

Laboratory Evaluation PM Monitor iMonPM



Outline

1. Background
2. $PM_{1.0}$
3. $PM_{2.5}$
4. PM_{10}

DRAFT

Background

Three **PM Monitor iMonPM** (hereinafter **iMonPM**) sensors were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (03/17/2022 to 05/17/2022) 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.

iMonPM (3 units tested in the lab):

- Particle sensor: **optical; non-FEM (Wuhan Cubic PM3006S)**
- Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu\text{g}/\text{m}^3$), T ($^{\circ}\text{C}$) and RH (%)
- **Unit cost: \$1,995**
- Time resolution: 1-min
- Units IDs: 0028, 0029, 0030



Reference instruments:

- $PM_{2.5}$ instrument (**Teledyne T640x, San Diego, CA; hereinafter FEM T640x**); **cost: ~\$37,000**
- Time resolution: 1-min
- PM_{10} instrument (**non-FEM, APS, TSI, Shoreview, MN**); **cost: ~\$55,000**
- Time resolution: 1-min



FEM T640x

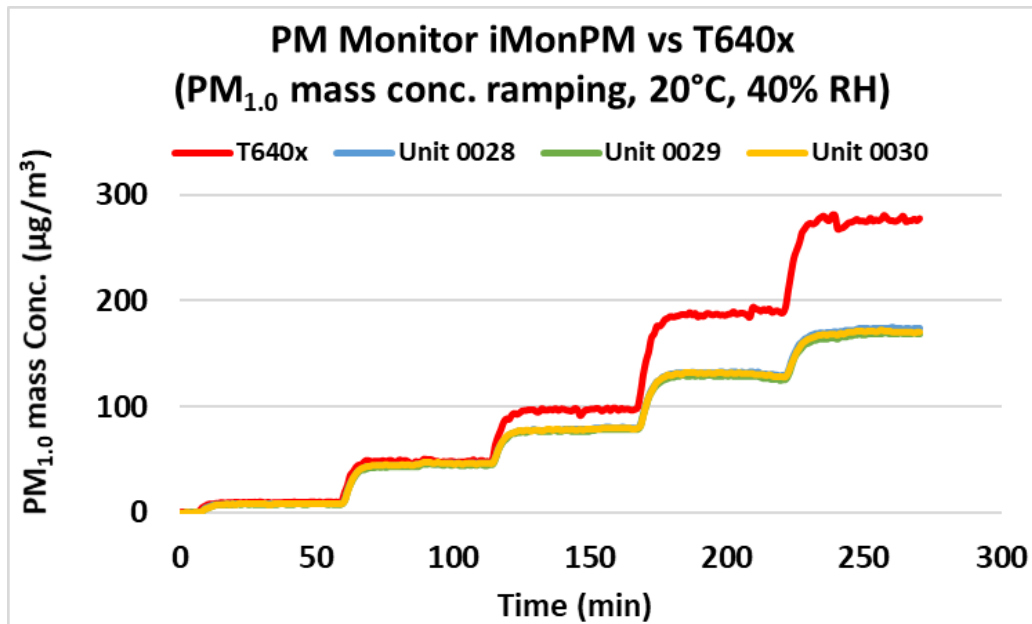


APS

PM_{1.0}

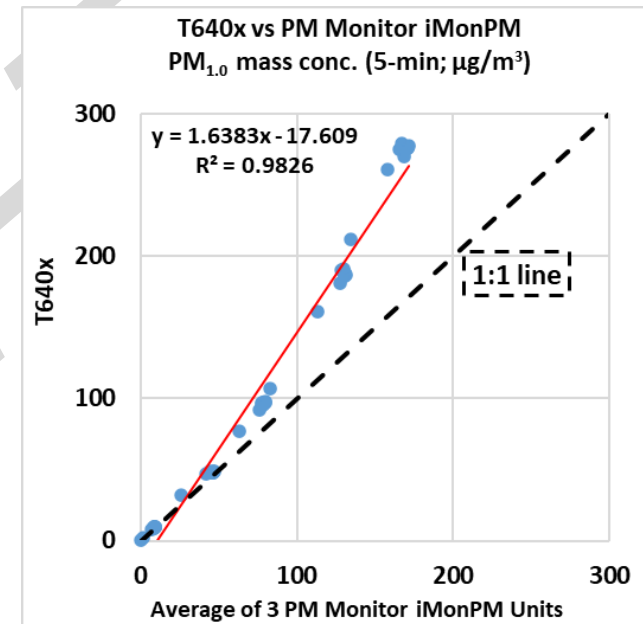
1. T640x vs iMonPM
2. Accuracy, data recovery, and intra-model variability
3. Precision
4. Climate susceptibility
5. Discussion

iMonPM vs T640x (PM_{1.0})



- The iMonPM sensors tracked well with the concentration variation but underestimated PM_{1.0}, compared to the T640x in the concentration range of 0 - 300 $\mu\text{g}/\text{m}^3$.

