Laboratory Evaluation

PurpleAir PA-I Indoor

South Coast AQMD

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Background

Three **PurpleAir PA-I Indoor** (Hereinafter PA-I Indoor) sensors (units IDs: 29D1, A3CA and BB9F) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (02/15/2018 to 04/25/2018) under ambient environmental conditions and have now been evaluated in the South Coast AQMD Chemistry Laboratory under controlled artificial aerosol concentration/size range, temperature, and relative humidity. The same three PA-I Indoor units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing).

- ***PA-I Indoor*** (*3 units tested*):
  - Particle sensor (optical; non-FEM)
  - PM sensor: Plantower PMS1003
  - Each unit measures: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) Temperature (°F)
  - Unit cost: ~$180
  - Time resolution: 2-min (during lab evaluation)
  - Units IDs: 29D1, A3CA and BB9F

GRIMM (*reference method*):

- Optical particle counter
- FEM $PM_{2.5}$
- Uses proprietary algorithms to calculate total PM, $PM_{2.5}$, and PM_1 mass conc. from particle number measurements
- Cost: ~$25,000
- Time resolution: 1-min

TSI APS 3321 (*reference 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

- PurleAir PA-I Indoor vs GRIMM $PM_{1.0}$ mass concentration
- PurleAir PA-I Indoor vs FEM GRIMM $PM_{2.5}$ mass concentration
- PurleAir PA-I Indoor vs GRIMM vs APS PM_{10} mass concentration

