

Laboratory Evaluation

HabitatMap AirBeam2 Sensor



Background

Three **HabitatMap AirBeam2** (Hereinafter AirBeam2) sensors (units IDs: F4F1, 6FE0 and 63CC) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (07/20/2018 to 09/19/2018) under ambient environmental conditions and have been evaluated in the South Coast AQMD Chemistry Laboratory under controlled artificial aerosol concentration/size range, temperature, and relative humidity. The same three AirBeam2 units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing).

- **AirBeam2 (3 units tested):**

- Particle sensor (**optical; non-FEM**)
- PM sensor: Plantower PMS7003
- Each unit measures: PM_{1.0}, PM_{2.5} and PM₁₀ ($\mu\text{g}/\text{m}^3$)
Temperature ($^{\circ}\text{F}$), Relative Humidity (%) (measures T and RH inside of sensor)
- **Unit cost: ~\$250**
- Time resolution: 1-min
- Units IDs: F4F1, 6FE0, 63CC
- Differences from 1st Generation:
 - Different hardware (temp/RH sensor, PM sensor) and design
 - Firmware: 3.19.18 AirBeam2
 - Wi-Fi and cellular capabilities
 - Different microcontroller
 - Measures PM_{1.0}, PM_{2.5} and PM₁₀ mass conc. only

- **GRIMM (reference method):**

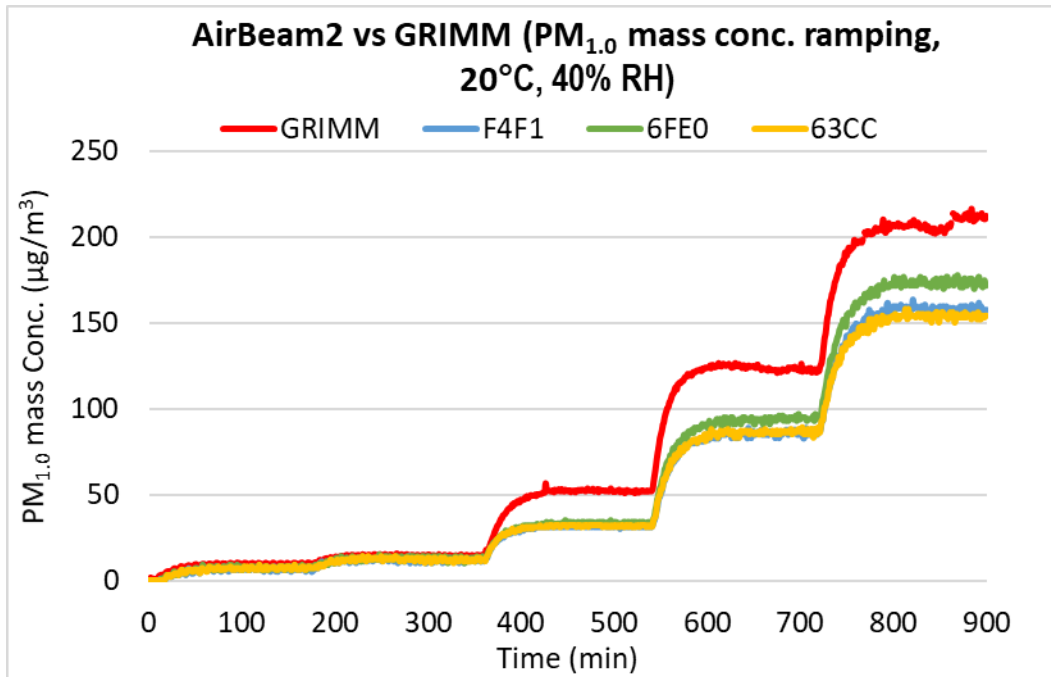
- Optical particle counter
- **FEM PM_{2.5}**
- Uses proprietary algorithms to calculate PM_{1.0}, PM_{2.5}, and PM₁₀ mass conc. from particle number measurements
- **Cost: ~\$25,000**
- Time resolution: 1-min



