Laboratory Evaluation

Piera Systems – Canāree R1

DRAFT

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Outline

1. **Background**

2. **PM$_{1.0}$**

3. **PM$_{2.5}$**

Background

Three **Piera Systems – Canāree R1 (hereinafter Canāree R1)** sensors were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (02/22/2022 to 04/23/2022) 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.

Canāree R1 (*3 units tested in the lab*):

- Particle sensor: optical; non-FEM (Piera IPS-7100)
- Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} (μg/m^3)
- Unit cost: $299 + $10/month for AQMS data and cloud services
- Time resolution: 1-min
- Units IDs: 0137, 0147, 0153

Reference instruments:

- $PM_{2.5}$ instrument (Teledyne T640x, San Diego, CA; hereinafter FEM T640x); cost: ~$37,000
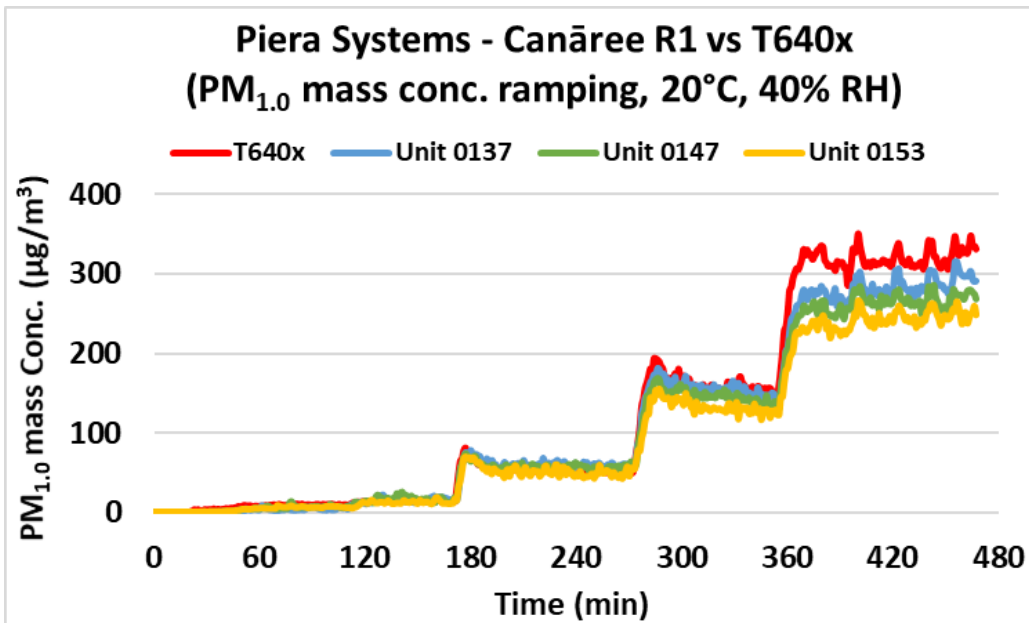 - Time resolution: 1-min


Piera Systems – Canāree R1

FEM T640x

PM$_{1.0}$

1. **T640x vs Canāree R1**

2. **Accuracy, data recovery and intra-model variability**

3. **Precision**

4. **Climate susceptibility**

5. **Discussion**

Canāree R1 vs T640x ($PM_{1.0}$)

Piera Systems - Canāree R1 vs T640x
($PM_{1.0}$ mass conc. ramping, 20°C, 40% RH)

Coefficient of Determination

T640x vs Piera Systems - Canāree R1
$PM_{1.0}$ mass conc. (5-min; $\mu g/m^3$)