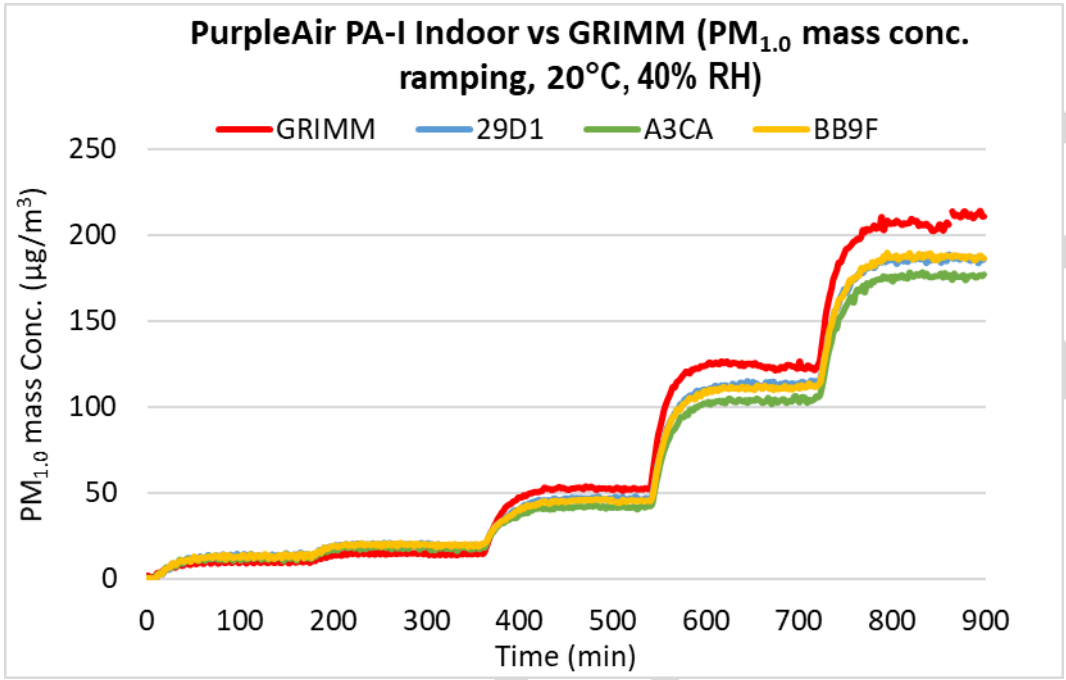
PurpleAir PA-I Indoor

TSI APS 3321

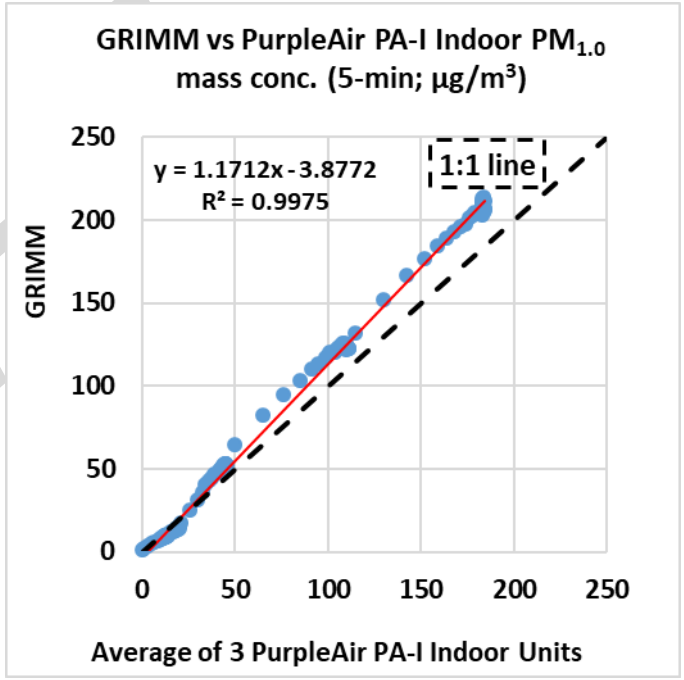
Evaluation results for $PM_{1.0}$ mass concentration

PurpleAir PA-I Indoor vs GRIMM

PA-I Indoor vs GRIMM ($PM_{1.0}$ mass conc.)



Coefficient of Determination



- The PA-I Indoor sensors tracked well with the $PM_{1.0}$ concentration variation as recorded by the GRIMM in the concentration range of 0 - ~200 µg/m^3.

- The PA-I Indoor sensors showed very strong correlations with the GRIMM $PM_{1.0}$ mass conc. (R^2 > 0.99).

PA-I Indoor vs GRIMM $PM_{1.0}$ Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m³)	GRIMM (µg/m³)	Accuracy (%)
1	12.8	9.5	65.1
2	18.8	14.2	67.5
3	44.5	52.1	85.3
4	109.5	123.1	89.0
5	183.3	199.1	92.1

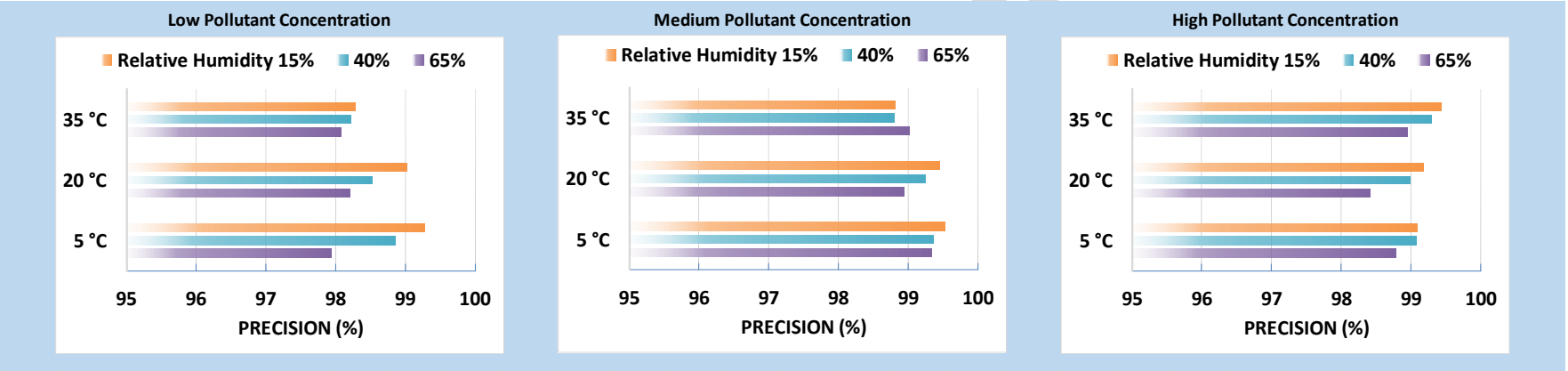
- The PA-I Indoor sensors underestimated GRIMM $PM_{1.0}$ at mass concentrations > 50 µg/m³ , while they overestimated mass concentrations < 50 µg/m³.The accuracy of the PA-I Indoor sensors increased as $PM_{1.0}$ mass concentrations increased.

