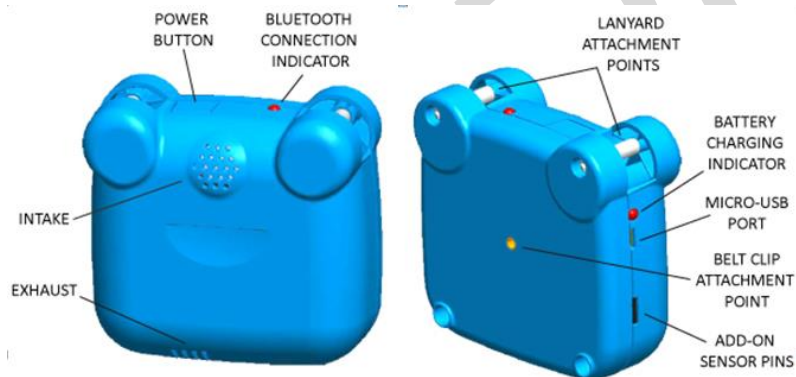


Laboratory Evaluation AirBeam PM_{2.5} Sensor



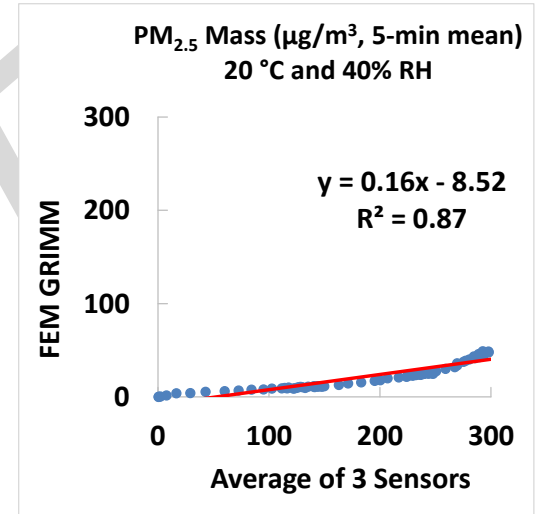
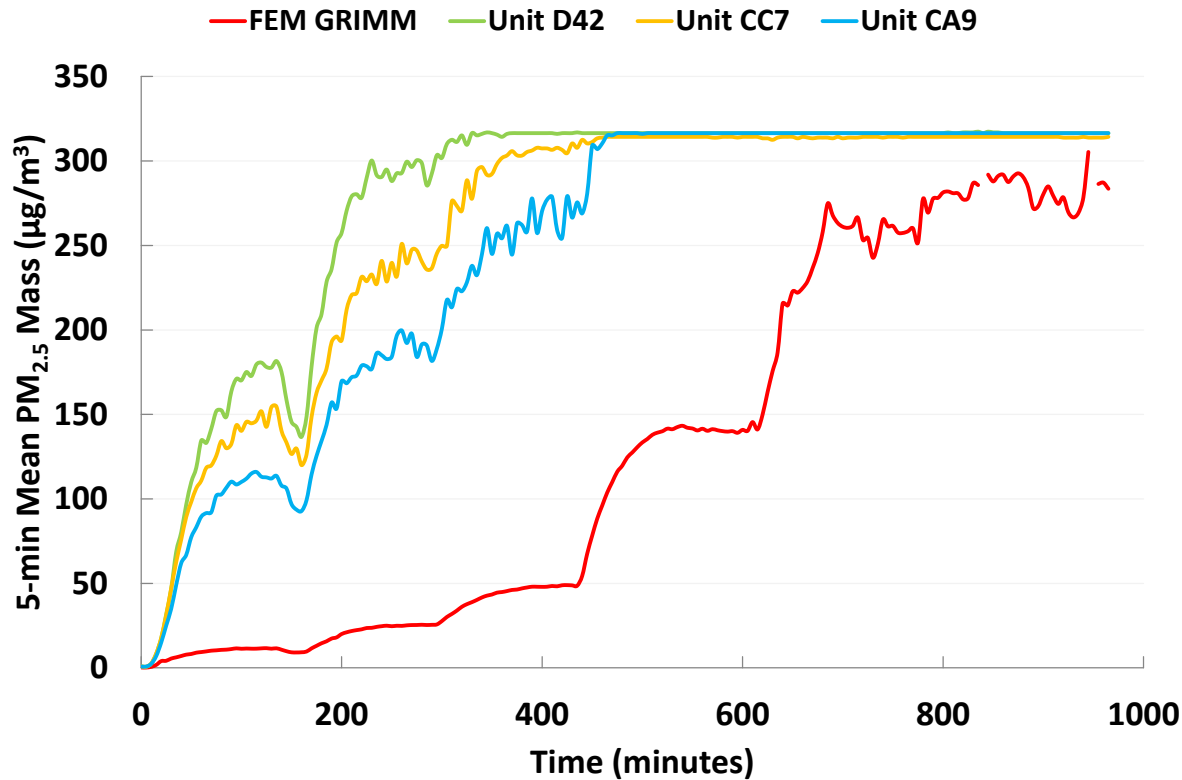
Background

