics Laboratory, Princeton University Keynote Address: Our hopes and our expectations for the new space-borne aerosol measurement techniques, Dr. Ralph Kahn, Research Scientist NASA – Jet Propulsion Laboratory, California Institute of Technology A ten-year spatial and temporal trend of sulfate across the United States, W.C. Malm Temporal and spatial characteristics of atmospheric aerosols in Texas during the Big Bend Regional Aerosol and Visibility Observational study, L.L. Ashbaugh Aerosol sources and atmospheric distribution over Southern Africa, S.J. Piketh	5	Keynote addresses were focused on Global Radiation Balance and the new satellite based technology that introduced new measurement techniques for the global measurement of haze. In addition, the plenary talks focused on the IMPROVE program and, the BRAVO and SAFARI 2000 special studies
Legal and Policy Issues	7	IMPROVE (1) RHR (2)
Instrumentation (Aerosol and Optical)	8	SEARCH (1)
Poster Session and Exhibition Viewing	10	SAFARI 2000 (1) BRAVO (1) IMPROVE (1)
Data Analysis, Modeling and Interpretation Techniques	10	IMPROVE (1), BRAVI (1), RHR (1)
Field Studies (California, British Columbia and Asia)	11	
Field Studies (Pacific Northwest, Midwest and Southern United States	7	RHR (1)
Field Studies (BRAVO)	14	BRAVO (14)
Field Studies (SAFARI)	14	SAFARI 2000 (14)
Poster Session and Exhibition	7	IMPROVE (1)
Field Studies (Western United States)	3	
Vegetative Burning	4	

One major legislative rule and two significant new field programs were introduced at the Bend conference:

The Regional Haze Rule. In July 1999, the EPA issued the Regional Haze Rule for Protection of Visibility in National Parks and Wilderness Areas. The rule was intended to improve visibility in 156 national parks and wilderness areas across the country. The regulation called for

states to establish goals for improving visibility in national parks and wilderness areas and to develop long-term strategies for reducing emissions of air pollutants that cause visibility impairment. The RHR required that state implementation plans (SIPs) be submitted to the EPA by December 17, 2007. As part of these SIPs, states needed to define reasonable progress goals providing for an improvement in visibility for the most anthropogenically impaired days and ensuring no degradation in visibility for the clearest days for each Class I area in the state. The SIPs also needed a long-term strategy for improving visibility, including enforceable emissions limitations for meeting the reasonable progress goals and best available retrofit technology (BART) determinations for certain older existing stationary sources.

The IMPROVE monitoring network was expanded to over 150 monitoring sites (Figure 1) to provide the data needed to track trends in 155 Class I areas for implementation of the RHR.

The Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study. Big Bend National Park is located in West Texas, bordering Mexico. The park has national significance as the largest protected area of Chihuahuan Desert topography and ecology in the United States. The park encompasses an area of 801,163 acres (1,251.8 sq mi). For more than 1,000 miles, the Rio Grande/Río Bravo forms the boundary between Mexico and the United States, and Big Bend National Park administers approximately 118 miles along that boundary. Increasing haze in the park had been a concern, and in 1993, a U.S. and Mexico bi-national work group was created to investigate the potential impact of two large Mexican power plants, Carbón I and Carbón II, located near Big Bend. In March 1996, this work group recommended that a comprehensive field study be established to identify the contributions from all major sources and source regions. This recommendation led to the creation of BRAVO, which was an intensive air quality monitoring project measuring fine aerosol mass and its constituents, atmospheric optical properties, gaseous air pollutants and meteorology from July through October 1999.

The study objectives were to

- quantify the impacts of major source regions and source types in both the United States and Mexico on Big Bend haze, including the Carbón I/II power plants in Mexico, eastern Texas, eastern United States, and all of Mexico;
- determine the chemical constituents of Big Bend haze;
- determine the role of meteorology on Big Bend haze; and
- identify the most likely pollutant transport corridors associated with Big Bend haze.

The research objectives of the study included

- characterizing inorganic and organic aerosol components;
- estimating the contributions of various sources to the carbonaceous fraction of the aerosols;
- measuring the physical aerosol size distribution of fine and coarse particles;
- estimating the contributions of scattering and absorption components of Big Bend haze;
- developing relationships between particle concentrations, composition, and light scattering; and
- measuring the hygroscopic properties of various aerosols.

As noted in Table 7, one complete session of 14 presentations plus an additional 3 presentations focused on the results of BRAVO. A final report was published in 2004 (http://vista.cira.colostate.edu/Improve/wp-content/uploads/2016/05/BRAVOFinalReport.pdf).