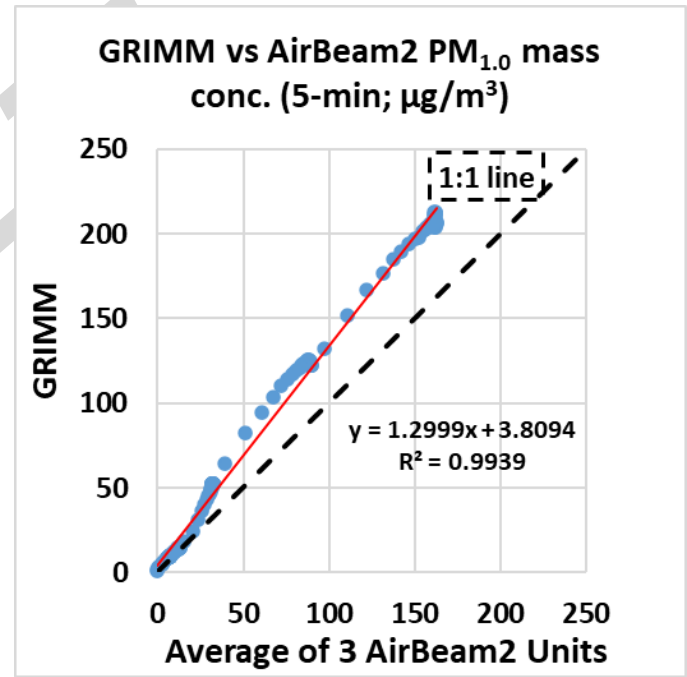
Evaluation results for PM_{1.0} mass concentration

HabitatMap AirBeam2 vs GRIMM

AirBeam2 vs GRIMM (PM_{1.0} mass conc.)



Coefficient of Determination



- The AirBeam2 sensors tracked well with the PM_{1.0} concentration variation as recorded by the GRIMM in the concentration range of 0 - $\sim 200 \mu\text{g}/\text{m}^3$.

- The AirBeam2 sensors showed very strong correlations with the GRIMM PM_{1.0} mass conc. ($R^2 > 0.99$) and underestimated PM_{1.0} mass concentration as recorded by GRIMM

AirBeam2 vs GRIMM PM_{1.0} Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	GRIMM (µg/m ³)	Accuracy (%)
1	7.0	9.5	73.3
2	11.8	14.2	83.3
3	32.0	51.9	61.6
4	89.1	123.4	72.2
5	162.0	211.8	76.5

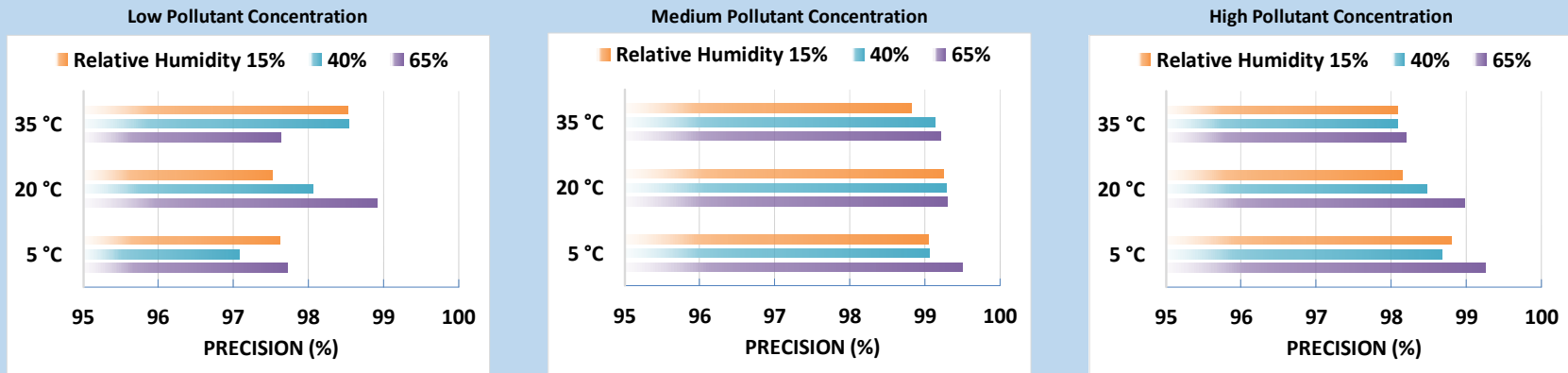
- The AirBeam2 sensors underestimated GRIMM PM_{1.0} mass concentration. The accuracy of the AirBeam2 sensors was fairly constant (62% to 83%) over the range of tested PM_{1.0} mass concentrations.