$y = 1.2177x - 5.2873$
$R^2 = 0.995$

- The Canāree R1 sensors tracked well with the concentration variation but underestimated $PM_{1.0}$, compared to the T640x in the concentration range of 0 - 300 $\mu g/m^3$.
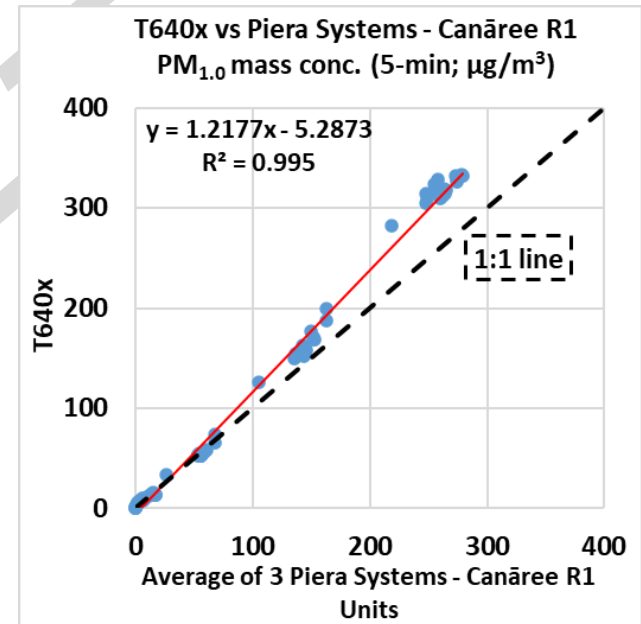
- The Canāree R1 sensors showed very strong correlations with the T640x $PM_{1.0}$ mass conc. ($R^2 > 0.99$)

Canāree R1 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	5.9	8.4	70.4
2	14.9	13.1	86.7
3	55.1	47.5	83.9
4	137.9	138.0	99.9
5	271.0	293.3	92.4

- Overall, the Canāree R1 sensors underestimated PM$_{1.0}$ concentration values compared to the T640x PM$_{1.0}$ mass concentration at 20°C and 40% RH, except at 15 and 50 µg/m^3. The Canāree R1 sensors' accuracy ranged from 70.4 to 99.9% in the range of 10 to 300 µg/m^3 as compared to the reference T640x.

Canāree R1 Data Recovery and Intra-model Variability

- Data recovery for PM$_{1.0}$ measurements was 100% for all units.
- Low to moderate 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.
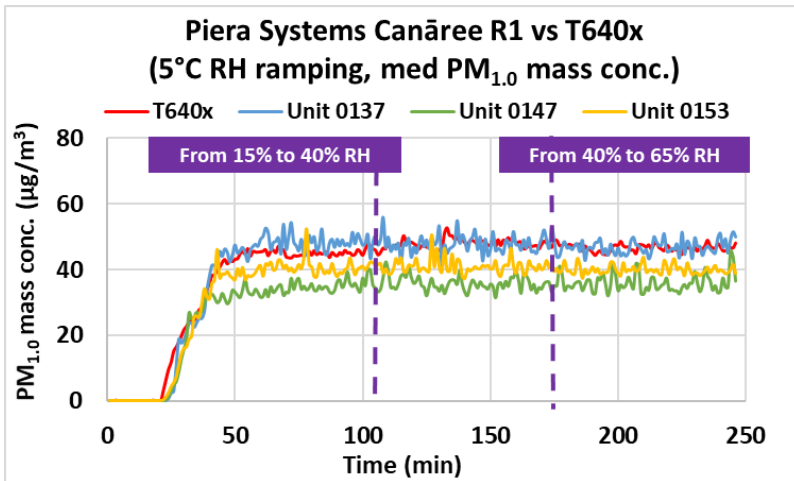
Precision: Canāree R1 (PM$_{1.0}$)