PA-I Indoor : Data Recovery and intra-model variability

- Data recovery for $PM_{1.0}$ mass concentration from all units was 100%
- Low $PM_{1.0}$ measurement variations were observed between the PA-I Indoor sensors

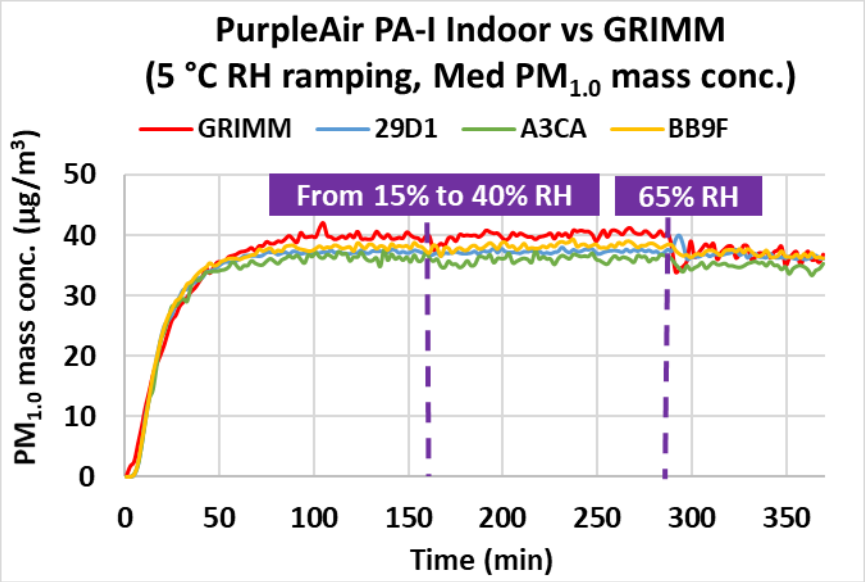
$PM_{1.0}$ Precision: PA-I Indoor

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



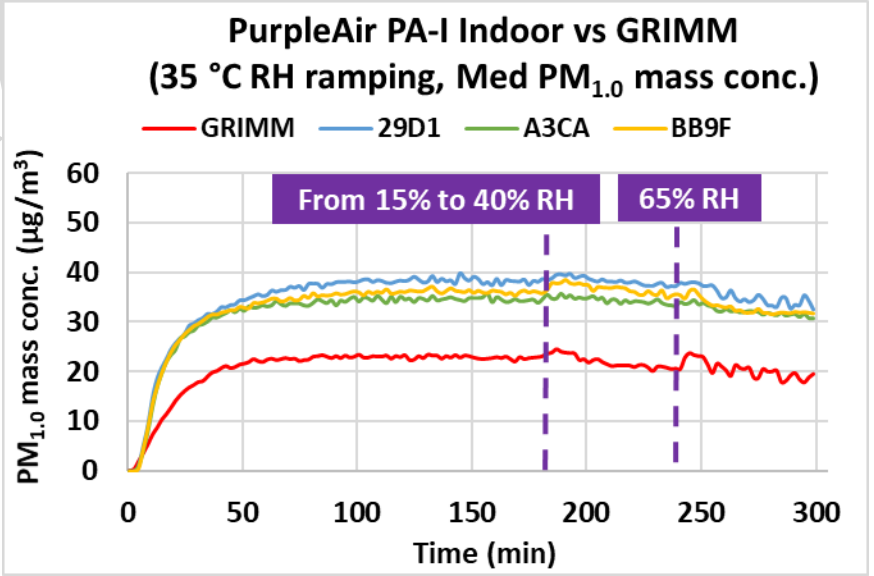
- Overall, the PA-I Indoor sensors showed high precision for all of the combinations of low, medium and high $PM_{1.0}$ conc., T and RH.

PA-I Indoor $PM_{1.0}$: Climate Susceptibility



Low Temp – RH ramping (medium conc.)

