

# Laboratory Evaluation HabitatMap AirBeam3



# Outline

1. Background
2.  $PM_{1.0}$
3.  $PM_{2.5}$

DRAFT

# Background

Three **HabitatMap AirBeam3** (hereinafter **AirBeam3**) sensors were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (02/02/2022 to 04/03/2022) under ambient environmental conditions. Following field-testing, the same three units were evaluated in the South Coast AQMD Sensor Environmental Testing Chamber 2 (SENTEC-2) under controlled artificial aerosol concentration/size range, temperature, and relative humidity.

## AirBeam3 (3 units tested in the lab):

- Particle sensor: **optical; non-FEM (Plantower PMS7003)**
- Each unit reports:  $PM_{1.0}$ ,  $PM_{2.5}$  and  $PM_{10}$  ( $\mu\text{g}/\text{m}^3$ )
- Also measures: internal temperature ( $^{\circ}\text{F}$ ) and internal relative humidity (%)
- **Unit cost: \$249**
- Time resolution: 1-min
- Units IDs: A350, 86B4, 9FF0



## Reference instruments:

- PM instrument (**Teledyne T640x, San Diego, CA; hereinafter FEM T640x**); **cost: ~\$37,000**
- Time resolution: 1-min

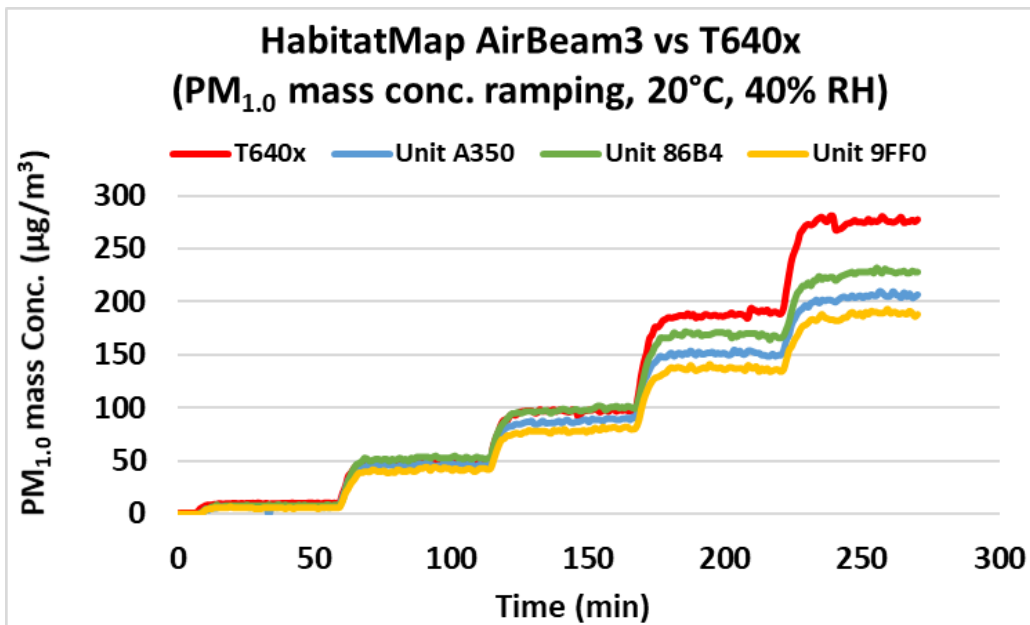


FEM T640x

# PM<sub>1.0</sub>

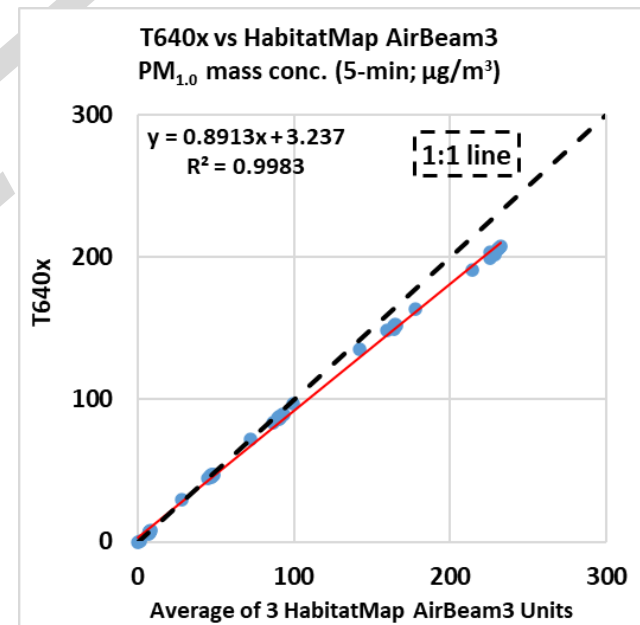
1. T640x vs AirBeam3
2. Accuracy, data recovery, and intra-model variability
3. Precision
4. Climate susceptibility
5. Discussion