Coefficient of Determination



- The iMonPM sensors showed very strong correlations with the T640x PM_{1.0} mass conc. ($R^2 > 0.98$)

iMonPM vs T640x PM_{1.0} Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	Sensor Mean (µg/m ³)	T640x (µg/m ³)	Accuracy (%)
1	8.9	9.4	94.6
2	46.4	48.0	96.8
3	79.5	97.3	81.6
4	129.9	189.4	68.6
5	171.2	276.6	61.9

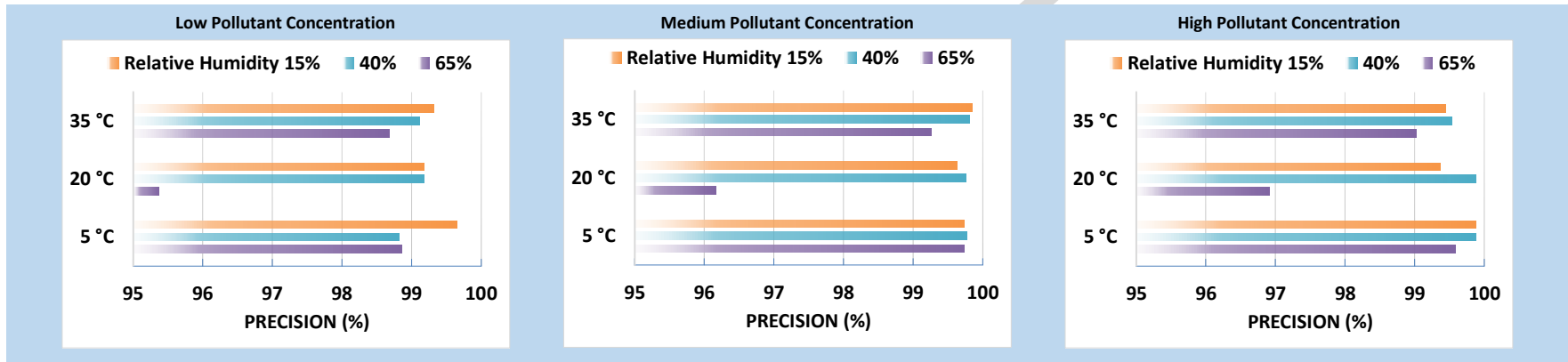
- The iMonPM sensors underestimated PM_{1.0} concentration values compared to the T640x PM_{1.0} mass concentration at 20 °C and 40% RH. The iMonPM sensors' accuracy decreased as concentrations increased from 10 to 300 µg/m³ as compared to the reference T640x.

iMonPM Data Recovery and Intra-model Variability

- Data recovery for PM_{1.0} measurements was 100% for units 0029 and 0030; Unit 0028 did not report data or reported flat-lined data for certain experiments.
- Low PM_{1.0} concentration variations were observed between the units at 20 °C and 40% RH, at low, medium, and high PM_{1.0} as measured by the T640x.

Precision: iMonPM (PM_{1.0})

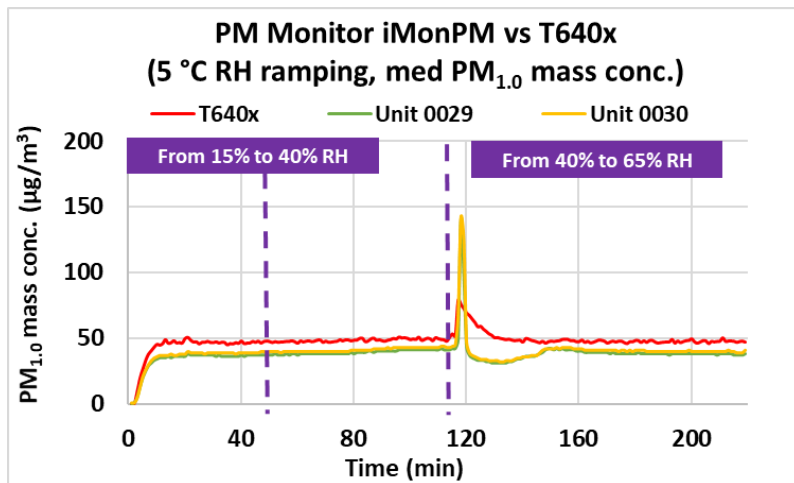
- Precision (effect of PM_{1.0} conc., temperature and relative humidity)



