Field Evaluation
Kaiterra Laser Egg 2+ Sensor

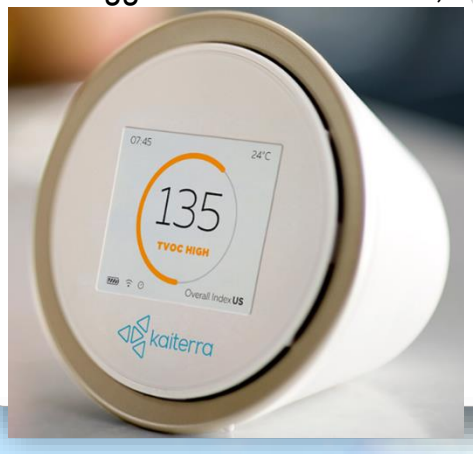
South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 02/19/2019 to 04/09/2019, three **Kaiterra Laser Egg 2+ Model #LE-201 (hereinafter Laser Egg 2+)** sensors were deployed at a South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with three reference instruments measuring the same pollutants

- Laser Egg 2+ (*3 units tested*):
  - Particle sensor: Laser Particle Counter (optical; non-FEM) (model PMS3003 by Plantower)
  - Each unit reports: $PM_{2.5}$ and PM_{10} (µg/m^3), Temperature (°C), Relative Humidity (%)
  - Also measures TVOC (ppb)
  - Unit cost: $199
  - Time resolution: 1 min
  - Units IDs: CED6, D0C3, D20E
  - Differences from Laser Egg: In addition to $PM_{2.5}$ and PM_{10}, Laser Egg 2+ also measures T, RH, and Total VOC



- MetOne BAM (*reference instrument*):
  - Beta-attenuation monitor ($FEM\ PM_{2.5}$ & PM_{10})
  - Measures $PM_{2.5}$ & PM_{10} (µg/m^3)
  - Unit cost: ~$20,000
  - Time resolution: 1-hr

- GRIMM (*reference instrument*):
  - Optical particle counter ($FEM\ PM_{2.5}$)
  - Measures $PM_{1.0}$, $PM_{2.5}$, and PM_{10} (µg/m^3)
  - Cost: ~$25,000 and up
  - Time resolution: 1-min

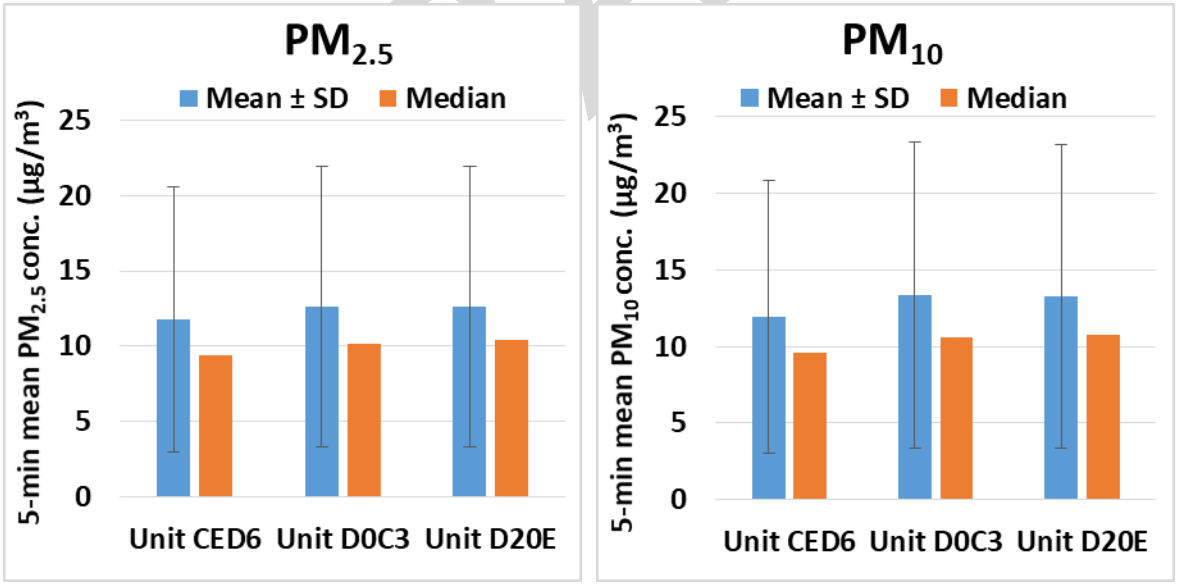
- Teledyne API T640 (*reference instrument*):
  - Optical particle counter ($FEM\ PM_{2.5}$)
  - Measures $PM_{2.5}$ & PM_{10} (µg/m^3)
  - Unit cost: ~$21,000
  - Time resolution: 1-min

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 from units CED6, D0C3, and D20E for $PM_{2.5}$ and PM_{10} mass conc. measurements is 75.7 % and 77.3 %, respectively.

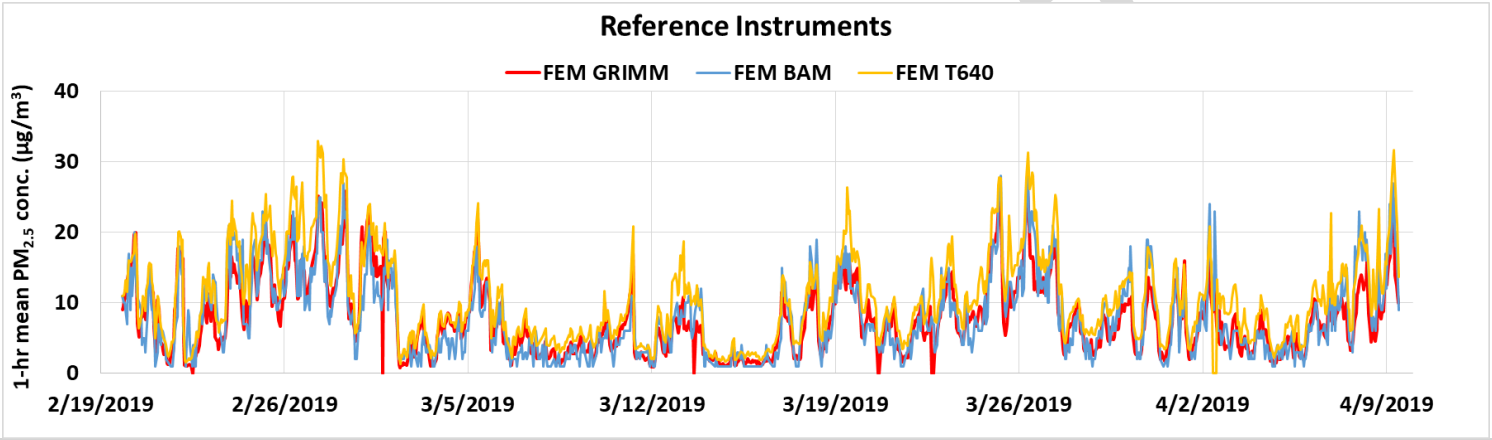
Laser Egg 2+; intra-model variability

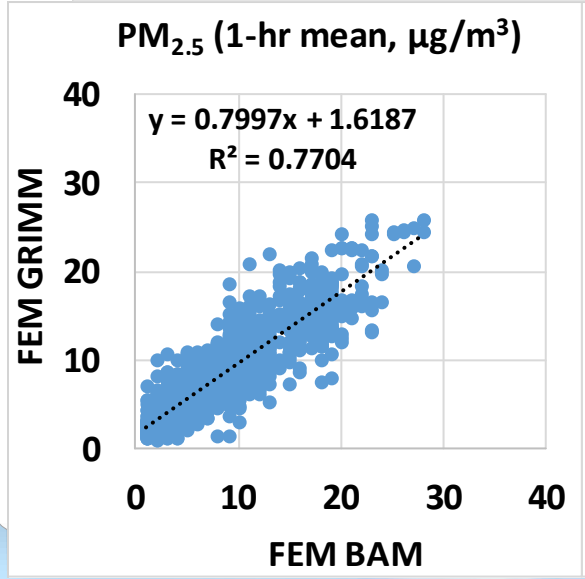
- Low measurement variability (~ 7% and 11.1%) was observed between the three Laser Egg 2+ units for $PM_{2.5}$ and PM_{10} mass conc. measurements, respectively

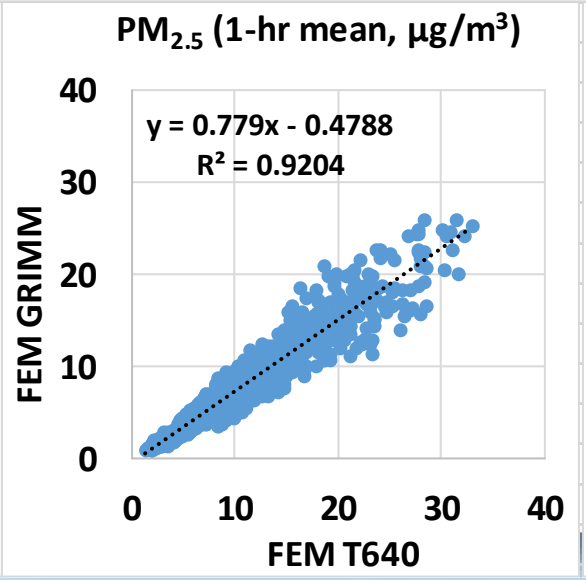


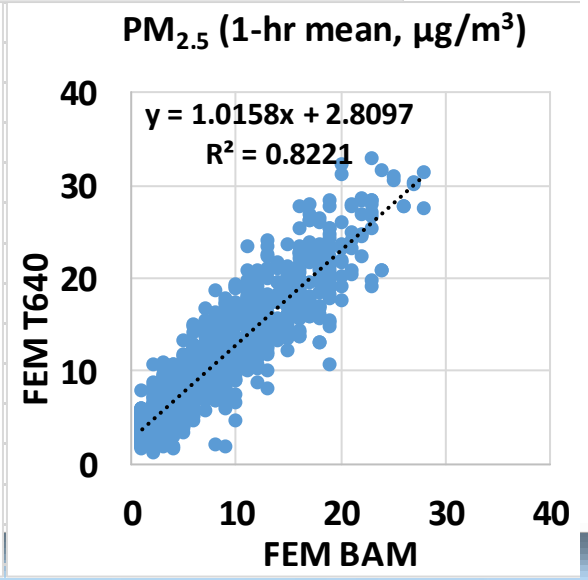
Reference Instruments: $PM_{2.5}$ GRIMM, BAM & T640

- Data recovery for $PM_{2.5}$ from FEM GRIMM, FEM BAM and FEM T640 is 99.6 %, 92.3 % and 99.7 %, respectively.
- Very good correlations between the three reference instruments for $PM_{2.5}$ measurements ($0.77 < R^2 < 0.93$) were observed.



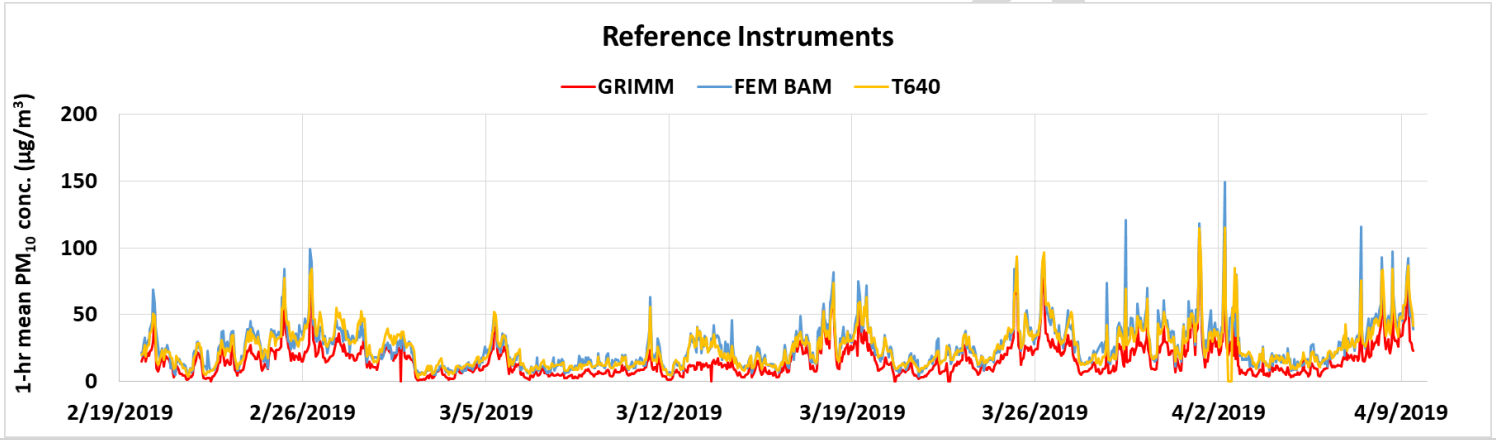


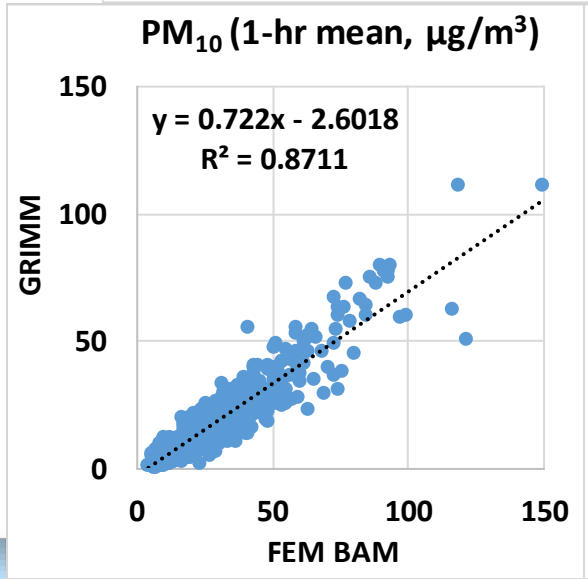


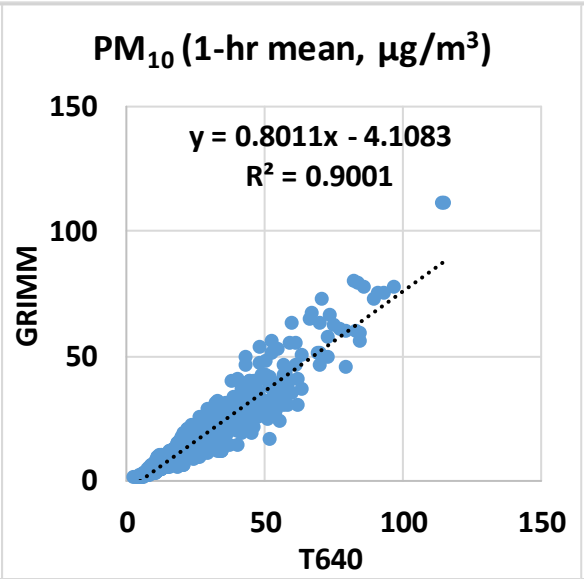


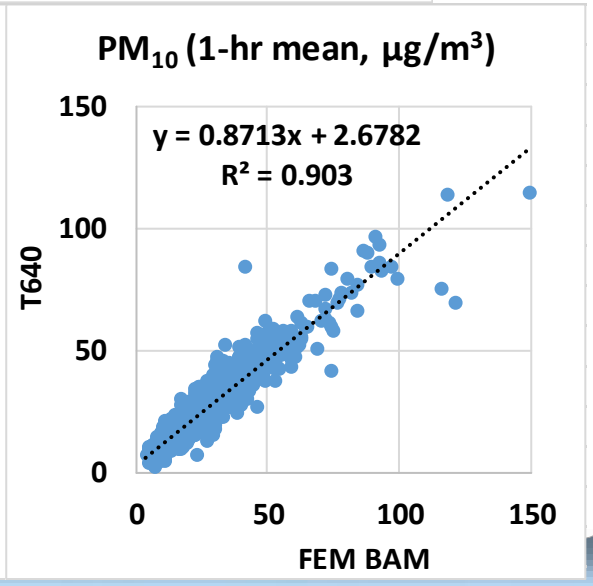
Reference Instruments: PM_{10} GRIMM, BAM & T640

- Data recovery for PM_{10} from GRIMM, FEM BAM and T640 is 99.6 %, 98.8 % and 99.7 %, respectively.
- Excellent correlations between the three reference instruments for $PM_{2.5}$ measurements ($0.87 < R^2 < 0.91$) were observed.