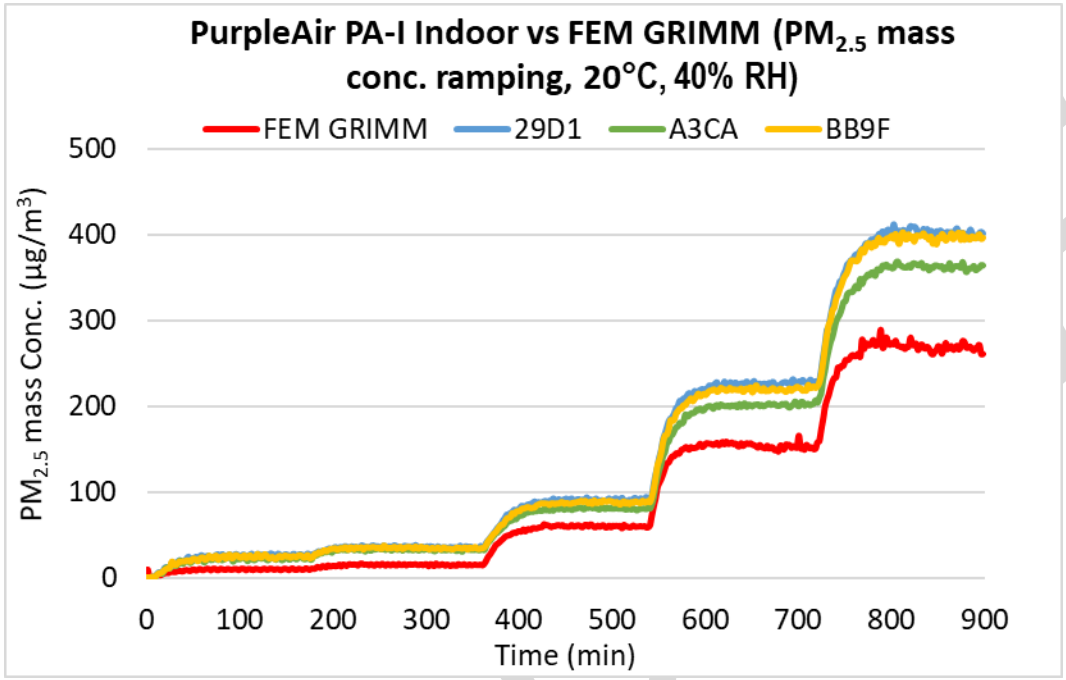
High Temp – RH ramping (medium conc.)



Evaluation results for $PM_{2.5}$ mass concentration

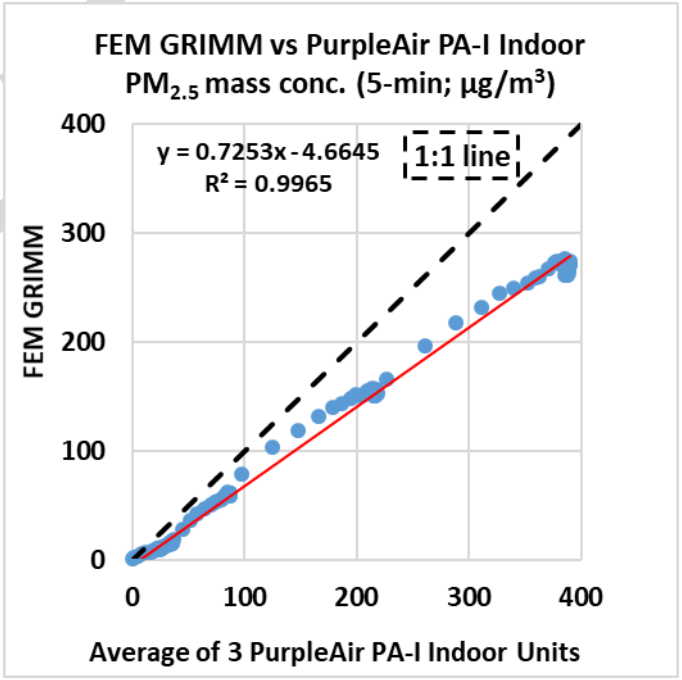
PurpleAir PA-I Indoor vs FEM GRIMM

PA-I Indoor vs FEM GRIMM ($PM_{2.5}$ mass conc.)



- The PA-I Indoor sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~300 µg/m^3.

Coefficient of Determination



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

PA-I Indoor vs FEM GRIMM $PM_{2.5}$ Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m³)	FEM GRIMM (µg/m³)	Accuracy (%)
1	24.4	10.3	-37.1
2	33.9	15.3	-21.5
3	86.3	60.2	56.6
4	216.1	152.6	58.3
5	387.4	255.2	48.2