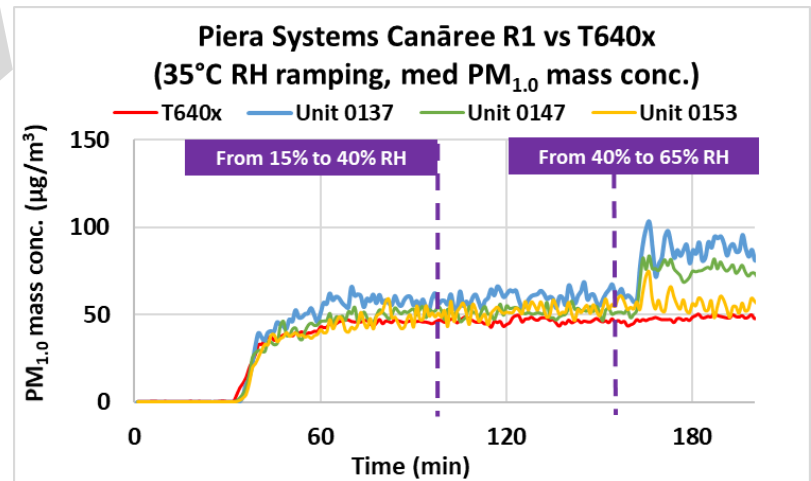- Precision (effect of PM$_{1.0}$ conc., temperature and relative humidity)
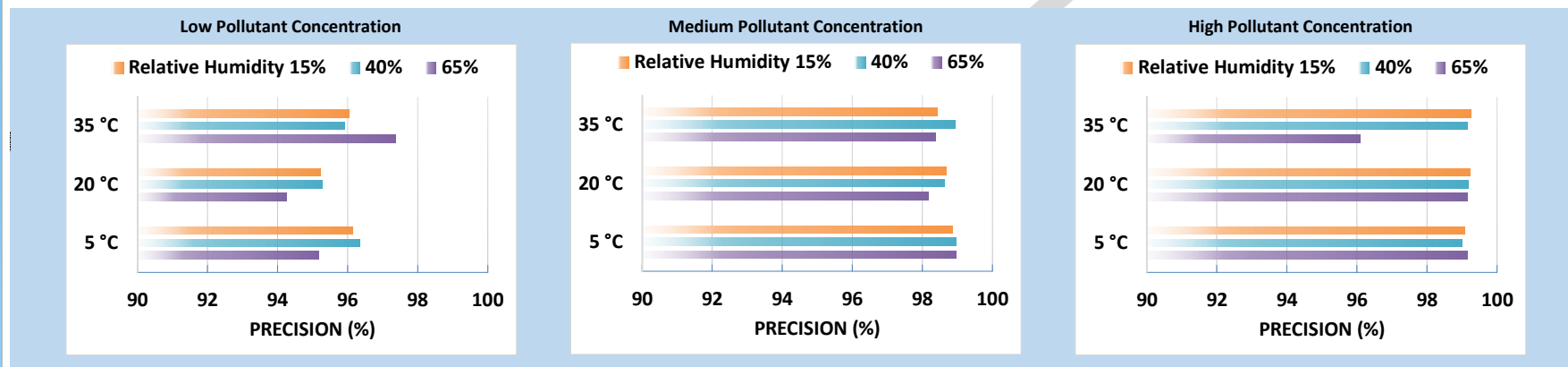
- Overall, Canāree R1 sensors showed high precision for all the combinations of low, medium, and high PM$_{1.0}$ conc., T, and RH.

Climate Susceptibility: Canāree R1 (PM$_{1.0}$)

Low Temp - RH ramping
(medium conc.)

Piera Systems Canāree R1 vs T640x
(5°C RH ramping, med PM$_{1.0}$ mass conc.)

Legend: T640x, Unit 0137, Unit 0147, Unit 0153

From 15% to 40% RH   From 40% to 65% RH

Y-axis: PM$_{1.0}$ mass conc. (µg/m³) — 0, 20, 40, 60, 80
X-axis: Time (min) — 0, 50, 100, 150, 200, 250

High Temp – RH ramping
(medium conc.)

Piera Systems Canāree R1 vs T640x
(35°C RH ramping, med PM$_{1.0}$ mass conc.)

Legend: T640x, Unit 0137, Unit 0147, Unit 0153

From 15% to 40% RH   From 40% to 65% RH

Y-axis: PM$_{1.0}$ mass conc. (µg/m³) — 0, 50, 100, 150
X-axis: Time (min) — 0, 60, 120, 180

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Discussion: $PM_{1.0}$

➢ **Accuracy**: Overall, the Canāree R1 sensors underestimated $PM_{1.0}$ concentration values compared to the T640x $PM_{1.0}$ mass concentration at 20°C and 40% RH, except at 15 and 50 $\mu g/m^3$. The Canāree R1 sensors' accuracy ranged from 70.4 to 99.9% in the range of 10 to 300 $\mu g/m^3$ as compared to the reference T640x.

➢ **Precision**: The three Canāree R1 sensors exhibited high precision during all tested $PM_{1.0}$ conc., T, and RH conditions.

➢ **Intra-model variability**: Low to moderate $PM_{1.0}$ measurement variations were observed among the three Canāree R1 sensors at 20°C and 40% RH.