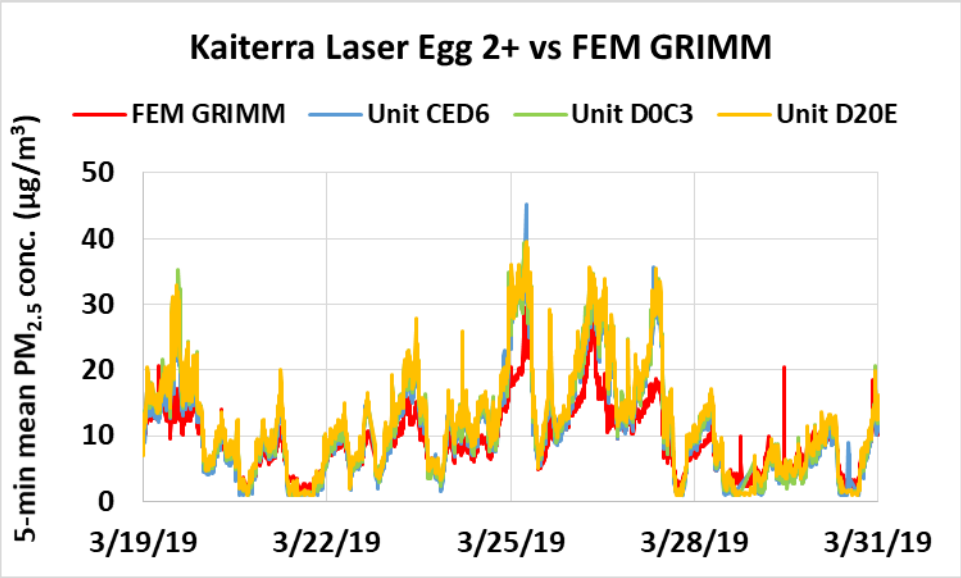




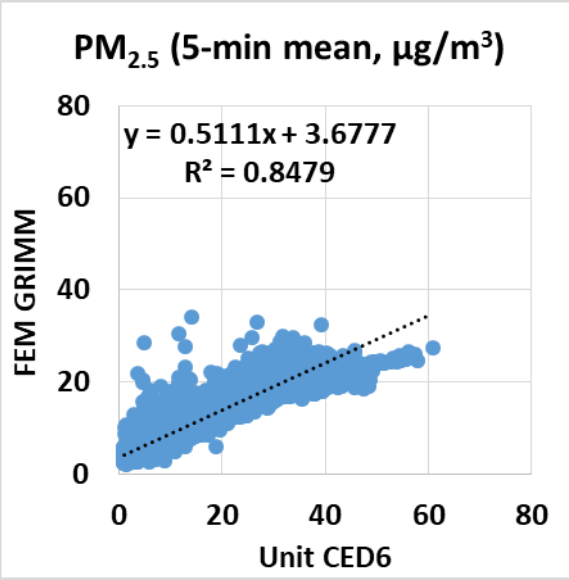


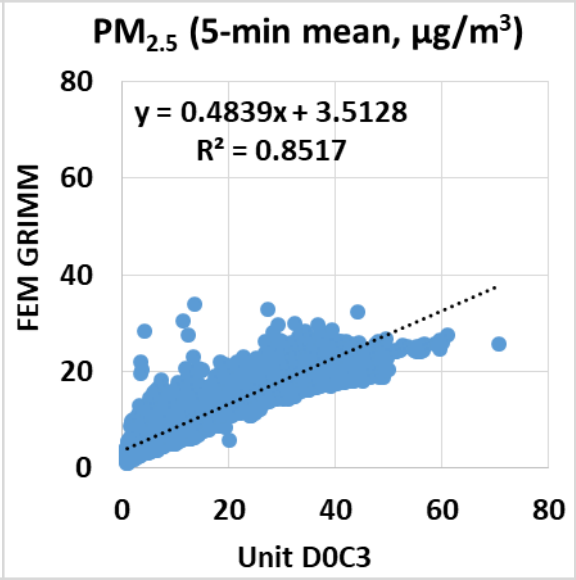


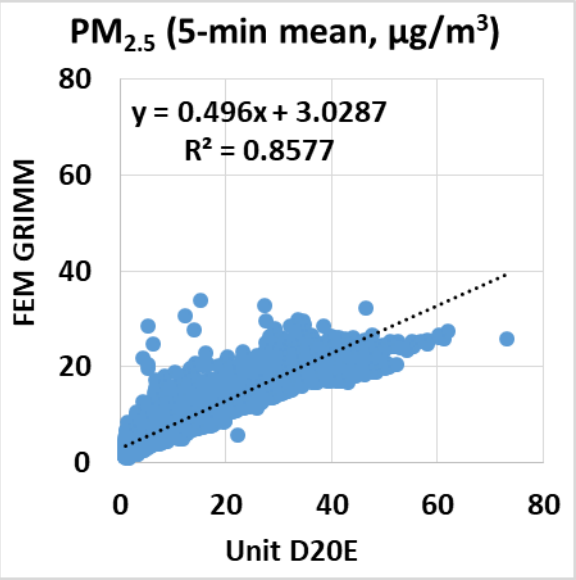
Laser Egg 2+ vs FEM GRIMM ($PM_{2.5}$; 5-min mean)



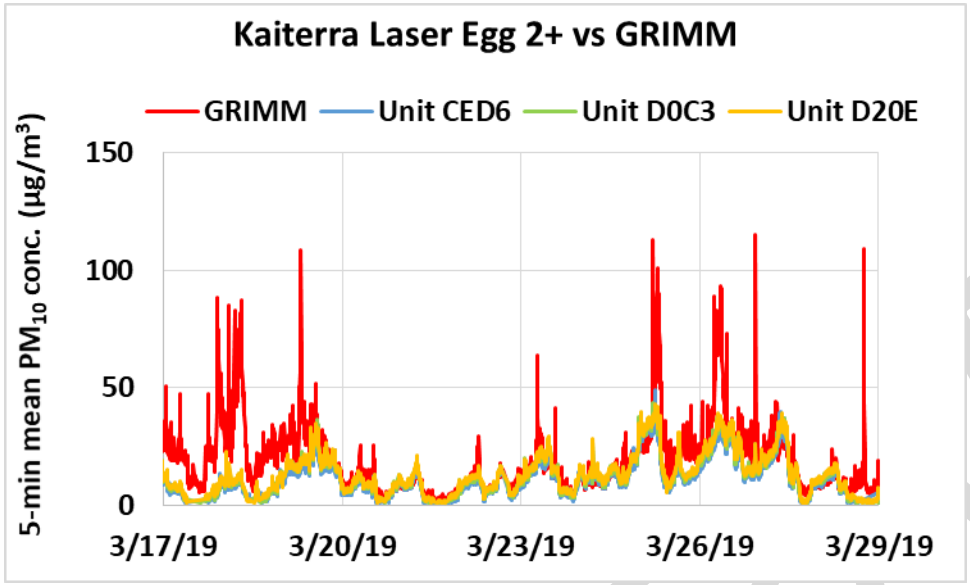
- Laser Egg 2+ sensors show good correlations with the corresponding FEM GRIMM data (R^2 ~ 0.85)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM GRIMM
- The Laser Egg 2+ sensors seem to track well the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



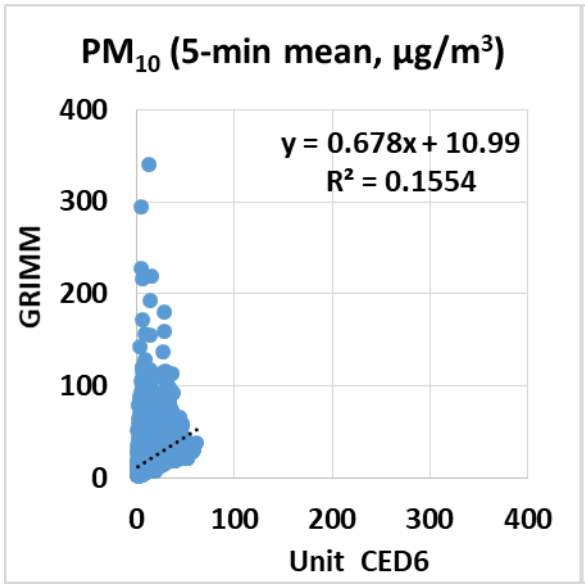


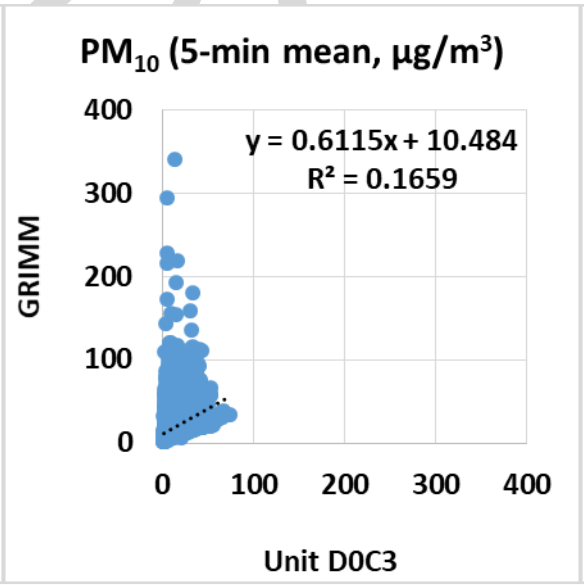


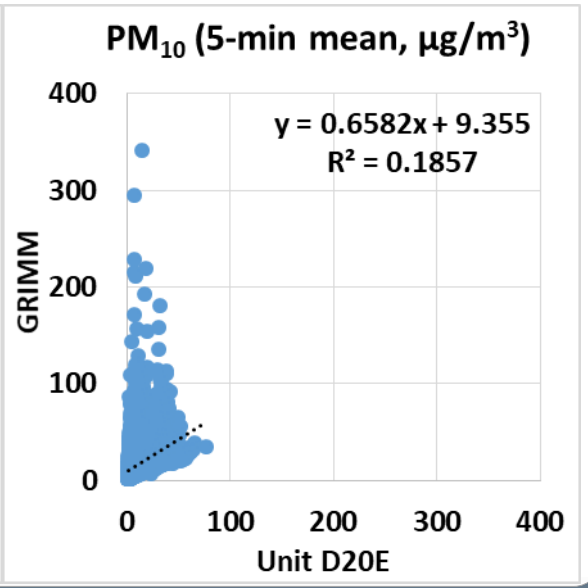
Laser Egg 2+ vs GRIMM (PM_{10}; 5-min mean)



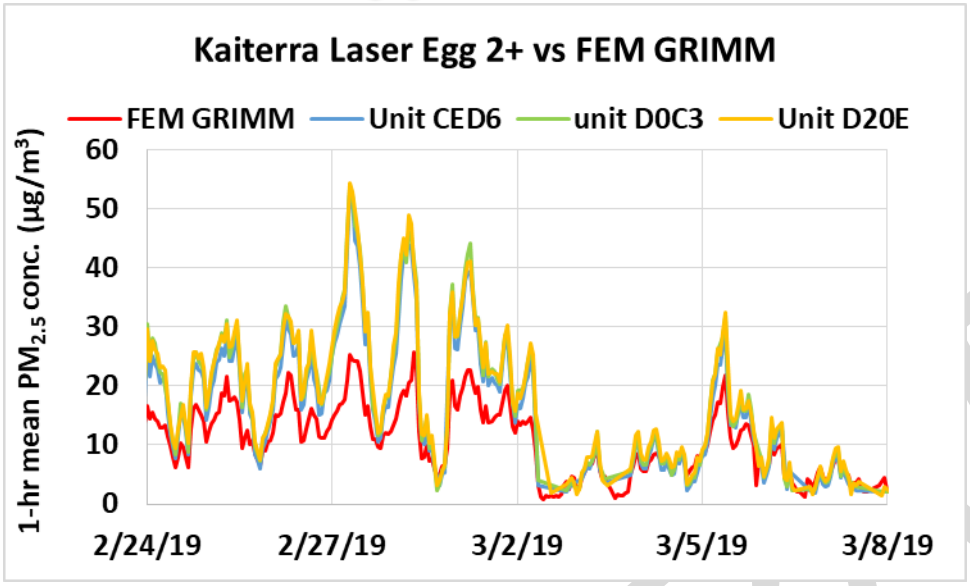
- Laser Egg 2+ sensors do not correlate with the corresponding GRIMM data (R^2 ~ 0.17)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by GRIMM
- The Laser Egg 2+ sensors seem to moderately track the PM_{10} diurnal variations as recorded by GRIMM



