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Real-Time Smoke Monitoring Using Rapid Deploy Equipment to Aid in Fire Management and Ensure Public Safety

Mike Slate, P.E.
Field Operations Manager/ Principal 970-484-7941
Air Resource Specialists, Inc., Fort Collins, CO, USA, mslate@air-resource.com

Ricardo Cisneros, Ph. D. MPH
Air Resource Specialist 559-297-0706 ext. 4904
U. S. Forest Service, Clovis, CA USA, rcisneros@fs.fed.us

Introduction

The USDA-Forest Service Fire Management and Air Programs in Region 5 established the two-year Southern Sierra Pilot Project (SSPP) to evaluate available beta attenuation monitoring (BAM) instrumentation, monitoring methods, and practical quick-response management tools to communicate potential air pollution impacts from prescribed and wildland fire. The Forest Service contracted Air Resource Specialists, Inc. (ARS) to procure, integrate, test, and provide technical support of this equipment.

PM_{10} and $PM_{2.5}$ are the predominant pollutants in smoke emitted from wildland fires and can have severe health effects for firefighters and at-risk populations, especially those with chronic pulmonary and cardiac diseases (Sandberg et al., 18). Stationary Met One BAM-1020s and portable E-BAM particle instruments were used to monitor PM_{10} and $PM_{2.5}$ emissions for the SSPP. Met One's BAM-1020 beta attenuation mass monitor is a federal reference method that meets the EPA requirements for monitoring PM_{10} compliance, but can be limited in use by land management agencies due to a lack of portability and reliance on AC power. The E-BAM was developed as a smaller portable device that does not require environmental housing (heating or air conditioning), and can be supported with AC or solar power.

This study demonstrated that wildfire smoke concentrations can be effectively monitored with BAM particulate monitors in real-time with live data posted to a website. Access to real-time data has proven to be an advantageous tool for both fire managers and land managers by enabling them to effectively predict the spread and intensity of a fire and evaluate smoke exposure for firefighters and neighboring populations.

Materials and methods

Instrumentation and Site Specifications

The SSPP has been developed to test the utility, accuracy, reliability, monitoring, and data management requirements of BAM particulate monitors in a comprehensive network. The test network for this study included 3 BAM-1020 units deployed in particulate-sensitive communities to characterize baseline and event conditions, and approximately 10 portable E-BAM units

deployed in rural locations to characterize the impacts of smoke events from prescribed burning and wildland fire. The SSPP site-network included 13 individual monitoring sites which can be seen on the map shown in Figure 1.

Each particle monitor site also included several meteorological parameters. Both the Kernville and Pinehurst BAM-1020 units were collocated with RAWS (Remote Automated Weather Station) instrumentation. All other sites (BAM-1020 and E-BAM) incorporated Met One meteorological instruments.

All units were equipped with ORBCOMM or Iridium satellite modems to deliver data in "near real-time" to the Interagency Smoke Monitoring Web site (http://app.airsis.com/USFS/). Each modem was equipped with a unique USFS identification tracking number. Individual site overviews by instrument type follow.