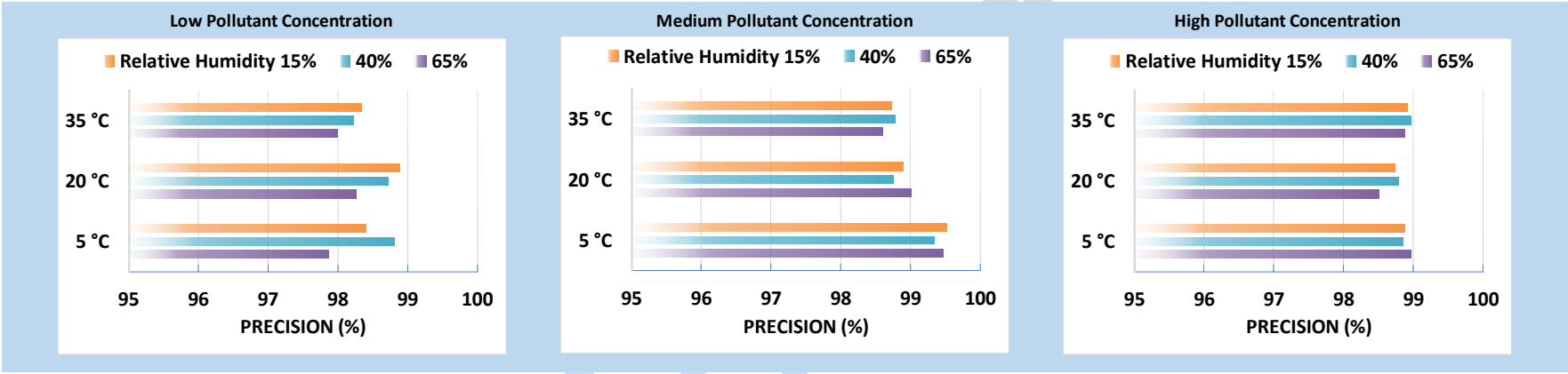
- The PA-I Indoor sensors overestimated FEM GRIMM $PM_{2.5}$ mass concentration at 20 °C and 40% RH. The accuracy of the PA-I Indoor sensors was negative at low $PM_{2.5}$ mass conc. and fairly constant (48% to 57%) for $PM_{2.5}$ mass concentrations > 50 µg/m³.

PA-I Indoor : Data Recovery and intra-model variability

- Data recovery for $PM_{2.5}$ mass concentration from all units was 100%
- Low $PM_{2.5}$ measurement variations were observed between the PA-I Indoor sensors