- Three **AirBeam** PM Sensors that were previously field-tested at the South Coast AQMD Rubidoux fixed air monitoring station (deployment period: 04/30/2015 to 06/19/2015) under ambient weather conditions, have now been evaluated in the South Coast AQMD Chemistry Laboratory under controlled PM concentration, temperature and relative humidity.
- AirBeam Sensor (3 units tested):
 - Particle sensors (**optical; non-FEM**)
 - Each unit measures: PM_{2.5} mass ($\mu\text{g}/\text{m}^3$) and PM_{2.5} count (hundred particles/ ft^3)
 - **Unit cost: ~\$200**
 - Time resolution: 1-min
 - Firmware: [March 2015 AirBeam firmware](#)
 - Units IDs: D42, CC7, CA9
- GRIMM (reference method):
 - Optical particle counter
 - **FEM PM_{2.5}**
 - Uses proprietary algorithms to calculate total PM, PM_{2.5}, and PM₁ mass conc. from particle number measurements
 - **Cost: ~\$25,000**
 - Time resolution: 1 min



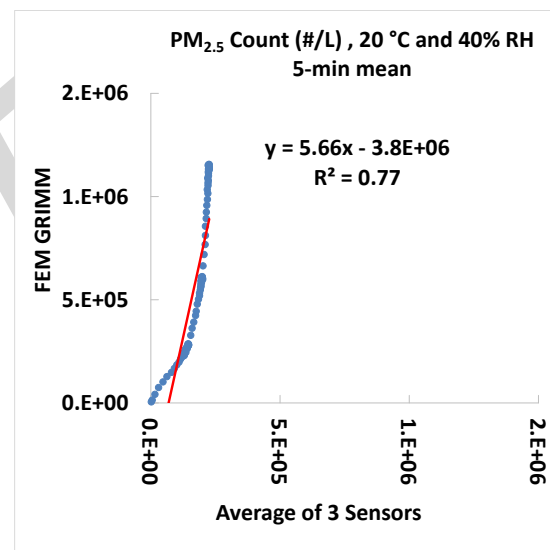
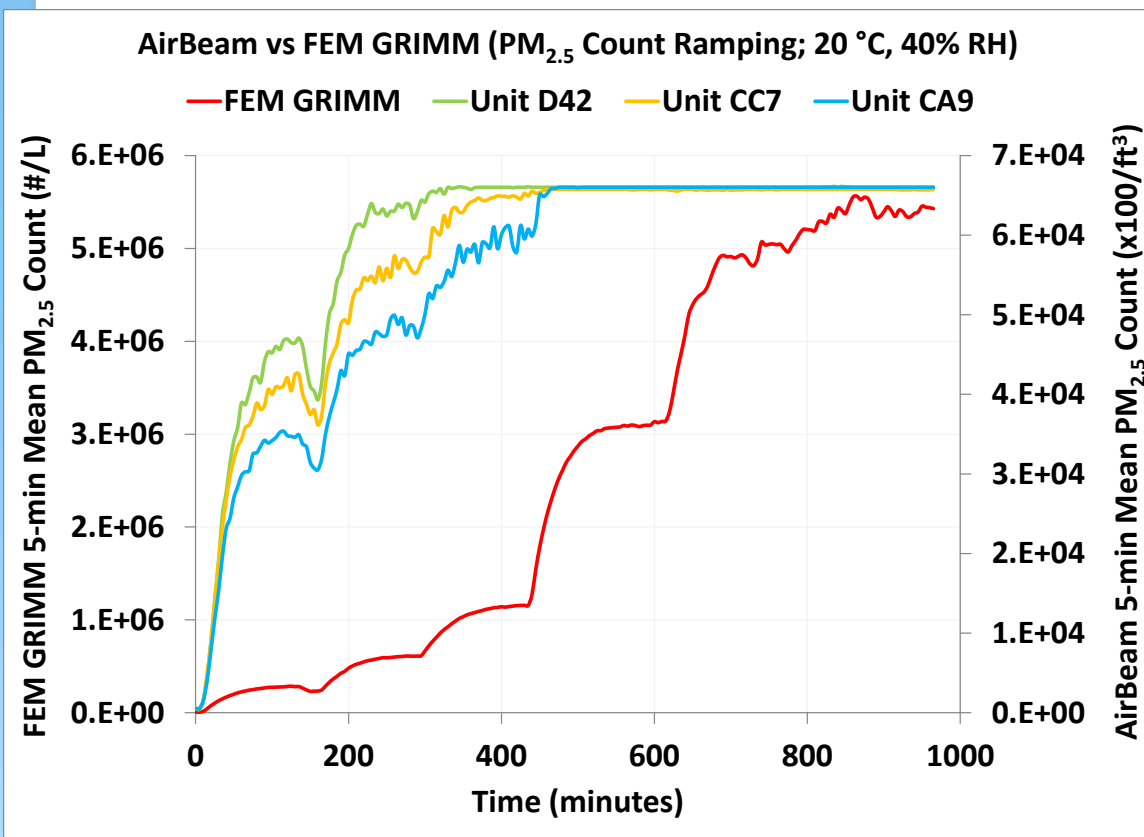
AirBeam vs FEM GRIMM (PM_{2.5} mass; 5-min mean)