The Southern African Regional Science Initiative (SAFARI 2000). This project was an international science initiative to study the linkages between land and atmosphere processes; it was conducted from 1999 through 2001 in the southern African region. This was the first major field program in the visibility conference series focused on understanding the linkages between human activities and global radiative balance, with 15 presentations. Included in the presentations was the assessment of the importance of semivolatile organic material in fine particles from savanna fires (Eatough et al., 2003). This material increased from 24% to 36% of the aerosol as the smoke aged. Nonvolatile organic matter was 48% of the aerosol in aged plumes.

2004 Asheville: Regional and Global Perspectives on Haze: Causes, Consequences, and Controversies

The final program for the 2004 conference is included in Appendix H.

The 2004 conference was sponsored by the A&WMA. The meeting was held October 25–29 at the Holiday Inn, Asheville, North Carolina. The conference technical co-chairs were Marc Pitchford and Rich Poirot. The general conference co-chairs were Pat Brewer and Doug Neeley. There were 135 attendees and 89 presentations. This conference had 12 sessions, including one plenary session and poster presentations associated with nine of the sessions. The presentations included 56 platform and 33 poster presentations.

This conference was preceded by four half-day short courses related to major topics of the conference. Dr William Malm taught a course on "Introduction to Visibility Concepts," Dr. Rudolf Husar a course on "Satellite Retrieval of Air Quality Related Variables," Dr. Bret Schichtel a course on "Introduction to the Views and IMPROVE Data Retrieval and Analysis Web Sites," and Dr. Charles McDade a course on "Bias and interferences in Aerosol Sampling."

On Wednesday afternoon the conference enjoyed a field trip to Shining Rock Wilderness Area. The conference also sponsored a photo contest with prizes from Air Resource Specialists.

Exhibitors at the conference were not listed in the final program.

Details for each Session in Table 8 are given in Appendix H.

Table 8. Plenary and technical sessions for the Asheville conference.

Session Title	Number of Presentations	Notes and Associated Special Studies
Keynote Address: W.C. Malm, An update of spatial and monthly trends in speciated fine particle concentration in the United States	1	IMPROVE (1)
Spatial and Temporal Trends Poster Introductions	3 4	 IMPROVE (2)

Session Title	Number of Presentations	Notes and Associated Special Studies
Optical Monitoring Methods Poster Introductions	3 5	 IMPROVE (1)
Monitoring Studies Poster Introductions	5 3	YACS (1) IMPROVE (1), BRAVO (1)
Monitoring Networks Poster Introductions	4 5	IMPROVE (2) IMPROVE (2)
Biogenic Smoke Poster Introductions	7 2	IMPROVE (1), YACS (3) YACS (1)
Science/Policy Interface and Implications Poster Introductions	5 4	RHR (4) IMPROVE (1)
Air Quality Simulation Models Poster Introductions	5 2	RHR (2) RHR (1)
Aerosol Monitoring Methods Poster Introductions	4 2	IMPROVE (4) IMPROVE (1)
Receptor Modeling Poster Introductions	7 6	BRAVO (1), IMPROVE (2)
Natural and Background Haze	4	
Satellite and Digital Photography	6	

One new significant field program was introduced at the Asheville conference:

The Yosemite Aerosol Characterization Study (YACS). This study was an intensive field measurement campaign conducted by the Department of Atmospheric Science at Colorado State University and the Cooperative Institute for Research in the Atmosphere (CIRA) from July 15 to September 4, 2002, at Yosemite National Park, California. The study was focused on better understanding organic material in the atmosphere. The objectives of the study were to

- determine appropriate values for converting analyzed aerosol carbon mass to ambient aerosol organic carbon mass;
- develop an improved understanding of the visibility-impairment-related characteristics of a smoke/organic carbon-dominated aerosol, including the role of relative humidity in modifying visibility impairment; and
- examine the sources contributing to high aerosol organic carbon mass concentrations.

The YACS-related presentations in the session on biogenic smoke outlined the importance of both high aerosol organic content and the impact of wildfires in Yosemite during the campaign. The YACS final report indicated that fine particulate material was dominated by organic carbon (over 80%), that about 70% of the extinction was due to scattering by organic carbon, and that significant impacts from aged emission from wildfires were present during the study. This was the first conference with presentations focused on wildfires. The issue would be discussed in future conferences and was a major focus of the 2021 visibility conference at Bryce Canyon.

The final report for YACS was published in 2016 (http://vista.cira.colostate.edu/Improve/wp-content/uploads/2016/04/YACS_FinalReport.pdf).