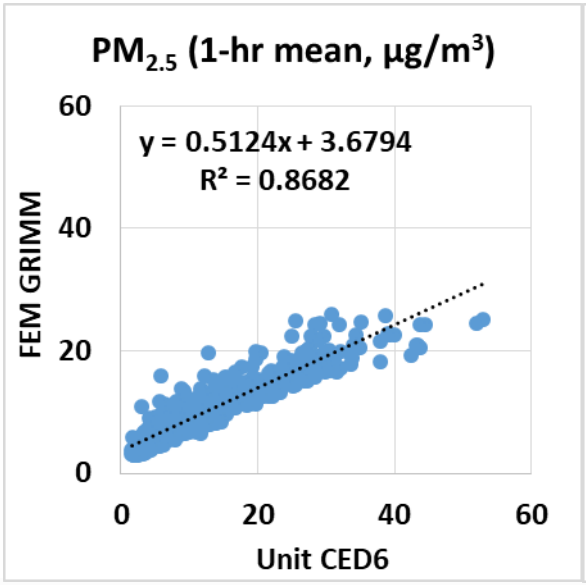


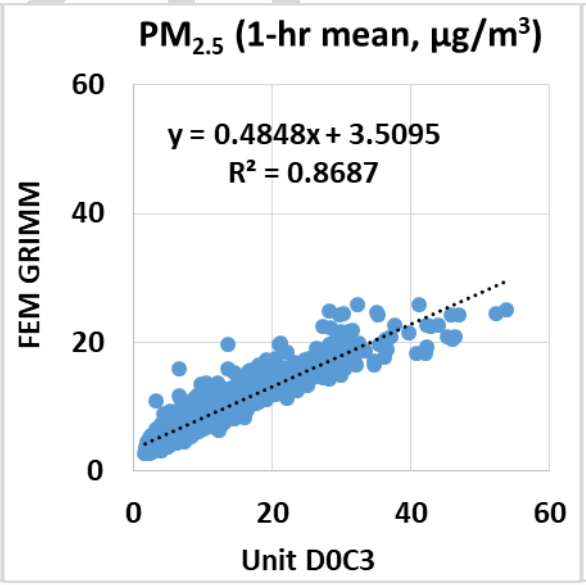


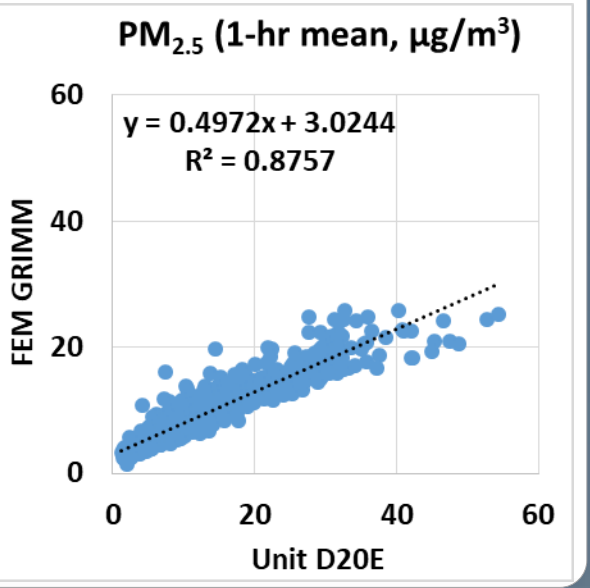
Laser Egg 2+ vs FEM GRIMM ($PM_{2.5}$; 1-hr mean)



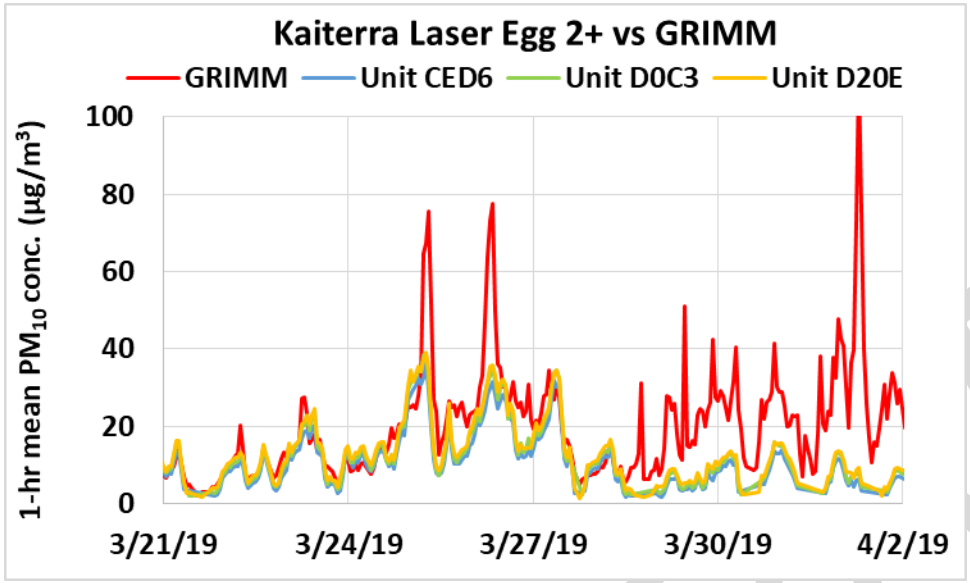
- Laser Egg 2+ sensors show good correlations with the corresponding FEM GRIMM data (R^2 ~ 0.87)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM GRIMM
- The Laser Egg 2+ sensors seem to track well the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM



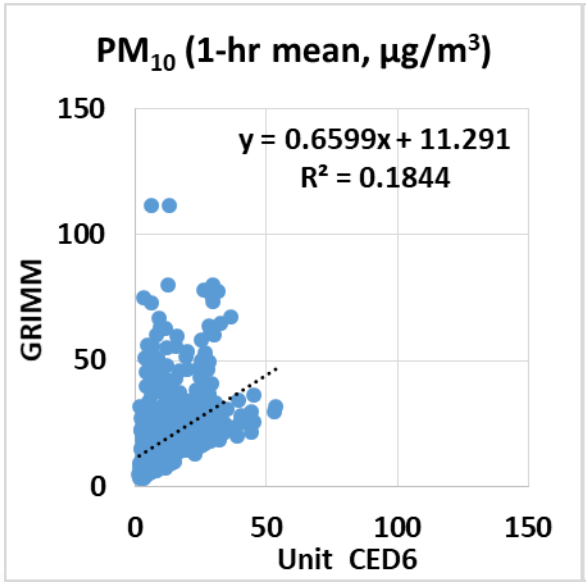


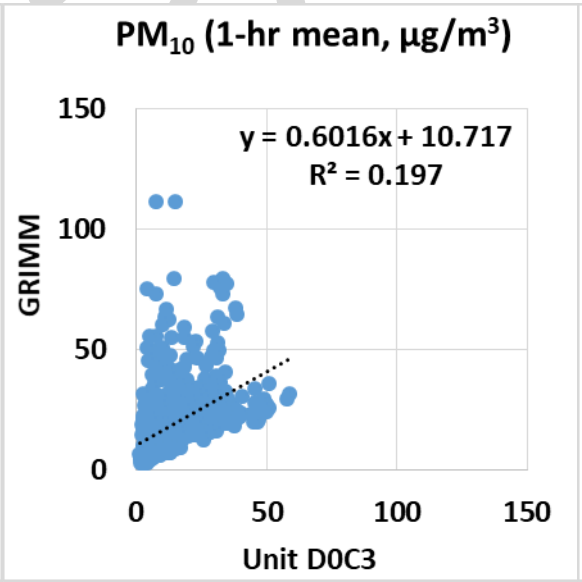


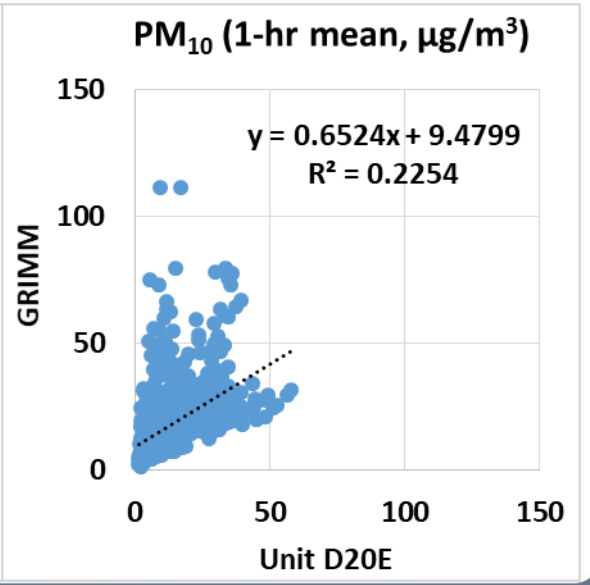
Laser Egg 2+ vs GRIMM (PM_{10}; 1-hr mean)



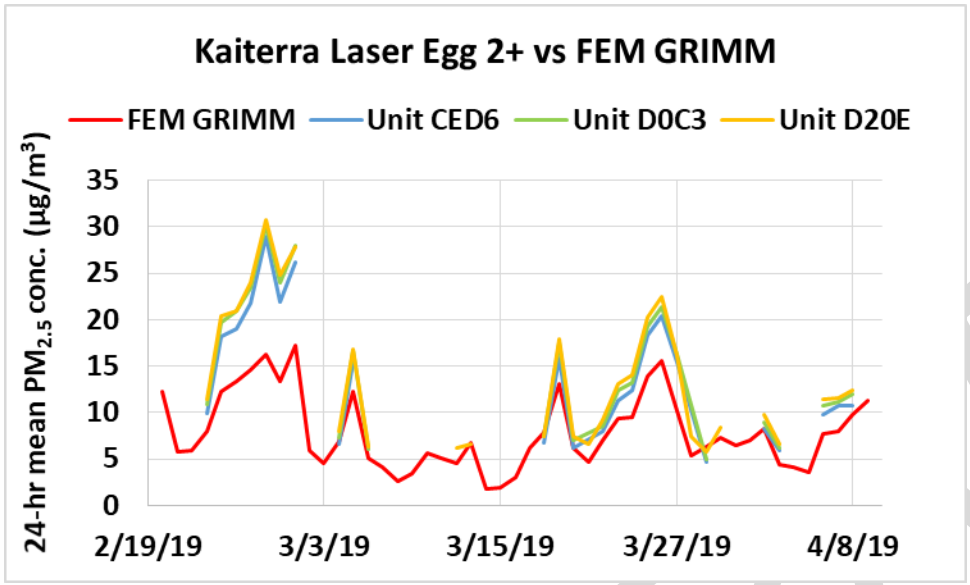
- Laser Egg 2+ sensors do not correlate with the corresponding GRIMM data (R^2 ~ 0.20)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by GRIMM
- The Laser Egg 2+ sensors seem to track the PM_{10} diurnal variations as recorded by GRIMM





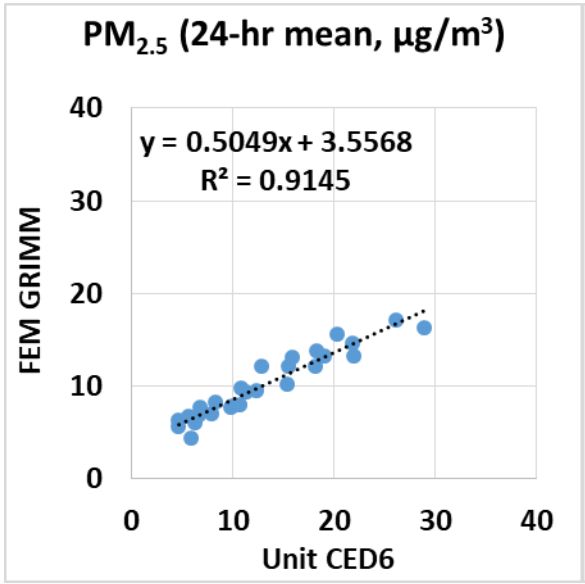


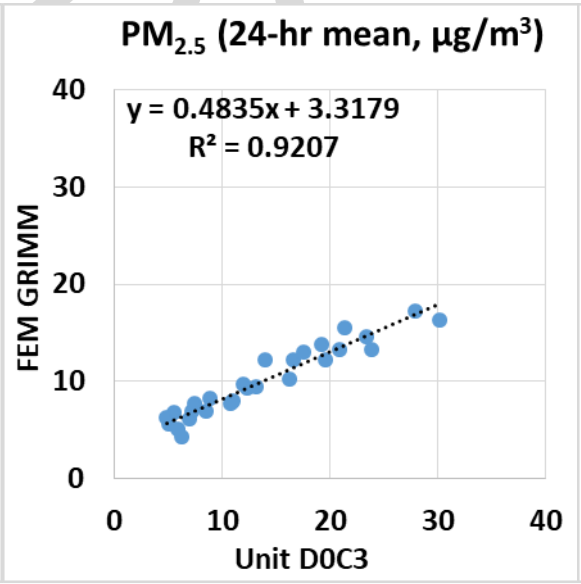
Laser Egg 2+ vs FEM GRIMM ($PM_{2.5}$; 24-hr mean)

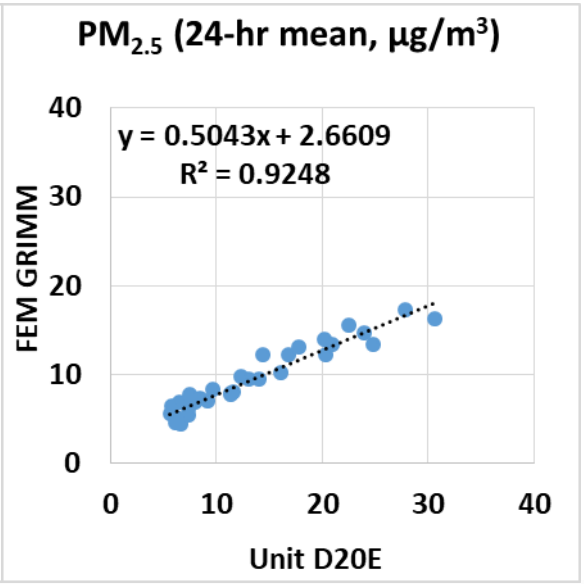


- Laser Egg 2+ sensors show excellent correlations with the corresponding FEM GRIMM data (R^2 ~ 0.92)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM GRIMM
- The Laser Egg 2+ sensors seem to track well the $PM_{2.5}$ diurnal variations as recorded by FEM GRIMM