# AirBeam3 vs T640x (PM<sub>1.0</sub>)



- The AirBeam3 sensors tracked well with the concentration variation but underestimated PM<sub>1.0</sub>, compared to the T640x in the concentration range of 0 - 300 µg/m<sup>3</sup>.

## Coefficient of Determination



- The AirBeam3 sensors showed very strong correlations with the T640x PM<sub>1.0</sub> mass conc. ( $R^2 > 0.99$ )

# AirBeam3 vs T640x PM<sub>1.0</sub> Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	Sensor Mean (µg/m <sup>3</sup> )	T640x (µg/m <sup>3</sup> )	Accuracy (%)
1	7.0	9.4	74.9
2	47.4	48.0	98.9
3	90.0	97.3	92.5
4	152.1	189.4	80.3
5	208.1	276.6	75.2

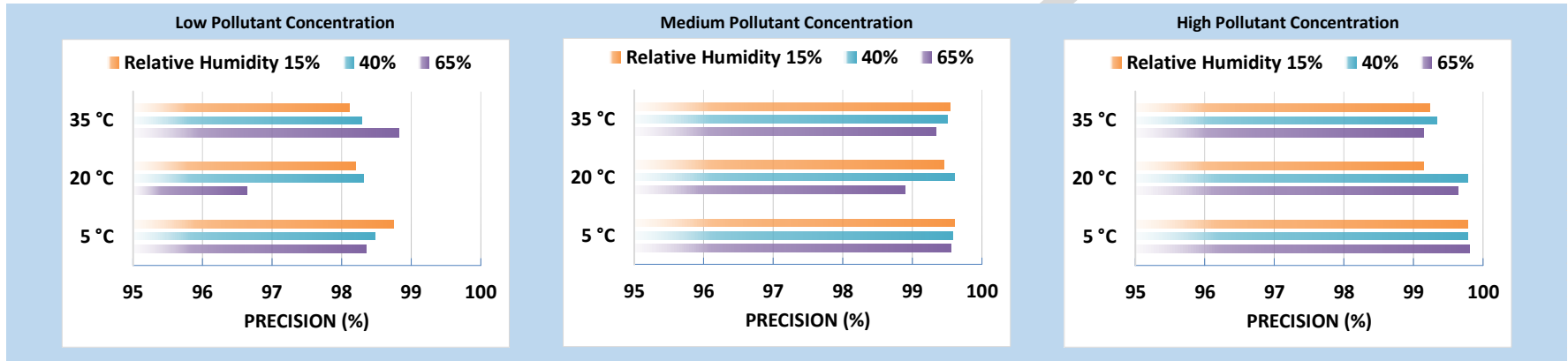
- The AirBeam3 sensors underestimated PM<sub>1.0</sub> concentration values compared to the T640x PM<sub>1.0</sub> mass concentration at 20 °C and 40% RH. The AirBeam3 sensors' accuracy increased from 10 to 50 µg/m<sup>3</sup> then decreased as concentrations increased to ~ 300 µg/m<sup>3</sup> as compared to the reference T640x.

## AirBeam3 Data Recovery and Intra-model Variability

- Data recovery for PM<sub>1.0</sub> measurements was 100% for all units
- Moderate PM<sub>1.0</sub> concentration variations were observed between the units at 20 °C and 40% RH, at low, medium, and high PM<sub>1.0</sub> as measured by the T640x.