Presentations from those involved in the IMPROVE program other than the those related to YACS focused on using the growing body of data to understand atmospheric and visibility trends and studies to validate the sampling and analysis methods being used by IMPROVE. This included the keynote address given by William C. Malm and several presentations from the Crocker Nuclear Laboratory, which has responsibility for the overall IMPROVE preprogram and for the elemental analysis of IMPROVE samples, and the Desert Research Laboratory, which has responsibility for the IMPROVE carbon analyses.

Initial reports related to the tools needed to develop implementation plans for the RHR requirements were presented. This area would become more important for the 2008 Moab conference after the December 2007 SIPS deadline and again for the 2016 Jackson Hole conference as the revised plans deadline approached.

This was also the first conference that included technical presentations on the use of satellite data for assessing air quality. The previous conference in Bend in 2001 had included a plenary address session that discussed the potential for the use of satellite data, but this conference had both a course on the use of satellite data and a session that included two papers on the subject. This became a regular feature of subsequent conferences.

Ten peer-reviewed manuscripts resulting from presentations at the Asheville conference were published in Volume 59, Issue 9 (2009) of the *Journal of the Air & Waste Management Association*.

2008 Moab: Aerosol & Atmospheric Optics: Visual Air Quality and Radiation

The final program and abstracts for the 2008 conference are included in Appendix I .

The 2008 conference was sponsored by the A&WMA. The meeting was held April 28 to May 29 at the Red Cliffs Lodge, 17 miles up the Colorado River from Moab, Utah. The conference technical co-chairs were Mark Green and Bret Schichtel. The general conference co-chairs were Delbert Eatough and David Maxwell. There were 130 attendees and 101 presentations. This conference included 12 platform sessions plus a Night Sky session and two poster sessions. The presentations included 62 platform and 39 poster presentations.

A night sky program, which included a presentation by the NPS and stargazing with telescopes, was held at Red Cliffs Lodge on Tuesday night. On Wednesday afternoon, the conference enjoyed a field trip to Arches National Park followed by a dinner at Canyonlands by Night & Day (on the Colorado River just outside Moab). On Thursday evening, there was an optional return to Canyonlands by Night & Day for a Colorado boat ride and dinner. The conference also sponsored a photo contest with prizes from Air Resource Specialists. The night sky program and photo contests have become a tradition of the visibility specialty conference and are held at every second conference.

Exhibitors at the conference included Air Resource Specialists, Inc., American Ecotech LLC., In-Tox Products, Magee Scientific Company, Met One Instruments, and URG Corp.

Details for each session in Table 9 are given in Appendix I.

Table 9. Technical sessions for the Moab conference.

Session Title	Number of Presentations	Notes and Associated Special Studies
Session 1. Aerosol Physical/Optical Properties	6	IMPROVE (1), RoMANS (1)
Session 2. Aerosol Climatology and Natural Sources	7	IMPROVE (1), RHR (1)
Session 3. Biomass Burning and Results from the FLAME Study	8	FLAME (3), IMPROVE (1)
Poster Session	20	VISTAS (1)
Night Sky	1	
Session 4. Decision Support Systems	4	RHR (1)
Session 5. Policy, Regulatory, and Economic Issues	3	
Sessions 6. Policy, Regulatory, and Economic Issues – Panel Session	5	RHR (4)
Sessions 7. Satellite and Other Remote Sensing	7	IMPROVE (1)
Session 8. Gaseous and Particulate Nitrogen – RoMANS Field Study Results	5	RoMANS (4)
Session 9. Gaseous and Particulate Nitrogen	5	SEARCH (1)
Session 10. Source Apportionment-Receptor Models	5	
Poster Session	19	RoMANS (2), IMPROVE (3) SEARCH (1) RHR (1)
Session 11. Source Apportionment – Source Oriented Models	8	
Session 12. Field Studies and Monitoring Networks	4	IMPROVE (4)

The Moab conference provided a technical forum on advances in the scientific understanding of the effects of aerosols on regional, continental, and global-scale haze and radiation balance. The conference specifically addressed emission sources, atmospheric conditions, and aerosol characteristics associated with haze and aerosol climate forcing; innovative aerosol, haze, and radiation balance monitoring assessments and modeling methods; and haze and aerosol climate forcing policy, regulatory, and economic issues, including the development of SIPS for the RHR.

