Field Evaluation
Aeroqual AQY (v0.5)

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 12/22/2017 to 03/27/2018, three Aeroqual AQY (Version 0.5) multi-sensor units were deployed in Rubidoux and run side-by-side South Coast AQMD Federal Equivalent Method (FEM) and Federal Reference Method (FRM) instruments measuring the same pollutants

- Aeroqual AQY (*3 units tested*):
  - Sensors: Ozone – Gas Sensitive Semiconductor (GSS) (non-FEM);
    NO_2 – Gas Sensitive Electrochemical (GSE) (non-FEM);
    $PM_{2.5}$ – Laser Particle Counter (LPC) (non-FEM), (model SDS011 by Nova Fitness)
  - Each unit measures: O_3 (ppb), NO_2 (ppb), $PM_{2.5}$ ($\mu g/m^3$), T (degrees C), RH (%)
  - Unit cost: ~$3,000 (includes 2-yr tech support + cloud data software license)
  - Time resolution: 1-min
  - Units IDs: AQY 130, AQY 131 (AQY 134), AQY 132
    (On 2/15/2018, entire unit AQY 131 was replaced by unit AQY 134 due to faulty NO_2 sensor)

- SCAQMD Reference instruments:
  - O_3 instrument (FEM); cost: ~$7,000
    - Time resolution; 1-min
  - NO_X instrument (FRM); cost: ~$11,000
    - Time resolution: 1-min
  - GRIMM (FEM $PM_{2.5}$); cost: $25,000 and up
    - Time resolution: 1-min
  - MetOne BAM (FEM $PM_{2.5}$); cost: ~$20,000
    - Time resolution: 1-hr
  - Met station (T, RH, P, WS, WD); cost: ~$5,000
    - Time resolution: 1-min