# Precision: AirBeam3 (PM<sub>1.0</sub>)

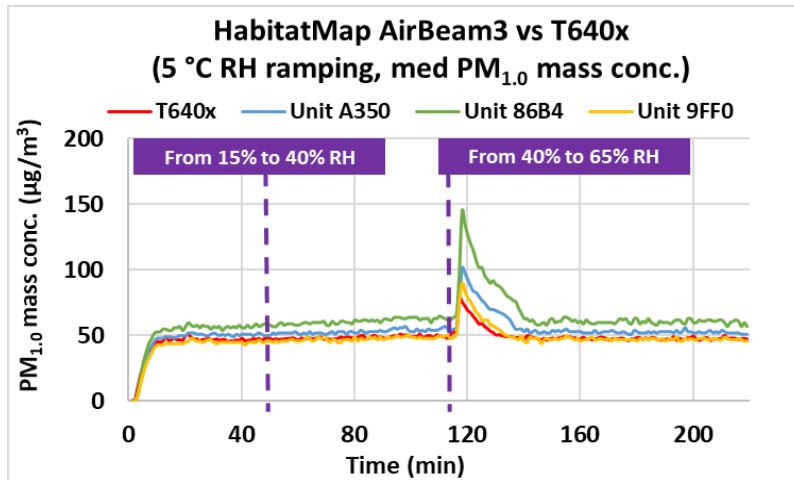
- Precision (effect of PM<sub>1.0</sub> conc., temperature and relative humidity)



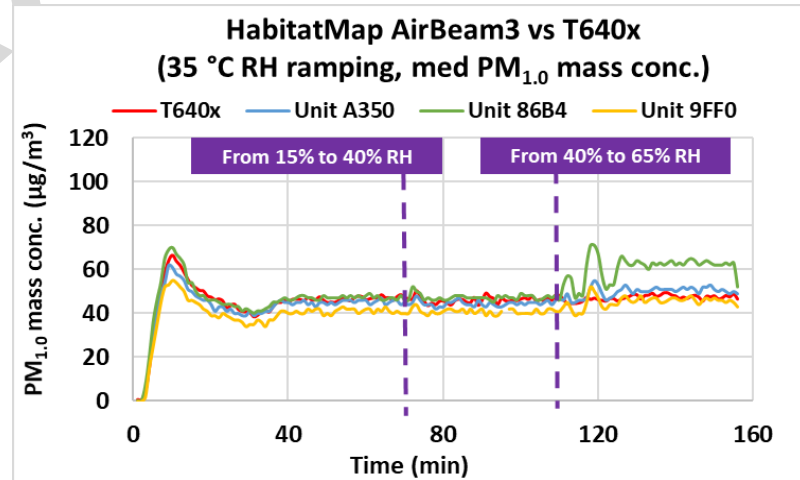
- Overall, the AirBeam3 sensors showed high precision for all combinations of PM<sub>1.0</sub> conc., T, and RH.

# Climate Susceptibility: AirBeam3 (PM<sub>1.0</sub>)

Low Temp - RH ramping  
(medium conc.)



High Temp - RH ramping  
(medium conc.)





# Discussion: PM<sub>1.0</sub>

- **Accuracy:** The AirBeam3 sensors underestimated PM<sub>1.0</sub> concentration values compared to the T640x PM<sub>1.0</sub> mass concentration at 20 °C and 40% RH. The AirBeam3 sensors' accuracy increased from 10 to 50 µg/m<sup>3</sup> then decreased as concentrations increased to ~ 300 µg/m<sup>3</sup> as compared to the reference T640x.
- **Precision:** The three AirBeam3 sensors exhibited high precision during all tested PM<sub>1.0</sub> conc., T, and RH conditions.
- **Intra-model variability:** Moderate PM<sub>1.0</sub> measurement variations were observed among the three AirBeam3 sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM<sub>1.0</sub> measurements was 100% for all units.
- **Bias:** N/A
- **Detection limit:** The detection limit cannot be estimated due to limitations in the chamber system design.
- **Response time:** Response time could not be studied due to the design of the chamber system. With a 1.6 m<sup>3</sup> chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three AirBeam3 sensors showed very strong correlation/linear response with the corresponding T640x PM<sub>1.0</sub> measurement data ( $R^2 > 0.99$ ).
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test