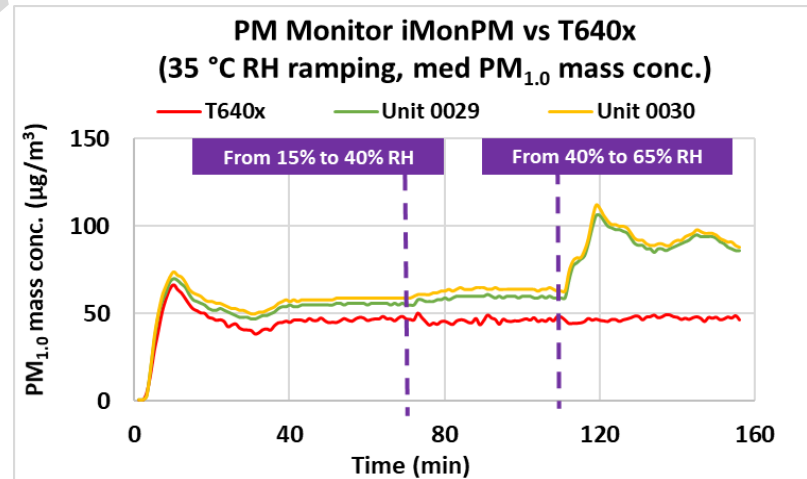
- Overall, the iMonPM sensors showed high precision for all combinations of PM_{1.0} conc., T, and RH.

Climate Susceptibility: iMonPM (PM_{1.0})

Low Temp - RH ramping
(medium conc.)



High Temp – RH ramping
(medium conc.)



Discussion: PM_{1.0}

- **Accuracy:** The iMonPM sensors underestimated PM_{1.0} concentration values compared to the T640x PM_{1.0} mass concentration at 20 °C and 40% RH. The iMonPM sensors' accuracy decreased as concentrations increased from 10 to 300 µg/m³ as compared to the reference T640x.
- **Precision:** The three iMonPM sensors exhibited high precision during all tested PM_{1.0} conc., T, and RH conditions.
- **Intra-model variability:** Low PM_{1.0} measurement variations were observed among the three iMonPM sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM_{1.0} measurements was 100% for units 0029 and 0030; Unit 0028 did not report data or reported flat-lined data for certain experiments.
- **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 m³ chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three iMonPM sensors showed very strong correlation/linear response with the corresponding T640x PM_{1.0} measurement data ($R^2 > 0.98$).
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test