AirBeam2: Data Recovery and intra-model variability

- Data recovery for PM_{1.0} mass concentration from all units was 100%
- Very low PM_{1.0} measurement variations were observed between the AirBeam2 sensors

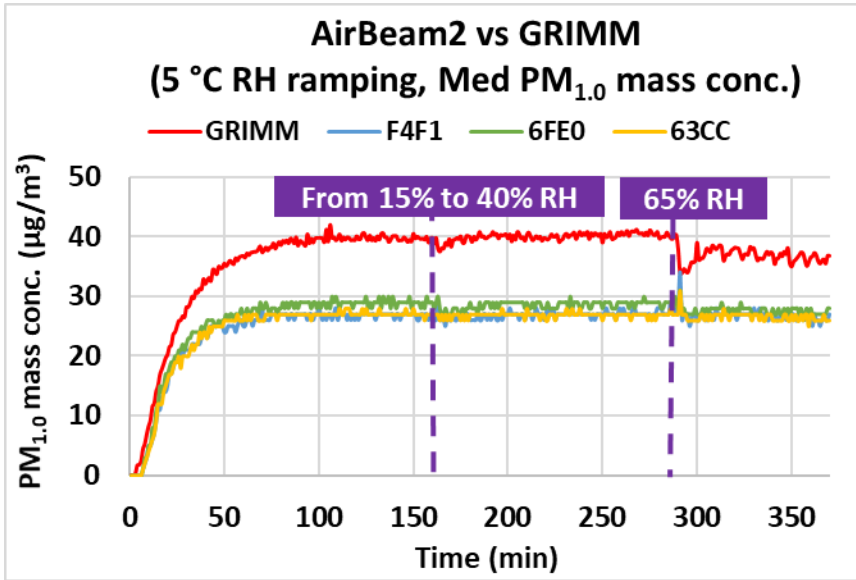
PM_{1.0} Precision: AirBeam2

- Precision (Effect of PM_{1.0} conc., Temperature and Relative Humidity)



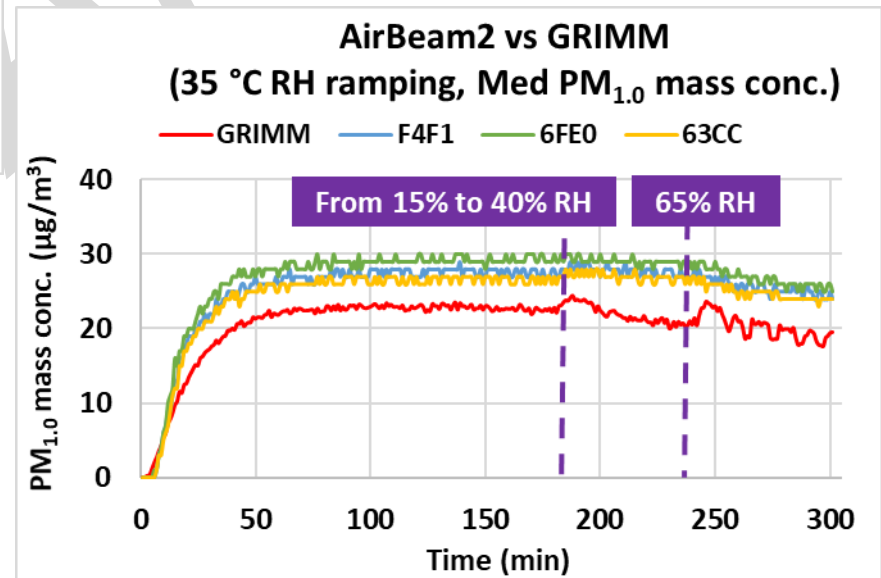
- Overall, the AirBeam2 sensors showed high precision for all of the combinations of low, medium and high PM_{1.0} conc., T and RH.

