

Laboratory Evaluation

Sensirion Nubo



Background

Three **Sensirion Nubo** sensors (units IDs: 2A3E, 1743, 051E) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (12/27/2019 to 02/27/2020) under ambient environmental conditions and have been evaluated in the South Coast AQMD Chemistry Laboratory under controlled artificial aerosol concentration/size range, temperature, and relative humidity. The same three Sensirion Nubo units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing).

- **Sensirion Nubo** (3 units tested):

- Particle sensor: **optical; non-FEM**
(model: **SPS30, Sensirion**)
- Each unit reports: PM_{1.0} and PM_{2.5} (µg/m³), temperature (°C), RH (%), dew point (°C)
- PM₁₀ algorithm measurement is currently under development by the manufacturer
- **Unit cost: \$2000 per unit with a yearly SaaS at \$500**
- Time resolution: 1-min
- Units IDs: 2A3E, 1743, 051E



- **GRIMM (reference method):**

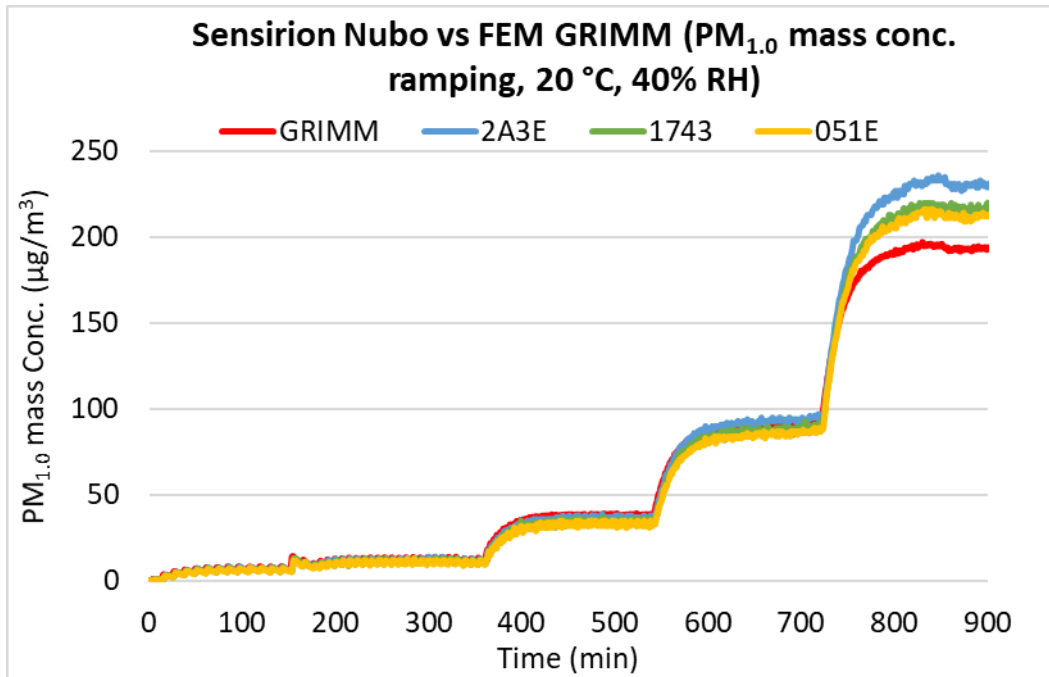
- Optical particle counter
- **FEM PM_{2.5}**
- Uses proprietary algorithms to calculate total PM, PM_{2.5}, and PM₁ mass conc. from particle number measurements
- **Cost: ~\$25,000**
- Time resolution: 1-min



