Laboratory Evaluation

Alphasense OPC-N2 PM Sensor

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

DRAFT

Background

Three **Alphasense OPC-N2** (units IDs: 216, 222, 308) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (07/10/2015 to 08/10/2015) under ambient weather conditions. Now, three new OPC-N2 (units ID: 0508, 1202, 1207) have been evaluated in the South Coast AQMD Chemistry Laboratory under controlled PM concentration, temperature, and relative humidity.

OPC-N2 PMS1003 (*3 units tested*):

- Particle sensors (optical; non-FEM)
- Each unit measures: $PM_{1.0}$, $PM_{2.5}$, PM_{10} mass concentration ($\mu g/m^3$)
- Unit cost: ~$450
- Time resolution: 1.4 to 20 seconds
- Units IDs: 0508, 1202, 1207

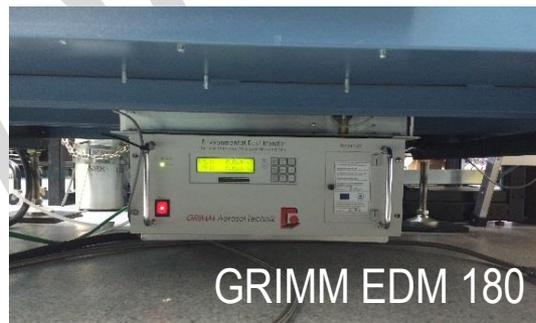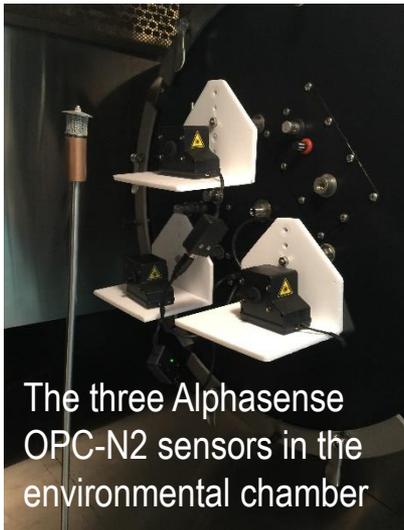## GRIMM EDM 180 (*ref. method for $PM_{1.0}$, $PM_{2.5}$ mass*):

- Optical particle counter
- FEM $PM_{2.5}$
- Uses proprietary algorithms to calculate total PM, $PM_{2.5}$, and $PM_{1.0}$ mass conc. from particle number measurements
- Cost: ~$25,000

TSI APS 3321 (*ref. method for PM_{10} mass*):

- Aerodynamic particle sizer
- Measures particles from 0.5 to 20 μm
- Uses a patented, double-crest optical system for unmatched sizing accuracy
- Cost: ~$50,000

Evaluation results guideline

- OPC-N2 *v.s.* GRIMM $PM_{1.0}$ mass concentration

- OPC-N2 *v.s.* GRIMM $PM_{2.5}$ mass concentration

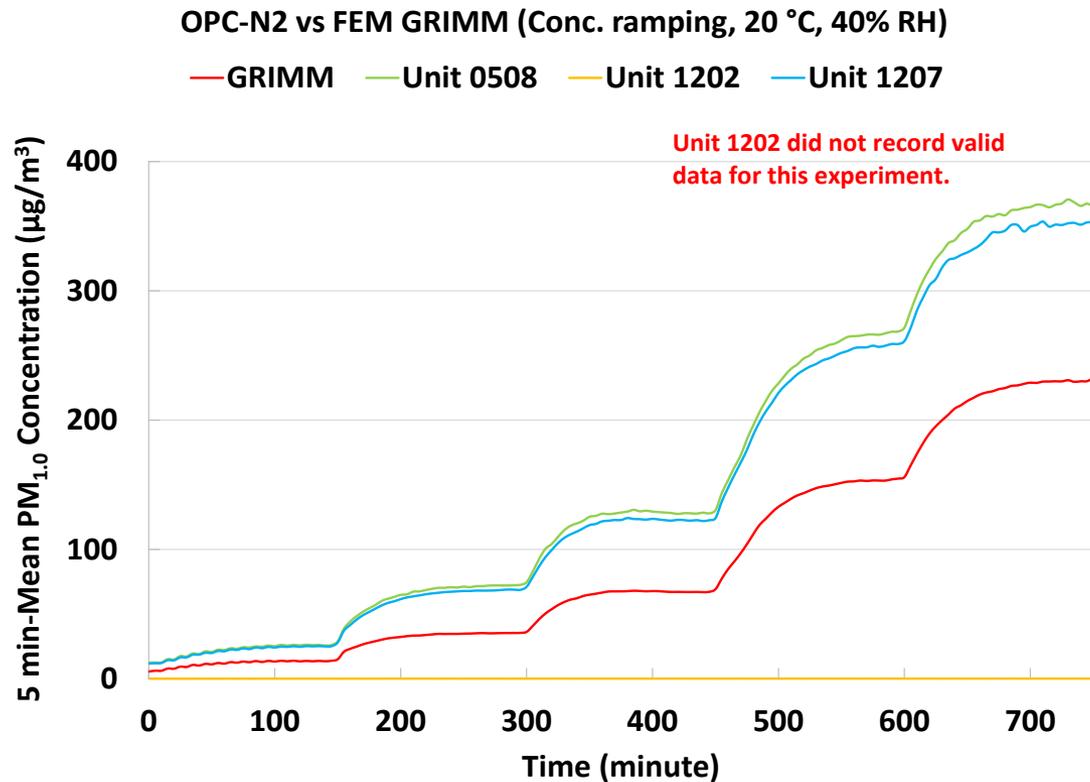- OPC-N2 *v.s.* APS *v.s.* GRIMM PM_{10} mass concentration

