Field Evaluation
Wicked Device – Air Quality Egg
2022 Model \( \text{O}_3 \) and \( \text{NO}_2 \)
From 03/18/2022 to 05/18/2022, three Wicked Device – Air Quality Egg 2022 Model O₃ and NO₂ (hereinafter Air Quality Egg 2022 Model) sensors were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with Federal Equivalent Method (FEM) and Federal Reference Method (FRM) instruments measuring the same pollutants.

**Air Quality Egg 2022 Model (3 units tested):**
- Gas sensor: Electrochemical; non-FEM (Winsen ZE12A)
- Each unit reports: O₃ (ppb), NO₂ (ppb), T (°C), RH (%)
- Unit cost: $971 (included data logging package)
- Time resolution: 1-min
- Units IDs: 233d, 1f4e, 8a60

**South Coast AQMD Reference Instruments:**
- O₃ instrument (Teledyne T400, hereinafter FEM T400); cost: ~$7,000
  - Time resolution: 1-min
- NO/NO₂ instrument (Teledyne T200, hereinafter FRM T200); cost: ~$11,000
  - Time resolution: 1-min
- Met station (T, RH, P, WS, WD); cost: ~$5,000
  - Time resolution: 1-min
Ozone ($O_3$) in Air Quality Egg 2022 Model
Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for O$_3$ from all units was ~ 100%

Air Quality Egg 2022 Model; Intra-model variability

- Absolute intra-model variability was ~ 2.2 ppb for the O$_3$ measurements (calculated as the standard deviation of the three sensor means)
- Relative intra-model variability was ~ 4.5% for the O$_3$ measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)
The Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding FEM T400 data (0.20 < R² < 0.51).

Overall, the Air Quality Egg 2022 Model sensors overestimated the O₃ concentration as measured by the FEM T400 instrument.

The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal O₃ variations as recorded by the FEM T400 instrument.
The Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding FEM T400 data ($0.21 < R^2 < 0.52$).

Overall, the Air Quality Egg 2022 Model sensors overestimated the $O_3$ concentration as measured by the FEM T400 instrument.

The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal $O_3$ variations as recorded by the FEM T400 instrument.
### Air Quality Egg 2022 Model vs FEM T400 ($O_3$; 8-hr mean)

- The Air Quality Egg 2022 Model sensors showed very weak to moderate correlations with the corresponding FEM T400 data ($0.17 < R^2 < 0.51$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the $O_3$ concentration as measured by the FEM T400 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal $O_3$ variations as recorded by the FEM T400 instrument

#### Graphs:

1. **Unit 233d**
   - $y = 0.9512x - 13.067$
   - $R^2 = 0.2121$

2. **Unit 1f4e**
   - $y = 1.7986x - 46.287$
   - $R^2 = 0.5076$

3. **Unit 8a60**
   - $y = 0.9486x - 11.324$
   - $R^2 = 0.1728$
## Summary: O₃

<table>
<thead>
<tr>
<th></th>
<th>Air Quality Egg 2022 Model vs FEM, O₃</th>
<th>FEM O₃ (ppb)</th>
<th></th>
<th>FEM O₃ (ppb)</th>
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<th>FEM O₃ (ppb)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Average of 3 Sensors O₃</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Average (ppb)</td>
<td>SD (ppb)</td>
<td>R²</td>
<td>Slope</td>
<td>Intercept</td>
<td>MBE¹ (ppb)</td>
<td>MAE² (ppb)</td>
</tr>
<tr>
<td>5-min</td>
<td>48.0</td>
<td>9.1</td>
<td>0.20 to 0.51</td>
<td>0.93 to 1.62</td>
<td>-37.7 to -10.0</td>
<td>9.5 to 14.5</td>
<td>13.2 to 18.0</td>
</tr>
<tr>
<td>1-hr</td>
<td>48.0</td>
<td>9.0</td>
<td>0.21 to 0.52</td>
<td>0.98 to 1.69</td>
<td>-41.5 to -14.0</td>
<td>10.5 to 15.7</td>
<td>13.8 to 18.7</td>
</tr>
<tr>
<td>8-hr</td>
<td>48.0</td>
<td>7.1</td>
<td>0.17 to 0.51</td>
<td>0.95 to 1.80</td>
<td>-46.3 to -11.3</td>
<td>10.3 to 15.5</td>
<td>12.4 to 17.4</td>
</tr>
</tbody>
</table>

¹ Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).

² Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

³ Root Mean Square Error (RMSE): another metric to calculate measurement errors.
Nitrogen Dioxide (NO$_2$) in Air Quality Egg 2022 Model
Data validation & recovery

• Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
• Data recovery for NO$_2$ from all units was ~ 100%

Air Quality Egg 2022 Model; Intra-model variability

• Absolute intra-model variability was ~ 4.8 ppb for the NO$_2$ measurements (calculated as the standard deviation of the three sensor means)
• Relative intra-model variability was ~ 12.2% for the NO$_2$ measurements (calculated as the absolute intra-model variability relative to the mean of the three sensor means)
The Air Quality Egg 2022 Model sensors showed weak to moderate correlations with the corresponding FRM T200 data ($0.38 < R^2 < 0.56$).

Overall, the Air Quality Egg 2022 Model sensors overestimated the NO$_2$ concentration as measured by the FRM T200 instrument.

The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal NO$_2$ variations as recorded by the FRM T200 instrument.
Air Quality Egg 2022 Model vs FRM T200 (NO$_2$; 1-hr mean)

- The Air Quality Egg 2022 Model sensors showed weak to moderate correlations with the corresponding FRM T200 data ($0.41 < R^2 < 0.58$)
- Overall, the Air Quality Egg 2022 Model sensors overestimated the NO$_2$ concentration as measured by the FRM T200 instrument
- The Air Quality Egg 2022 Model sensors sometimes seemed to track the diurnal NO$_2$ variations as recorded by the FRM T200 instrument
The Air Quality Egg 2022 Model sensors showed weak to moderate correlations with the corresponding FRM T200 data ($0.46 < R^2 < 0.69$).

Overall, the Air Quality Egg 2022 Model sensors overestimated the NO$_2$ concentration as measured by the FRM T200 instrument.

The Air Quality Egg 2022 Model sensors sometimes seemed to track the daily NO$_2$ variations as recorded by the FRM T200 instrument.
### Summary: NO$_2$

<table>
<thead>
<tr>
<th>Average of 3 Sensors NO$_2$</th>
<th>Air Quality Egg 2022 Model vs FRM, NO$_2$</th>
<th>FRM NO$_2$ (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FRM Average</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>SD</strong></td>
<td><strong>R$^2$</strong></td>
</tr>
<tr>
<td><strong>5-min</strong></td>
<td>38.9</td>
<td>20.1</td>
</tr>
<tr>
<td><strong>1-hr</strong></td>
<td>38.9</td>
<td>19.9</td>
</tr>
<tr>
<td><strong>24-hr</strong></td>
<td>38.9</td>
<td>5.0</td>
</tr>
</tbody>
</table>

1 Mean Bias Error (MBE): the difference between the sensors and the reference instruments. MBE indicates the tendency of the sensors to underestimate (negative MBE values) or overestimate (positive MBE values).

2 Mean Absolute Error (MAE): the absolute difference between the sensors and the reference instruments. The larger MAE values, the higher measurement errors as compared to the reference instruments.

3 Root Mean Square Error (RMSE): another metric to calculate measurement errors.
The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$)

Overall, the Air Quality Egg 2022 Model sensors overestimated the temperature measurement as recorded by South Coast AQMD Met Station

The Air Quality Egg 2022 Model sensors seemed to track the diurnal temperature variations as recorded by South Coast AQMD Met Station.
The Air Quality Egg 2022 Model sensors showed very strong correlations with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.99$).

- Overall, the Air Quality Egg 2022 Model sensors underestimated the RH measurement as recorded by South Coast AQMD Met Station.
- The Air Quality Egg 2022 Model sensors seemed to track the diurnal RH variations as recorded by South Coast AQMD Met Station.
Discussion

• The three **Air Quality Egg 2022 Model** sensors’ data recovery from all units was ~ 100% for O₃ and NO₂ measurements

• The absolute intra-model variability was ~ 2.2 ppb for O₃ and ~ 4.8 ppb for NO₂ measurements

• During the **entire** field deployment testing period:
  - Ozone sensors showed very weak to moderate correlation with the FEM T400 instrument (0.20 < R² < 0.51, 5-min mean) and generally overestimated the corresponding FEM T400 data
  - NO₂ sensors showed weak to moderate correlations with the FRM T200 instrument (0.38 < R² < 0.56, 5-min mean) and overestimated the corresponding FRM T200 data

• No sensor calibration was performed by South Coast AQMD Staff for this evaluation

• Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions

• **All results are still preliminary**