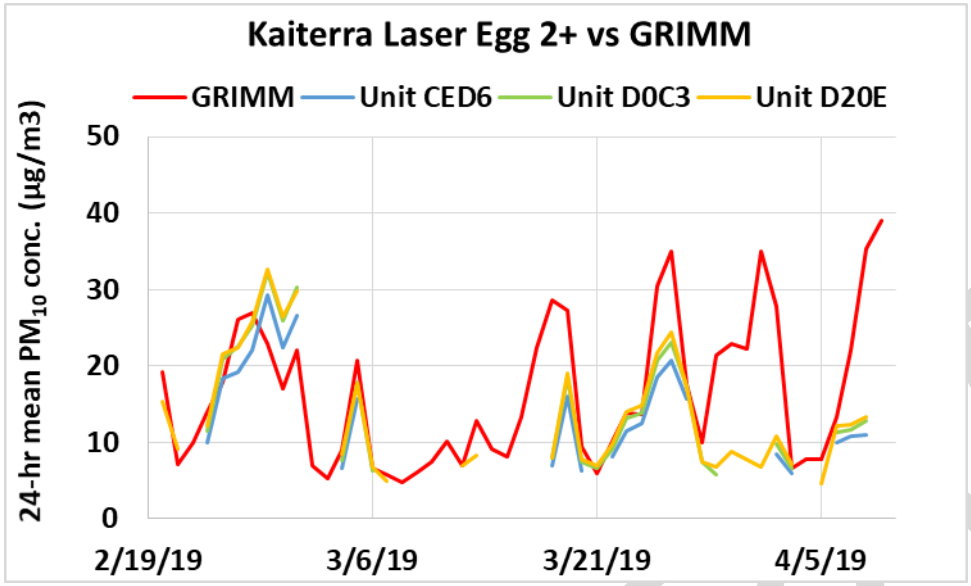
Note: Gaps in the sensor data indicate that less than 75% of the 24-hr sensor data were observed and thus excluded from the plots





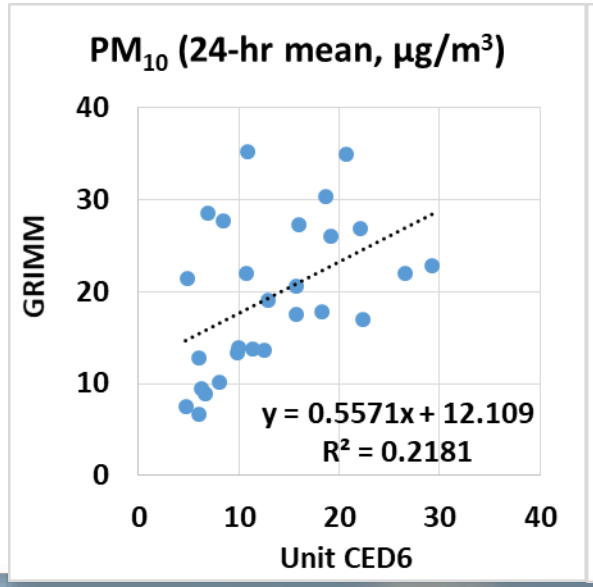


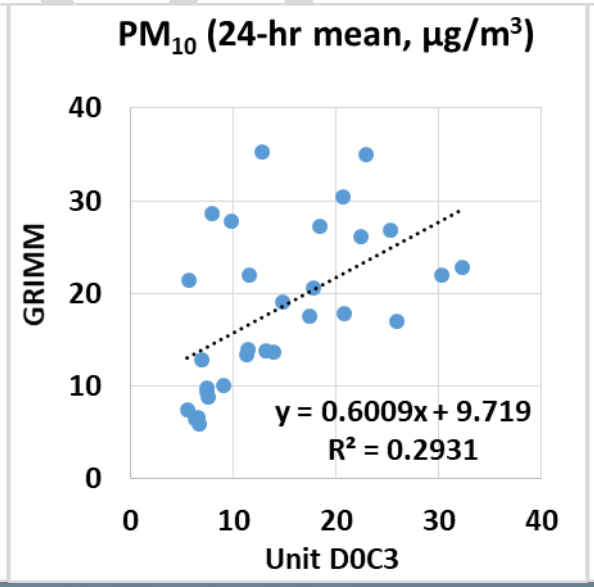
Laser Egg 2+ vs GRIMM (PM_{10}; 24-hr mean)

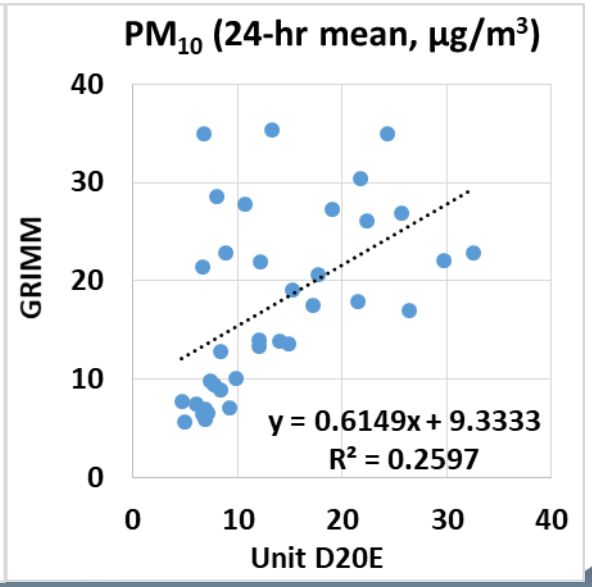


- Laser Egg 2+ sensors do not correlate with the corresponding GRIMM data (R^2 ~ 0.26)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by GRIMM
- The Laser Egg 2+ sensors seem to moderately track the PM_{10} diurnal variations as recorded by GRIMM

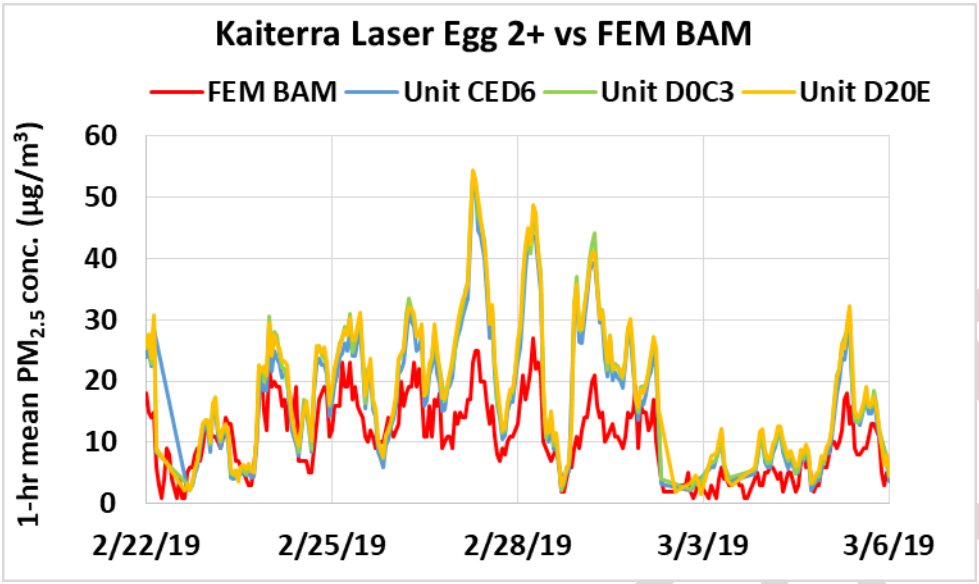
Note: Gaps in the sensor data indicate that less than 75% of the 24-hr sensor data were observed and thus exclude from the plots



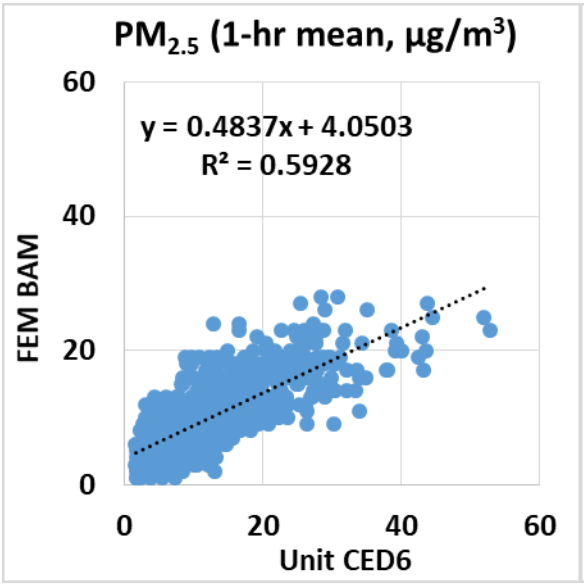


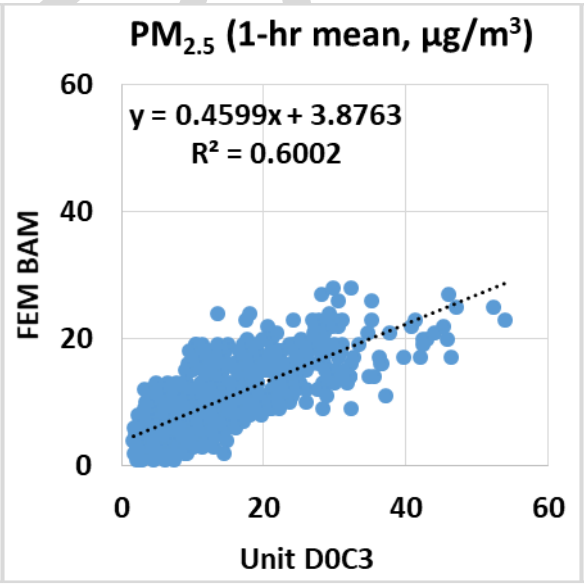


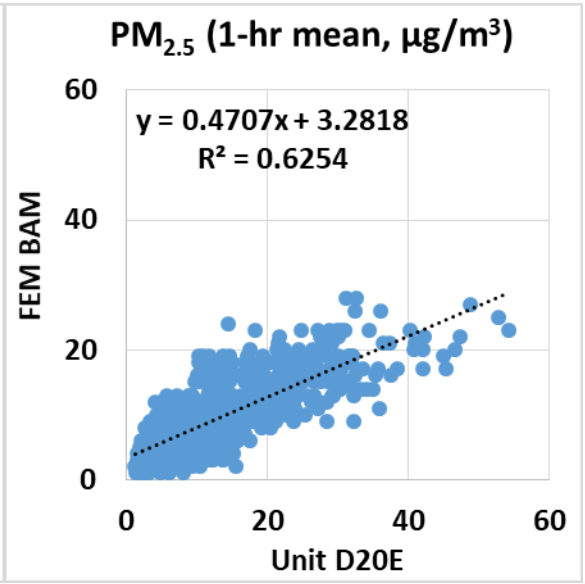
Laser Egg 2+ vs FEM BAM ($PM_{2.5}$; 1-hr mean)



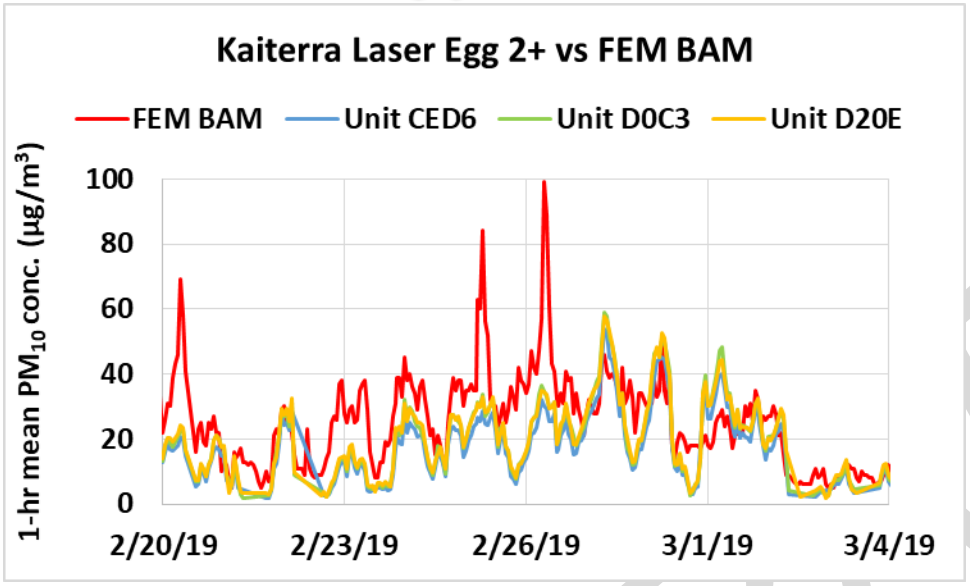
- Laser Egg 2+ sensors show moderate correlations with the corresponding FEM BAM data (R^2 ~ 0.61)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM BAM
- The Laser Egg 2+ sensors seem to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM



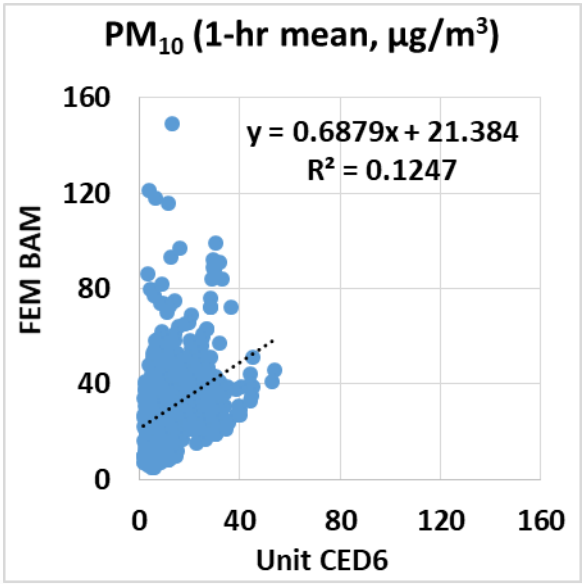


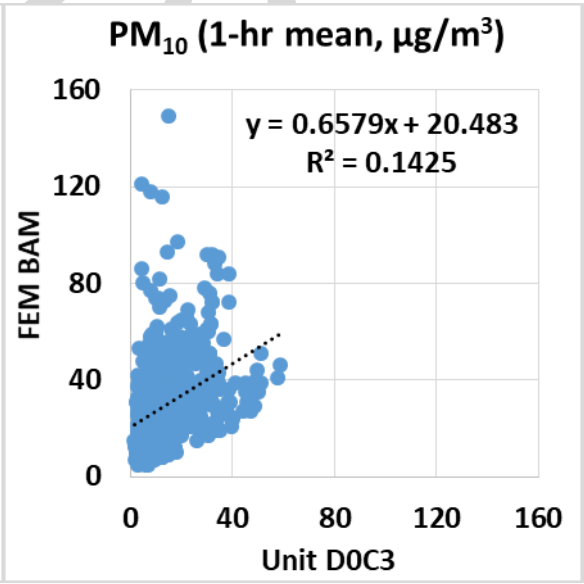


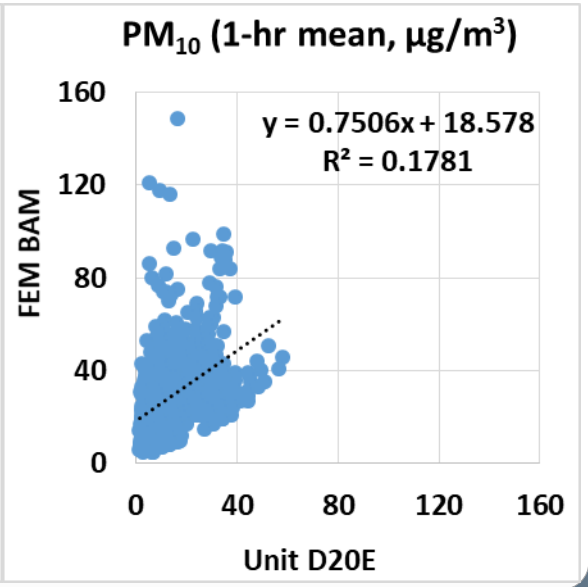
Laser Egg 2+ vs FEM BAM (PM_{10}; 1-hr mean)



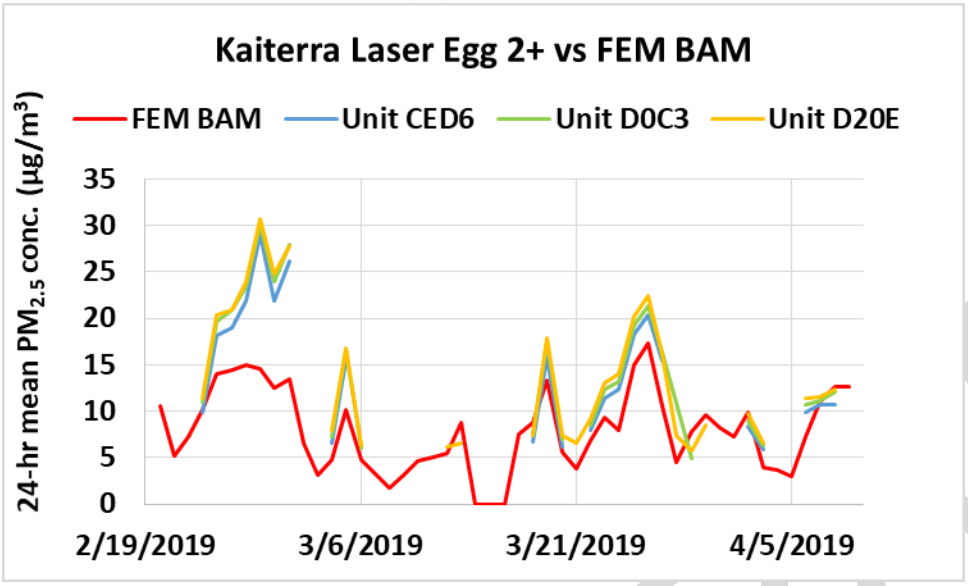
- Laser Egg 2+ sensors do not correlate with the corresponding FEM BAM data (R^2 ~ 0.15)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by FEM BAM
- The Laser Egg 2+ sensors seem to track the PM_{10} diurnal variations as recorded by FEM BAM





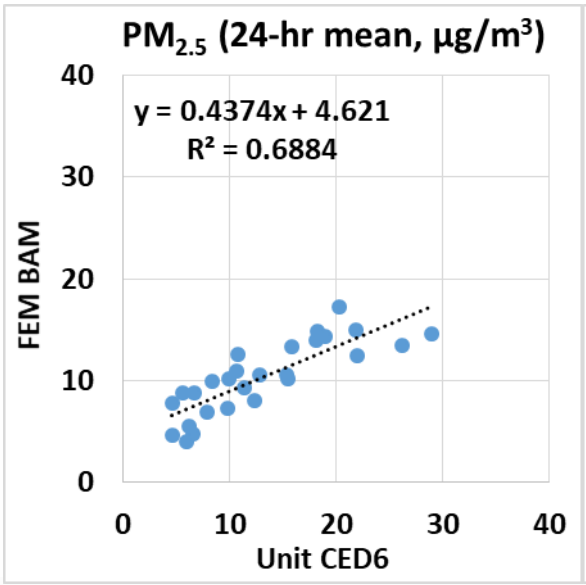


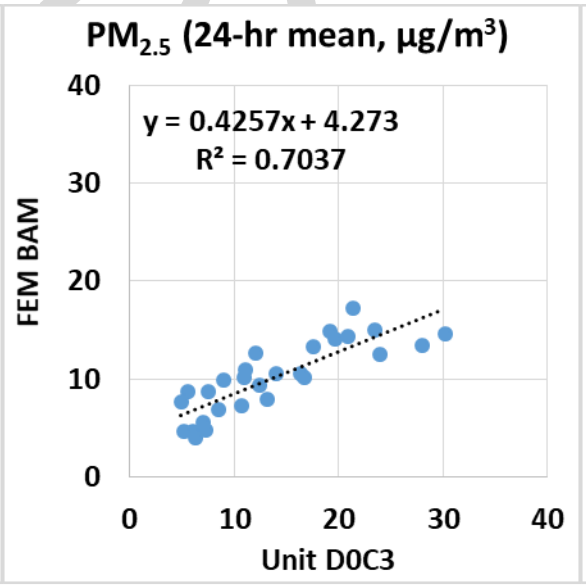
Laser Egg 2+ vs FEM BAM ($PM_{2.5}$; 24-hr mean)

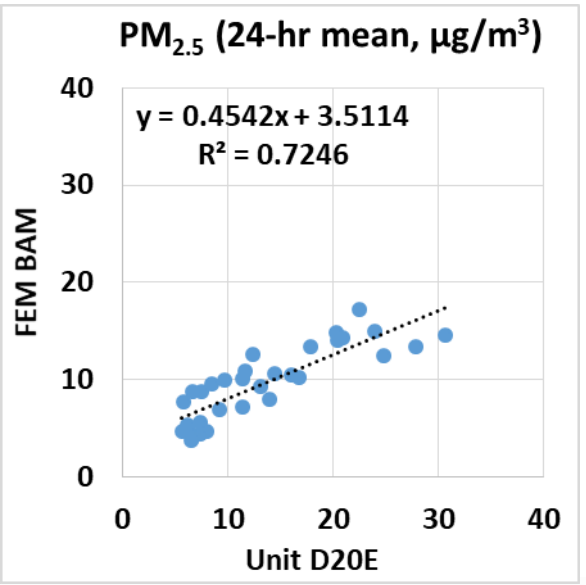


- Laser Egg 2+ sensors show good correlations with the corresponding FEM BAM data (R^2 ~ 0.71)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM BAM
- The Laser Egg 2+ sensors seem to track the $PM_{2.5}$ diurnal variations as recorded by FEM BAM

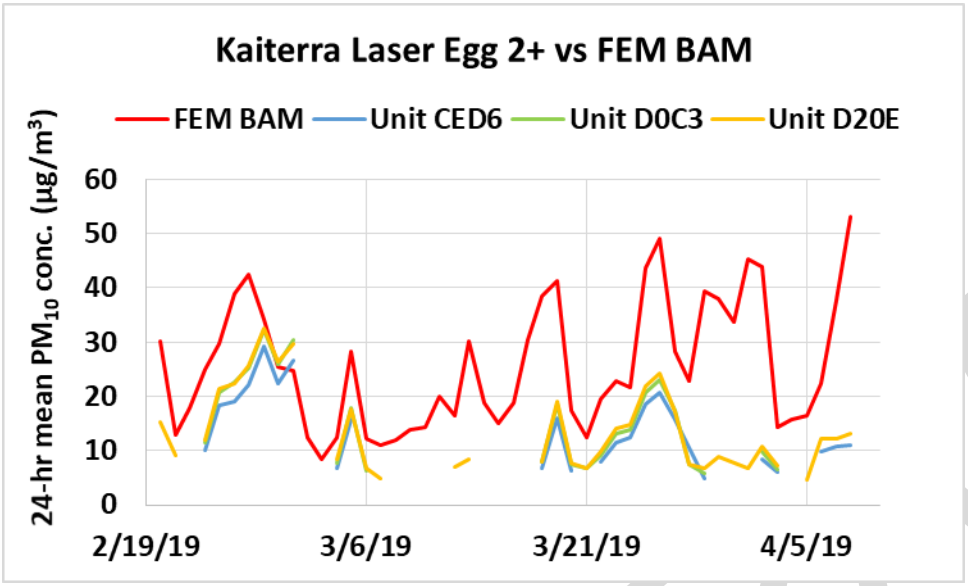
Note: Gaps in the sensor data indicate that less than 75% of the 24-hr sensor data were observed and thus exclude from the plots





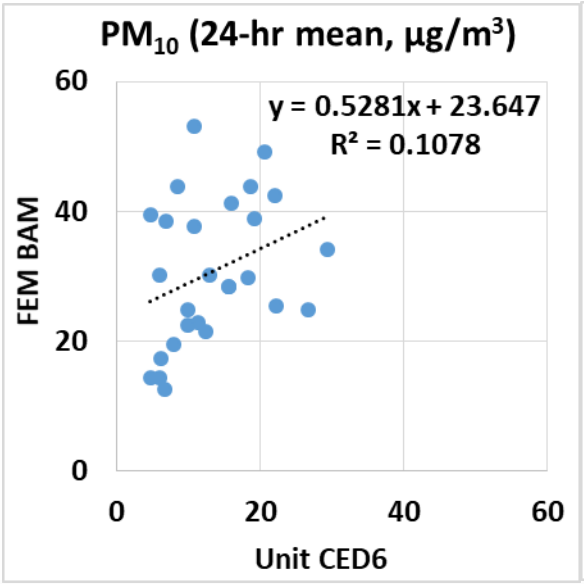


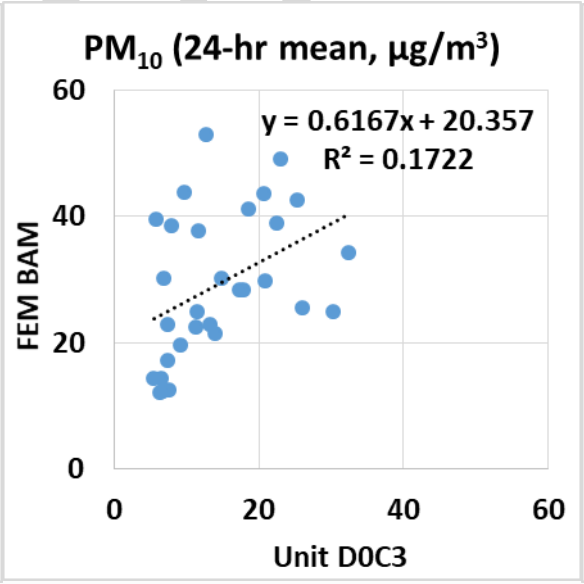
Laser Egg 2+ vs FEM BAM (PM_{10}; 24-hr mean)

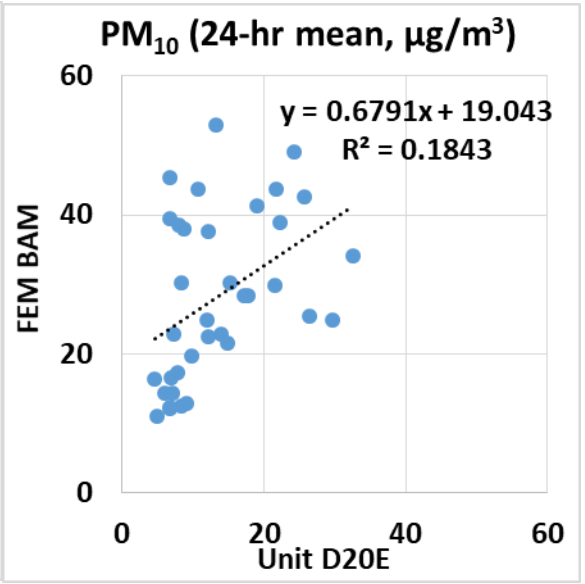


- Laser Egg 2+ sensors do not correlate with the corresponding FEM BAM data (R^2 ~ 0.15)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by FEM BAM
- The Laser Egg 2+ sensors seem to track the PM_{10} diurnal variations as recorded by FEM BAM

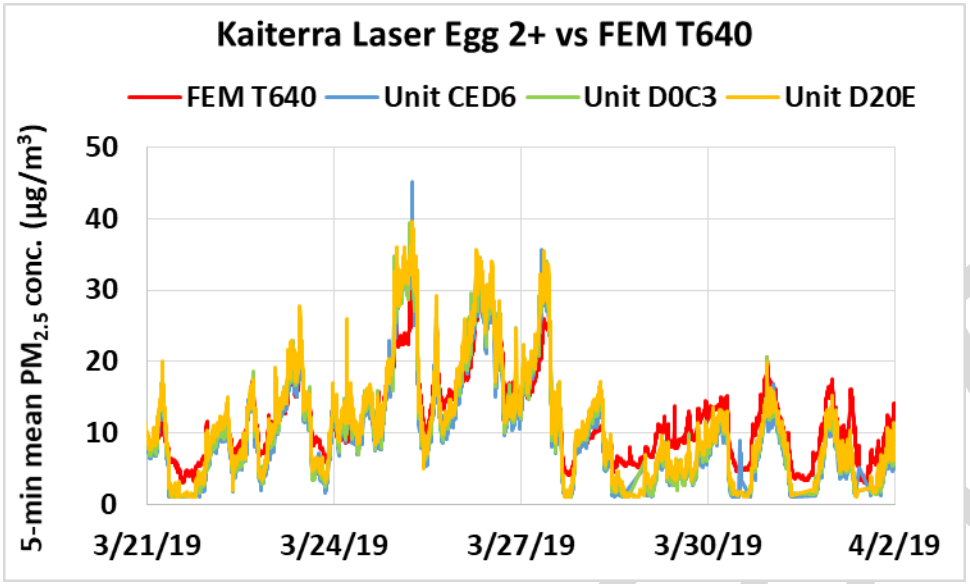
Note: Gaps in the sensor data indicate that less than 75% of the 24-hr sensor data were observed and thus exclude from the plots