Evaluation results for PM_{1.0} mass concentration

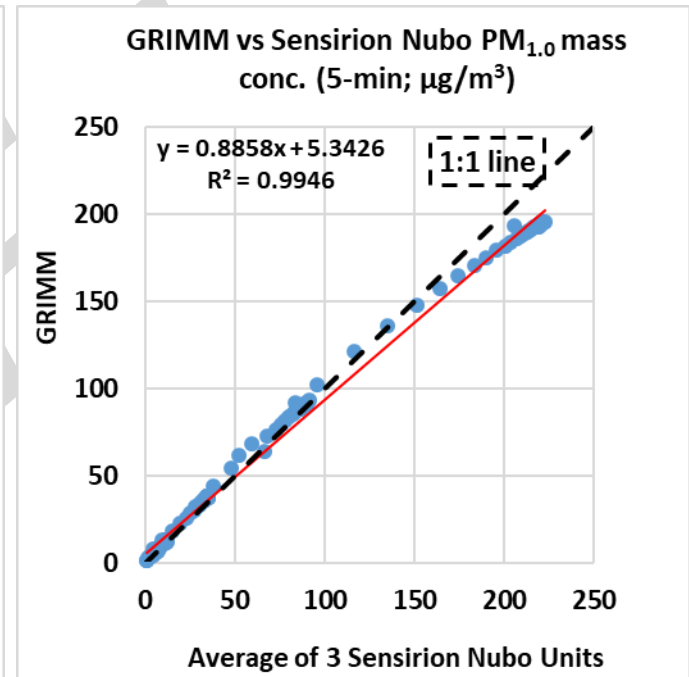
Sensirion Nubo vs GRIMM

Sensirion Nubo vs GRIMM (PM_{1.0} mass conc.)



- The Sensirion Nubo sensors tracked well with the PM_{1.0} concentration variation as recorded by the GRIMM in the concentration range of 0 - ~200 µg/m³.

Coefficient of Determination



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

Sensirion Nubo vs GRIMM PM_{1.0} Accuracy

- Accuracy* (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	GRIMM (µg/m ³)	Accuracy (%)
1	6.6	7.2	92.3
2	10.7	12.0	89.4
3	34.6	37.8	91.4
4	90.6	92.1	98.4
5	219.8	193.5	86.4

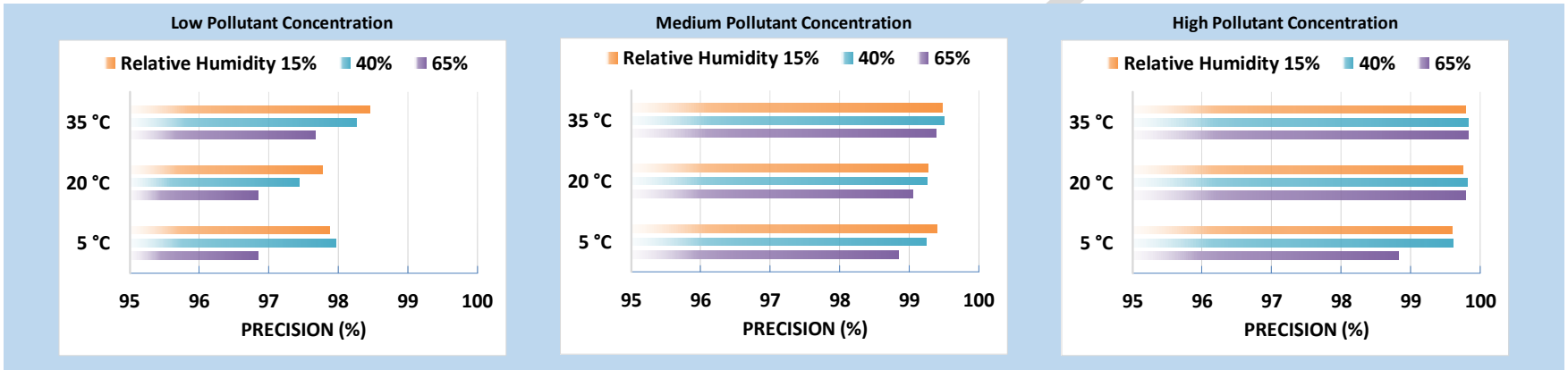
- Overall, the Sensirion Nubo sensors overestimated GRIMM PM_{1.0} measurements when PM_{1.0} mass concentrations were > 100 µg/m³. The accuracy of the Sensirion Nubo sensors fairly constant (86% to 98%) over the range of PM_{1.0} mass concentration tested.