Discussion: PM_{1.0}

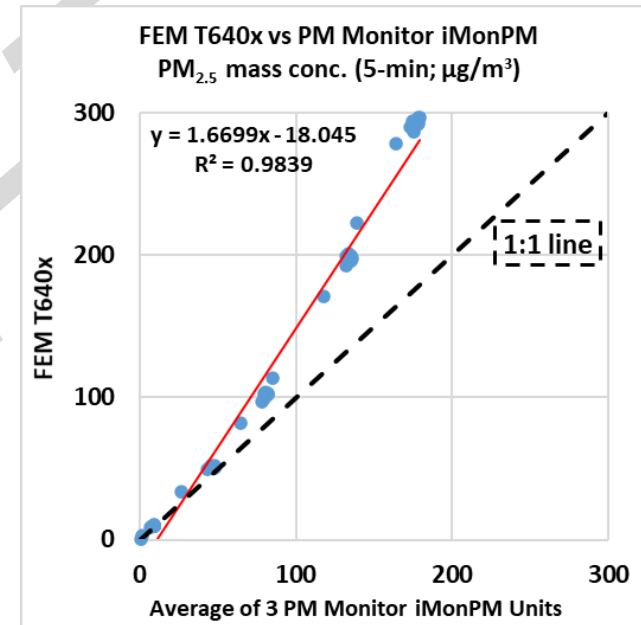
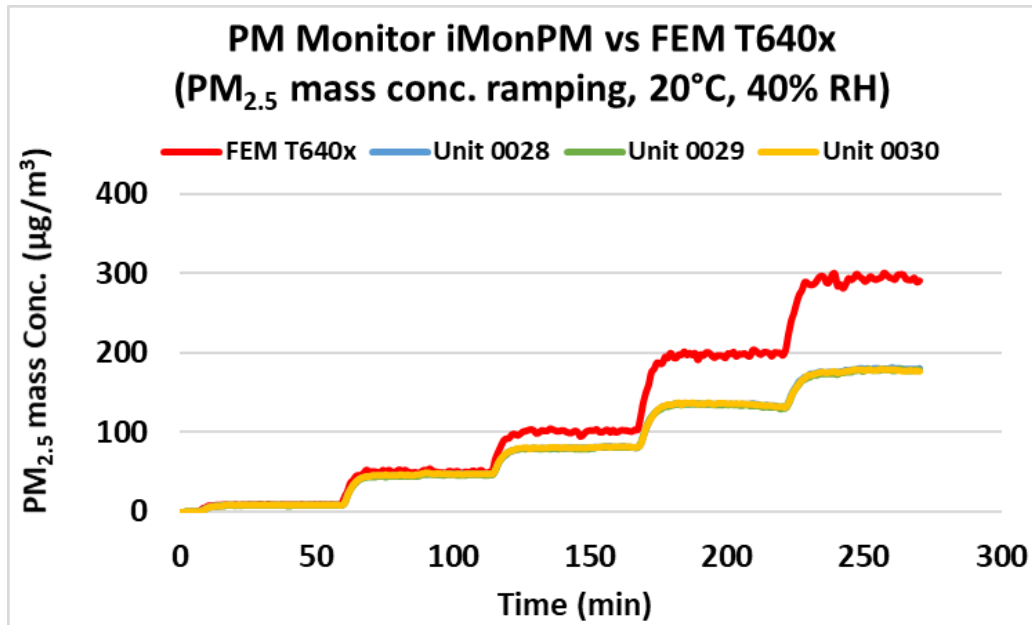
- **Measurement duration:** iMonPM sensors report 1-min averaged values.
- **Measurement frequency:** iMonPM sensors report 1-min averaged values. The obtained data was used for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), and condensed to 5-minute averages for linear correlation studies against the T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the iMonPM sensors were tested in the field for two months. The PM_{1.0} laboratory studies lasted for about 9 days with intermittent non-operating periods and a storage period of ~ 3 months.
- **Concentration range:** Up to 1000 µg/m³ as suggested by the manufacturer. During the laboratory evaluation, the iMonPM sensors were challenged with PM_{1.0} concentrations up to 300 µg/m³.
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the RH change points, especially at the 65% RH change point. The sensors overestimated the PM_{1.0} concentrations at 65% RH at 20 °C and 35 °C compared to the T640x.
- **Response to loss of power:** iMonPM sensors were powered through the entirety of the lab tests.

PM_{2.5}

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

iMonPM vs FEM T640x (PM_{2.5})

Coefficient of Determination



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

- The iMonPM sensors showed very strong correlations with the FEM T640x PM_{2.5} mass conc. ($R^2 > 0.98$)

iMonPM vs FEM T640x PM_{2.5} Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	Sensor Mean (µg/m ³)	FEM T640x (µg/m ³)	Accuracy (%)
1	9.0	9.8	91.5
2	47.5	50.7	93.7
3	81.4	102.4	79.5
4	133.8	199.3	67.1
5	178.5	294.4	60.7