Two new significant programs were introduced at the Moab conference, one on laboratory experiments of biomass burning emissions and the second on reactive nitrogen deposition. This was the first conference to discuss deposition issues and linkages between the effects of particulate matter on visibility and ecological systems:

FLAME. Over 40 different fuels were burned at the Fire Science Laboratory in Missoula, Montana, during the Fire Lab at Missoula Experiments (FLAME) 1 and 2 in 2006 and 2007, respectively. This program examined the visible and near-UV light absorption of organic and elemental carbon emitted by these fires using a spectrometer, thermal-optical analysis (TOA) techniques, and a variety of chemical extraction and analysis methods. A large range in

elemental to total carbon ratios was observed, reflecting the variety of fuels and combustion conditions during the burns. Organic carbon in some samples, particularly those dominated by smoldering-phase combustion, absorbed visible and near-UV light. The study also investigated the impacts that light absorbing organic carbon may have on the TOA techniques used to identify organic and elemental carbon in atmospheric monitoring networks and subsequent consequences for light absorption predictions based on these measurements.

Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS). Recent ecological studies had shown a number of deleterious effects due to elevated and increasing deposition of nitrogen compounds in Rocky Mountain National Park (RMNP). Both nitrogen and sulfur species contribute substantially to visibility degradation in the region. The RoMANS study was conducted to improve our understanding of the sources and transport of airborne nitrogen and sulfur species to RMNP as well as their deposition pathways. Two field campaigns were conducted, in spring and summer 2006, to characterize pollutant transport and deposition during seasons with historically high nitrogen deposition inputs. Several measurement sites were operated within the park, at locations to the west and east of the park boundaries, and at locations near the northeastern, northwestern, and southeastern boundaries of the state of Colorado. Measurements at several sites included 24-hour integrated gas concentrations (ammonia, nitric acid, sulfur dioxide), $PM_{2.5}$ composition, and wet deposition. A core measurement site in the park included more-detailed and higher time resolution chemical, optical, and size distribution measurements.

Ten peer-reviewed manuscripts resulting from presentations at the Moab conference were published in Volume 59, Issue 9 (2009) of the *Journal of the Air & Waste Management Association*.

2012 Whitefish: Aerosol & Atmospheric Optics: Visibility and Air Pollution

The final program for the 2012 conference is included in Appendix J.

The 2012 conference was sponsored by the A&WMA. The meeting was held September 24–28 at the Grouse Mountain Lodge in Whitefish, Montana. The conference chair was Delbert Eatough. Joe Adlhoch, Air Resource Specialists, Inc., Eric Edgerton, Atmosphere Research & Analysis, Inc., Phil Hopke, Clarkson University, C.V Mathai, Arizona Public Service Company, Chuck McDade, University of California, Davis, Tom Moore, Western Governors' Association, Bret Schichtel, NPS, Ivar Tombach, Consultant, Jay Turner, Washington University in St. Louis, and Tony Ward, University of Montana, served on the conference committee. There were 155 attendees and 149 presentations. This conference included a plenary session, 24 platform sessions (three of which were panel sessions), and a poster session. The presentations numbered 134, including two plenary, 90 platform, and 29 poster presentations and 13 panel presenters in three panels.

On Monday, September 24, prior to the start of the technical program, four half-day professional development courses were offered: Introduction to Visibility and Aerosol Optics, taught by William Malm and Bret Schichtel, NPS Air Resources Division (ARD); the Relationship of Visibility to Particle Composition and Sources, taught by Phillip Hopke, Clarkson University; Sampling and Analysis for Extinction Calculation, taught by Judith C. Chow and John G.

Watson, Desert Research Institute; and Contemporary Aerosol Optics, taught by Hans Moosemuller and Rajan K. Chakrabarty, Desert Research Institute.

On Wednesday afternoon, the conference enjoyed a field trip to Glacier National Park. That evening attendees enjoyed a night sky program with telescopes at Whitefish Lake State Park. The conference also sponsored a photo contest with prizes from Air Resource Specialists.

Exhibitors at the conference included AethLabs, Air Resource Specialists, Inc., Belfort Instrument Company, Droplet Measurement Technologies, Ecotech Pty Ltd, Magee Scientific, Met One Instruments, Inc., MSP Corporation, Sunset Laboratory Inc., and URG Corporation.

Funds to support the attendance of student, postdoctoral, and young professional attendees were provided by the National Science Foundation, the Department of Energy, and the NPS.

Details for each session in Table 10 and the abstracts for each presentation are given in Appendix J.

Table 10. Plenary and Technical sessions for the Whitefish conference.