Sensirion Nubo: 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 Sensirion Nubo sensors

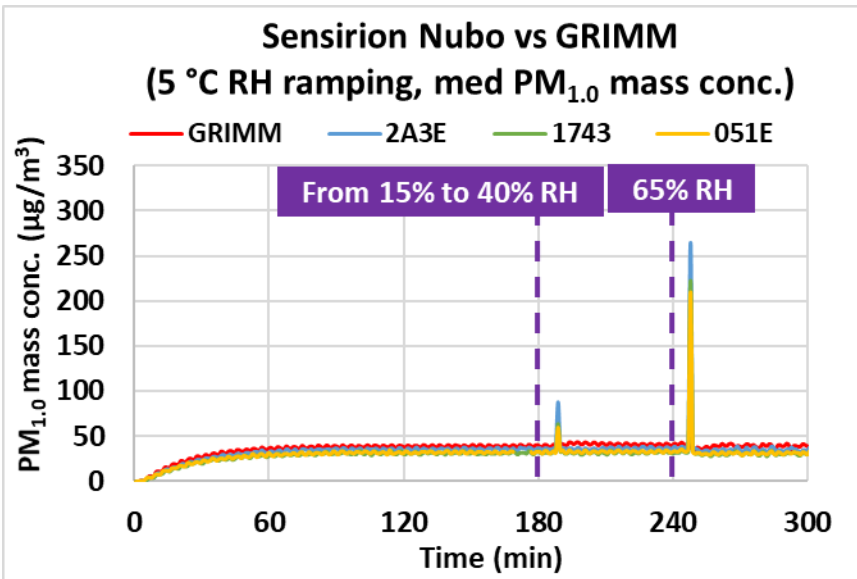
Sensirion Nubo PM_{1.0}: Precision

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



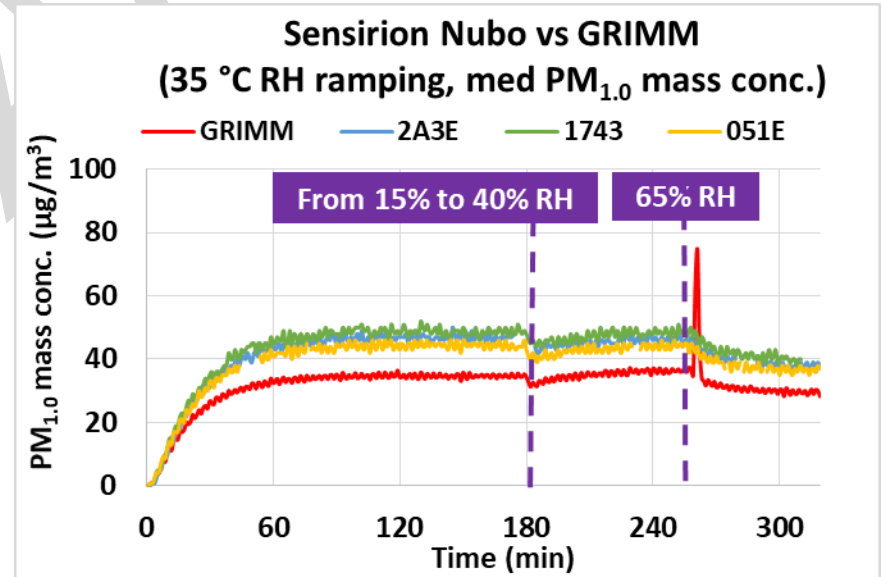
- Overall, the Sensirion Nubo sensors showed high precision for all of the combinations of low, medium and high PM_{1.0} conc., T, and RH.
- Precision was relatively higher at higher PM_{1.0} mass concentrations.