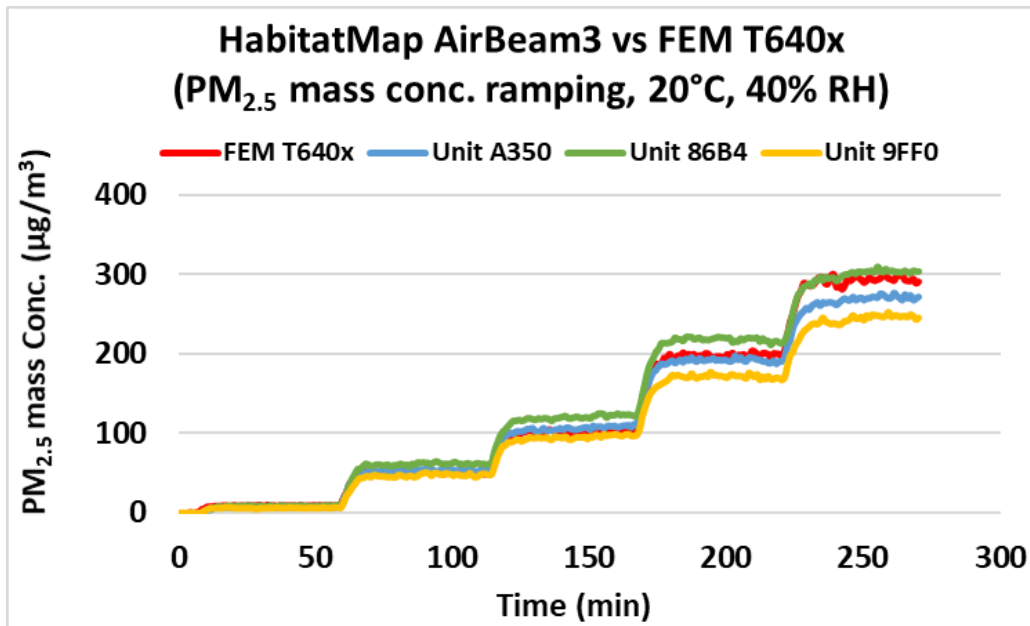
# Discussion: PM<sub>1.0</sub>

- **Measurement duration:** AirBeam3 sensors report 1-min averaged values.
- **Measurement frequency:** AirBeam3 sensors report 1-min averaged values. The obtained data was used for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), and condensed to 5-minute averages for linear correlation studies against the T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the AirBeam3 sensors were tested in the field for two months and a storage period of ~ 4 months prior to laboratory evaluations. The PM<sub>1.0</sub> laboratory studies lasted for about 9 days with intermittent non-operating periods.
- **Concentration range:** Up to 1000 µg/m<sup>3</sup> as suggested by the manufacturer. During the laboratory evaluation, the AirBeam3 sensors were challenged with PM<sub>1.0</sub> concentrations up to 300 µg/m<sup>3</sup>.
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the 65% RH change point.
- **Response to loss of power:** AirBeam3 sensors were powered through the entirety of the lab tests.

# PM<sub>2.5</sub>

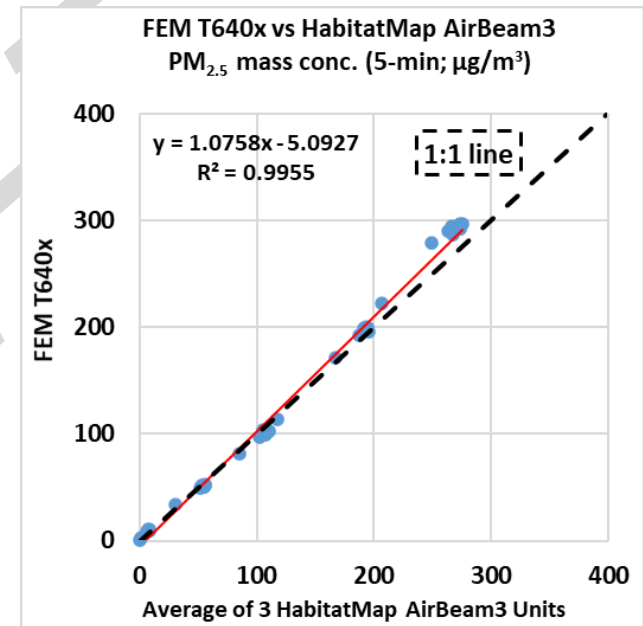
1. **FEM T640x vs AirBeam3**
2. **Accuracy, data recovery, and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Discussion**

# AirBeam3 vs FEM T640x (PM<sub>2.5</sub>)



- The AirBeam3 sensors tracked well with the concentration variation but underestimated PM<sub>2.5</sub>, compared to the FEM T640x in the concentration range of 0 - 300  $\mu\text{g}/\text{m}^3$ .