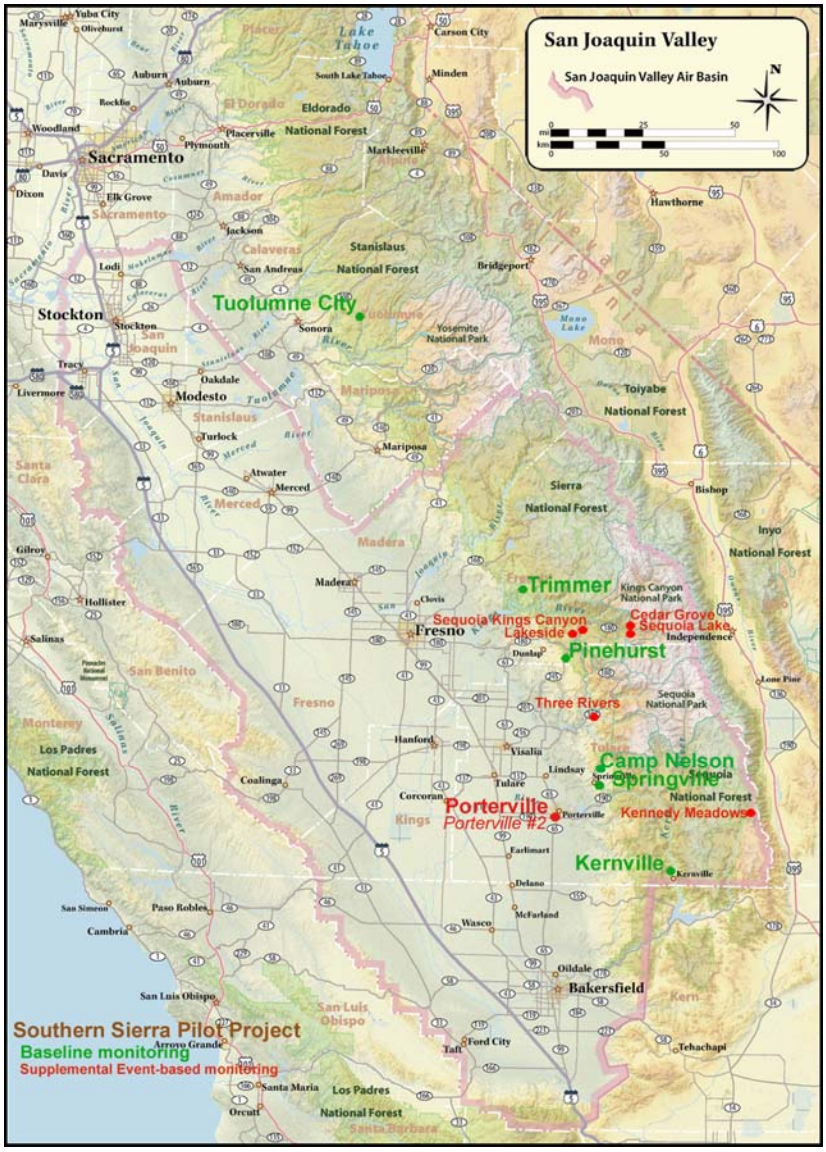

Figure 1: Southern Sierra Pilot Project Monitoring Locations


Figure 2: Pinehurst Monitoring Station


Figure 3: Camp Nelson Monitoring Station

The Kernville site contained one BAM-1020 and a collocated RAWS Meteorological Station. The site was located in the Sequoia National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #49.

The Pinehurst site contained one BAM-1020 and a collocated RAWS Meteorological Station. The site was located in the Sequoia National Forest. Figure 2 above shows the site configuration. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #50.

The Springville site contained one BAM-1020 with several Met One meteorological sensors, a 2B Technologies ozone analyzer, and an AUTOMET datalogger. The site was located in the Sequoia National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #51.

The Camp Nelson site contained one E-BAM with several meteorological sensors. The site was located in the Sequoia National Forest. Figure 3 above shows the site configuration. Data were configured to collect and post on the Smoke Monitoring Website under the ORBCOMM modem identification #45.

The Cedar Grove site contained one E-BAM with several meteorological sensors. The site was located in the Sequoia National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #55.

The Kennedy Meadows site contained one E-BAM with several meteorological sensors. The site was located in the Sequoia National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #47. The event-based unit was used to monitor $PM_{2.5}$ emissions from the Crag Wildland Fire Use, a prescribed burn in the surrounding area.

The Lakeside site contained one E-BAM with several meteorological sensors. The site was located in the Sierra National Forest at the Lakeside work center next to Hume Lake. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #55, to monitor a prescribed burn in the Hume Lake region.

The Porterville site contained two E-BAMs with several meteorological sensors. The site was located in the Sequoia National Forest headquarters parking lot in Porterville, California. The site configuration can be seen in Figure 4 below. Data were collected and posted on the Smoke Monitoring Web site under the ORBCOMM modem identification #46 and #47.

Figure 4: Porterville Monitoring Station

Figure 5: Trimmer Monitoring Station

The Sequoia Kings Canyon (or Hume Lake) site contained one E-BAM with several meteorological sensors. The site was located in the Sequoia National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #46 to monitor the Comb Fire Wildland Fire Use burn in the surrounding area

The Sequoia Lake site contained one E-BAM with several meteorological sensors. The site was located at Sequoia Lake in the Sequoia National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #55 to monitor the Grant E and Grant G prescribed fires in the surrounding area.

The Three Rivers site contained one E-BAM with several meteorological sensors. The site was located in the Sierra National Forest. Data were collected and posted on the Smoke Monitoring Web site under the ORBCOMM modem identification #55 to monitor the High Bridge prescribed burn in the surrounding area.

The Trimmer site contained one E-BAM with several meteorological sensors. The site was located in the Sierra National Forest. Data were collected and posted on the Smoke Monitoring Website under the ORBCOMM modem identification #52. The site configuration can be seen above in Figure 5.

The Tuolumne City site contained one E-BAM with several meteorological sensors. The site was located in the Stanislaus National Forest. Data were collected and posted on the Smoke Monitoring Web site under the ORBCOMM modem identification #48.