AirBeam vs FEM GRIMM (PM_{2.5} Mass; 20 °C, 40% RH)



- When GRIMM PM_{2.5} concentration was less than 50 µg/m³, the AirBeam sensors tracked well with PM_{2.5} (µg/m³) variations (concentration ramping) recorded by the GRIMM.
- The AirBeam sensors reached their maximum PM_{2.5} reading of about 300 µg/m³ when GRIMM PM_{2.5} exceeded 50 µg/m³.
- The GRIMM showed very low measurement variability at low PM_{2.5} concentration compared to the AirBeam sensors.

AirBeam vs FEM GRIMM (PM_{2.5} count; 5-min mean)



- AirBeam sensors showed strong correlation with GRIMM PM_{2.5} measurement data ($R^2 \sim 0.76$) when GRIMM PM_{2.5} count was lower than 2.0×10^6 #/L. However, the AirBeam sensors significantly underestimated (about 80% less) the GRIMM PM_{2.5} (slope = 5.66 and intercept = -3.8×10^6).

- When GRIMM PM_{2.5} count was less than 2.0×10^6 #/L, the AirBeam sensors tracked well with PM_{2.5} (#/L) diurnal variations (concentration ramping) recorded by the GRIMM.
- The Airbeam sensors reached their maximum PM_{2.5} reading of about 6.5×10^4 (x100/ft³) when GRIMM PM_{2.5} exceeded 1.0×10^6 #/L.
- The GRIMM showed very low measurement variability at low PM_{2.5} count compared to the AirBeam sensors.

AirBeam PM_{2.5} mass accuracy

- Accuracy (20 °C and 40% RH)

Steady State (#)	Sensor mean (µg/m ³)	FEM GRIMM (µg/m ³)	Accuracy (%)
1	147.9	11.5	-1086
2	243	25.4	-757
3	296.2	48.7	-408

- Overall, the three AirBeam sensors showed very low accuracy compared to FEM GRIMM at 20 °C and 40% RH, when varying PM_{2.5} mass concentration from 10 to 50 µg/m³. The AirBeam significantly overestimated the FEM GRIMM readings. According to the method of calculating accuracy, the %accuracy for the sensors were all negative. When PM_{2.5} mass conc. was over 50 µg/m³, AirBeam sensors reached a plateau of 315 µg/m³.