Sensirion Nubo PM_{1.0}: Climate Susceptibility



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

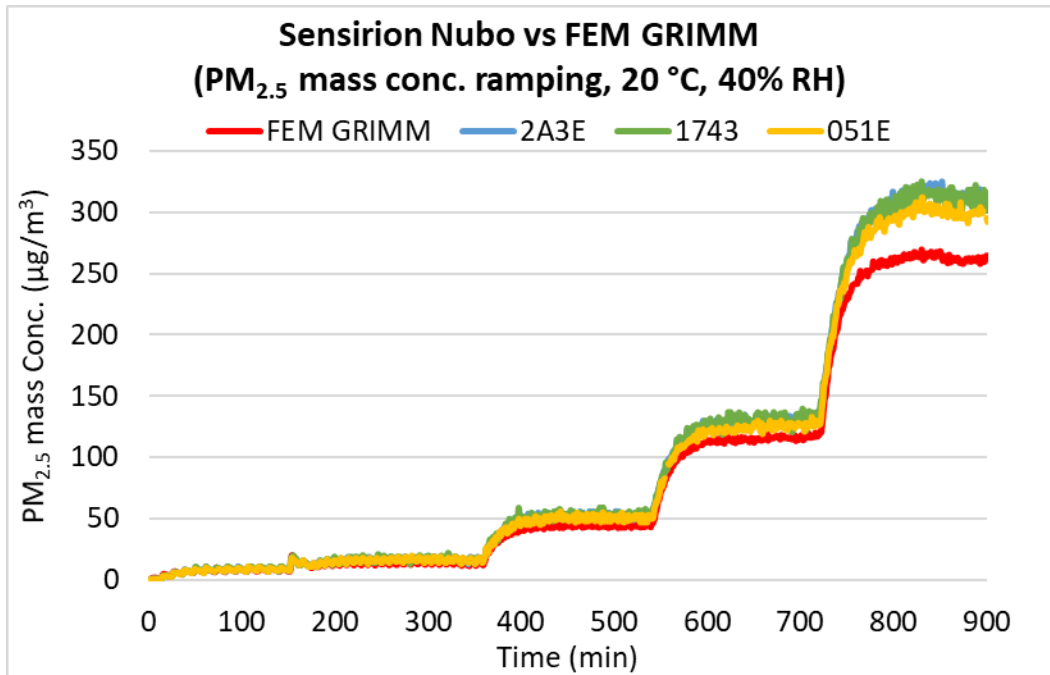
**High Temp – RH ramping
(medium conc.)**



Evaluation results for PM_{2.5} mass concentration

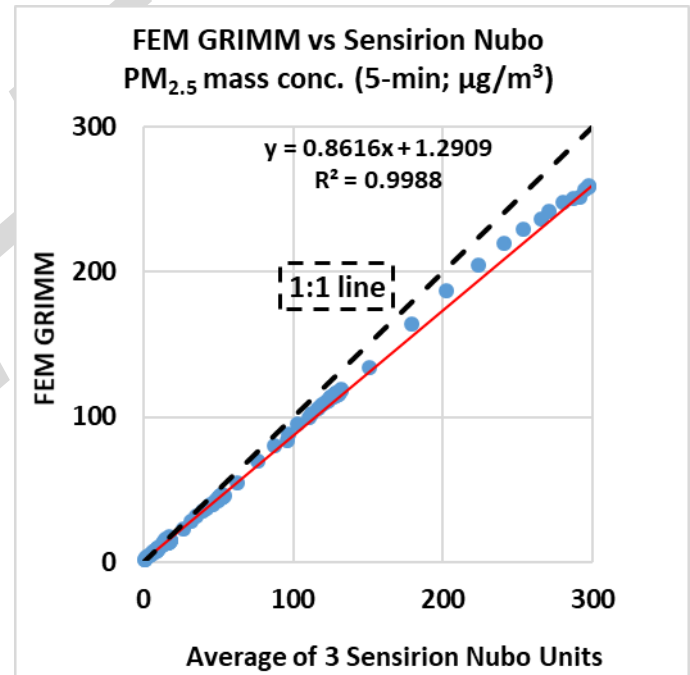
Sensirion Nubo vs FEM GRIMM

Sensirion Nubo vs FEM GRIMM (PM_{2.5} mass conc.)



