Wildfires engulf Runyon Canyon near Sunset Boulevard in Los Angeles, CA, January 8, 2025. The fire was very close to Hollywood and was named the Sunset Fire.

# Monitoring Smoke:

## An Exploration of Low-Cost Sensors

**by Edward Ballaron, Eli Lessman, David Frisbey, and Shawn Boyle**

This article explores the Monterey Bay Air Resources District's shift toward using low-cost sensors to monitor and analyze smoke from regional wildfires.

**Like much of California, the Monterey Bay Air Resources District (MBARD)** has had its share of smoke impacts from wildfires. MBARD encompasses the North Central Coast Air Basin (NCCAB), an area along California's central coast that covers Monterey, San Benito, and Santa Cruz counties. Decades of fire suppression have contributed to increased vegetation loads in forests and other wildlands, which has led to larger, more frequent, and costly wildfires. Recently, western states have seen record breaking wildfire activity. Wildfire smoke from as far as Washington, Oregon and Canada has caused impacts in the NCCAB. The frequency and severity of wildfires have also led to longer duration smoke impacts. In 2016, the Soberanes Fire, which burned in Monterey County, lasted two and a half months and burned over 132,000 acres. Other subsequent wildfires in the NCCAB; such as the 2020 Dolan, River, and CZU Lightening Complex fires, demonstrated the increase in wildfire activity along with the public's need for real-time air quality data to make informed health-based decisions.

## The Desire for Easier Deployment

MBARD maintains a regulatory a network, which measures fine particulate matter ($PM_{2.5}$) at seven stations throughout the region. While the distribution of these seven air monitoring stations meets national requirements, a more comprehensive spatial data set was needed to enhance understanding of smoke impacts from wildfires. During the 2016 Soberanes Fire, MBARD air monitoring staff augmented their regulatory network with Environmental Beta Attenuation Monitors (E-BAMs) to better grasp smoke impacts and provide the public with additional air quality information. E-BAMs, which are similar to a regulatory $PM_{2.5}$ monitor (BAM 1020), are designed for rapid field deployment; nonetheless, E-BAMs can be relatively challenging to deploy since they require an external power source and a secure placement and foundation. Frequent maintenance, including bi-weekly quality control checks, replacement of filter media, and the occasional pump replacement are notably burdensome in contrast to low-cost sensor (LCS) requirements. Additionally, publishing E-BAM data was difficult due to unreliable satellite data transmission and a lack of data integration. The data collected by E-BAMs ended up being too cumbersome for public review and its usefulness was limited for locations that are more remote.

## The Need for Near Real-Time Data

Early on, MBARD found that the 24-hr health-based standard was not meant to communicate real-time risk. Its purpose is to observe the status of attainment for the National Ambient Air Quality Standards (NAAQS). The NAAQS 24-hr standard for $PM_{2.5}$ is insufficient for informing the public about immediate air quality impacts, especially during dynamic events like wildfires, where conditions can change from hour to hour. For example, an air monitoring station might indicate an Air Quality Index (AQI)—the U.S. Environmental Protection Agency's (EPA) guide to communicating air quality—in the "Unhealthy" range; however, the public may not be experiencing any smoke impacts at that moment and vice-versa. This led MBARD to explore new LCS technology to provide the public with near real-time air quality data.

## Better Understanding Smoke Impacts

Another issue that helped begin MBARD's shift to LCSs was prompted by an investigation into smoke complaints from recreational fires in the California beach community of Carmel-by-the-Sea. To understand local smoke impacts, MBARD installed an E-BAM adjacent to the beach. However, this instrument drew attention and required staff time to maintain and operate. Initially, MBARD attempted to adopt a brand of LCS that required an external power source, access to wi-fi to collect and publish data, and security for public installation. These LCSs were installed inside metal boxes with a battery system and downloaded data to an SD card. The batteries had to be recharged and replaced every few days. Publishing the data from this LCS was difficult as there were thousands of data points, which had to be evaluated before sharing with the public. Other issues stemmed from power losses and environmental factors, such as moss growing in the sensors, which further limited the data sets.

## The Need Shifts to LCS

These shortcomings induced MBARD to look to different LCS brands to deploy and establish a smoke sensor network. This pre-deployed LCS network would collect $PM_{2.5}$ data in each municipality and within unincorporated areas of the NCCAB. For this to happen, the LCS network needed the following: a secure location; internal power source; data transfer through a cellular modem rather than wi-fi; shorter duration averaging period, different from the NAAQS; the ability to publish data on a single web-based map; reduced maintenance; and no consumable filter media.