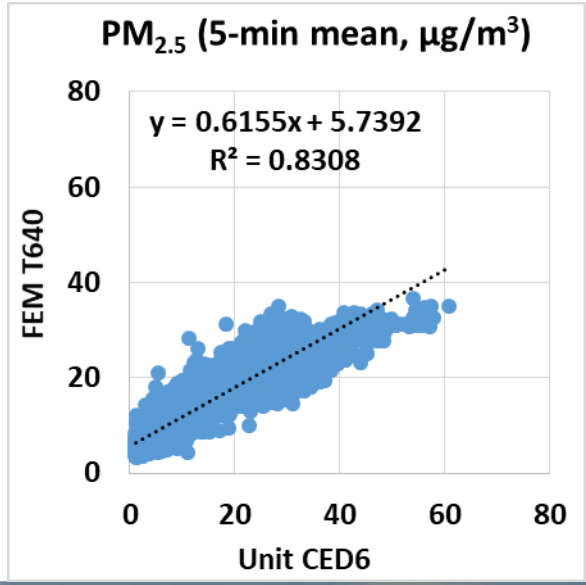


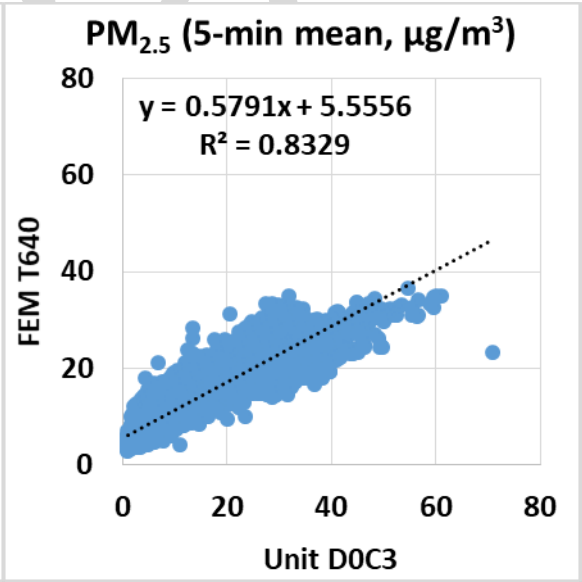


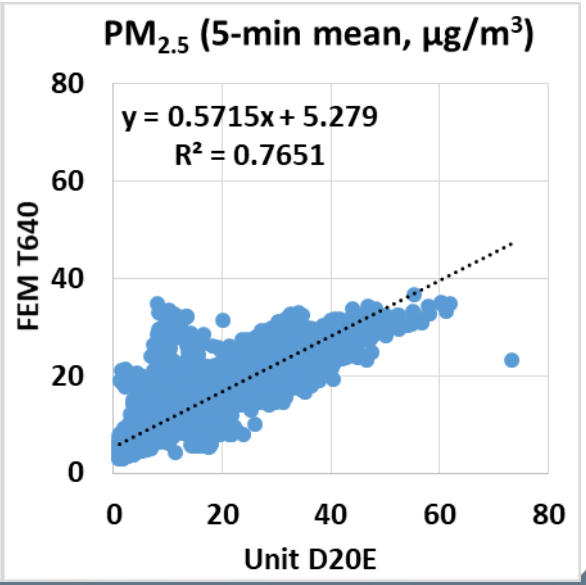
Laser Egg 2+ vs FEM T640 ($PM_{2.5}$; 5-min mean)



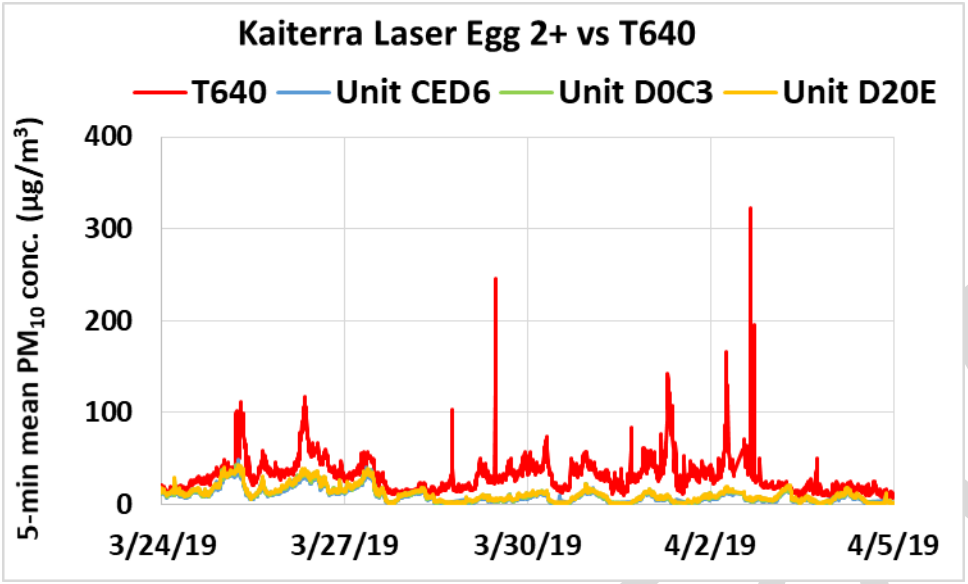
- Laser Egg 2+ sensors show good correlations with the corresponding FEM T640 data (R^2 ~ 0.81)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM T640
- The Laser Egg 2+ sensors seem to track well the $PM_{2.5}$ diurnal variations as recorded by FEM T640



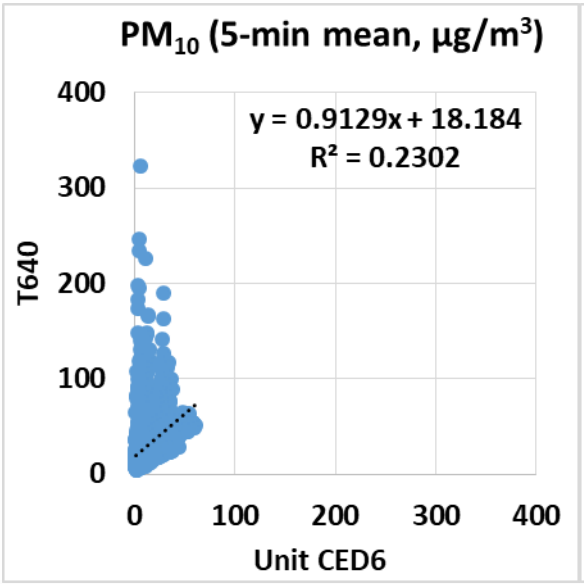


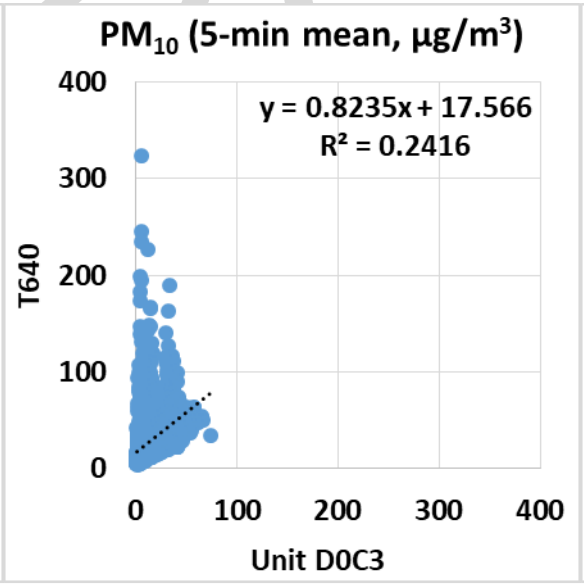


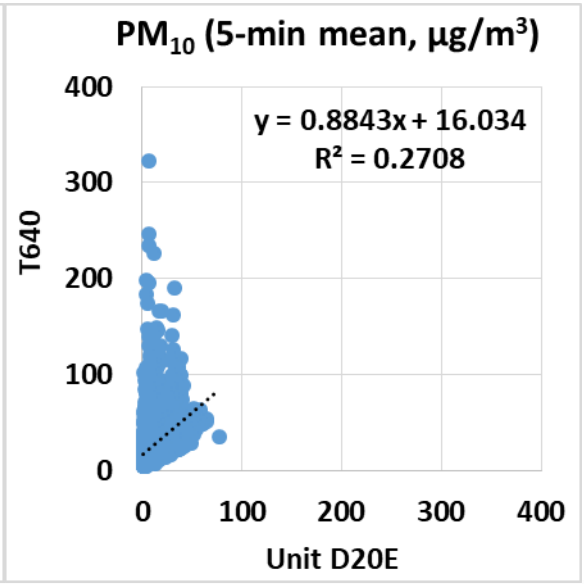
Laser Egg 2+ vs T640 (PM_{10}; 5-min mean)



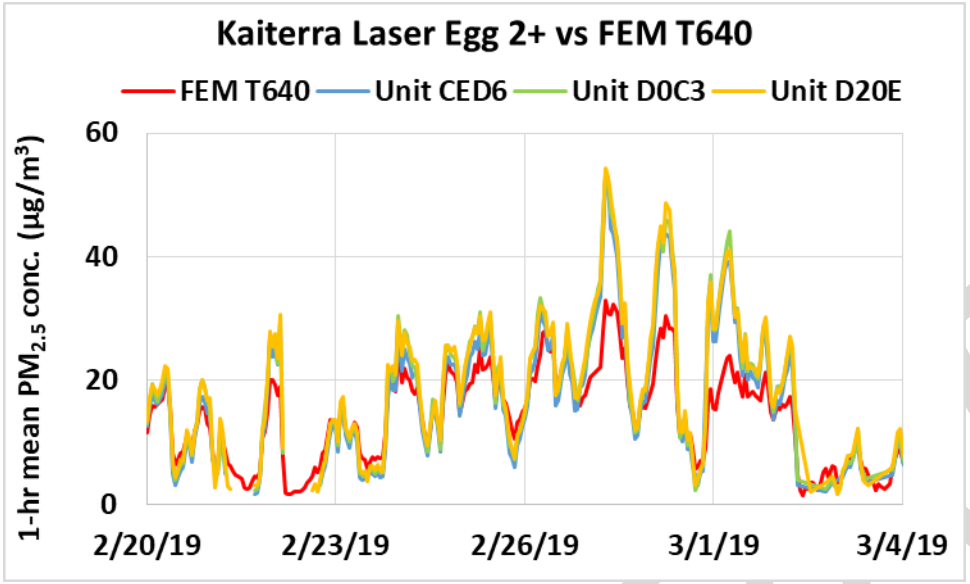
- Laser Egg 2+ sensors do not correlate with the corresponding T640 data (R^2 ~ 0.25)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by T640
- The Laser Egg 2+ sensors seem to moderately track the PM_{10} diurnal variations as recorded by T640



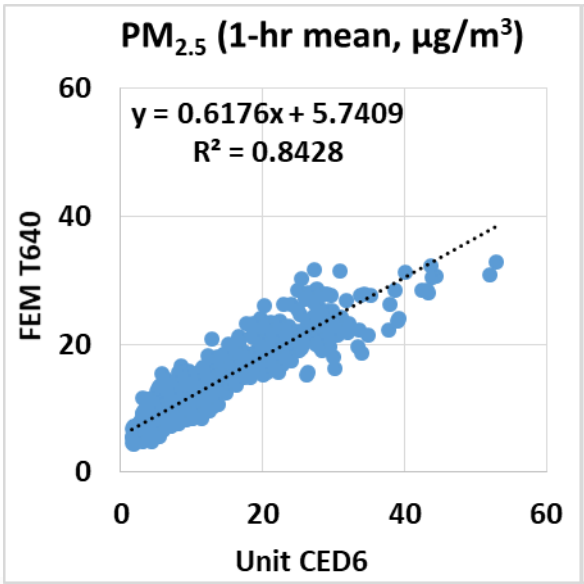


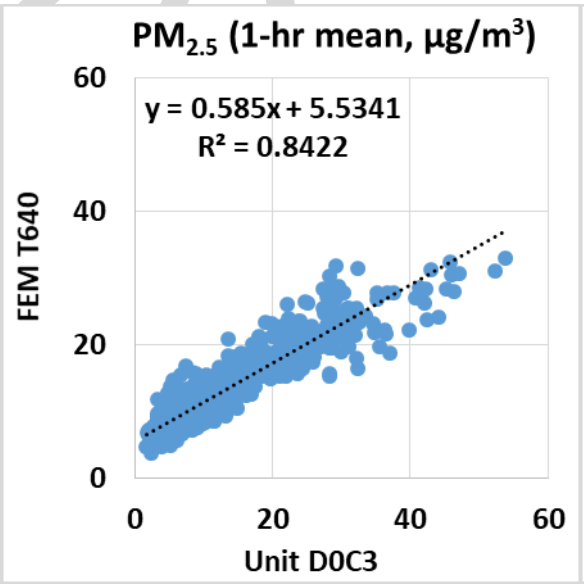


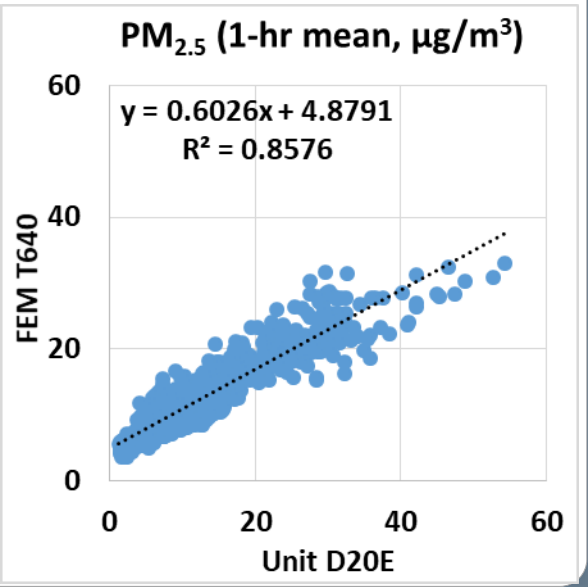
Laser Egg 2+ vs FEM T640 ($PM_{2.5}$; 1-hr mean)