➢ **Data Recovery:** Data recovery for $PM_{1.0}$ 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^3 chamber volume, it was not possible to reach a high pollutant concentration within a short time.

➢ **Linear Correlation**: The three Canāree R1 sensors showed very strong correlation/linear response with the corresponding T640x $PM_{1.0}$ measurement data ($R^2 > 0.99$).

➢ **Selectivity:** N/A for PM sensors test
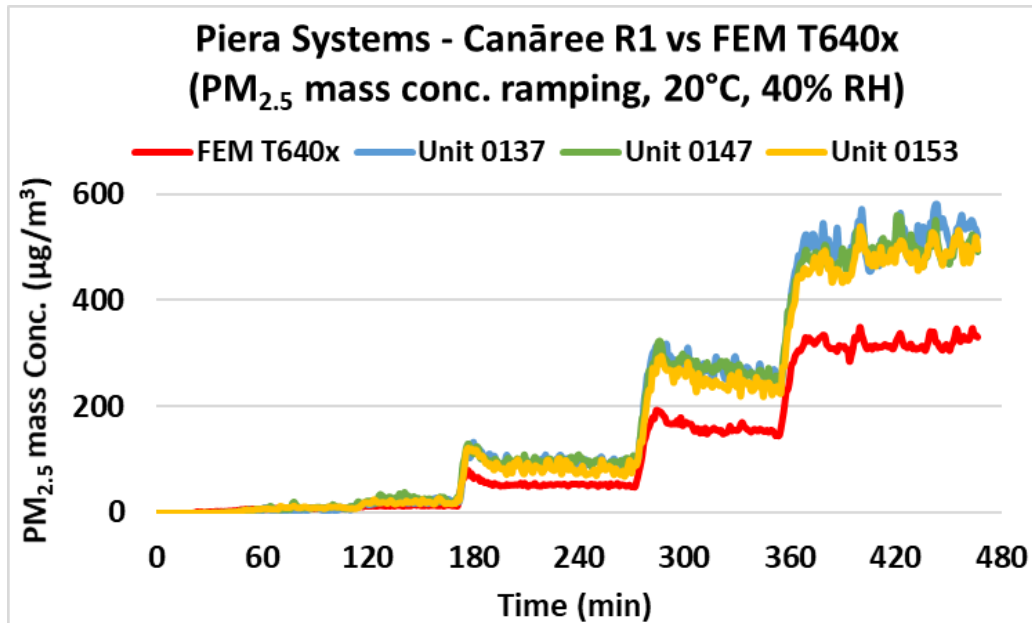
➢ **Interferences:** N/A for PM sensors test

Discussion: PM$_{1.0}$

➤ **Measurement duration**: Canāree R1 sensors report 1-min averaged values.

➤ **Measurement frequency:** Canāree R1 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 Canāree R1 sensors were tested in the field for two months. The PM$_{1.0}$ laboratory studies lasted for about three weeks with intermittent non-operating periods and a storage period of ~12 months.

➤ **Concentration range**: Up to 1000 µg/m^3 as suggested by the manufacturer. During the laboratory evaluation, the Canāree R1 sensors were challenged with PM$_{1.0}$ concentrations up to 300 µg/m^3.

➤ **Drift**: N/A

➤ **Climate susceptibility**: During the lab studies, climate did not significantly impact sensors' 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**: Canāree R1 sensors were powered through the entirety of the lab tests.
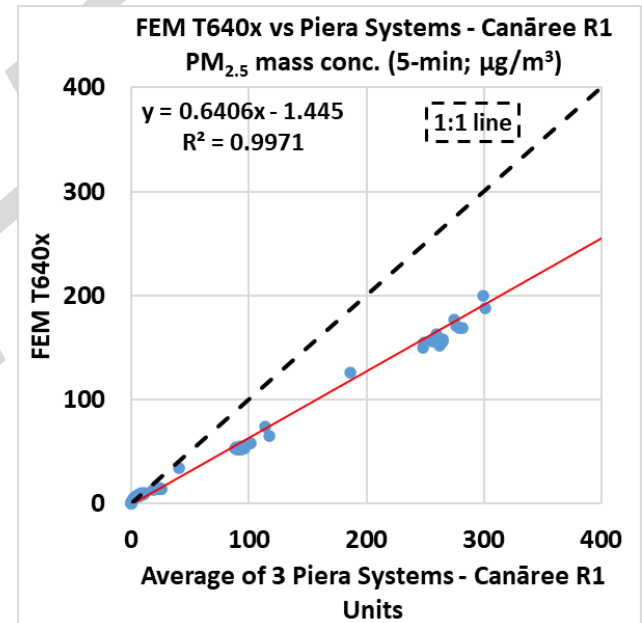
PM$_{2.5}$