The three Alphasense OPC-N2 sensors in the environmental chamber

GRIMM EDM 180

TSI APS 3321

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Evaluation results for OPC-N2 PM$_{1.0}$ mass

OPC-N2 *vs* GRIMM

Coefficient of Determination: OPC-N2 $PM_{1.0}$ vs GRIMM

OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)

— GRIMM   — Unit 0508   — Unit 1202   — Unit 1207

Unit 1202 did not record valid data for this experiment.

Y-axis: 5 min-Mean $PM_{1.0}$ Concentration (μg/m^3) — 0, 100, 200, 300, 400
X-axis: Time (minute) — 0, 100, 200, 300, 400, 500, 600, 700

$PM_{1.0}$ mass (μg/m^3) 20 °C, 40% RH
1-min mean data

$y = 0.64x - 7.80$
$R^2 = 0.99$

Y-axis: FEM GRIMM — 0, 100, 200, 300, 400
X-axis: Avg. of units 0508 and 1207 — 0, 100, 200, 300, 400

- OPC-N2 units 0508 and 1207 showed very strong correlation with GRIMM $PM_{1.0}$ measurement data ($R^2 = 0.99$) between 0-230 μg/m^3.

- The OPC-N2 units overestimated the GRIMM $PM_{1.0}$ concentration.

- Over the full $PM_{1.0}$ concentration range tested (0-230 μg/m^3), OPC-N2 units 0508 and 1207 tracked well the diurnal variations as recorded by the GRIMM.

- For this experiment, Unit 1202 did not record valid measurements. Later, Unit 1202 resumed normal data logging by itself.

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OPC-N2 $PM_{1.0}$ Accuracy

- Accuracy (20 °C and 40% RH)

| Steady State (#)	Sensor mean ($\mu g/m^3$)	GRIMM ($\mu g/m^3$)	Accuracy (%)
1	25.6	13.7	13.4
2	70.6	35.3	0.3
3	125.2	67.2	13.8
4	262.8	153.9	29.2
5	360.2	230.7	43.8

- The OPC-N2 units showed low to moderate accuracy levels compared to GRIMM $PM_{1.0}$ over the concentration range of 0-230 $\mu g/m^3$. Accuracy ranged from 0.3% to 43.8%. In general, OPC-N2 units overestimated the $PM_{1.0}$ mass measured by GRIMM.

OPC-N2 $PM_{1.0}$ Data Recovery & Intra-model Variability

- Data recovery for $PM_{1.0}$ mass concentration from 0508, 1202, and 1207 was 100%, 42.4%, and 100%.

- Low $PM_{1.0}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
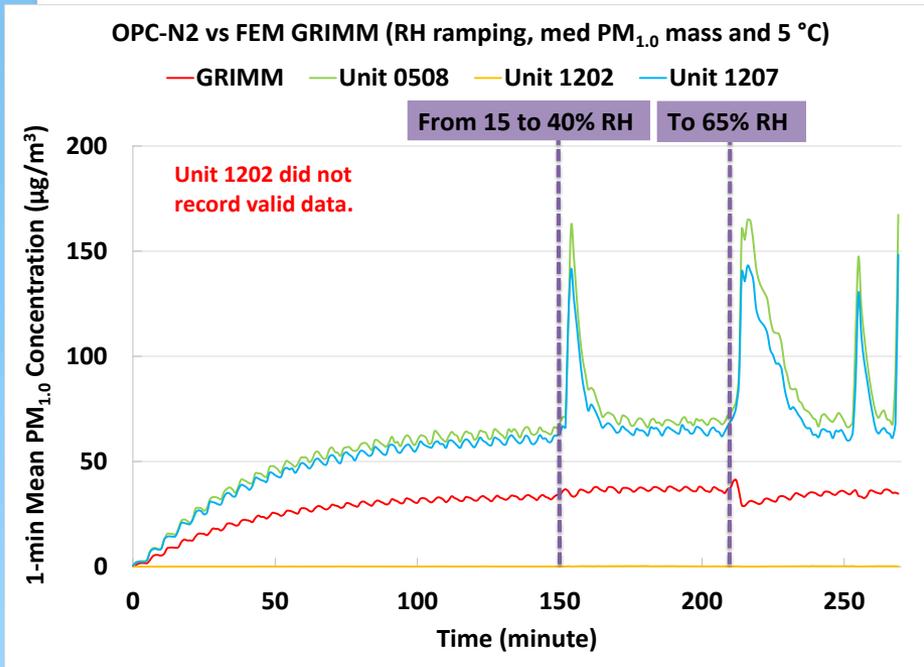
OPC-N2 PM$_{1.0}$ Precision