After much research, MBARD contracted with the Clarity Movement Company (Clarity) to develop and deploy a network of Clarity S-Node sensors throughout the NCCAB, with a focus on disadvantaged and low-income communities, schools, and larger urban centers. Clarity sensors are self-contained units with a $PM_{2.5}$ monitor, cellular modem, and combined battery and solar panel needed to power the unit, freeing them of the challenges associated with E-BAMs. MBARD deployed 30 sensors around the NCCAB to provide the public with near real-time data, 24 hours a day, 7 days a week.

Prior to making a final decision on a particular sensor, MBARD referred to the South Coast Air Quality Management District, Sensor Performance Evaluation Center (AQ-SPEC) lab, which has done extensive testing to evaluate the quality of various brands of LCS. In these studies, it was determined that Clarity sensors showed strong correlations with

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reference field monitors displaying $R^2$ values of 0.73–0.76. To provide further assurances to the public, Clarity sensors were collocated to MBARD regulatory air monitoring stations in our region for several months. MBARD found that the readings from the Clarity sensor tracked consistently with the readings from the regulatory monitor located at the station, although somewhat high. Based on the results of the collocated data, a correction factor was provided by Clarity which sufficiently adjusted for the higher readings.

MBARD worked with the Environmental Systems Research Institute, Inc. (ESRI) to establish a publicly available map to convey the Clarity air quality data with a shorter averaging period. To report a shorter averaging period for $PM_{2.5}$, MBARD used EPA's NowCast AQI. The NowCast AQI is a calculated value that includes the 3 to12 most recent hours of measured $PM_{2.5}$ data and translates this air quality data into the AQI. The NowCast is intended to inform the public of the potential health risks associated with the most recent measured air quality values. The NAAQS for $PM_{2.5}$ is similar to the NowCast, but is based on a midnight-to-midnight, 24-hr average.

## The MBARD Clarity OpenMap

MBARD now uses the MBARD Clarity OpenMap (https://map.clarity.io/mbard/ds/DYBSI4314?longitude=-121.97418&latitude=36.54029&zoom=8.697&aqiStdId=US-EPA), customized from Clarity's OpenMap. The MBARD Clarity OpenMap includes an enhanced summary of the current and recent NowCast AQI values giving the public the latest local air quality sensor information. Since its deployment, MBARD's smoke sensor network has demonstrated effectiveness during wildfire events and beyond. During winter months, MBARD has historically set up E-BAMS in smoke sensitive communities where meteorological and geographical conditions caused concerning accumulations of woodsmoke. One of these is in the San Lorenzo Valley, a narrow and deep river valley near Santa Cruz, CA. In past years, MBARD set up E-BAMs to monitor woodsmoke in winter months to give residents access to $PM_{2.5}$ data. However, following the successful implementation of MBARD's smoke sensor network, these LCSs have replaced the need for seasonal deployment and use of E-BAMs.

An additional benefit of MBARD's smoke sensor network is its use for smoke monitoring during prescribed burning. As California mandates an increase in prescribed burning, smoke impacts will also increase. While professionals responsible for implementing prescribed burns have a goal of burning vegetation to protect communities from wildfire, it must be done without creating smoke impacts on the public. The smoke sensor network helps MBARD understand smoke impacts from prescribed burning and empowers professional burners to be accountable and understand how smoke generated from prescribed burns affects the public.

Historically, low-income and disadvantaged communities have been exposed to an inequitable portion of air quality impacts. California's Assembly Bill 617 provides local air districts with the opportunity to measure, administer grants and improve air quality in these communities. The first step in making planning or funding decisions to address these inequities is to understand to what degree these communities are being impacted. The established LCS network has aided MBARD in attaining data from communities which would otherwise be unrepresented in the data set.

## Moving Forward

The demand for rapid and reliable data emphasizes the importance of the deployment of the LCS network. The resources used to implement the MBARD LCS network is an investment for the public which MBARD serves to access reliable air quality data and assist in making informed health-based decisions. MBARD plans to continue to expand its LCS network to provide timely information to more of its local communities. Proudly, MBARD has outlined an approach for establishing an LCS network for other California Air Districts and beyond. Air quality professionals and advocates can further pioneer this exciting LCS field and continue to expand LCS networks to ensure the public has access to accurate, local, and near real-time data so they can make their own informed health-based decisions. **em**

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