## Coefficient of Determination



- The AirBeam3 sensors showed very strong correlations with the FEM T640x PM<sub>2.5</sub> mass conc. ( $R^2 > 0.99$ )

# AirBeam3 vs FEM T640x PM<sub>2.5</sub> Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	Sensor Mean (µg/m <sup>3</sup> )	FEM T640x (µg/m <sup>3</sup> )	Accuracy (%)
1	7.7	9.8	78.6
2	54.9	50.7	91.8
3	109.6	102.4	93.0
4	193.3	199.3	97.0
5	274.1	294.4	93.1

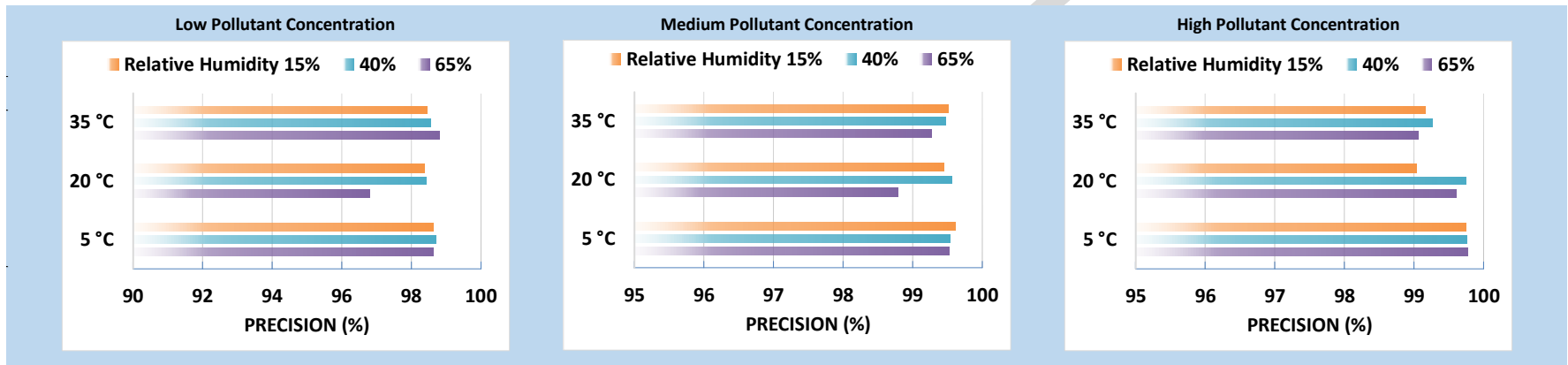
- Overall, the AirBeam3 sensors underestimated PM<sub>2.5</sub> concentration values compared to the FEM T640x PM<sub>2.5</sub> mass concentration at 20 °C and 40% RH. The AirBeam3 sensors showed high accuracy at high PM<sub>2.5</sub> concentrations compared to the reference FEM T640x.

## AirBeam3 Data Recovery and Intra-model Variability

- Data recovery for PM<sub>2.5</sub> measurements was 100% for all units
- Moderate PM<sub>2.5</sub> concentration variations were observed between the units at 20 °C and 40% RH, at low, medium, and high PM<sub>2.5</sub> as measured by the T640x.

# Precision: AirBeam3 (PM<sub>2.5</sub>)

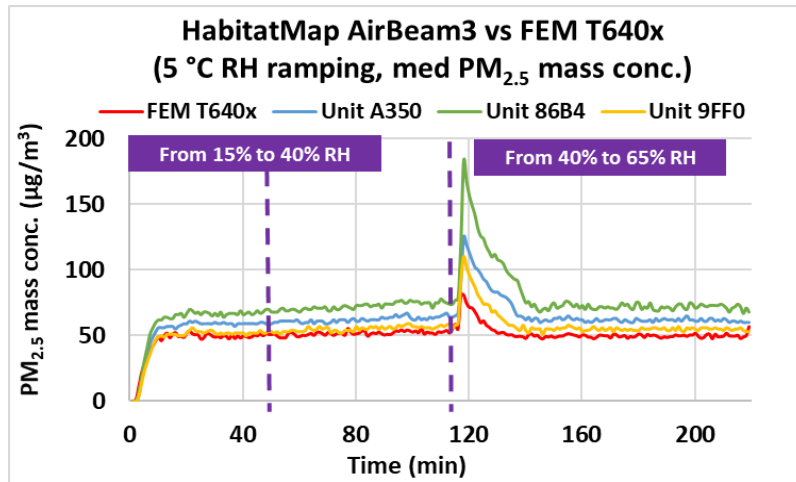
- Precision (effect of PM<sub>2.5</sub> conc., temperature and relative humidity)