Routine Operations

Each site operator received a BAM-1020 and/or E-BAM User's Guide which outlined instrument-specific, bi-weekly and monthly maintenance checks. Site operators were responsible for maintaining the instrument and reporting noted problems to ARS instrument

specialist Mike Slate. Completed bi-weekly and monthly maintenance checklist sheets were sent to ARS after each site maintenance visit was completed. Semiannual (six-month) maintenance and calibration checks were performed by ARS field specialists.

Data Management, Validation and Reporting

Real-time data was collected via ORBCOMM satellite using an instrument-specific modem identification number. All particulate and meteorological data were transmitted hourly to the Interagency Smoke Monitoring Web server (located at Oceaneering headquarters in San Diego) and to Air Resource Specialist's Air Quality Data Base (AQDB).

Each business day, ARS' specialized team of data analysts verified that all data were received and identified operational problems or data inconsistencies. Preliminary data validation was performed monthly by data analysts. During both the preliminary and final validation processes, all data were screened for quality, consistency, and instrument-related malfunctions.

Weekly updates consisting of raw stack plots and brief operational timelines for all operational sites within the SSPP were routinely provided to the Region 5 Air Program Managers. Graphic and tabular data summaries of validated data for all operational sites were provided to Region 5 Air Program Managers on a monthly basis. Real-time data could be viewed at the Interagency Smoke Monitoring Website. An example of the detailed site data that can be obtained from the website is shown below in Figure 6. The website is maintained by Oceaneering of San Diego, CA. Questions about the website can be directed to Cole Morton at cmorton2@oceaneering.com

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Date	Time (pst)	ConcRT (µg/m³)	ConcHR (µg/m³)	Flow (l/m)	Wind Speed (m/s)	Wind Direction (°)	Ambient Temp (C)	Ambient Temp (F)	RH external (%)	RH internal (%)	Battery Voltage (volts)	Filter Temp (C)	Filter Temp (F)	Alarm	Type
7/24/2015	00:00	5	-1	16.7	0.6	101	20.2	68.36	0	26	13.9	24.5	76.1	0	PM 2.5
7/24/2015	01:00	6	8	16.7	0.7	93	19.3	66.74	0	28	13.9	23.3	73.94	0	PM 2.5

Figure 6: Real-time data from the Interagency Real Time Smoke Monitoring website (http://app.airsis.com/USFS/)

Results

The use of BAM particulate monitors in conjunction with the Interagency Real Time Smoke Monitoring website was successful in providing up-to-date conditions of smoke concentrations

and local meteorological conditions, such as wind speed and wind direction, during wildland fire events. This has helped to assist fire managers' ability to predict fire movement and intensity, allowing them to more efficiently make decisions regarding when and where to focus fire mitigation resources.

Smoke concentration data can be used to estimate long- and short-term smoke exposure to firefighters and support personnel; real-time access to this data can help determine shift changes or identify instances when personnel should be removed from a fire in order to prevent respiratory health issues. In addition, smoke concentration data has aided in estimating smoke exposure to residents in the vicinity of a wildfire or prescribed burn. In the case of a wildfire, it may provide the evidence needed to initiate the evacuation of communities in danger. In the case of prescribed burns, it can be used as evidence to prove that there is no smoke inhalation danger despite unfounded complaints of nearby residents. This evidence can allow burning to continue without the risk of lawsuits.

These systems can be deployed and operational by one person in 30 minutes or less. This allows the monitoring system to be moved quickly as conditions change so that monitoring can be conducted down-wind of the fire without danger of being consumed by the fire. Because they have low power requirements, systems are easily operated with solar panels and batteries, which optimizes their mobility and ease of setup. Monitoring is not restricted to places with line power.

The iridium satellite network allows data transmissions from anywhere on Earth in two minutes or less with no dish or antenna alignment necessary. This system ensures reliable communications in any location, regardless of access to cellular service, and can be set up by personnel without any communications experience.

Discussion

Since the study was conducted, other agencies and land managers have contracted ARS to design and construct similar systems. The National Park Service, the Bureau of Land Management, the U.S. Fish and Wildlife Service, Environment Canada, and multiple state governments and industrial clients have all purchased and successfully utilized similar systems.

The technology used to measure particulates continues to improve. Most recently, ARS has developed a portable system that utilizes a DustTrak DRX which allows simultaneous measurement of PM_{total}, PM_{10}, $PM_{respiratory}$, $PM_{2.5}$ and PM_{1}. Furthermore, the satellite communications supporting these systems continue to advance and decrease in cost.

Website design continues to improve and can be customized to meet the needs of the user. Website accessibility is versatile and can be made available to the public, password protected for internal use only, or can be accessed via smart phone.

References

Sandberg DV, Ottmar RD, Peterson JL, Core J (2002) 'Wildland fire in ecosystems: effects of fire on air.' USDA Forest Service, Rocky Mountain Research Station Research Paper RMRS-GTR-42. (Ogden, UT)