AirBeam2 PM_{1.0}: Climate Susceptibility



Low Temp – RH ramping
(medium conc.)

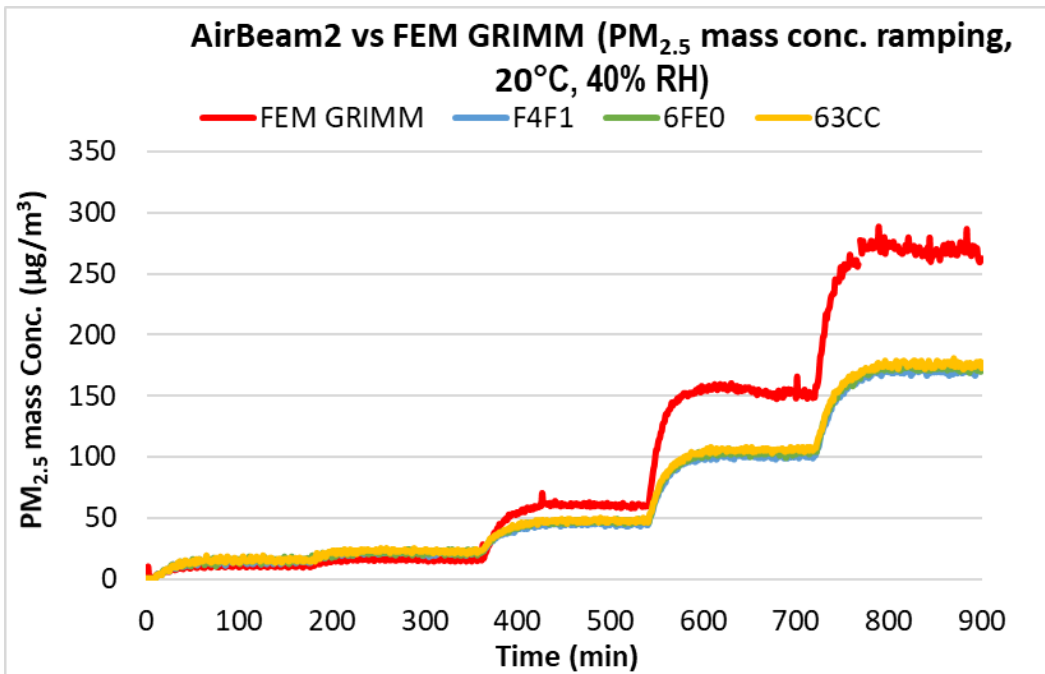
High Temp – RH ramping
(medium conc.)



Evaluation results for PM_{2.5} mass concentration

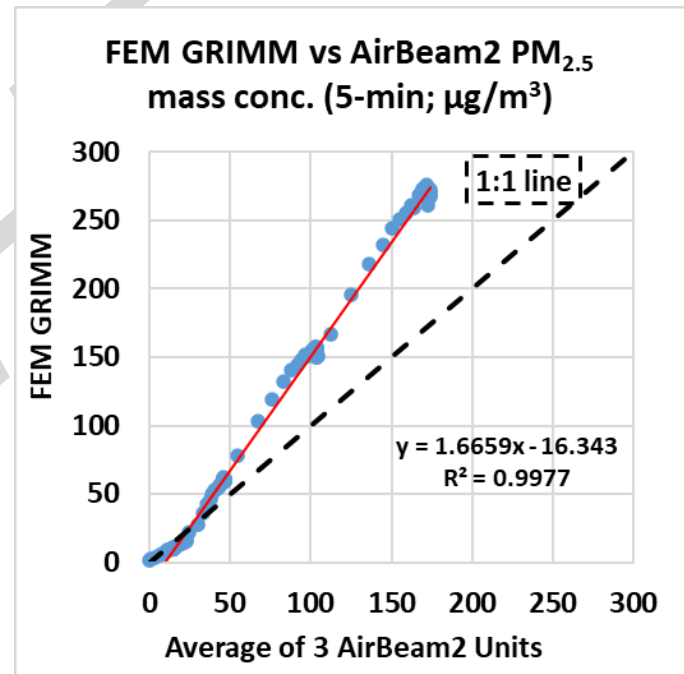
HabitatMap AirBeam2 vs FEM GRIMM

AirBeam2 vs FEM GRIMM (PM_{2.5} mass conc.)