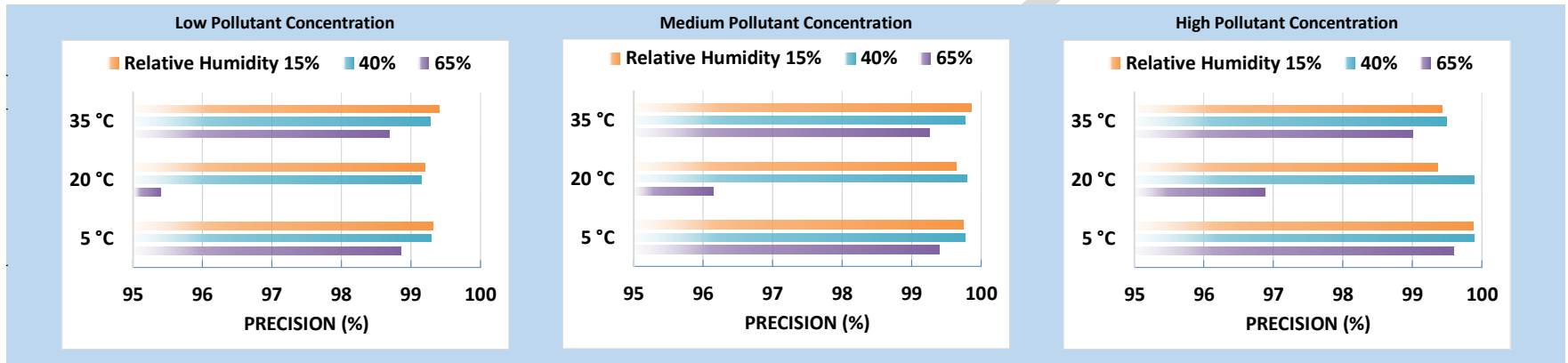
- Overall, the iMonPM sensors underestimated PM_{2.5} concentration values compared to the FEM T640x PM_{2.5} mass concentration at 20 °C and 40% RH. The iMonPM sensors' accuracy decreased as concentrations increased from 10 to 300 µg/m³ as compared to the reference FEM T640x.

iMonPM Data Recovery and Intra-model Variability

- Data recovery for PM_{2.5} measurements was 100% for units 0029 and 0030; Unit 0028 did not report data or reported flat-lined data for certain experiments.
- Low PM_{2.5} concentration variations were observed between the units at 20 °C and 40% RH, at low, medium, and high PM_{2.5} as measured by the T640x.

Precision: iMonPM (PM_{2.5})

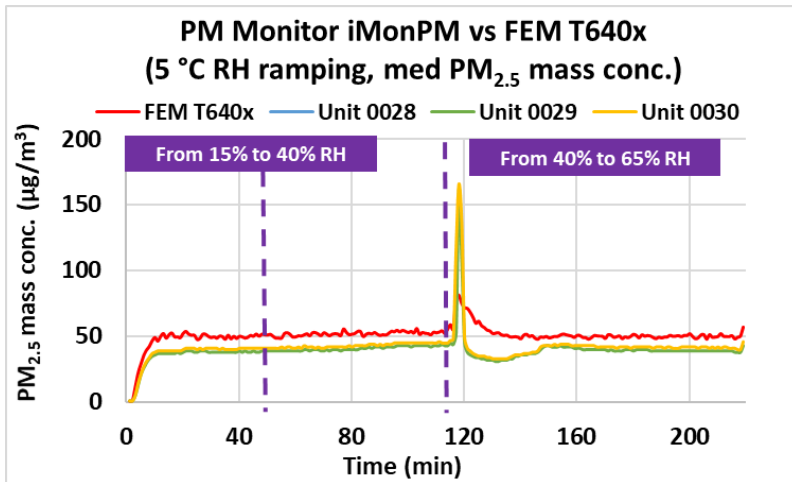
- Precision (effect of PM_{2.5} conc., temperature and relative humidity)



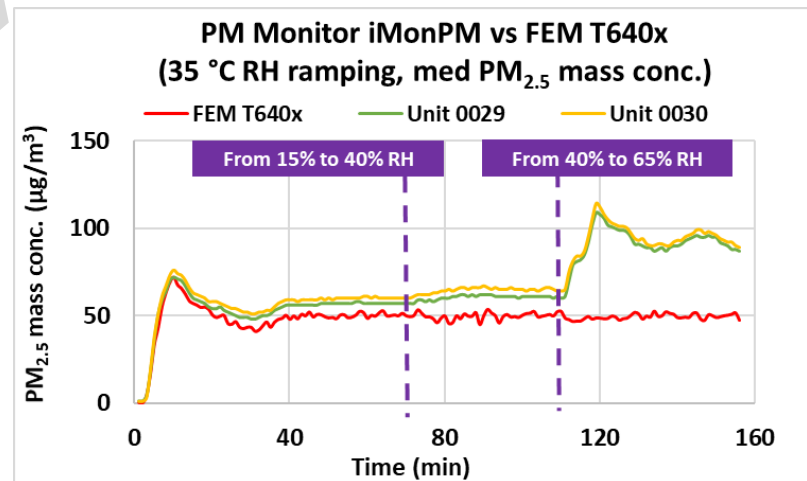
- Overall, the iMonPM sensors showed high precision for all combinations of PM_{2.5} conc., T, and RH.