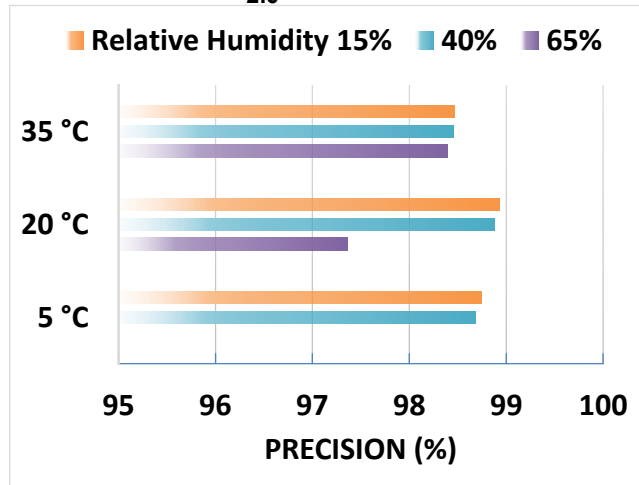
AirBeam data recovery & intra-model variability & LDL

- Data recovery for PM_{2.5} from all three AirBeam units was 100%.
- Substantial intra-model variability (45%) was observed between the three AirBeam sensors at low PM_{2.5} concentration (measured by GRIMM) at 20 °C and 40% RH. When the PM_{2.5} concentration measured by the GRIMM exceeded 50 µg/m³, the AirBeam sensors quickly reached their maximum of 300 µg/m³, and they stopped responding to any further concentration increase. Thus, intra-model variability for medium and high PM_{2.5} concentration could not be estimated.
- AirBeam sensors' LDL were close to 0 µg/m³.

AirBeam vs FEM GRIMM (PM_{2.5}; 5-min mean)

- Precision (Low PM_{2.5} conc., and various Temperature and Relative Humidity)