- Precision (%, Effect of PM$_{1.0}$ conc., temperature and relative humidity)
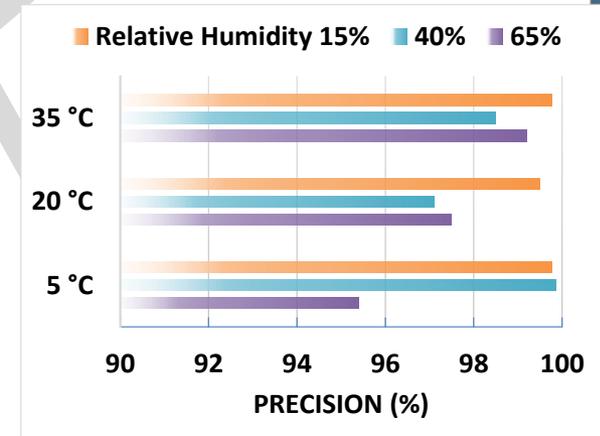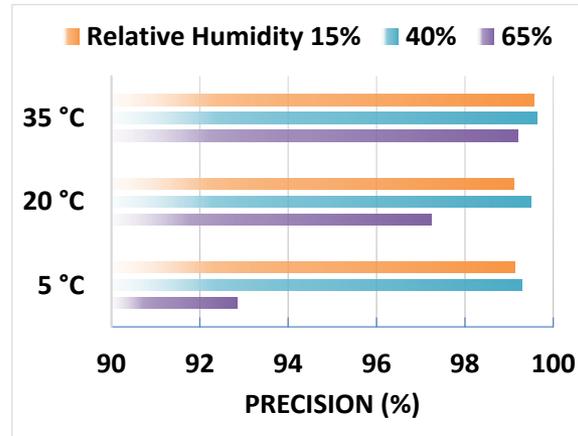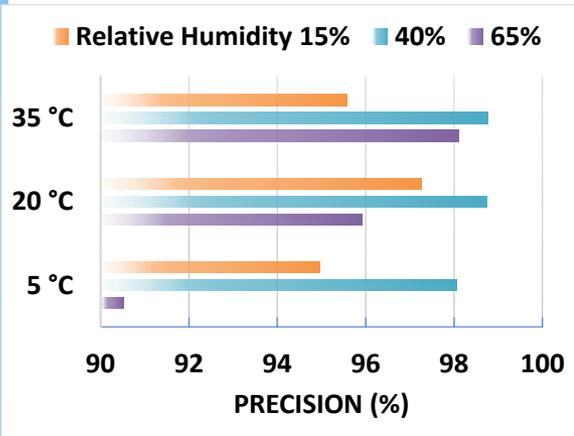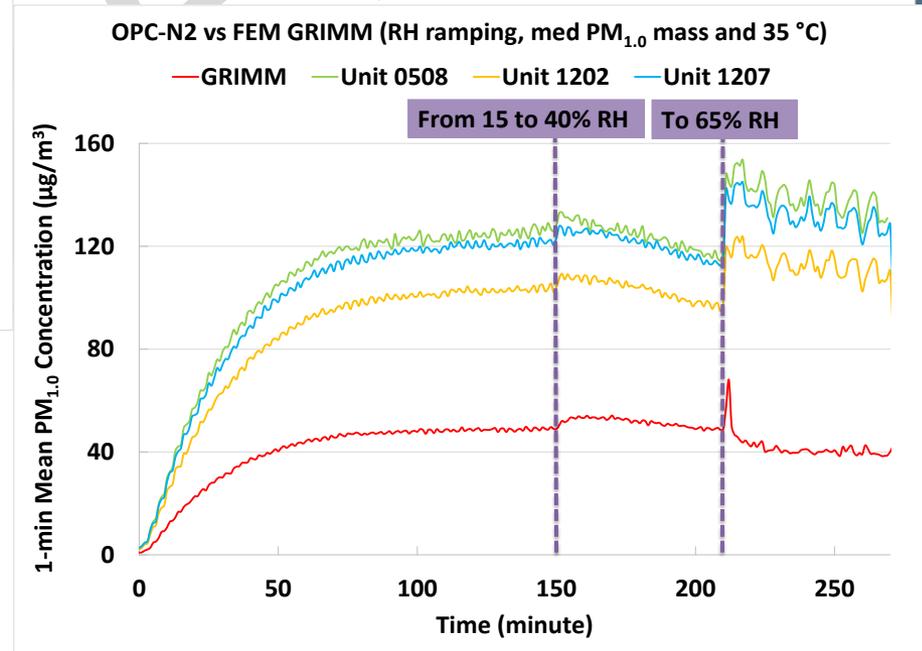

- Overall, the OPC-N2 units showed high precision for most of T, RH, and PM conc. combinations, except for very high humidity conditions at 5, and 20 °C.

- GRIMM's precision was high across all conditions.

*100% represents high precision.