1. **FEM T640x vs Canāree R1**

2. **Accuracy, data recovery and intra-model variability**

3. **Precision**

4. **Climate susceptibility**

5. **Discussion**

Canāree R1 vs FEM T640x (PM$_{2.5}$)

Coefficient of Determination

Piera Systems - Canāree R1 vs FEM T640x
(PM$_{2.5}$ mass conc. ramping, 20°C, 40% RH)

FEM T640x — Unit 0137 — Unit 0147 — Unit 0153

FEM T640x vs Piera Systems - Canāree R1
PM$_{2.5}$ mass conc. (5-min; µg/m³)

$y = 0.6406x - 1.445$
$R^2 = 0.9971$

1:1 line

- The Canāree R1 sensors tracked well with the concentration variation but overestimated PM$_{2.5}$, compared to the FEM T640x in the concentration range of 0 - 300 µg/m³.

- The Canāree R1 sensors showed very strong correlations with the FEM T640x PM$_{2.5}$ mass conc. ($R^2 > 0.99$)

Canāree R1 vs FEM T640x PM$_{2.5}$ Accuracy

- Accuracy (20°C and 40% RH)

| Steady State #	Sensor Mean (µg/m³)	FEM T640x (µg/m³)	Accuracy (%)
1	9.8	9.3	94.7
2	23.3	14.3	37.7
3	92.3	52.6	24.5
4	252.2	154.1	36.4
5	508.7	327.1	44.5

- Overall, the Canāree R1 sensors overestimated PM$_{2.5}$ concentration values compared to the FEM T640x PM$_{2.5}$ mass concentration at 20°C and 40% RH. The Canāree R1 sensors' accuracy ranged from 24.5% to 94.7% in the range of 10 to 300 µg/m³ as compared to the reference FEM T640x.

Canāree R1 Data Recovery and Intra-model Variability

- Data recovery for PM$_{2.5}$ measurements was 100% for all units.

- Low PM$_{2.5}$ 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 FEM T640x.
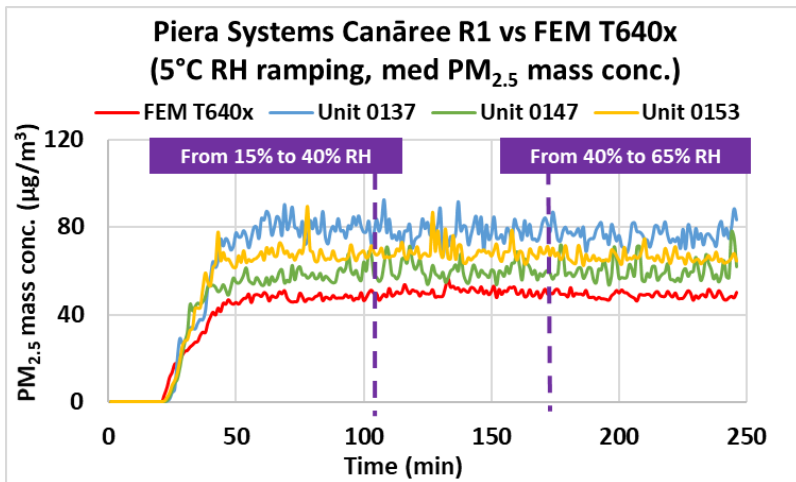
Precision: Canāree R1 (PM$_{2.5}$)