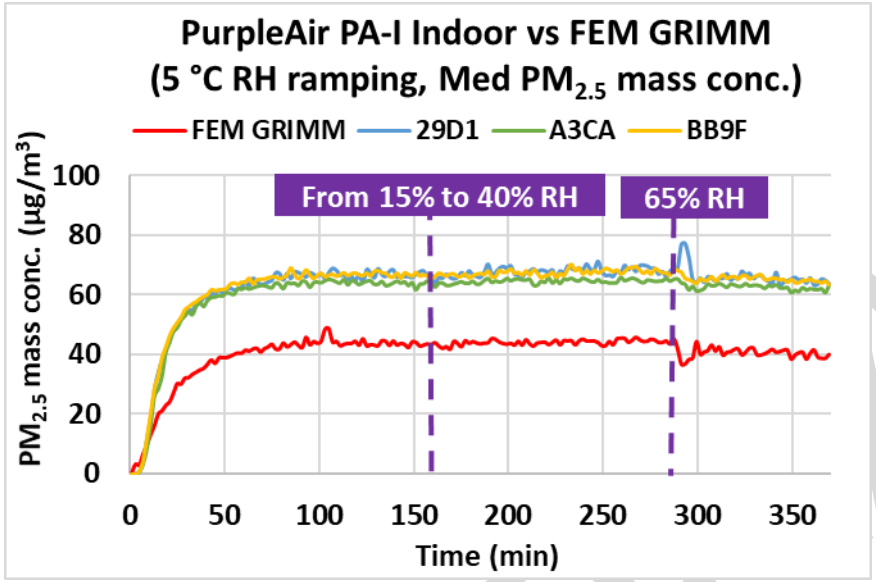
$PM_{2.5}$ Precision: PA-I Indoor

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



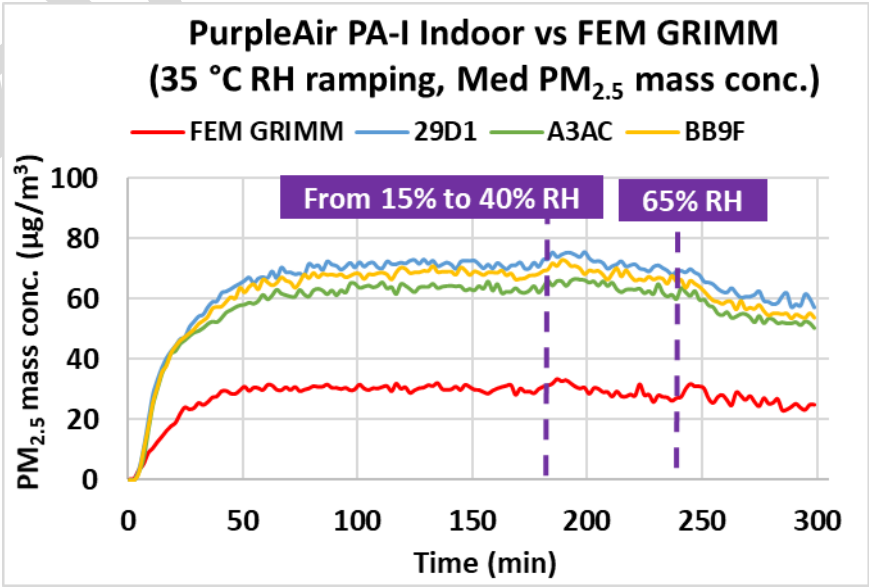
- Overall, the PA-I Indoor sensors showed high precision for all of the combinations of low, medium and high $PM_{2.5}$ conc., T and RH.

PA-I Indoor $PM_{2.5}$: Climate Susceptibility



Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)



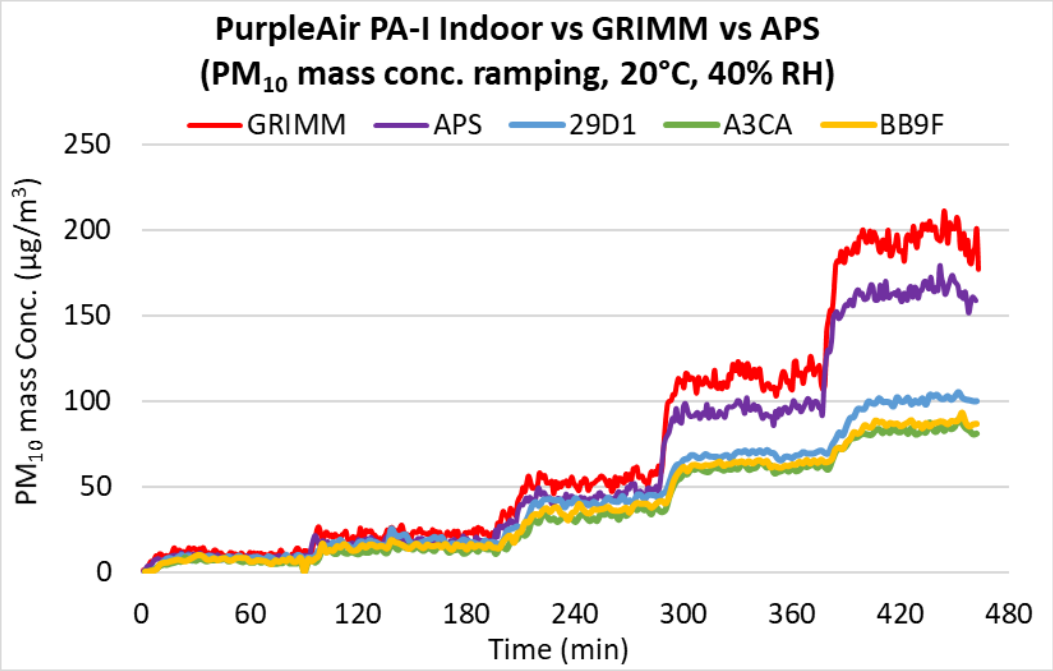
Discussion ($PM_{1.0}$ and $PM_{2.5}$)