Session Title	**Number of Presentations**	**Notes and Associated Special Studies**
Plenary Session William Malm, National Park Service Air Resources Division Eric Wilcox, Division of Atmospheric Sciences, Desert Research Institute	2	 Visibility perception: Past, present, and future Physical connections between atmospheric visibility, and regional climate change
Track A.		
Session 1A. Aerosol and Visibility Field Studies and Monitoring Networks	6	IMPROVE (3) SEARCH (1)
Session 1B. Aerosols and Visibility Field Studies and Monitoring Networks	6	IMPROVE (1)
Session 4. Panel Discussion: Monitoring and Analysis Methods for Routine Networks	4	SEARCH and IMPROVE
Session 1C. Aerosol and Visibility Field Studies and Monitoring Networks	2	IMPROVE
Session 6A. Information and Technology Needs for Future Revisions of the Secondary PM NAAQS	5	
Session 6B. Information and Technology Needs for Future Revisions of the Secondary PM NAAQS	1	
Session 9. Panel Discussion: Scientific Issues and Information for a Visibility-related $PM_{2.5}$ NAAQS	4	
Session 10A. Aerosol and Visibility Modeling at Global, Regional, and Local Scales	6	

Session Title	Number of Presentations	Notes and Associated Special Studies
Session 13. Panel Discussion: Implementing Visibility Regulation: Policy & Technical Issues	4	
Session 15. Haze Rule 2013 Check-In and 2018 Planning Milestone to Achieve the U.S. National Visibility Goal	5	RHR (5)
Session 16. Assessment of Haze from Natural Sources	1	
Poster Session	29	IMPROVE (3)
Session 18. Potential Impacts on Emissions from Oil and Gas Fields on Visibility and Haze	6	
Session 20.		
Tract B		
Session 2. New and Current Field Monitoring Techniques for Measuring Black Carbon and Aerosol Organic Material	6	IMPROVE
Session 3A. Black Carbon Emissions in Developed and Developing Countries	6	
Session 3B. Black Carbon Emissions in Developed and Developing Countries	3	
Session 5. Biomass Burning, Carbonaceous Aerosols and Short Lived Climate Forcers Effects on Haze and Climate	3	
Session 7. Satellite and Other Remote Sensing Applications to Haze/Aerosol Monitoring	5	
Session 8. Aerosol–Optical Relationships	6	SEARCH (2)
Session 11. Aerosol, Optical and Radiometric Monitoring Met,hods	3	IMPROVE (2)
Session 12. Human Perception of Visibility	3	
Session 14. Critical Loads and Atmospheric Deposition Techniques in Developing and Implementing Deposition-based Air Quality Standards	5	
Session 10B. Aerosol and Visibility Modeling at Global, Regional, and Local Scales	2	
Session 17. Aerosol Effects on Haze, Direct and Indirect Forcing	5	
Session 20. Source Attribution of Aerosol and Haze	1	
Session 19A. Atmospheric Nitrogen – A Bridge between Visibility, Ecological and Agricultural Issues	6	RoMANS II (2), Grand TReNDS (4)

Session Title	Number of Presentations	Notes and Associated Special Studies
Session 19B. Atmospheric Nitrogen – A Bridge between Visibility, Ecological and Agricultural Issues	3	IMPROVE (1), SEARCH (1)

This conference provided a technical forum on advances in the scientific understanding of the effects of aerosols on urban, regional, continental, and global-scale haze and radiation balance. The conference specifically addressed emission sources, atmospheric conditions, and aerosol characteristics associated with haze and aerosol urban visibility; regional haze; climate forcing; innovative aerosol, haze, and radiation balance monitoring assessments and modeling methods; urban and regional haze and aerosol climate forcing policy, regulatory, and economic issues related to implementation of U.S. EPA standards and rules, including the adopted emissions controls in state and EPA permits, rules, and implementation plans for the RHR; and the expected impact of the anticipated PM visibility and SO_2/NOx secondary standards.

Results from a new field study, the Grand Teton Reactive Nitrogen Deposition Study (GrandTReNDS), were introduced at the Whitefish conference. Because excess inputs of reactive nitrogen can adversely affect terrestrial and aquatic ecosystems, particularly in sensitive ecosystems found at high elevations, and Grand Teton National Park is home to such sensitive natural areas and is in proximity to potentially large reactive nitrogen sources, the study was conducted in spring–summer 2011, with the aim of better understanding sources of reactive nitrogen influencing the regional, spatial, and temporal variability of reactive nitrogen in the atmosphere and current levels of nitrogen deposition.

A new topic at this conference included presentations related to an EPA-proposed new secondary PM NAAQS based on visibility. This topic was discussed in the platform presentations in Sessions 6A and 6B and the panel discussion in Session 9. The EPA did not adopt a new secondary PM standard, and the topic did not appear again in subsequent conferences.

Eleven peer-reviewed manuscripts resulting from presentations at the Whitefish conference were published in Volume 63, Issue 9 (2013) of the *Journal of the Air & Waste Management Association*.