Climate Susceptibility: iMonPM (PM_{2.5})

Low Temp - RH ramping
(medium conc.)



High Temp - RH ramping
(medium conc.)



Discussion: PM_{2.5}

- **Accuracy:** the iMonPM sensors underestimated PM_{2.5} concentration values compared to the FEM T640x PM_{2.5} mass concentration at 20 °C and 40% RH. The iMonPM sensors' accuracy decreased as concentrations increased from 10 to 300 µg/m³ as compared to the reference FEM T640x.
- **Precision:** The three iMonPM sensors exhibited high precision during all tested PM_{2.5} conc., T, and RH conditions.
- **Intra-model variability:** Low PM_{2.5} measurement variations were observed among the three iMonPM sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM_{2.5} measurements was 100% for units 0029 and 0030; Unit 0028 did not report data or reported flat-lined data for certain experiments.
- **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 m³ chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three iMonPM sensors showed very strong correlation/linear response with the corresponding FEM T640x PM_{2.5} measurement data ($R^2 > 0.98$).
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test

Discussion: PM_{2.5}

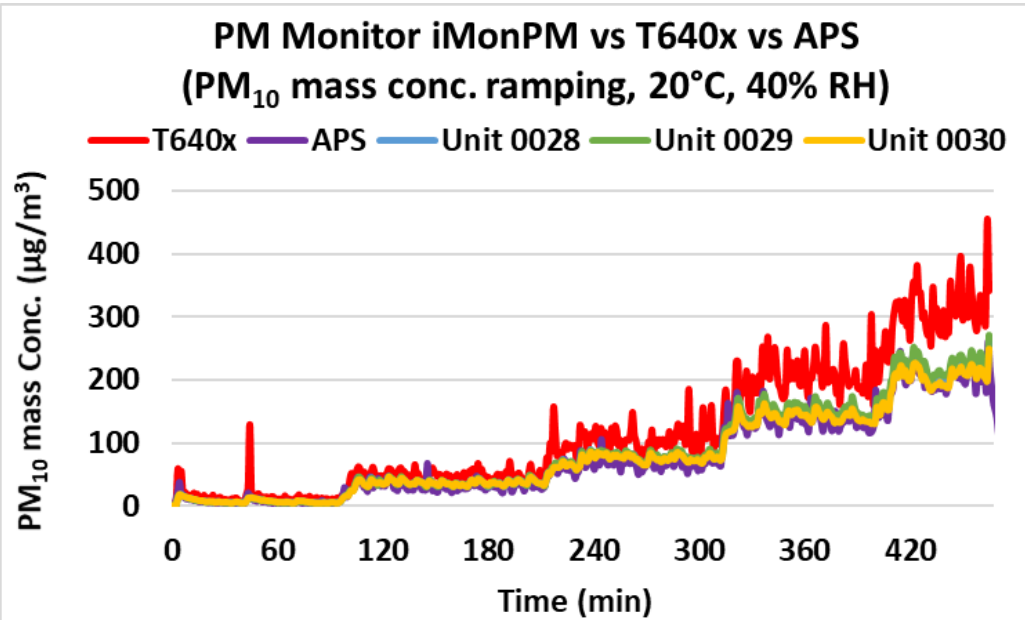
- **Measurement duration:** iMonPM sensors report 1-min averaged values.
- **Measurement frequency:** iMonPM sensors report 1-min averaged values. The obtained data was used for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), and condensed to 5-minute averages for linear correlation studies against the FEM T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the iMonPM sensors were tested in the field for two months. The PM_{2.5} laboratory studies lasted for about 9 days with intermittent non-operating periods and a storage period of ~ 3 months.
- **Concentration range:** Up to 1000 µg/m³ as suggested by the manufacturer. During the laboratory evaluation, the iMonPM sensors were challenged with PM_{2.5} concentrations up to 300 µg/m³. (refer to slide 8)
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the RH change points, especially at the 65% RH change point. Increasing RH led to less underestimation compared to the FEM T640x.
- **Response to loss of power:** iMonPM sensors were powered through the entirety of the lab tests.