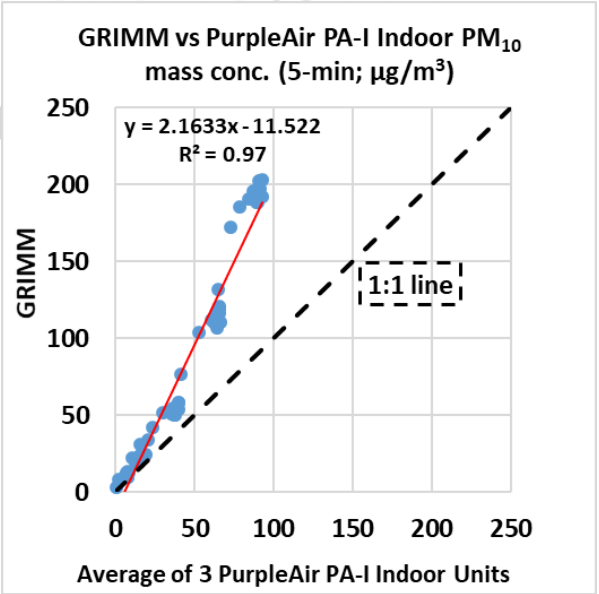
- **Accuracy**: Overall, the accuracy of the PA-I Indoor sensors increased with increasing $PM_{1.0}$ mass concentration. The accuracy of the PA-I Indoor sensors was negative at lower $PM_{2.5}$ mass conc. and fairly constant (48% to 57%) for $PM_{2.5}$ mass concentrations > 50 µg/m^3. The PA-I Indoor sensors underestimated $PM_{1.0}$ at $PM_{1.0}$ mass conc. > 50 µg/m^3, while they overestimate $PM_{1.0}$ mass conc. < 50 µg/m^3. The sensors overestimated all $PM_{2.5}$ measurements from GRIMM in the laboratory experiments at 20 °C and 40% RH.
- **Precision**: The PA-I Indoor 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 PA-I Indoor sensors.
- **Data Recovery:** Data recovery for $PM_{1.0}$ and $PM_{2.5}$ mass concentration from all units was 100%.
- **Coefficient of Determination**: The PA-I Indoor 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 PA-I Indoor sensors except that the sensors showed some small spiked concentration changes at the 65% RH set-point at 5°C.

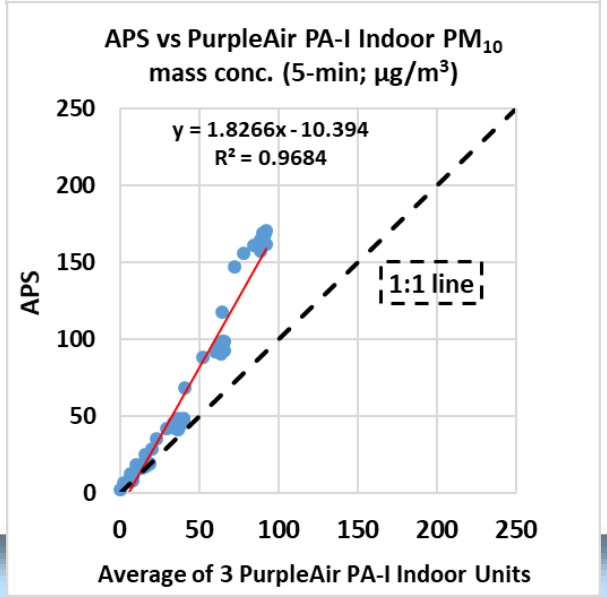
Evaluation results for PM_{10} mass concentration

PurpleAir PA-I Indoor vs GRIMM vs APS

PA-I Indoor vs GRIMM vs APS (PM_{10} mass conc.) Concentration Ramping at 20 °C and 40% RH







- The PA-I Indoor sensors tracked well with the concentration variation as recorded by the APS and GRIMM in the concentration range of 0 - ~200 µg/m^3.
- The PA-I Indoor sensors showed very strong correlations with the corresponding GRIMM and APS PM_{10} mass conc. (R^2 > 0.96).

PA-I Indoor vs GRIMM vs APS PM_{10} Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m³)	GRIMM (µg/m³)	Accuracy (%)
1	7.1	10.1	70.3
2	15.2	21.8	69.7
3	36.0	51.5	70.0
4	65.0	116.9	55.6
5	90.3	198.5	45.5