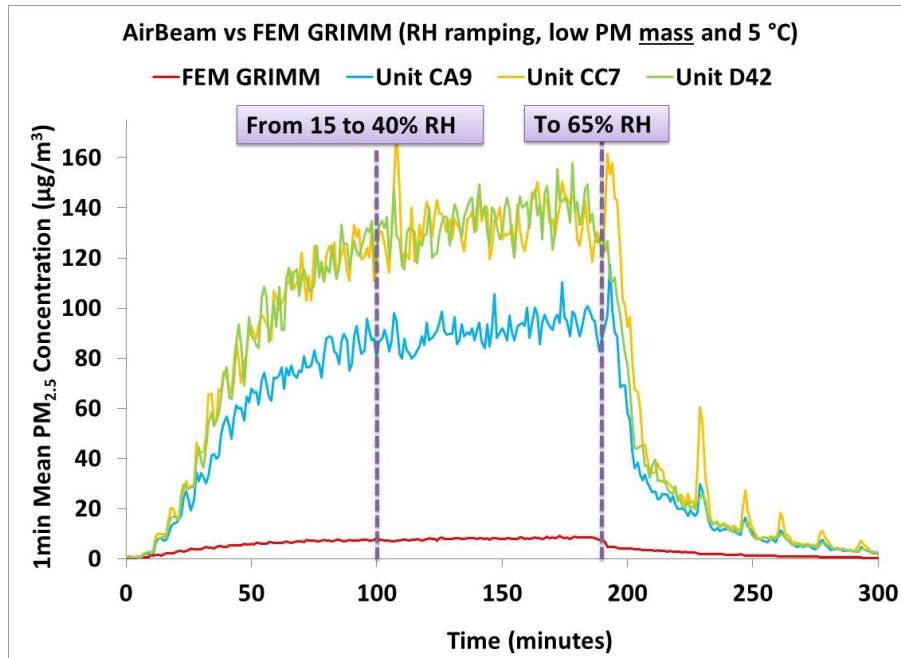
Low PM_{2.5} Concentration



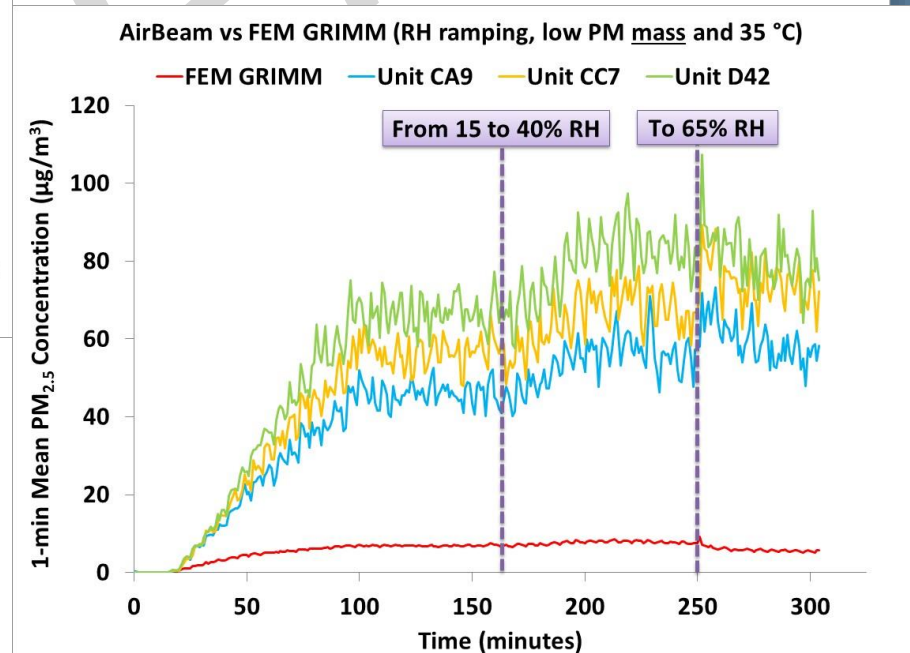
Precision could not be estimated at medium to high PM_{2.5} concentration; at least one of the three AirBeam sensors reached the maximum PM_{2.5} it could measure.

- Overall, the three AirBeam sensors showed good precision for almost all combinations of T and RH at low PM_{2.5} concentration.
- At medium to high GRIMM PM_{2.5}, sensors' precision could not be estimated, because the sensors were only reporting their maximum measurement value of 300 µg/m³.
- FEM GRIMM precision was very high across all conditions.

AirBeam PM_{2.5} Climate Susceptibility



Low Temp – RH ramping
(medium conc.)



High Temp – RH ramping
(low conc.)

Discussion

- **Accuracy:** Overall, the three AirBeam sensors showed very low accuracy compared to FEM GRIMM at 20 °C and 40% RH, when varying PM_{2.5} mass concentration from 10 to 50 µg/m³. The AirBeam sensors significantly overestimated the FEM GRIMM readings. According to the method of calculating accuracy, the %accuracy for the sensors were all negative. When PM_{2.5} mass conc. was over 50 µg/m³, Airbeam sensors reached plateau of 315 µg/m³. (refer to slides 3, 4, and 5)
- **Precision:** Overall, the three AirBeam sensors showed good precision for almost all combinations of T and RH at low PM_{2.5} concentration. At moderate to high GRIMM PM_{2.5}, sensors' precision could not be estimated, because the sensors were only reporting their maximum value of 300 µg/m³. (refer to slide 6)
- **Data recovery:** Data recovery for PM_{2.5} from all three AirBeam units was 100%.
- **Coefficient of Determination:** AirBeam sensors showed strong correlation/linear response with the corresponding FEM GRIMM PM_{2.5} measurement data ($R^2 \sim 0.87$) for mass concentrations below 50 µg/m³ (refer to slides 3 and 4)
- **Lower detection limit (LDL):** AirBeam sensors' LDL was close to 0 µg/m³.
- **Climate susceptibility:** From the laboratory studies, temperature and relative humidity had little effect on the sensor performance at low GRIMM PM_{2.5}. However, at high PM_{2.5} concentrations, sensors failed to respond to the diurnal variations and all reached their maximum output reading of about 300 µg/m³, therefore, the effect under those conditions could not be studied. (refer to slide 7)