2016 Jackson Hole: Atmospheric Optics: Aerosols, Visibility, and the Radiative Balance

The final program and abstracts for the 2016 conference are included in Appendix K.

The 2012 conference was sponsored by the A&WMA. The meeting was held September 27–30 at the Snow King Hotel in Jackson Hole, Wyoming. The conference chair was Delbert Eatough, BYU. Joe Adlhoch, Air Resource Specialists, Elizabeth Andrews, University of Colorado, Boulder, Junji Cao, Chinese Academy of Sciences, Kip Carrico, New Mexico Institute of Mining and Technology, Rajan Chakrabarty, Washington University in St. Louis, Zhen (Stephen) Cheng, Shanghai Jiaotong University, Judith Chow, Desert Research Institute, Jenny Hand, Colorado State University, Nicole Hyslop, University of California, Davis, Phil Hopke, Clarkson University, Mukesh Khare, Indian Institute of Technology, Byeong-Kye Lee, University of Ulsan, Taehyoung Lee, Hankuk University of Foreign Studies, Shun Cheng (Frank), Hong Kong

Polytechnic University, William Malm, Colorado State University, Chuck McDade, University of California, Davis, Tom Moore, WESTAR-WRAP, Shamsh Pervez, Pt. Ravishankar University, Bret Schichtel, NPS, Ivar Tombach, Consultant, Kostas Tsigaridis, Columbia University, Jay Turner, Washington University in St. Louis, Ricky Tropp, Desert Research Institute, Rebecca Washenfelder, NOAA, John Watson, Desert Research Institute, Chung-Shin (Johnathan) Yuan, National Sun Yatsen University, and Qi Zhang, University of California, Davis, served on the conference committee. There were 175 attendees and 140 presentations. This conference included a plenary session, 21 platform sessions, three panel sessions, and a poster session. The presentations numbered 134 including two plenary, 95 platform, and 29 poster presentations and 14 presenters in three panels.

On Monday, September 26, prior to the start of the technical program, two half-day and three full-day professional development courses were offered:

- Half-day courses: Application of Time Series Methods to IR Quality Data, taught by Phillip Hopke, Clarkson University; and Contemporary Aerosol Optics, taught by Hans Moosemuller, Desert Research Institute, and Rajan K. Chakrabarty, Washington University in St. Louis.
- Full-day courses: Air Quality Modeling, taught by Mukseh Khare and S.M. Shiva Negenrea, Indian Institute of Technology; the Practical Use of Satellite Observation for Visibility and Air Quality Analysis, taught by Pawan Gupta, NASA Goddard Flight Center and Sean Raffuse, University of California, Davis; Regional Haze Rule: Science, Modification, and State Implementation Plan Requirements, taught by Bret Schichtel, NPS ARD and Tom Moore, WESTAR-WRAP.

On Wednesday afternoon, the conference enjoyed a field trip to Teton National Park. That evening, attendees enjoyed a Park Service fireside and a night sky program with telescopes at Colter Bay in Teton National Park. The conference also sponsored a photo contest with prizes from Air Resource Specialists.

Exhibitors at the conference included the “Platinum Sponsor” Sunset Laboratory Inc., Aerosol Devices Inc., Ambilabs, ARA Instruments, AethLabs, Air Resource Specialists, Inc., the EPA, Magee Scientific, Met One Instruments, Inc., the National Atmospheric Deposition Program, and URG Corp.

Funds to support the attendance of student, postdoctoral, young professional, and state attendees for the RHR program were provided by the EPA, U.S. National Science Foundation, U.S. Department of Energy, NPS, Electric Power Research Institute, California Air Resources Board, and South Coast Air Quality Management District.

Details for each session in Table 11 and the abstracts for each presentation are given in Appendix K.

Table 11. Plenary and Technical sessions for the Jackson Hole conference.