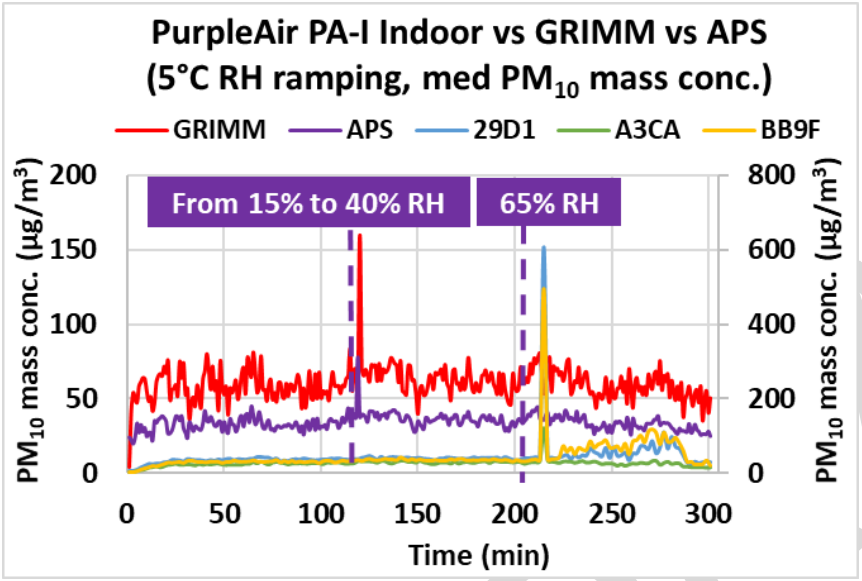
Steady state #	Sensor Mean (µg/m³)	APS (µg/m³)	Accuracy (%)
1	7.1	7.9	89.8
2	15.2	17.4	87.2
3	36.0	42.5	84.7
4	65.0	96.4	67.4
5	90.3	166.7	54.2

- The PA-I Indoor sensors underestimated the corresponding GRIMM and APS PM_{10} mass concentration at 20 °C and 40% RH. The accuracy of the PA-I Indoor sensors decreased as PM_{10} mass concentration increased.

PA-I Indoor : Data Recovery and intra-model variability

- Data recovery for PM_{10} mass concentration from all units was 100%
- Moderate PM_{10} measurement variations were observed between the PA-I Indoor sensors

PA-I Indoor PM_{10}: Climate Susceptibility



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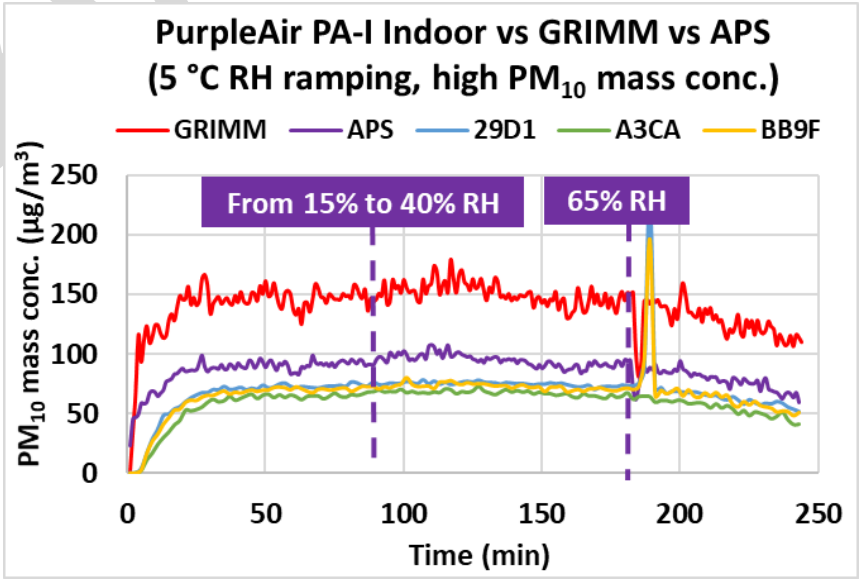
High Temp – RH ramping (medium conc.)



Discussion (PM_{10})

- **Accuracy**: Overall, the accuracy of the PA-I Indoor sensors decreased as PM_{10} mass concentration increased. The PA-I Indoor sensors underestimated PM_{10} mass concentrations as measured by GRIMM and APS in the laboratory experiments at 20 °C and 40% RH.
- **Precision**: Due to the nature of Arizona test dust, the aerosol concentration showed some variability, therefore, the precision cannot be fairly estimated.
- **Intra-model variability**: Moderate intra-model variability was observed among the PA-I Indoor sensors.
- **Data Recovery:** Data recovery for PM_{10} mass concentration from all units was ~ 99%.
- **Coefficient of Determination**: The PA-I Indoor sensors showed very strong correlation/linear response with the corresponding GRIMM PM_{10} (R^2 = 0.97) and APS PM_{10} (R^2 = 0.968).
- **Climate susceptibility**: For most of the temperature and relative humidity combinations, the climate condition had minimal effect on the PA-I Indoor sensors except that the sensors showed spiked concentration changes at the 65% RH set-point at 5 °C.