- The AirBeam2 sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~300 µg/m³.

Coefficient of Determination



- The AirBeam2 sensors showed very strong correlations with the FEM GRIMM PM_{2.5} mass conc. ($R^2 > 0.99$)

AirBeam2 vs FEM GRIMM PM_{2.5} Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	FEM GRIMM (µg/m ³)	Accuracy (%)
1	15.1	10.2	51.4
2	21.6	15.2	57.8
3	46.3	59.6	77.7
4	103.7	153.1	67.7
5	173.0	270.1	64.1

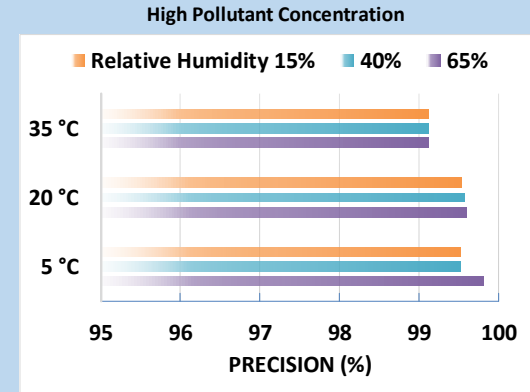
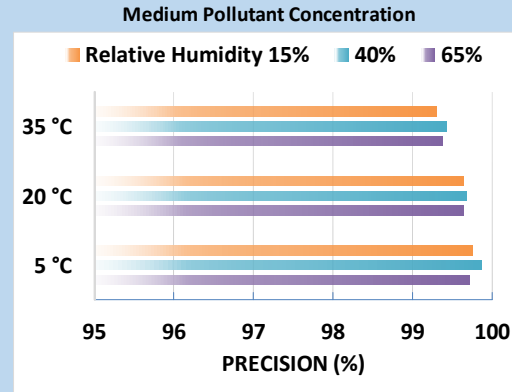
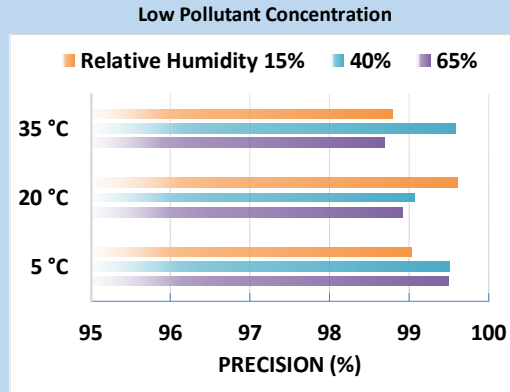
- The AirBeam2 sensors underestimated FEM GRIMM PM_{2.5} mass concentration at 20 °C and 40% RH. The accuracy of the AirBeam2 sensors was fairly constant (51% to 78%) over the range of PM_{2.5} mass concentrations tested.

AirBeam2: Data Recovery and intra-model variability

- Data recovery for PM_{2.5} mass concentration from all units was 100%
- Very low PM_{2.5} measurement variations were observed between the AirBeam2 sensors