Session Title	Number of Presentations	Notes and Associated Special Studies
Plenary Session Bjorn Samset, Center for International Climate and Energy Research – Oslo Ann Marie Carlton, University of California, Irvine	2	 The many cloudy faces of black carbon in the climate system Aerosol water: Now you see it, now you don't
Track A.		
Session 1. Visibility as an Indicator of Human Health Effects	6	
Session 3. Human Perceptions of Visibility	5	Related to Proposed EPA Secondary PM NAAQS based on visibility (1)
Session 5. Panel: Evolving Issues in Air Quality Related to a Changing Climate	6	
Session 7. Panel: Regional Perspectives on the Second Planning Period for Regional Haze State Implementation Plans	4	RHR
Session 9A. Regional Haze Rule	5	RHR (5)
Session 10. Panel: Air Quality Issues in the WESTAR Region	4	
Session 9B. Regional Haze Rule	5	RHR (5)
Session 13. Potential Impacts of Emissions from Oil and Gas Fields on Air Quality and Visibility	6	
Poster Session	29	SEARCH (1)
Session 15. Aerosol Field Studies and Monitoring Networks	6	
Session 17. Trends in Visibility	5	
Track B.		
Session2 Satellite and Remote Sensing Applications to Haze/Aerosol Monitoring	5	
Session 4. Aerosol and Visibility Modeling at Local, Regional, and Global Scales	6	
Session 6. Atmospheric Nitrogen – A Bridge Between Visibility, Ecological and Agricultural Issues	5	
Session 8A. Aerosol–Optical Relationships	5	
Session 8B. Aerosol–Optical Relationships	6	IMPROVE (1)
Session 11. New Instruments and Measurement Techniques	5	IMPROVE (2)
Session 12. Secondary Organic Aerosols	6	IMPROVE (1)
Session 14. Mineral Dust Aerosols & Impacts on Air Quality and Visibility	6	
Session 16A. Light Absorbing Carbon	5	IMPROVE (1)
Session 16B. Light Absorbing Carbon	6	

This international conference provided a technical forum on advances in the scientific understanding of the effects of aerosols on urban, regional, continental, and global-scale haze and the radiative balance. The conference took a multipronged approach and addressed scientific topics (e.g., related to measurements, modeling, etc.) as well as regulatory and policy issues. There were sessions on black and brown carbon, as recent research had shown the importance of these particles for radiative forcing. In addition, there were sessions related to the synergistic and increasing concerns of the effects of atmospheric nitrogen and carbonaceous material on haze, climate change, and nitrogen deposition on ecosystems.

The RHR was a special focus of this conference because the next round of the RHR SIPs were due in 2018. Elements of the program related to the RHR included the full-day course taught by Bret Schichtel, NPS ARD, and Tom Moore, WESTAR-WRAP; the Session 7 panel discussion presented by regional representatives from WESTAR-WRAP, WESTAR, Central States Air Resource Agencies (CenSARA), Lake Michigan Air Directors Consortium (LADCO), and NESCAUM; the Session 10 panel discussion presented by state air quality directors from Wyoming, Utah, Colorado, and Montana; and the technical presentations in sessions 9A and 9B. Funds were available to support the attendance of 13 state air quality personnel.

Nine peer-reviewed manuscripts resulting from presentations at the Jackson Hole conference were published in Volume 68, Issue 5 (2018) of the *Journal of the Air & Waste Management Association*.

2021 Bryce Canyon: Atmospheric Optics: Aerosols, Visibility, and the Radiative Balance

The final program and abstracts for the 2021 conference are included in Appendix L.

The 2021 conference was sponsored by the A&WMA. The meeting was originally planned for the fall of 2020 but was postponed to 2021 because of the COVID-19 pandemic beginning in January 2020. The meeting was held October 5–8 at Ruby's Inn in Bryce Canyon City, Utah. The conference chair was Delbert Eatough, BYU. Joe Adlhoch, Air Resource Specialists, Elizabeth Andrews, NOAA, Pat Brewer, Consultant, Kip Carrico, New Mexico Institute of Mining and Technology, Rajan Chakrabarty, Washington University in St. Louis, Judith Chow, Desert Research Institute, Jenny Hand, Colorado State University, Phil Hopke, Clarkson University, William Malm, Colorado State University, Chuck McDade, University of California, Davis, Tom Moore, WESTAR-WRAP, Ralph Morris, Ramboll, Bret Schichtel, NPS ARD, Kostas Tsigaridis, Columbia University, Jay Turner, Washington University in St. Louis, Rebecca Washenfelder, NOAA, and John Watson, Desert Research Institute, served on the conference committee. There were 140 attendees and 131 presentations. Due to travel restrictions still in place from the pandemic, 21 of the presentations were virtual. This conference included a plenary session, 18 platform sessions, three panel sessions, and a poster session. The presentations numbered 131, including three plenary, 113 platform, and 11 poster presentations a 18 panel presenters in three panels.

On Monday, September 26, prior to the start of the technical program, three half-day and one full-day professional development courses were offered:

- Half-day courses: Back Trajectory Analysis, taught by Kristi Gebhart, Colorado State University; Low-Cost Sensors, taught by Jay Turner, Washington University in St. Louis;

and the Relationship of Visibility to Particle Composition and Sources, taught by Phillip Hopke, Clarkson University

- Full-day course: Aerosol Data from the Next Generation of Satellites for Air Quality & Climate Research, taught by Pawan Gupta and Robert Levy, NASA Goddard Space Flight Center

On Wednesday afternoon, the conference enjoyed a field trip to Bryce Canyon National Park. That evening attendees enjoyed a night sky program. The conference also sponsored a photo contest with prizes from Air Resource Specialists.