OPC-N2 PM$_{1.0}$ Climate Susceptibility
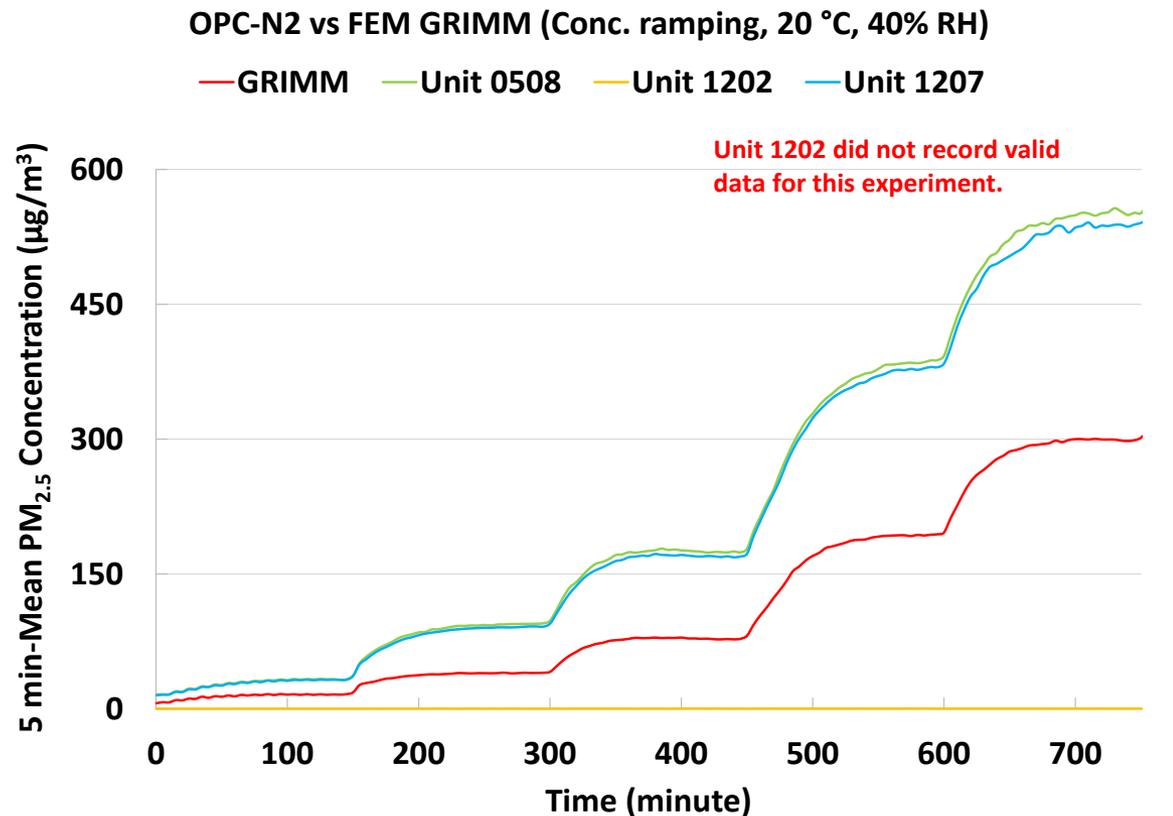

Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)
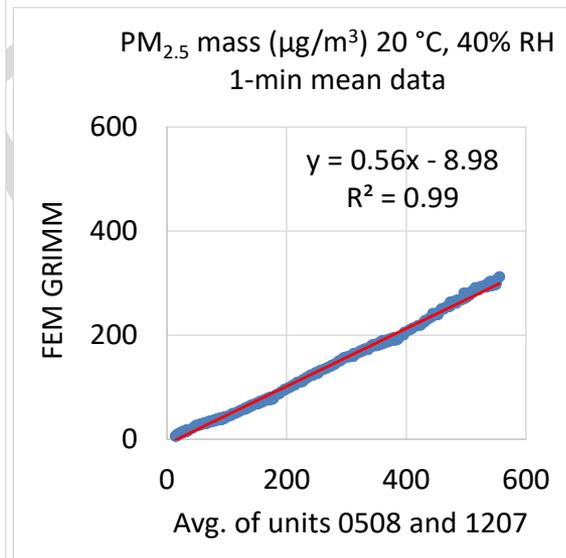
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Evaluation results for OPC-N2 PM$_{2.5}$ mass

OPC-N2 *vs* GRIMM

Coefficient of Determination: OPC-N2 PM$_{2.5}$ vs GRIMM

OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)

— GRIMM — Unit 0508 — Unit 1202 — Unit 1207

Unit 1202 did not record valid data for this experiment.

(chart: 5 min-Mean PM$_{2.5}$ Concentration (µg/m³) vs Time (minute))

PM$_{2.5}$ mass (µg/m³) 20 °C, 40% RH
1-min mean data

$y = 0.56x - 8.98$
$R^2 = 0.99$

(scatter plot: FEM GRIMM vs Avg. of units 0508 and 1207)

- OPC-N2 units 0508 and 1207 showed very strong correlation with FEM GRIMM PM$_{1.0}$ measurement data ($R^2 = 0.99$) between 0-300 µg/m³.

- The OPC-N2 units overestimated the FEM GRIMM PM$_{2.5}$ mass concentration.

- Over the full PM$_{2.5}$ concentration range tested (0-300 µg/m³), OPC-N2 units 0508 and 1207 tracked well the diurnal variations as recorded by the FEM GRIMM.

- For this experiment, Unit 1202 did not record valid measurements. Later, Unit 1202 resumed normal data logging by itself.

