Laboratory Evaluation

Alphasense OPC-N3 Sensor
Three Alphasense OPC-N3 sensors (units IDs: 0217, 0218 and 0219) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (08/15/2018 to 10/11/2018) 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 Alphasense OPC-N3 units were tested both in the field (1\textsuperscript{st} stage of testing) and in the laboratory (2\textsuperscript{nd} stage of testing).

- **Alphasense OPC-N3 (3 units tested):**
  - Particle sensor (optical; non-FEM)
  - Each unit measures: PM\textsubscript{1.0}, PM\textsubscript{2.5} and PM\textsubscript{10} (\(\mu g/m^3\))
  - Temperature (°C), Relative Humidity (%)
  - Unit cost: ~$340
  - Time resolution: 10-sec
  - Units IDs: 0217, 0218, 0219
  - Differences from OPC-N2:
    - Increased particle size range: 0.38 - 40 \(\mu m\) and channels: 24 software bins
    - Equipped with onboard temperature and humidity sensor that is enclosed in raw sensor housing
    - Auto switching when detecting higher range
    - Increased sampling flow rate to 5.5 L/min

- **GRIMM (reference method):**
  - Optical particle counter
  - FEM PM\textsubscript{2.5}
  - Uses proprietary algorithms to calculate PM\textsubscript{10}, PM\textsubscript{2.5}, and PM\textsubscript{1.0} mass conc. from particle number measurements
  - Cost: ~$25,000
  - Time resolution: 1-min

- **TSI APS 3321 (reference method for PM\textsubscript{10} mass):**
  - Aerodynamic particle sizer
  - Measures particles from 0.5 to 20 \(\mu m\)
  - Uses a patented, double-crest optical system for unmatched sizing accuracy
  - Cost: ~$50,000
Evaluation results guideline

- Alphasense OPC-N3 vs GRIMM PM$_{1.0}$ mass concentration
- Alphasense OPC-N3 vs FEM GRIMM PM$_{2.5}$ mass concentration
- Alphasense OPC-N3 vs GRIMM vs APS PM$_{10}$ mass concentration
Evaluation results for PM$_{1.0}$ mass concentration

Alphasense OPC-N3 vs GRIMM
The Alphasense OPC-N3 sensors tracked well with the PM$_{1.0}$ concentration variations as recorded by GRIMM in the concentration range of 0 - ~200 μg/m$^3$.

The Alphasense OPC-N3 sensors showed very strong correlations with the corresponding GRIMM PM$_{1.0}$ mass conc. ($R^2 > 0.99$).
Alphasense OPC-N3 vs GRIMM PM$_{1.0}$ Accuracy

- Accuracy (20 °C and 40% RH)

<table>
<thead>
<tr>
<th>Steady state #</th>
<th>Sensor Mean (µg/m$^3$)</th>
<th>GRIMM (µg/m$^3$)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.2</td>
<td>9.5</td>
<td>12.2</td>
</tr>
<tr>
<td>2</td>
<td>2.0</td>
<td>14.2</td>
<td>14.0</td>
</tr>
<tr>
<td>3</td>
<td>6.2</td>
<td>51.9</td>
<td>12.0</td>
</tr>
<tr>
<td>4</td>
<td>14.2</td>
<td>123.4</td>
<td>11.5</td>
</tr>
<tr>
<td>5</td>
<td>22.8</td>
<td>211.8</td>
<td>10.7</td>
</tr>
</tbody>
</table>

- The Alphasense OPC-N3 sensors underestimated GRIMM PM$_{1.0}$ mass concentration. The accuracy of the Alphasense OPC-N3 sensors was constant (11% to 14%) over the range of PM$_{1.0}$ mass concentrations tested.

Alphasense OPC-N3: Data Recovery and intra-model variability

- Data recovery for PM$_{1.0}$ mass concentration from all units was 100%
- High PM$_{1.0}$ measurement variations were observed between the Alphasense OPC-N3 sensors
PM$_{1.0}$ Precision: Alphasense OPC-N3

• Precision (Effect of PM$_{1.0}$ conc., Temperature and Relative Humidity)

Overall, the Alphasense OPC-N3 sensors showed high precision for all of the combinations of low, medium and high PM$_{1.0}$ conc., T and RH.
Alphasense OPC-N3 PM$_{1.0}$: Climate Susceptibility

Low Temp – RH ramping (medium conc.)

High Temp – RH ramping (medium conc.)
Evaluation results for \( \text{PM}_{2.5} \) mass concentration

Alphasense OPC-N3 vs FEM GRIMM
The Alphasense OPC-N3 sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~300 μg/m³. The Alphasense OPC-N3 sensors showed very strong correlations with the corresponding FEM GRIMM PM$_{2.5}$ mass conc. (R$^2 > 0.99$).
**Alphasense OPC-N3 vs FEM GRIMM PM$_{2.5}$ Accuracy**

- **Accuracy (20 °C and 40% RH)**

<table>
<thead>
<tr>
<th>Steady state #</th>
<th>Sensor Mean (µg/m$^3$)</th>
<th>FEM GRIMM (µg/m$^3$)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.7</td>
<td>10.2</td>
<td>16.6</td>
</tr>
<tr>
<td>2</td>
<td>2.9</td>
<td>15.2</td>
<td>18.9</td>
</tr>
<tr>
<td>3</td>
<td>11.4</td>
<td>59.6</td>
<td>19.1</td>
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<tr>
<td>4</td>
<td>33.3</td>
<td>153.1</td>
<td>21.7</td>
</tr>
<tr>
<td>5</td>
<td>65.3</td>
<td>270.1</td>
<td>24.2</td>
</tr>
</tbody>
</table>

- The Alphasense OPC-N3 sensors underestimated FEM GRIMM PM$_{2.5}$ mass concentration at 20 °C and 40% RH. The accuracy of the Alphasense OPC-N3 sensors increased slightly as PM$_{2.5}$ mass conc. increased.

