Sensor Variations in Wintertime PM Among Communities in Sacramento Measured with a Combination of Traditional and Low-Cost Sensor Methods Use for Real-World Applications

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Study Summary

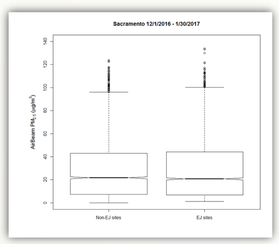
To understand how wood smoke contributions and particulate matter (PM) concentrations varied across Sacramento, California, and between environmental justice (EJ) and non-EJ communities, we conducted measurements during December 2016 and January 2017 of (1) PM with low-cost AirBeam sensors at 15 locations, (2) hourly PM with beta attenuation monitors (BAMs), and (3) 24-hour PM via filter measurements at two locations. Before and after the main study period, the AirBeam sensors were collocated with a BAM and filter PM instrument to determine correction factors for the sensors. In addition, the AirBeam sensors were collocated with a BAM and filter PM instrument at two locations during the study to assess whether there was drift in the sensor measurements, and to determine the comparability of PM measurements among the sensors, BAMs, and filter instruments.

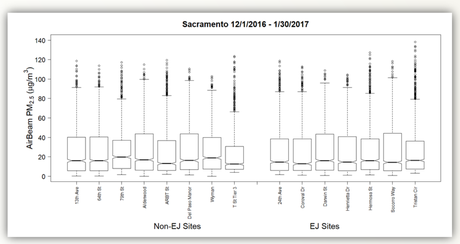
Study Findings

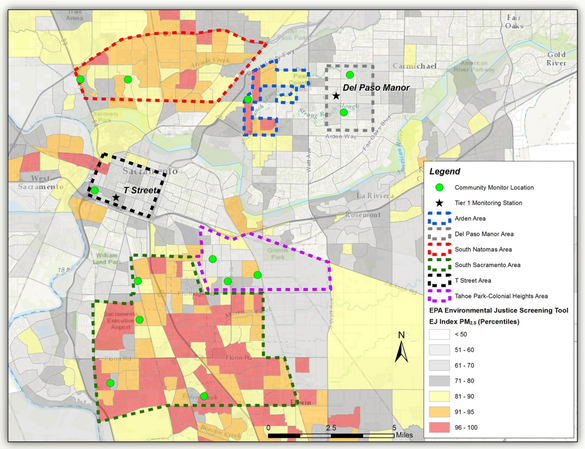
- Overall, there was no statistically significant difference in $PM_{2.5}$ levels between EJ and non-EJ communities.
- The AirBeams had excellent precision, based on (1) two-week pre- and post-study collocations, (2) AirBeam-to-AirBeam correlation coefficients that were greater than 0.95, and (3) little-to-no drift during the study.
- The AirBeams showed consistent bias, but since this bias was characteristic to each AirBeam, it could be corrected using the collocation study results.
- The AirBeams had modest correlation with collocated BAM and federal reference method (FRM) monitor measurements, with r^2 values of ~0.60. Variation was due to changes in dew point; under low dew point conditions, the AirBeam and BAM measurements had a nearly 1:1 relationship.
- Ambient $PM_{2.5}$ values during the study had a modestly high correlation to the values in the emissions inventory (EI) when average values in each 4 km^2 EI grid cell were compared to winter weekend emissions (r^2=0.76).

Concentrations at EJ vs non-EJ Areas

There was no statistically significant difference between $PM_{2.5}$ concentrations in EJ and non-EJ areas when all sites were grouped together (p=0.238). The non-parametric Pairwise Wilcoxon Rank comparison for the nine paired EJ and non-EJ sites shows that, for eight cases, there was no statistically significant difference between the means (p value >0.68); for one case (the T Street non-EJ site and the South Sacramento EJ site), there was a statistically significant difference in the means (p value =0.00046, a difference of 1.5 µg/m^3).





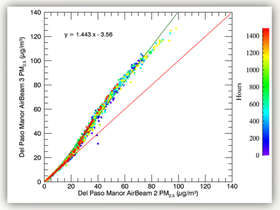


The map above shows the Sacramento communities where monitoring was conducted, the monitoring locations, and the EJ Index for $PM_{2.5}$, which is based on the U.S. EPA's Environmental Justice screening tool, EJScreen (epa.gov/ejscreen). The study used three EJ and three non-EJ communities, each with between one to four locations with PM sensors and other measurements.

Sensor Precision and Accuracy

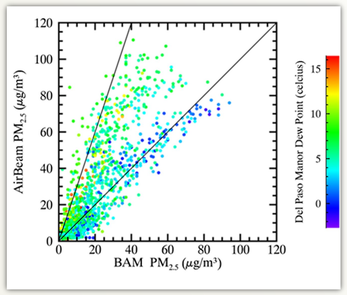
To assess sensor accuracy and utility, we collocated AirBeam PM sensors with FRM monitors for two months at two locations in Sacramento. Three collocated AirBeams at the Del Paso Manor site showed very little drift and extremely high precision, but also significant bias in the uncorrected data.

We performed pre- and post-study collocations of all 19 AirBeams used in the study. These collocations showed that the precision of the AirBeam measurements was very good and drift was minimal. Thus, we were able to correct for sensor-to-sensor bias and use the AirBeams during the study to assess (with high confidence) how PM varied at multiple sites across Sacramento.



The AirBeams at Del Paso Manor showed high precision and very little drift (uncorrected data shown).

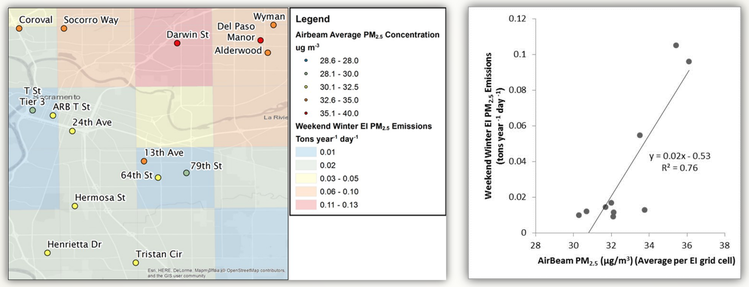
The pre-study (left) and post-study (right) collocations of 19 AirBeams showed very high correlation among all sensors (r^2 >0.95).



At the Del Paso Manor collocation site, the AirBeam had a nearly 1:1 relationship with BAM $PM_{2.5}$ data when dew point was low (~less than 5°C), but was nearly 3:1 under higher dew point conditions. This bias is common in light-scattering instruments such as the AirBeam.

Comparison to Emissions Inventory

We compared the average $PM_{2.5}$ concentrations to the 2012 4 km^2 gridded $PM_{2.5}$ wintertime emissions inventory for each EI grid cell. For each AirBeam, the average $PM_{2.5}$ concentration for the study period was calculated from hourly values; only data points collected at times when data were available from all AirBeam sites were used to calculate the averages. The average of all AirBeam measurements falling in a single EI grid was then calculated. A linear regression equation was fit for the average PM measurement and the EI data, and the r^2 was calculated for the regression.



Map and scatter plot of 4 km^2 gridded winter weekend $PM_{2.5}$ emissions with average AirBeam $PM_{2.5}$ concentrations.

The EI captures the spatial variability of $PM_{2.5}$ relatively well on a 4 km^2 scale, with higher concentrations in the northeast. The two cells with the largest disagreement are EJ areas (Tristan, Socorro), which may indicate unknown sources of PM in these areas.

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