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OPC-N2 PM$_{2.5}$ Accuracy

- Accuracy (20 °C and 40% RH)

| Steady State (#)	Sensor mean (µg/m^3)	FEM (µg/m^3)	Accuracy (%)
1	32.6	16.0	-3.9
2	93.0	39.9	-33.2
3	171.8	77.8	-20.9
4	382.6	193.3	2.1
5	545.8	299.5	17.8

- The OPC-N2 units showed low accuracy compared to FEM GRIMM PM$_{2.5}$ over the concentration range tested (0-300 µg/m^3). Accuracy varied from -33.2% to 17.8%. At low to medium PM$_{2.5}$ concentrations, the sensors overestimated the FEM GRIMM by more than 100%, therefore, the calculated accuracy generated negative values.

OPC-N2 PM$_{2.5}$ Data Recovery & Intra-model Variability

- Data recovery for PM$_{2.5}$ mass concentration from 0508, 1202, and 1207 was 100%, 42.4%, and 100%.

- Low PM$_{2.5}$ measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.
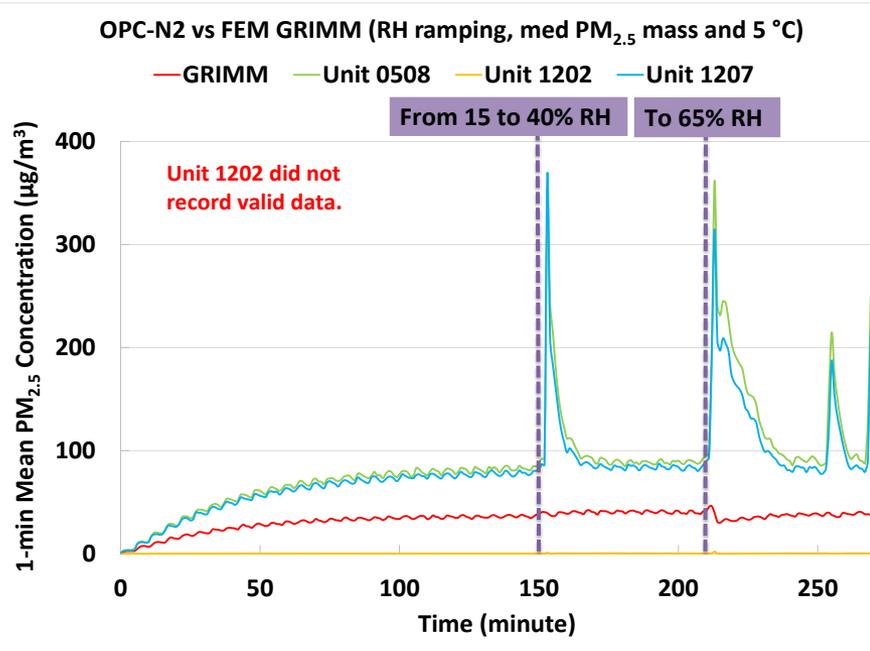
OPC-N2 PM$_{2.5}$ Precision

- Precision (%, Effect of PM$_{2.5}$ conc., temperature and relative humidity)
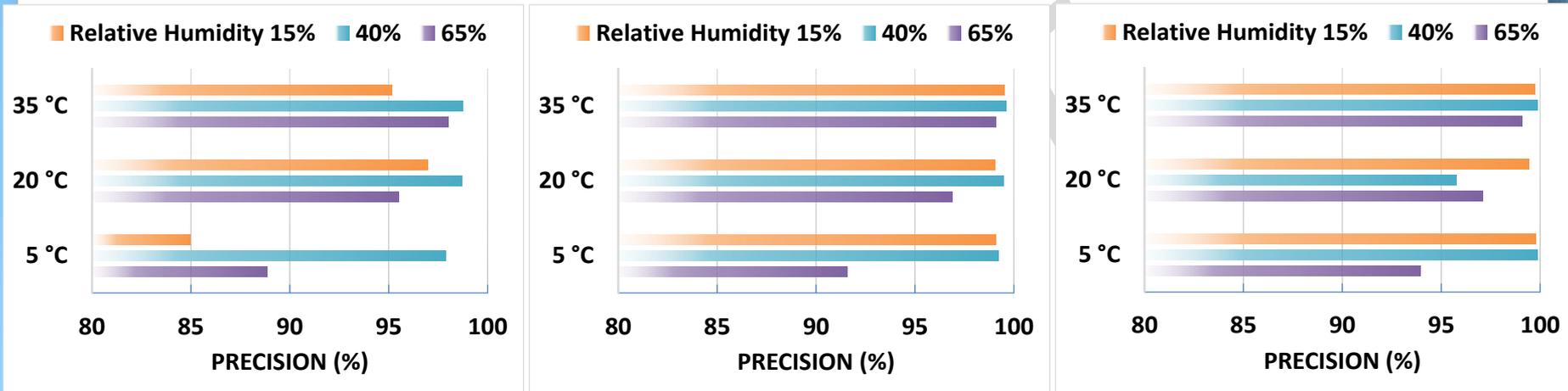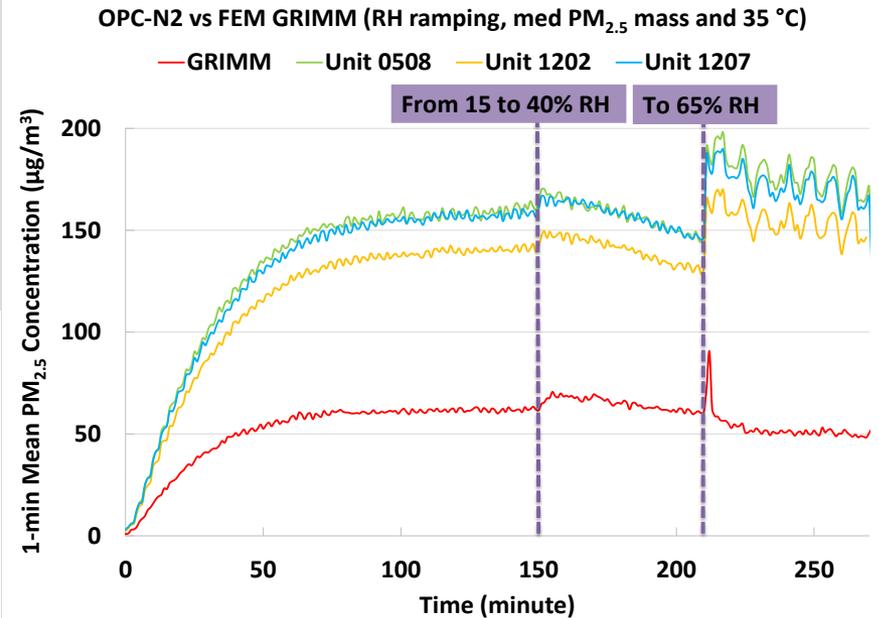