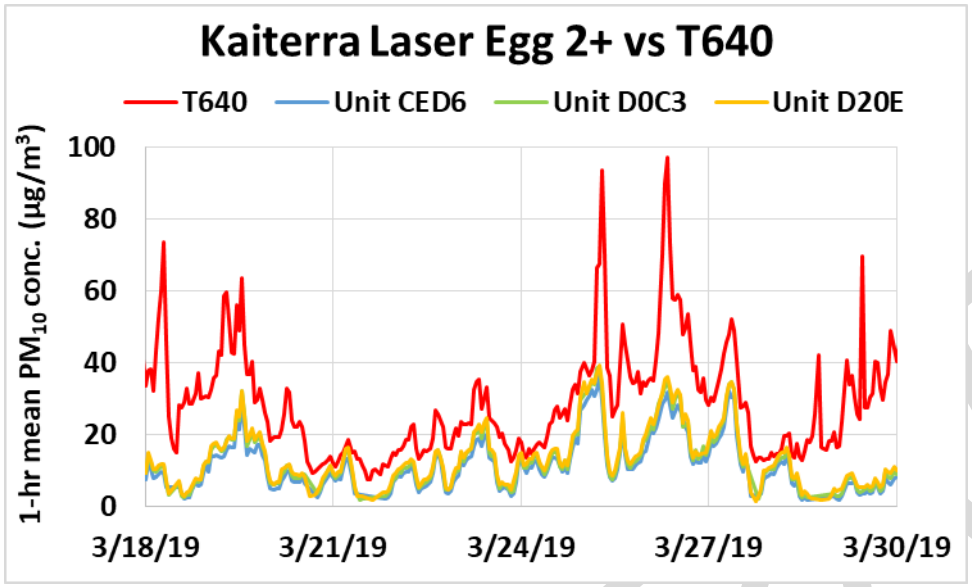
- Laser Egg 2+ sensors show good correlations with the corresponding FEM T640 data (R^2 ~ 0.85)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM T640
- The Laser Egg 2+ sensors seem to track well the $PM_{2.5}$ diurnal variations as recorded by FEM T640



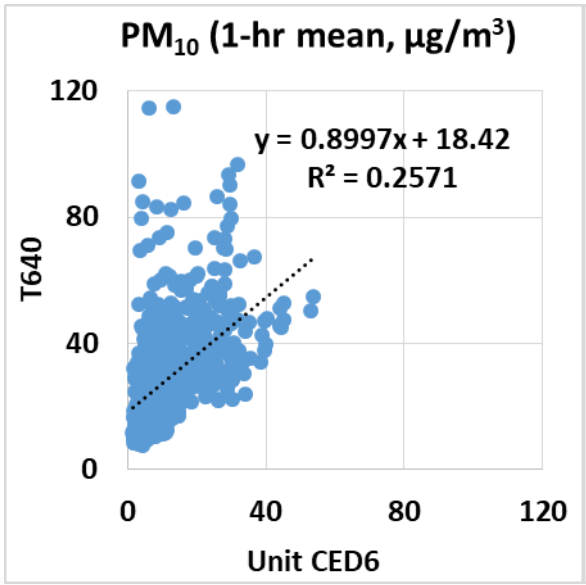


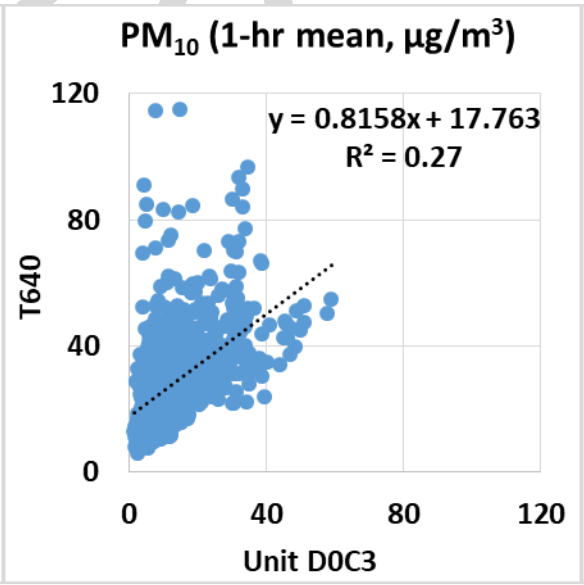


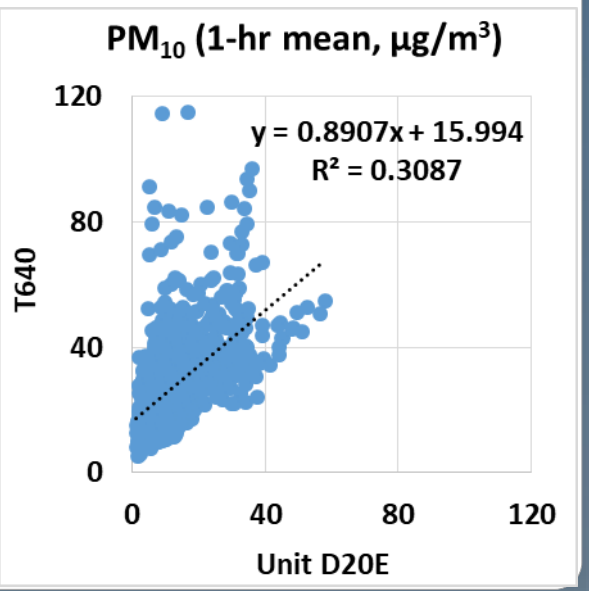
Laser Egg 2+ vs T640 (PM_{10}; 1-hr mean)



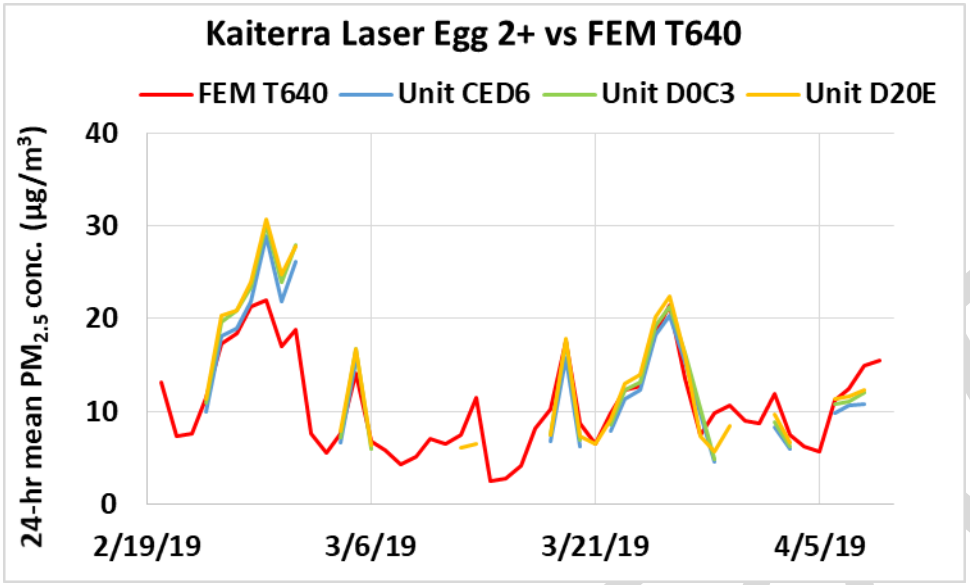
- Laser Egg 2+ sensors do not correlate with the corresponding T640 data (R^2 ~ 0.28)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by T640
- The Laser Egg 2+ sensors seem to moderately track the PM_{10} diurnal variations as recorded by T640





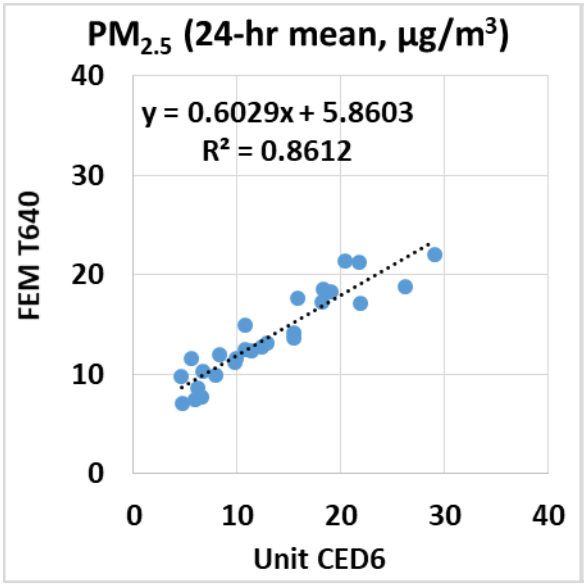


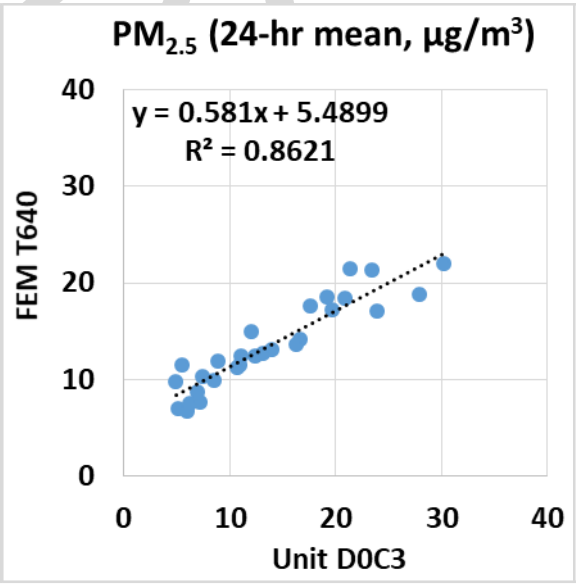
Laser Egg 2+ vs FEM T640 ($PM_{2.5}$; 24-hr mean)

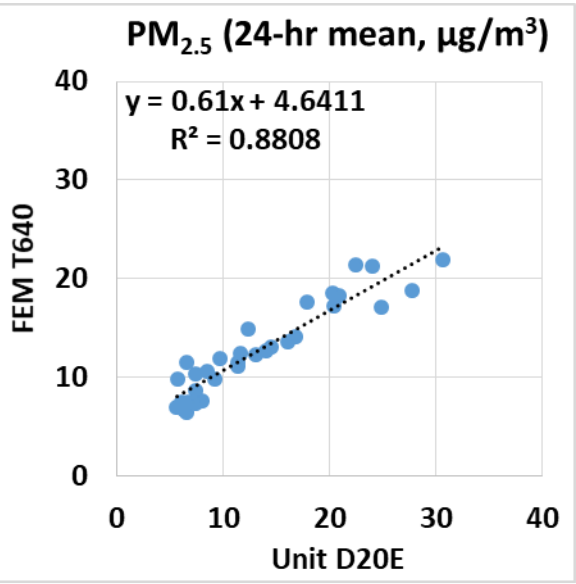


- Laser Egg 2+ sensors show good correlations with the corresponding FEM T640 data (R^2 ~ 0.87)
- Overall, the Laser Egg 2+ sensors overestimate the $PM_{2.5}$ mass concentrations measured by FEM T640
- The Laser Egg 2+ sensors seem to track the $PM_{2.5}$ diurnal variations as recorded by FEM T640

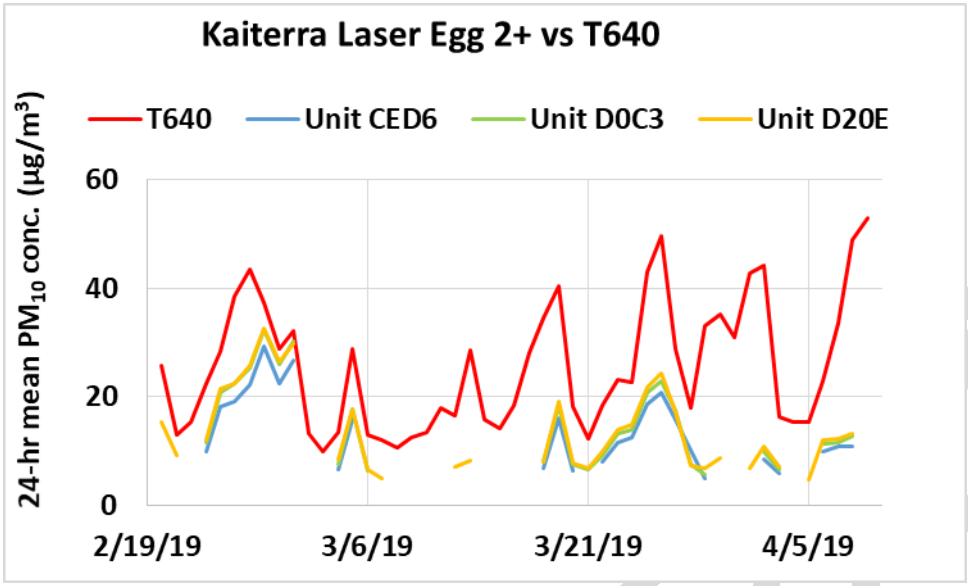
Note: Gaps in the sensor data indicate that less than 75% of the 24-hr sensor data were observed and thus exclude from the plots