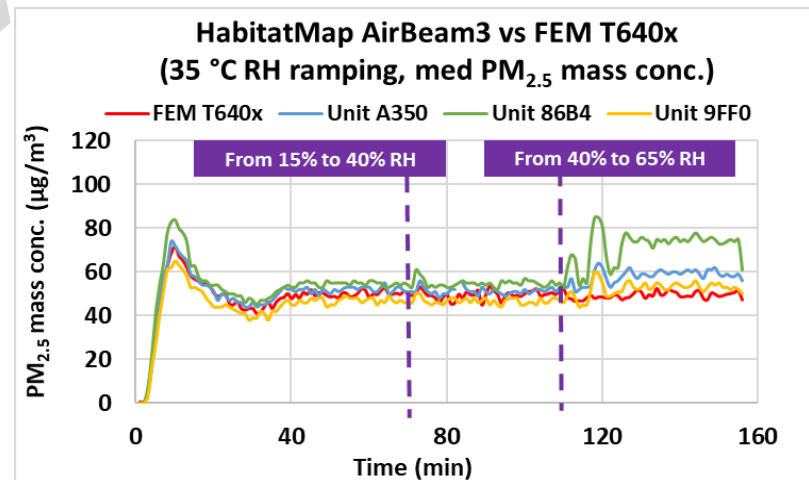
- Overall, the AirBeam3 sensors showed high precision for all combinations of PM<sub>2.5</sub> conc., T, and RH.

# Climate Susceptibility: AirBeam3 (PM<sub>2.5</sub>)

Low Temp - RH ramping  
(medium conc.)



High Temp - RH ramping  
(medium conc.)



# Discussion: PM<sub>2.5</sub>

- **Accuracy:** The AirBeam3 sensors underestimated PM<sub>2.5</sub> concentration values compared to the FEM T640x PM<sub>2.5</sub> mass concentration at 20 °C and 40% RH. The AirBeam3 sensors showed accuracy from 78.6% to 97.0% for all tested PM<sub>2.5</sub> concentrations compared to the reference FEM T640x for the entirety of test.
- **Precision:** The three AirBeam3 sensors exhibited high precision during all tested PM<sub>2.5</sub> conc., T, and RH conditions.
- **Intra-model variability:** Moderate PM<sub>2.5</sub> measurement variations were observed among the three AirBeam3 sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM<sub>2.5</sub> measurements was 100% for all units.
- **Bias:** N/A
- **Detection limit:** The detection limit cannot be estimated due to limitations in the chamber system design.
- **Response time:** Response time could not be studied due to the design of the chamber system. With a 1.6 m<sup>3</sup> chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three AirBeam3 sensors showed very strong correlation/linear response with the corresponding FEM T640x PM<sub>2.5</sub> measurement data ( $R^2 > 0.99$ ).
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test



# Discussion: PM<sub>2.5</sub>

- **Measurement duration:** AirBeam3 sensors report 1-min averaged values.
- **Measurement frequency:** AirBeam3 sensors report 1-min averaged values. The obtained data was used for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), and condensed to 5-minute averages for linear correlation studies against the FEM T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the AirBeam3 sensors were tested in the field for two months. The PM<sub>2.5</sub> laboratory studies lasted for about 9 days with intermittent non-operating periods and a storage period of ~ 4 months.
- **Concentration range:** Up to 1000 µg/m<sup>3</sup> as suggested by the manufacturer. During the laboratory evaluation, the AirBeam3 sensors were challenged with PM<sub>2.5</sub> concentrations up to 300 µg/m<sup>3</sup>.
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the 65% RH change point.
- **Response to loss of power:** AirBeam3 sensors were powered through the entirety of the lab tests.