- Overall, the OPC-N2 units showed high precision for most of T, RH, and PM conc. combinations, except for high humidity levels at 5 °C, and also at 5 °C/15% RH.

- FEM GRIMM's precision was also high across all conditions.

*100% represents high precision.

OPC-N2 PM$_{2.5}$ Climate Susceptibility

OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{2.5}$ mass and 5 °C)

Low Temp – RH ramping
(medium conc.)

OPC-N2 vs FEM GRIMM (RH ramping, med PM$_{2.5}$ mass and 35 °C)

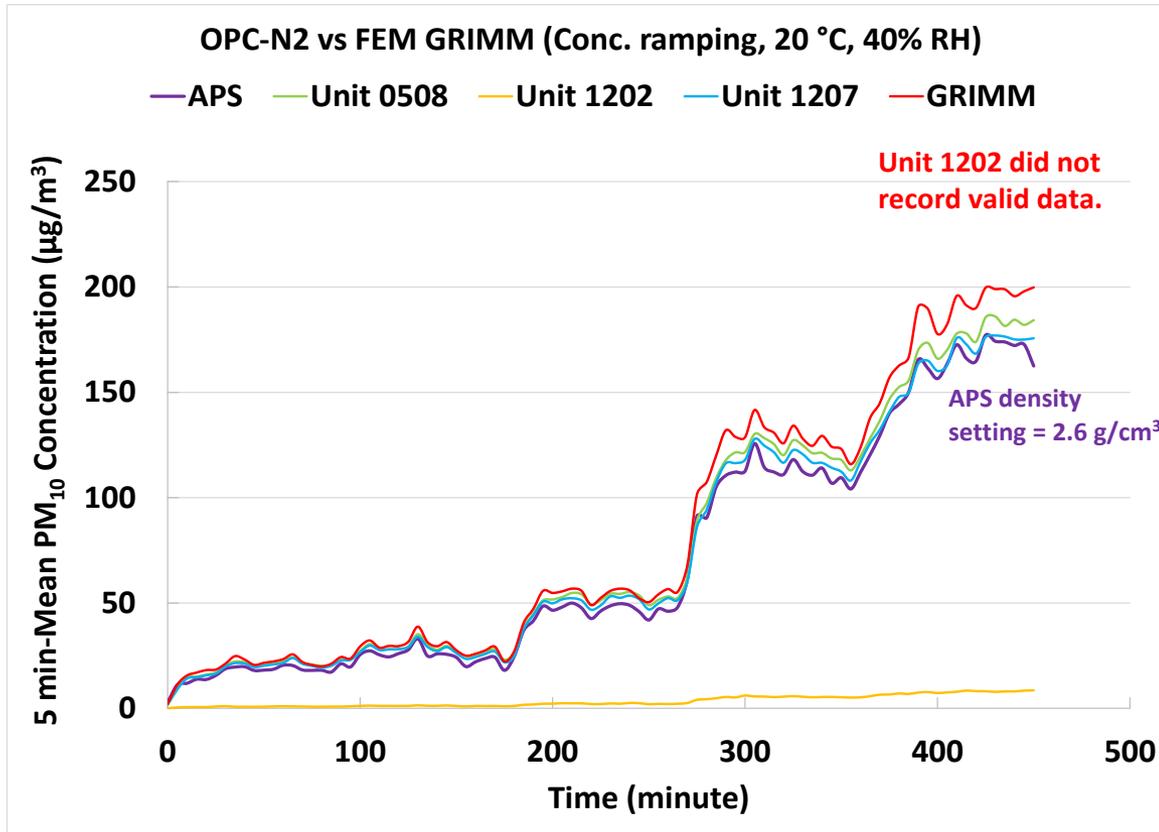High Temp – RH ramping
(medium conc.)

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Discussion

➤ **Accuracy**: Overall, the OPC-N2 units have low accuracy, compared to the GRIMM $PM_{1.0}$ and $PM_{2.5}$ in the tested range. The OPC-N2 units overestimated the $PM_{1.0}$ and $PM_{2.5}$ mass measured by GRIMM. (refer to slide 6 and 11).