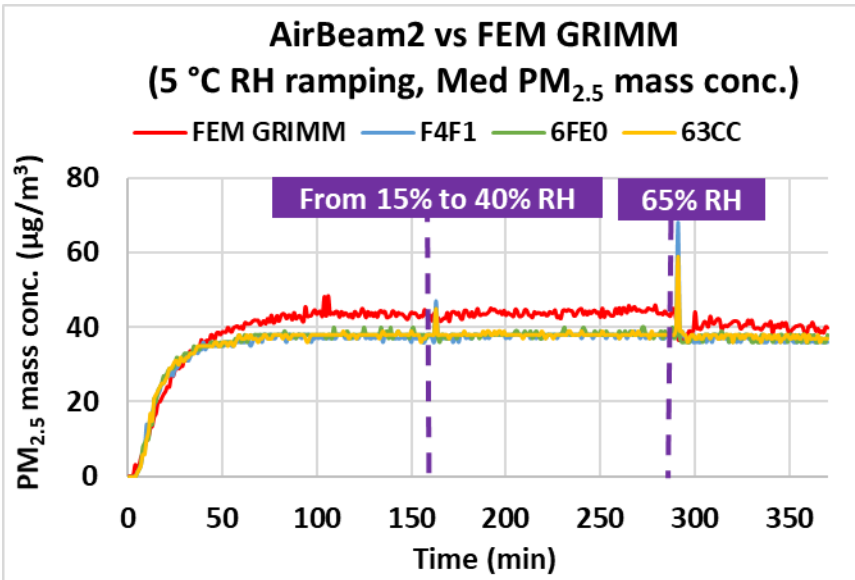
PM_{2.5} Precision: AirBeam2

- Precision (Effect of PM_{2.5} conc., Temperature and Relative Humidity)



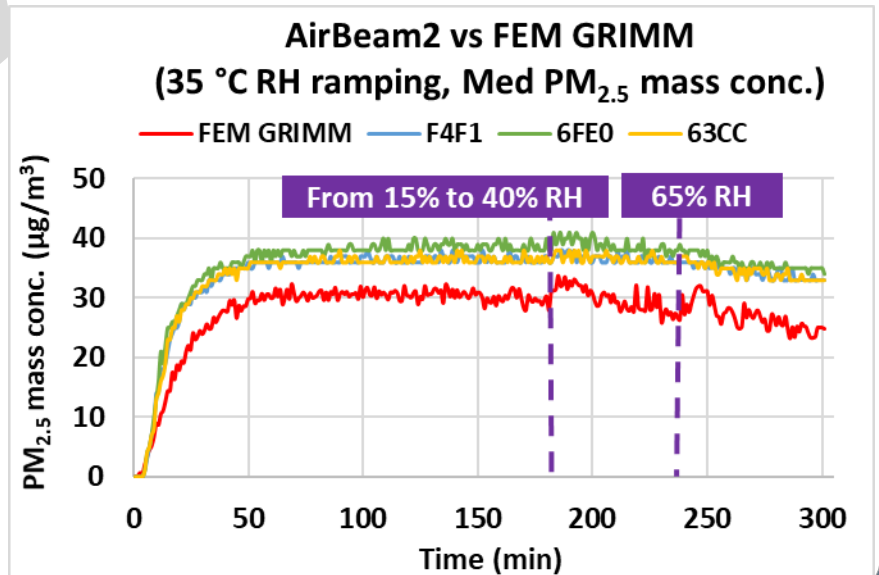
- Overall, the AirBeam2 sensors showed high precision for all of the combinations of low, medium and high PM_{2.5} conc., T and RH.

AirBeam2 PM_{2.5}: Climate Susceptibility



Low Temp – RH ramping
(medium conc.)

High Temp – RH ramping
(medium conc.)



Discussion

- **Accuracy:** Overall, the accuracy of the AirBeam2 sensors was fairly constant over the range of PM_{1.0} and PM_{2.5} mass concentrations tested. The AirBeam2 sensors underestimated both PM_{1.0} and PM_{2.5} measurements from GRIMM in the laboratory experiments at 20 °C and 40% RH.
- **Precision:** The AirBeam2 sensors have high precision for all test combinations (PM concentrations, T and RH) for both PM_{1.0} and PM_{2.5} mass concentrations
- **Intra-model variability:** Low intra-model variability was observed among the AirBeam2 sensors.
- **Data Recovery:** Data recovery for PM_{1.0} and PM_{2.5} mass concentration from all units was 100%.
- **Coefficient of Determination:** The AirBeam2 sensors showed very strong correlation/linear response with the corresponding GRIMM PM_{1.0} and FEM GRIMM PM_{2.5} measurement data ($R^2 > 0.99$).
- **Climate susceptibility:** For most of the temperature and relative humidity combination, the climate condition had minimal effect on the AirBeam2's precision. The AirBeam2 sensors showed some small spikes at the 65% RH set-point at 5°C.