PM₁₀

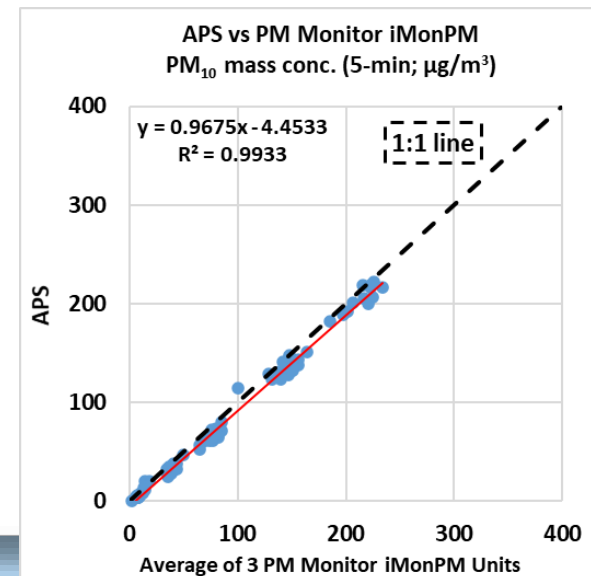
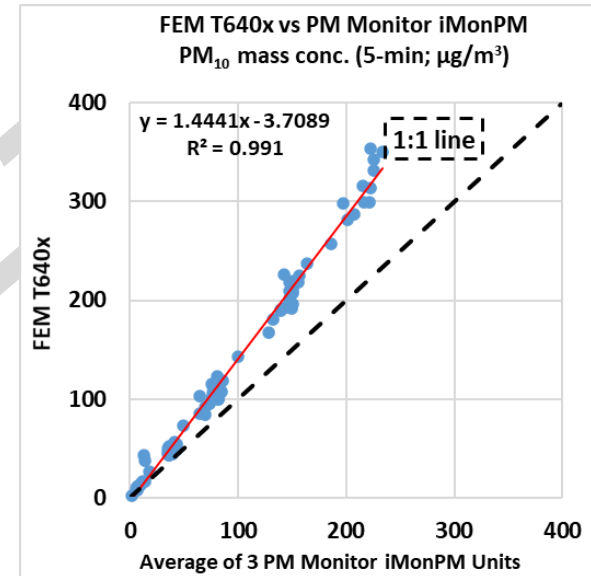
1. **FEM T640x vs APS vs iMonPM**
2. **Accuracy, data recovery, and intra-model variability**
3. **Climate susceptibility**
4. **Discussion**

iMonPM vs FEM T640x vs APS (PM₁₀)

Coefficient of Determination



- The iMonPM sensors tracked well with the PM₁₀ concentration variations as recorded by the FEM T640x and APS in the concentration range of 0 - 300 µg/m³.
- The iMonPM sensors showed very strong correlations with the FEM T640x and APS PM₁₀ mass conc. ($R^2 > 0.99$)



iMonPM vs FEM T640x vs APS: PM₁₀ Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	Sensor Mean (µg/m ³)	FEM T640x (µg/m ³)	Accuracy (%)	Steady State #	Sensor Mean (µg/m ³)	APS (µg/m ³)	Accuracy (%)
1	6.7	10.3	65.0	1	6.7	4.1	36.3
2	39.5	47.4	83.2	2	39.5	30.3	70.0
3	79.4	104.6	75.9	3	79.4	66.4	80.5
4	146.8	207.3	70.8	4	146.8	136.5	92.5
5	222.5	321.7	69.1	5	222.5	210.4	94.3