➤ **Precision**: The OPC-N2 units have high precision for most of tested combinations (PM concentrations, T and RH), except at high humidity levels at 5 °C. (refer to slide 7 and 12)

➤ **Intra-model variability**: Low intra-model variability was observed between units 0508 and 1207. Unit 1202 had significant data loss, and did not record valid data during the intra-model variability experiment.

➤ **Data Recovery:** Data recovery from 0508, 1202, and 1207 was 100%, 42.4%, and 100%. Unit 1202 did not record valid data for a period of time, but later it resumed normal performance on its own.

➤ **Coefficient of Determination**: OPC-N2 units showed very strong correlation/linear response with the corresponding GRIMM $PM_{1.0}$ and $PM_{2.5}$ measurement data (R^2 = 0.99 and 0.99, respectively) for mass concentration range between 0 and 300 $\mu g/m^3$. (refer to slides 5 and 10)

➤ **Climate susceptibility**: From the laboratory studies, low temperature and high humidity affected the precision of OPC-N2 units. (refer to slide 7 and 12)

Evaluation results for OPC-N2 PM$_{10}$ mass

OPC-N2 *vs* APS *vs* GRIMM

Coefficient of Determination: OPC-N2 PM$_{10}$ vs GRIMM and APS

OPC-N2 vs FEM GRIMM (Conc. ramping, 20 °C, 40% RH)

— APS   — Unit 0508   — Unit 1202   — Unit 1207   — GRIMM

Unit 1202 did not record valid data.

APS density setting = 2.6 g/cm^3

PM$_{10}$ mass (µg/m^3) 20 °C, 40% RH
1-min mean data

$y = 0.97x - 1.72$
$R^2 = 0.99$

APS PM$_{10}$

Avg. of units 0508 and 1207

PM$_{10}$ mass (µg/m^3) 20 °C, 40% RH
1-min mean data

$y = 1.10x - 1.44$
$R^2 = 0.99$

GRIMM PM$_{10}$

Avg. of units 0508 and 1207

5 min-Mean PM$_{10}$ Concentration (µg/m^3)

Time (minute)

- Over the full PM$_{10}$ concentration range tested (0-200 µg/m^3), the OPC-N2 units tracked well the diurnal variations as recorded by the APS and GRIMM.
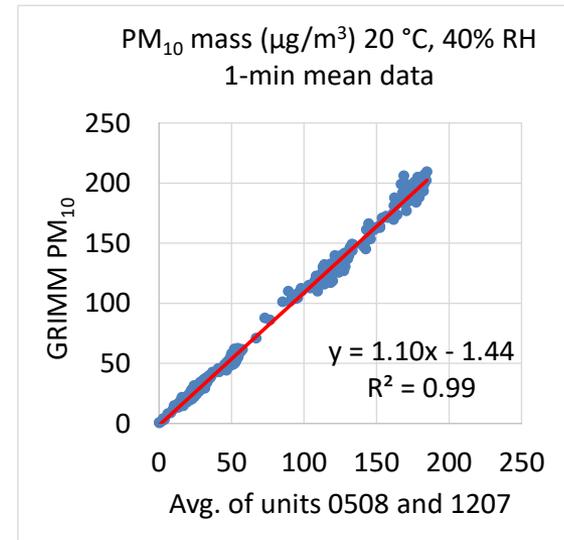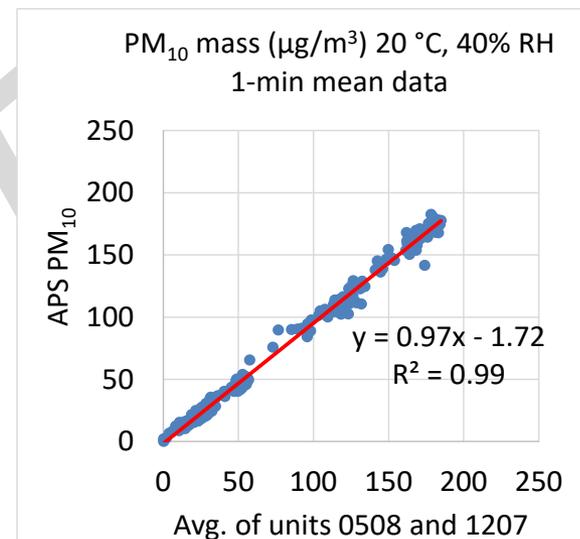
OPC-N2 vs APS: Accuracy

- Accuracy* (20 °C and 40% RH)

Steady State (#)	Sensor mean ($\mu g/m^3$)	APS-2.6 ($\mu g/m^3$)	Accuracy (%)
1	18.7	21.3	86.3
2	22.0	25.3	85.1
3	46.5	51.6	89.1
4	109.3	116.3	93.6
5	172.5	179.6	95.9