- The Sensirion Nubo sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~250 µg/m³.

Coefficient of Determination



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

Sensirion Nubo vs FEM GRIMM PM_{2.5} Accuracy

- Accuracy* (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	FEM GRIMM (µg/m ³)	Accuracy (%)
1	8.9	8.4	93.9
2	16.4	13.7	80.9
3	52.3	45.3	84.5
4	131.5	117.7	88.3
5	308.5	261.5	82.0

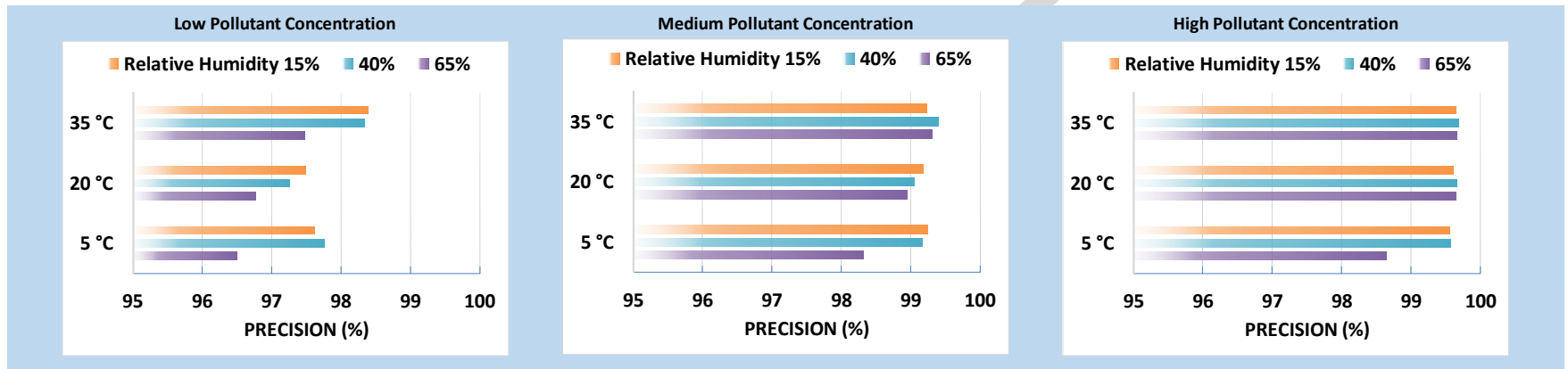
- The Sensirion Nubo sensors overestimated FEM GRIMM PM_{2.5} mass concentration at 20 °C and 40% RH. The accuracy of the Sensirion Nubo sensors was fairly constant (81% to 94%) for the PM_{2.5} mass concentration range tested.

Sensirion Nubo: 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 Sensirion Nubo sensors