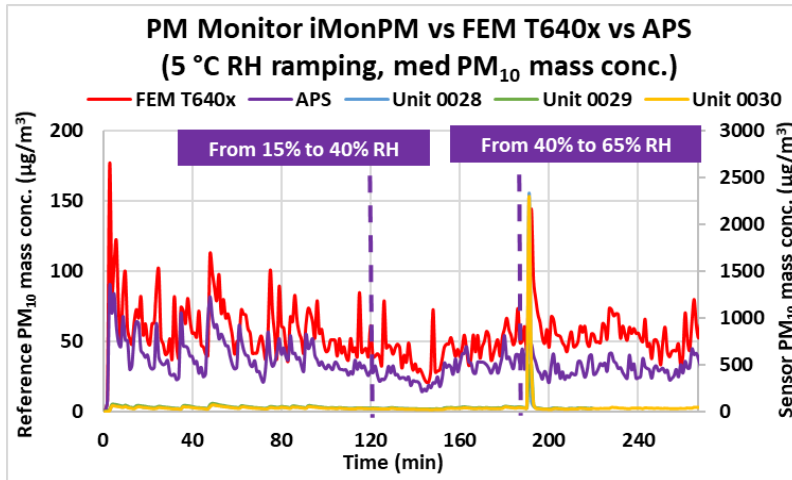
- The iMonPM sensors underestimated and overestimated PM₁₀ concentration values compared to the FEM T640x and APS PM₁₀ mass concentration at 20 °C and 40% RH, respectively. The iMonPM sensors' accuracy decreased as concentrations increased from 10 to 300 µg/m³ as compared to FEM T640x and the accuracy increased with increased PM₁₀ mass concentration as compared to the APS.

iMonPM Data Recovery and Intra-model Variability

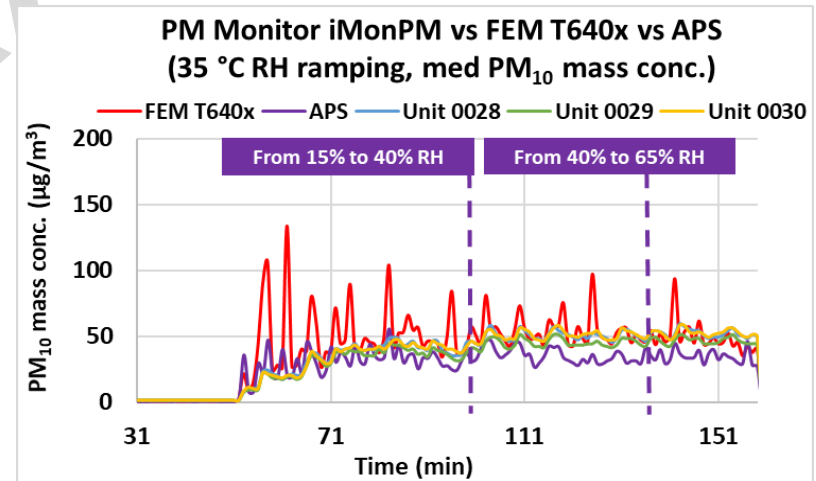
- Data recovery for PM₁₀ measurements was 100% for units 0029 and 0030. Unit 28 did not report data in several experiments because it had connectivity issues or had flatlined at 30,000 µg/m³
- Low PM₁₀ concentration variations were observed between the units at 20 °C and 40% RH, at low, medium, and high PM₁₀ as measured by the FEM T640x and the APS.

Climate Susceptibility: iMonPM (PM₁₀)

Low Temp - RH ramping
(medium conc.)



High Temp - RH ramping
(medium conc.)



Discussion: PM₁₀

- **Accuracy:** The iMonPM sensors underestimated and overestimated PM₁₀ concentration values compared to the FEM T640x and APS PM₁₀ mass concentration at 20 °C and 40% RH, respectively. The iMonPM sensors' accuracy decreased as concentrations increased from 10 to 300 µg/m³ as compared to FEM T640x and the accuracy increased with increased PM₁₀ mass concentration as compared to the APS.
- **Precision:** Due to the nature of Arizona Test Dust dispersion, the aerosol concentration showed some variability, therefore, the precision cannot be fairly estimated.
- **Intra-model variability:** Low PM₁₀ measurement variations were observed among the three iMonPM sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM₁₀ measurements was 100% for units 0029 and 0030. Unit 28 did not report data in several experiments because it had connectivity issues or had flatlined at 30,000 µg/m³
- **Bias:** N/A
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Discussion: PM₁₀

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- **Concentration range:** Up to 1000 µg/m³ as suggested by the manufacturer. During the laboratory evaluation, the iMonPM sensors were challenged with PM₁₀ concentrations up to 300 µg/m³.
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact precision. Spiked concentrations were observed at the 65% RH change points at 5 °C.
- **Response to loss of power:** iMonPM sensors were powered through the entirety of the lab tests.