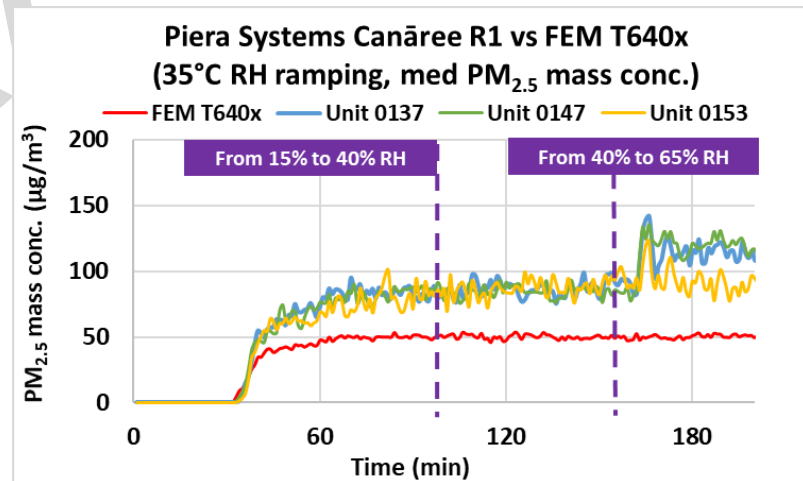- Precision (effect of PM$_{2.5}$ conc., temperature and relative humidity)
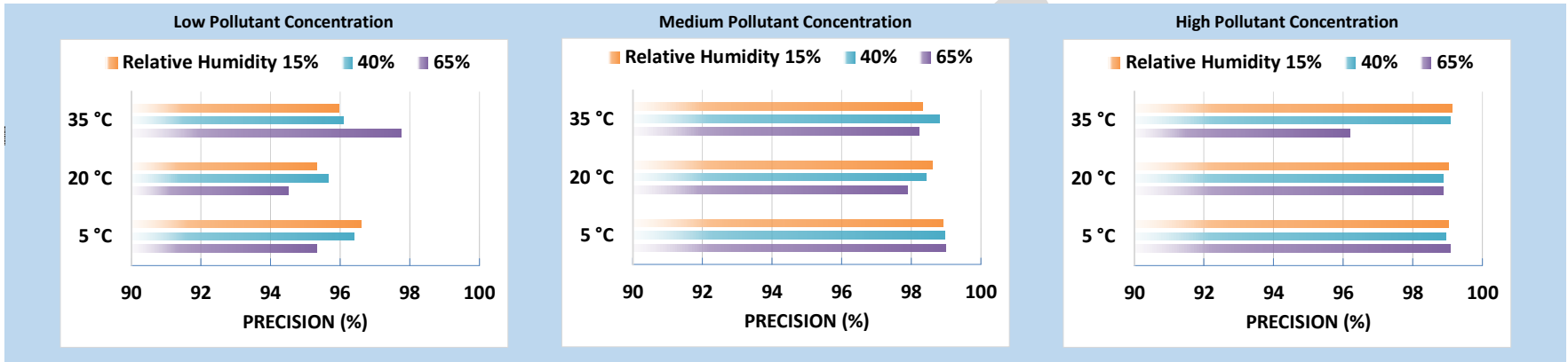
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Climate Susceptibility: Canāree R1 (PM$_{2.5}$)

**Low Temp - RH ramping
(medium conc.)**

**Piera Systems Canāree R1 vs FEM T640x
(5°C RH ramping, med PM$_{2.5}$ mass conc.)**

FEM T640x — Unit 0137 — Unit 0147 — Unit 0153

From 15% to 40% RH   From 40% to 65% RH

PM$_{2.5}$ mass conc. (µg/m^3)

120 · 80 · 40 · 0

Time (min): 0 · 50 · 100 · 150 · 200 · 250

**High Temp – RH ramping
(medium conc.)**

**Piera Systems Canāree R1 vs FEM T640x
(35°C RH ramping, med PM$_{2.5}$ mass conc.)**

FEM T640x — Unit 0137 — Unit 0147 — Unit 0153

From 15% to 40% RH   From 40% to 65% RH

PM$_{2.5}$ mass conc. (µg/m^3)

200 · 150 · 100 · 50 · 0

Time (min): 0 · 60 · 120 · 180

Discussion: PM$_{2.5}$

➢ **Accuracy**: Overall, the Canāree R1 sensors overestimated PM$_{2.5}$ concentration values compared to the FEM T640x PM$_{2.5}$ mass concentration at 20°C and 40% RH. The Canāree R1 sensors' accuracy ranged from 24.5% to 94.7% in the range of 10 to 300 µg/m^3 as compared to the reference FEM T640x.

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