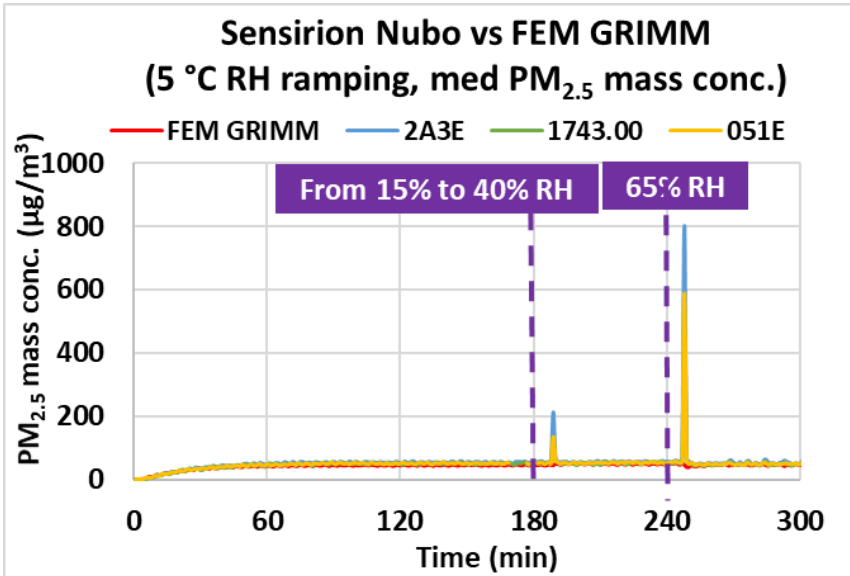
Sensirion Nubo PM2.5: Precision

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



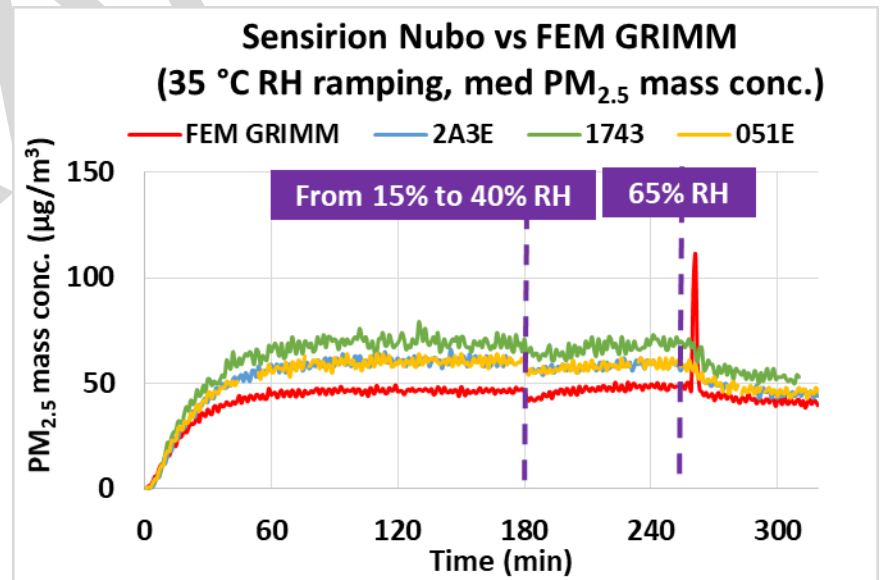
- Overall, the Sensirion Nubo sensors showed high precision for all of the combinations of low, medium and high PM_{2.5} conc., T, and RH.
- Precision was relatively higher at higher PM_{2.5} mass concentrations.

Sensirion Nubo PM_{2.5}: Climate Susceptibility



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

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



Discussion

- **Accuracy:** Overall, the accuracy of the Sensirion Nubo sensors fairly constant (86% to 98% and 81% to 94%) over the range of PM_{1.0} and PM_{2.5} mass concentration tested, respectively. Overall, the Sensirion Nubo sensors overestimated PM_{1.0} measurements when PM_{1.0} mass concentrations were > 100 µg/m³ and overestimated PM_{2.5} measurements from GRIMM in the laboratory experiments at 20 °C and 40% RH.
- **Precision:** The Sensirion Nubo 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 Sensirion Nubo sensors.
- **Data Recovery:** Data recovery for PM_{1.0} and PM_{2.5} mass concentration from all units was 100%.
- **Coefficient of Determination:** The Sensirion Nubo 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 Sensirion Nubo's precision. At the set-points of RH changes, the Sensirion Nubo sensors reported spiked changes in concentrations for all PM levels at 5 °C.