**Alphasense OPC-N3: Data Recovery and intra-model variability**

- Data recovery for PM$_{2.5}$ mass concentration from all units was 100%
- High PM$_{2.5}$ measurement variations were observed between the Alphasense OPC-N3 sensors
**PM$_{2.5}$ Precision: Alphasense OPC N-3**

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

Overall, the Alphasense OPC-N3 sensors showed high precision for all of the combinations of low, medium and high PM$_{2.5}$ conc., T and RH.
Alphasense OPC-N3 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 Alphasense OPC-N3 sensors was constant (11% to 14%) over the range of PM$_{1.0}$ mass concentrations tested. The accuracy of the Alphasense OPC-N3 sensors increased slightly as PM$_{2.5}$ mass conc. increased. The Alphasense OPC-N3 sensors largely underestimated both PM$_{1.0}$ and PM$_{2.5}$ measurements from GRIMM in the laboratory experiments at 20 °C and 40% RH.

- **Precision:** The Alphasense OPC-N3 sensors showed 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:** High intra-model variability was observed among the Alphasense OPC-N3 sensors.

- **Data Recovery:** Data recovery for PM$_{1.0}$ and PM$_{2.5}$ mass concentration from all units was 100%.

- **Coefficient of Determination:** The Alphasense OPC-N3 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 Alphasense OPC-N3 sensors except that the sensors showed significant variations in PM conc. at 65% RH at 5°C.
Evaluation results for PM$_{10}$ mass concentration

Alphasense OPC-N3 vs GRIMM vs APS
The Alphasense OPC-N3 sensors tracked well with the concentration variation as recorded by GRIMM and APS in the concentration range of 0 - ~200 μg/m³.

The Alphasense OPC-N3 sensors showed very strong correlations with the corresponding GRIMM and APS PM₁₀ mass conc. (R² > 0.99).
Alphasense OPC-N3 vs GRIMM vs APS PM$_{10}$ Accuracy

- Accuracy (20 °C and 40% RH)

<table>
<thead>
<tr>
<th>Steady state #</th>
<th>Sensor Mean (µg/m$^3$)</th>
<th>GRIMM (µg/m$^3$)</th>
<th>Accuracy (%)</th>
<th>Steady state #</th>
<th>Sensor Mean (µg/m$^3$)</th>
<th>APS (µg/m$^3$)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4</td>
<td>10.1</td>
<td>4.1</td>
<td>1</td>
<td>0.4</td>
<td>7.5</td>
<td>5.5</td>
</tr>
<tr>
<td>2</td>
<td>0.9</td>
<td>21.8</td>
<td>4.0</td>
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<td>0.9</td>
<td>17.5</td>
<td>5.0</td>
</tr>
<tr>
<td>3</td>
<td>2.0</td>
<td>51.5</td>
<td>4.0</td>
<td>3</td>
<td>2.0</td>
<td>42.5</td>
<td>4.8</td>
</tr>
<tr>
<td>4</td>
<td>4.9</td>
<td>116.9</td>
<td>4.2</td>
<td>4</td>
<td>4.9</td>
<td>96.4</td>
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<tr>
<td>5</td>
<td>9.0</td>
<td>198.5</td>
<td>4.5</td>
<td>5</td>
<td>9.0</td>
<td>166.7</td>
<td>5.4</td>
</tr>
</tbody>
</table>

- The Alphasense OPC-N3 sensors underestimated GRIMM and APS PM$_{10}$ mass concentration at 20 °C and 40% RH. The accuracy of the Alphasense OPC-N3 sensors was fairly constant (~4% to 5%) over the PM$_{10}$ mass concentration range tested.

Alphasense OPC-N3: Data Recovery and intra-model variability

- Data recovery for PM$_{10}$ mass concentration from all units was 100%
- High PM$_{10}$ measurement variations were observed between the Alphasense OPC-N3 sensors
Alphasense OPC-N3 PM$_{10}$: Climate Susceptibility

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

**Low Temp – RH ramping (medium conc.)**
Discussion (PM$_{10}$)

- **Accuracy**: The Alphasense OPC-N3 sensors underestimated the corresponding GRIMM and APS PM$_{10}$ mass concentration at 20 °C and 40% RH. The accuracy of the Alphasense OPC-N3 sensors was constant (~4% to 5%) over the PM$_{10}$ mass concentration range tested.

- **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**: High intra-model variability was observed among the Alphasense OPC-N3 sensors.

- **Data Recovery**: Data recovery for PM$_{10}$ mass concentration from all units was 100%.

- **Coefficient of Determination**: The Alphasense OPC-N3 sensors showed very strong correlation/linear response with the corresponding GRIMM and APS PM$_{10}$ 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 Alphasense OPC-N3 sensors except that the sensors showed significant variations in PM$_{10}$ conc. At 65% RH at 5°C.