- The OPC-N2 units had high accuracy when compared to APS. The units' accuracy ranges from 85.1% to 95.9%.
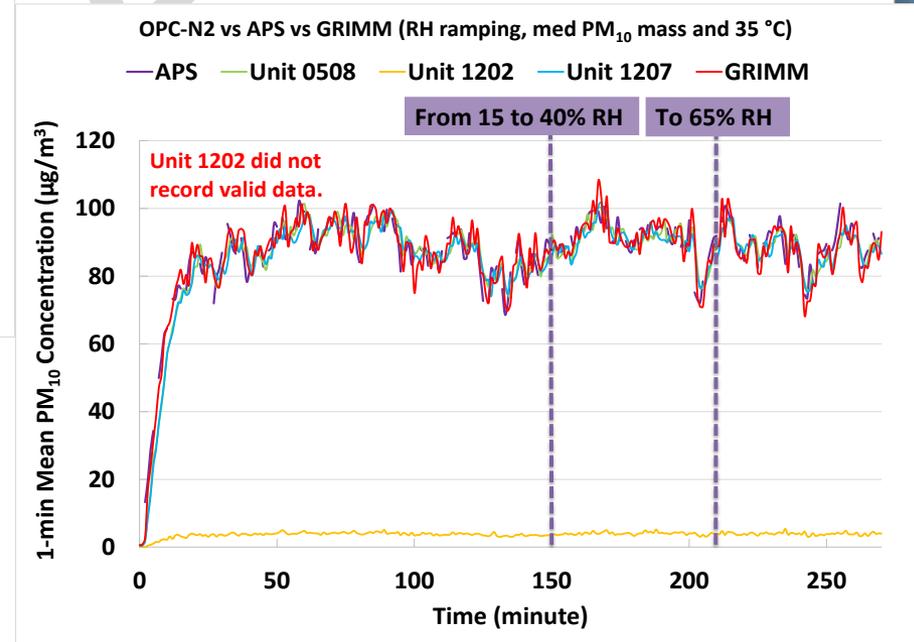
OPC-N2 PM_{10} Data Recovery & Intra-model Variability

- Data recovery for PM_{10} mass concentration from 0508, 1202, and 1207 was 96.8%, 9.5%, and 96.8%.

- Low PM_{10} measurement variations were observed between the units 0508 and 1207. Unit 1202 did not record valid data during the intra-model variability test.

OPC-N2 PM$_{10}$ Climate Susceptibility
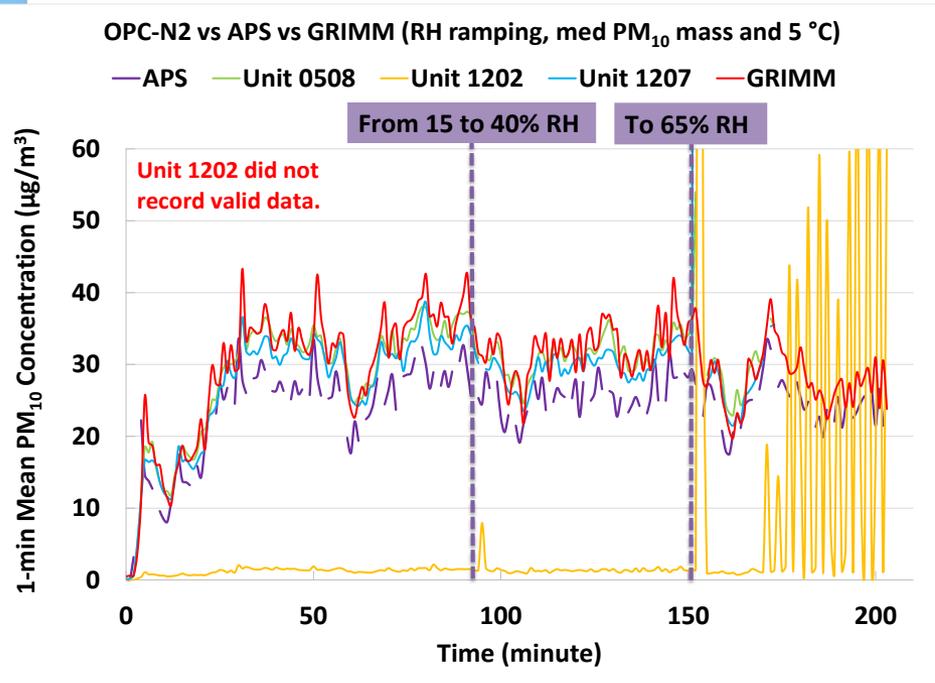
Low Temp – RH ramping
(medium conc.)

High Temp – RH ramping
(medium conc.)

Discussion

- **Accuracy**: The OPC-N2 units had high accuracy when compared to APS. The units' accuracy ranges from 85.1% to 95.9%. (refer to slide 17)

- **Precision**: Due to the nature of Arizona test dust, the aerosol concentration showed some variability in the chamber, therefore, the precision could not be estimated. At high humidity levels at 5 °C the OPC-N2 units recorded out of range PM_{10} concentrations in thousands of micrograms per cubic meter. (refer to slide 18)

- **Intra-model variability**: Low intra-model variability was observed between units 0508 and 1207. Unit 1202 had significant data loss, and did not record valid data during the intra-model variability experiment.

- **Data Recovery:** Data recovery for PM_{10} mass concentration from 0508, 1202, and 1207 were 96.8%, 9.5%, and 96.8%.

- **Coefficient of Determination**: OPC-N2 units showed very strong correlation/linear response with the corresponding APS PM_{10} ($R^2 = 0.99$) and GRIMM PM_{10} ($R^2 = 0.99$). (refer to slide 16)

- **Climate susceptibility**: At low temperature and high humidity levels, the OPC-N2 units recorded out of range PM_{10} mass concentrations.