On Friday afternoon after the close of the technical program, the conference sponsored an optional tour to the southernmost part of the park. The included a stop at the new BLM site installed to determine if emissions from the Alton Coal Field west of the park contributed to visibility reduction in the park. This new program was discussed in Session 8 of the technical program.

Exhibitors at the conference included the "Platinum Sponsor" Sunset Laboratory Inc., Distributed Sensing Technologies, Magee Scientific, Sonoma Technology, URG Corp., 2B Technologies, Atmosphere, Air Resource Specialists, and TSI.

Funds to support the attendance of student, postdoctoral, young professional, and other attendees were provided by the EPA, U.S. National Science Foundation, U.S. Department of Energy, NASA, Electric Power Research Institute, and Bay Area Air Quality Management District.

Details for each session in Table 12 and the abstracts for each presentation are given in Appendix L.

Table 12. Technical sessions for the Bryce Canyon conference.

Session Title	**Number of Presentations**	**Notes and Associated Special Studies**
Plenary Session	3	
Manish Shrivastava, Pacific Northwest National Laboratory		Secondary organic aerosols and radiative effects
Charles Ichoku, Howard University		Wildfires: Fire behavior, forecasting, impact on visibility and radiative balance
Michael Jarrett, UCLA		Wildfires: Exposure and health effects
Plenary Panel: Wildfires in the Western United States	5	Wildfires (5)
Track A.		
Session 1. Visibility as an Indicator of Human Health	6	Related to wildfire exposure and health (4)
Session 3. Wildfire and Impacts on Visibility	5	Wildfires (4)

Session Title	Number of Presentations	Notes and Associated Special Studies
Session 5. Panel: NASA Earth Science Capabilities for Investigating Aerosol Impacts	7	
Session 7. Aerosol and Visibility Trends	4	
Session 9. Regional Haze Rule Panel	7	RHR (7)
Session 11. Regional Haze Rule 1	6	RHR (5), Wildfires (1)
Session 13. Regional Haze Rule 2	5	RHR (5), Wildfires (1)
Poster Session	11	IMPROVE (2)
Session 16. Satellite and Remote Sensing Application	5	
Session 18. New Instruments and Measurement Techniques	4	
Track B.		
Session 2. Atmospheric Nitrogen: A Bridge Between Visibility, Ecology, and Air Quality	5	
Session 4. Mineral Dust Aerosols: Impacts in Air Quality and Visibility	5	
Session 6. Organic and Light-Absorbing Carbon	6	IMPROVE (1), SEARCH (1)
Session 8. U.S. Field Studies	5	
Session 10. Radiative Balance and Modeling	4	Wildfires (1)
Session 12. Light Absorbing Carbon 1	6	Wildfires (2), IMPROVE (1)
Session 14. Light Absorbing Carbon 2	5	IMPROVE (1)
Session 17. Low-Cost Sensors	5	Wildfires (3)
Session 19. Oil and Gas Field Impacts on Ozone and PM	5	RHR (1)

A topic emphasized in the program was wildfires, reflecting the large increase in the importance of wildfire contributions to visibility and health since the last conference. A total of 17 of the 131 presentations were related to this topic. Another topic of significance in both the last and this conference was the RHR; 18 presentations were related to this topic. In addition, the increasing contributions of satellite data to understanding visibility was a topic of importance, with 13 presentations related to this topic. These three areas accounted for 48 of the 131 total presentations.

APPENDICES

The Report "History of the Visibility Conference" was prepared using available documentation for each conference. These documents were organized into appendices with each appendix containing all of the documents for an individual conference. The appendices are available from the IMPROVE website. http://vista.cira.colostate.edu/Improve/HistVisibilityConf/. Following is a list of these appendices.

Appendix A. 1979 Denver conference topics and keynote address

Appendix B. 1980 Grand Canyon conference topics and abstracts

Appendix C. 1986 Grand Teton Conference program and introductory remarks

Appendix D. 1989 Estes Park conference program and introductory remarks

Appendix E. 1994 Snowbird conference program and proceeding's preface

Appendix F. 1997 Bartlett conference program and proceeding's preface

Appendix G. 2001 Bend conference preface and program

Appendix H. 2004 Ashville conference program

Appendix I. 2008 Moab conference program and abstracts

Appendix J. 2012 Whitefish conference program and abstracts

Appendix K 2010 Jackson Hole conference program and abstracts

Appendix L. 2021 Bryce Canyon conference program and abstracts

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