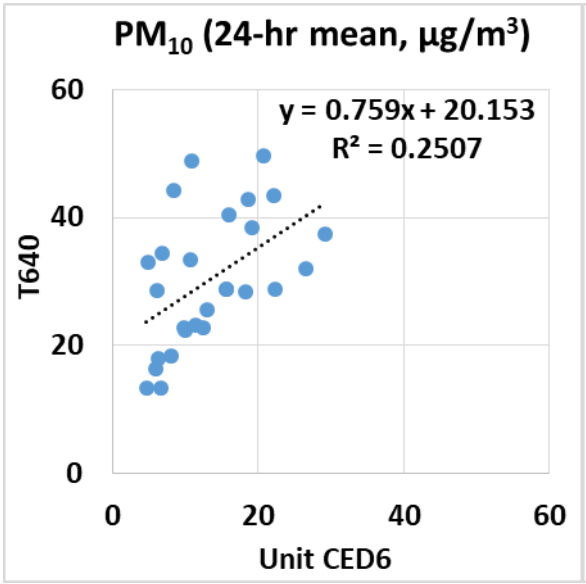


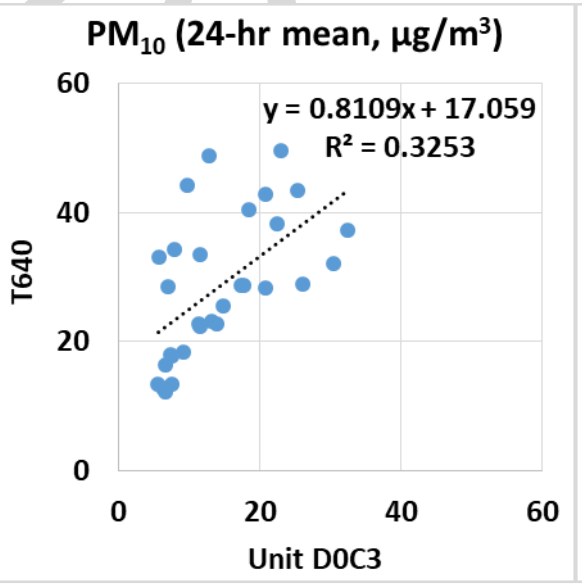
Laser Egg 2+ vs T640 (PM_{10}; 24-hr mean)

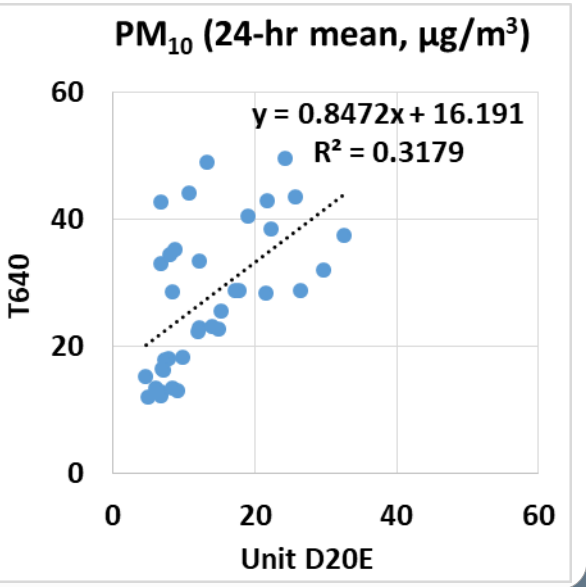


- Laser Egg 2+ sensors do not correlate with the corresponding T640 data (R^2 ~ 0.30)
- Overall, the Laser Egg 2+ sensors underestimate the PM_{10} mass concentrations measured by T640
- The Laser Egg 2+ sensors seem to moderately track the PM_{10} diurnal variations as recorded by T640

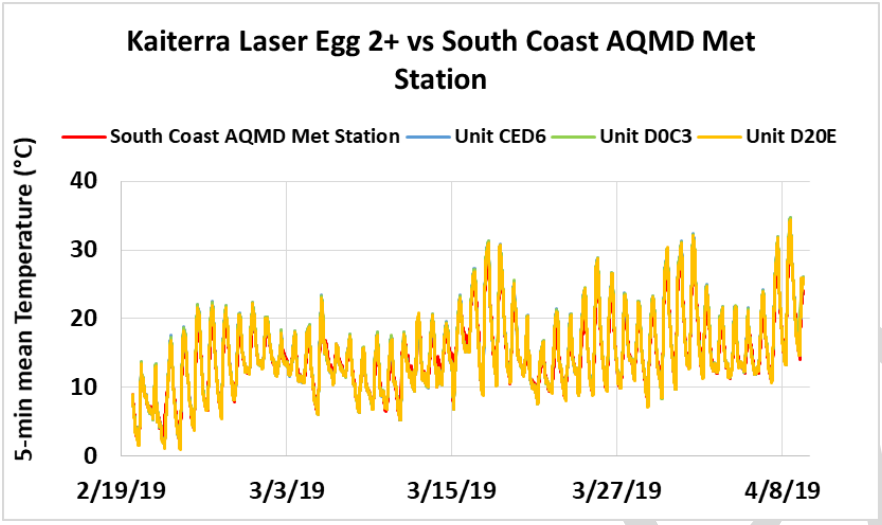
Note: Gaps in the sensor data indicate that less than 75% of the 24-hr sensor data were observed and thus exclude from the plots



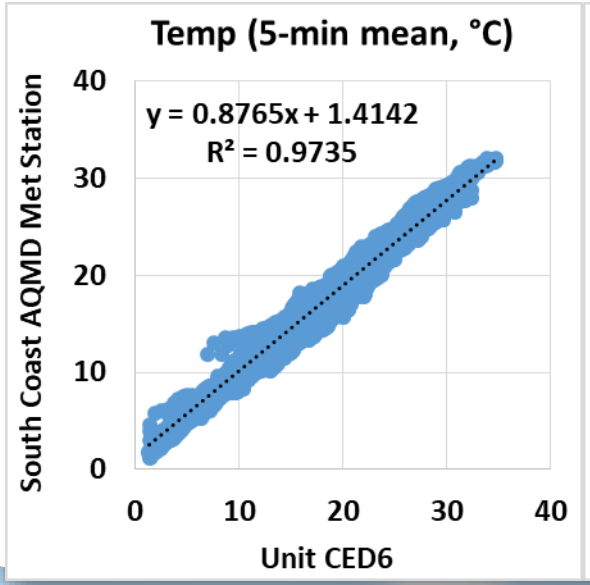


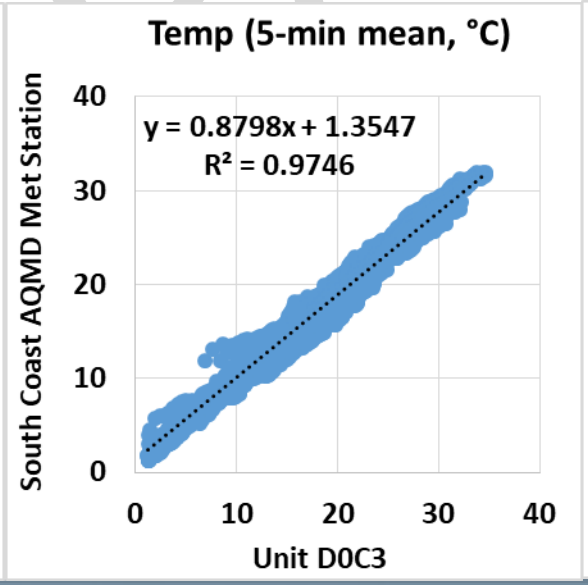


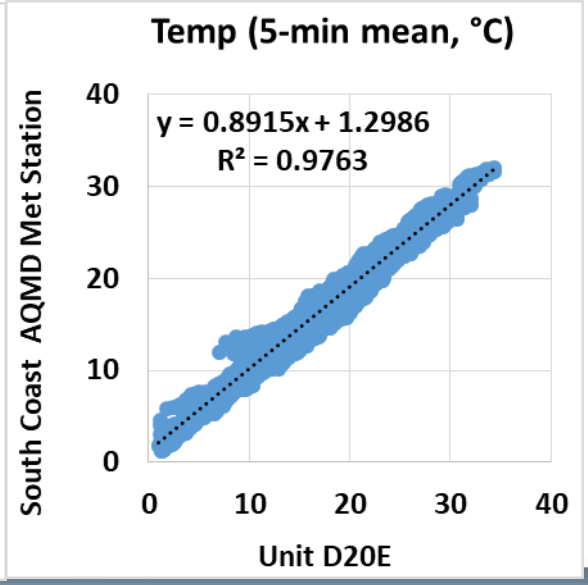
Laser Egg 2+ vs South Coast AQMD Met Station (Temp; 5-min mean)



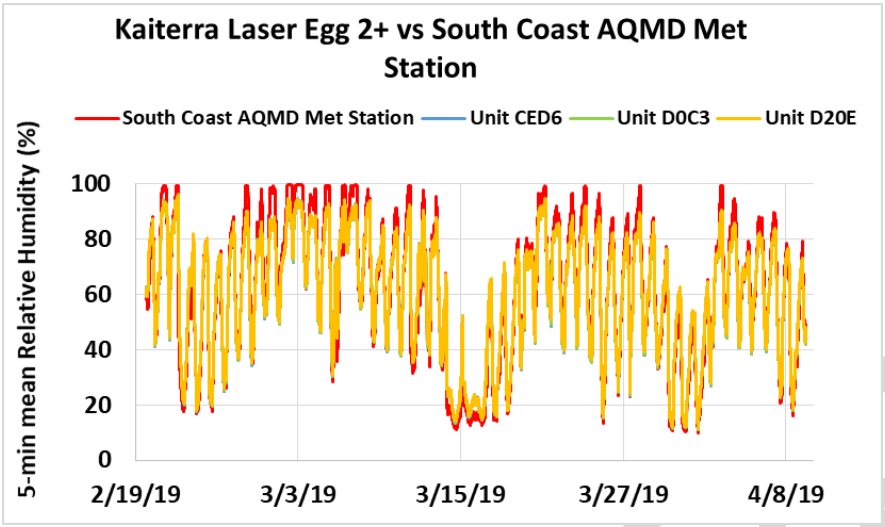
- Laser Egg 2+ temperature measurements correlate very well with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.97)
- Overall, the Laser Egg 2+ temperature measurements slightly overestimate the corresponding South Coast AQMD Met Station data
- The Laser Egg 2+ sensors seem to track well the temperature diurnal variations as recorded by South Coast AQMD Met Station



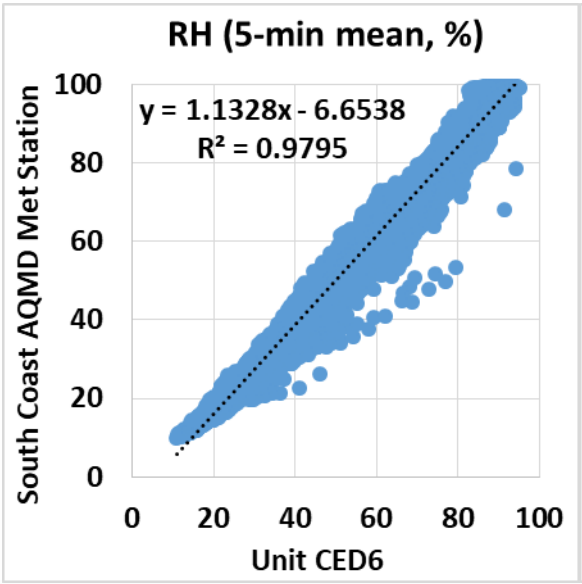


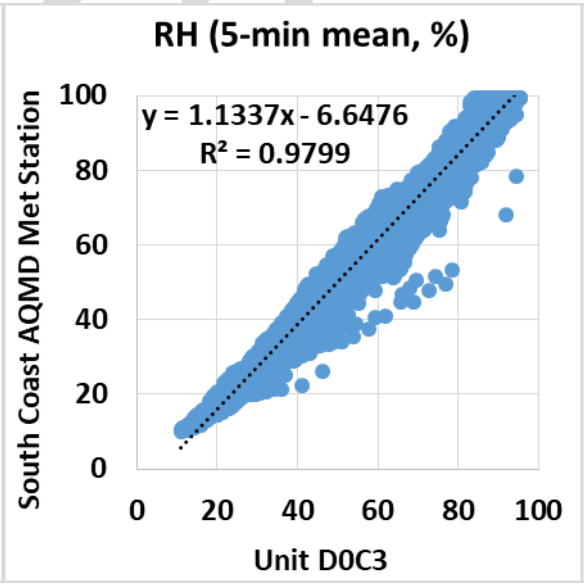


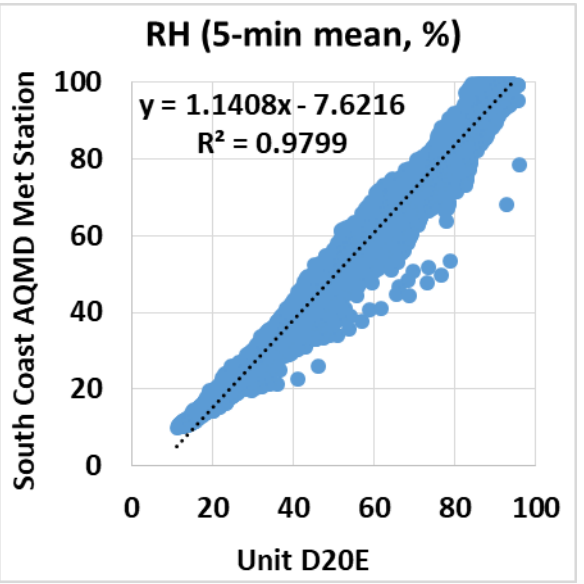
Laser Egg 2+ vs South Coast AQMD Met Station (RH; 5-min mean)



- The Laser Egg 2+ RH measurements correlate very well with the corresponding South Coast AQMD Met Station data (R^2 ~ 0.98)
- Overall, the Laser Egg 2+ slightly underestimate RH measurements as recorded by the South Coast AQMD Met Station
- The Laser Egg 2+ sensors seem to track well the RH diurnal variations as recorded by South Coast AQMD Met Station







Discussion

- The three **Kaiterra Laser Egg 2+** sensors' data recovery from units CED6, D0C3, and D20E for $PM_{2.5}$ and PM_{10} mass conc. measurements is 75.7 % and 77.3 %, respectively.
- The three sensors showed low intra-model variability (~7 % and 11.1 % for $PM_{2.5}$ and PM_{10} mass conc. measurements, respectively)
- The reference instruments (GRIMM, BAM and T640) correlate well with each other for both $PM_{2.5}$ (R^2 ~ 0.84) and PM_{10} (R^2 ~ 0.89) mass concentration measurements (1-hr mean)
- $PM_{2.5}$ mass concentration measurements measured by Laser Egg 2+ sensors show moderate to good correlations with the corresponding FEM GRIMM, FEM BAM and FEM T640 data (R^2 ~ 0.87, 0.61 and 0.85, respectively, 1-hr mean) and overestimate $PM_{2.5}$ mass concentrations measured by FEM GRIMM, FEM BAM and FEM T640
- PM_{10} mass concentration measurements measured by Laser Egg 2+ sensors do not correlate with the corresponding GRIMM, FEM BAM and T640 data (R^2 ~ 0.20, 0.15 and 0.28, respectively; 1-hr mean) and underestimate PM_{10} mass concentrations measured by GRIMM, FEM BAM andT640
- No sensor calibration was performed by South Coast AQMD Staff prior to the beginning of this test
- 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