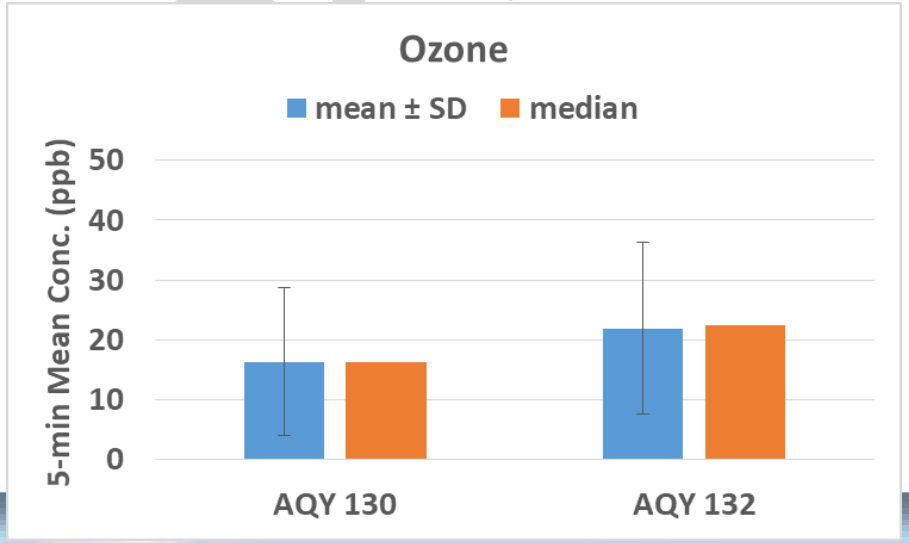
Ozone (O_3) in AQY

Data validation & recovery

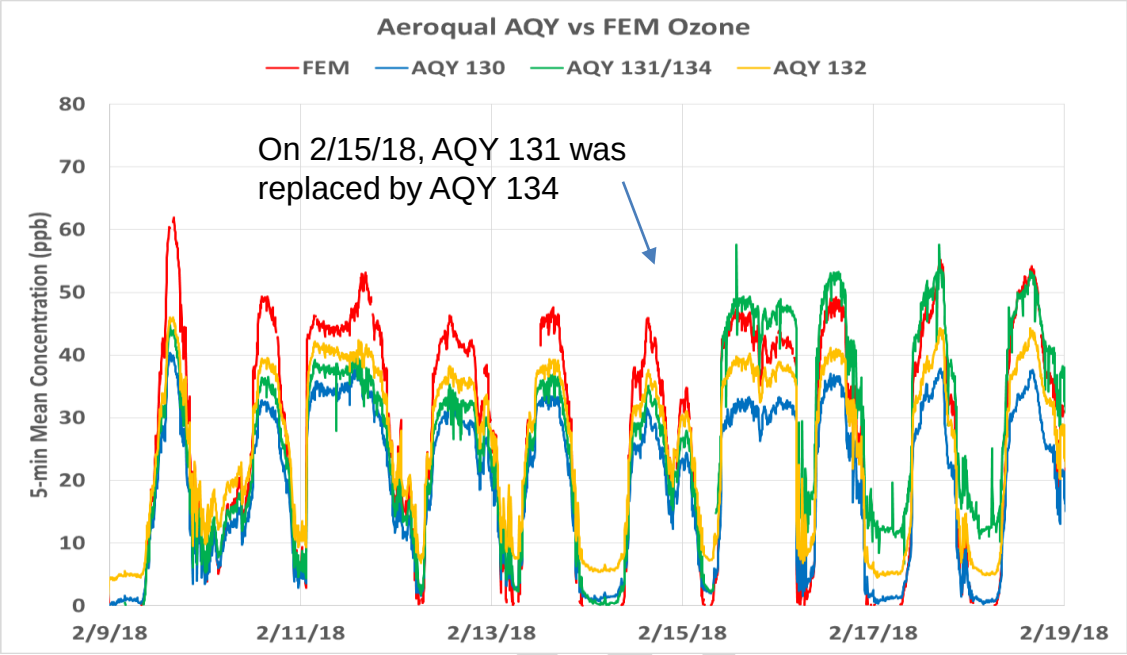
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for ozone in the four AQYs was high (i.e., 92% for AQY 130; 76% for AQY 131; 97% for AQY 132 and 100% for AQY 134).

Aeroqual AQY; Intra-model variability

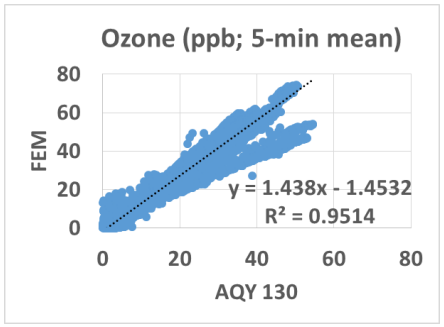
- Low measurement variability was observed between the two AQY units (130, 132) for ozone during the entire deployment period.

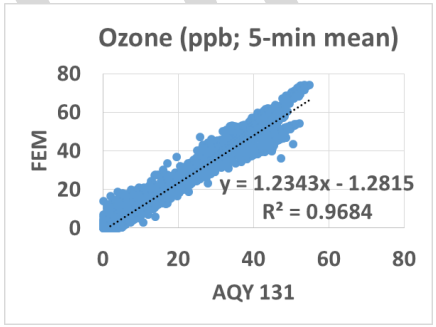


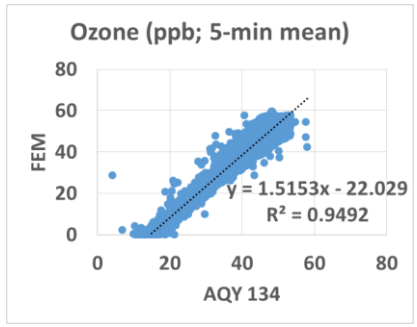
Aeroqual AQY vs FEM (Ozone; 5-min mean)

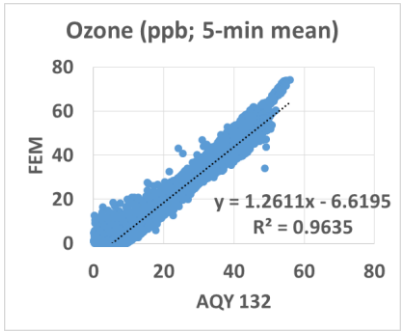


- AQY Ozone measurements showed very strong correlations with the corresponding FEM data (R^2 ~ 0.96)
- Overall, the AQY sensors underestimated ozone concentration as measured by the FEM instrument
- The AQYs seem to track well the diurnal ozone variations recorded by the FEM instrument

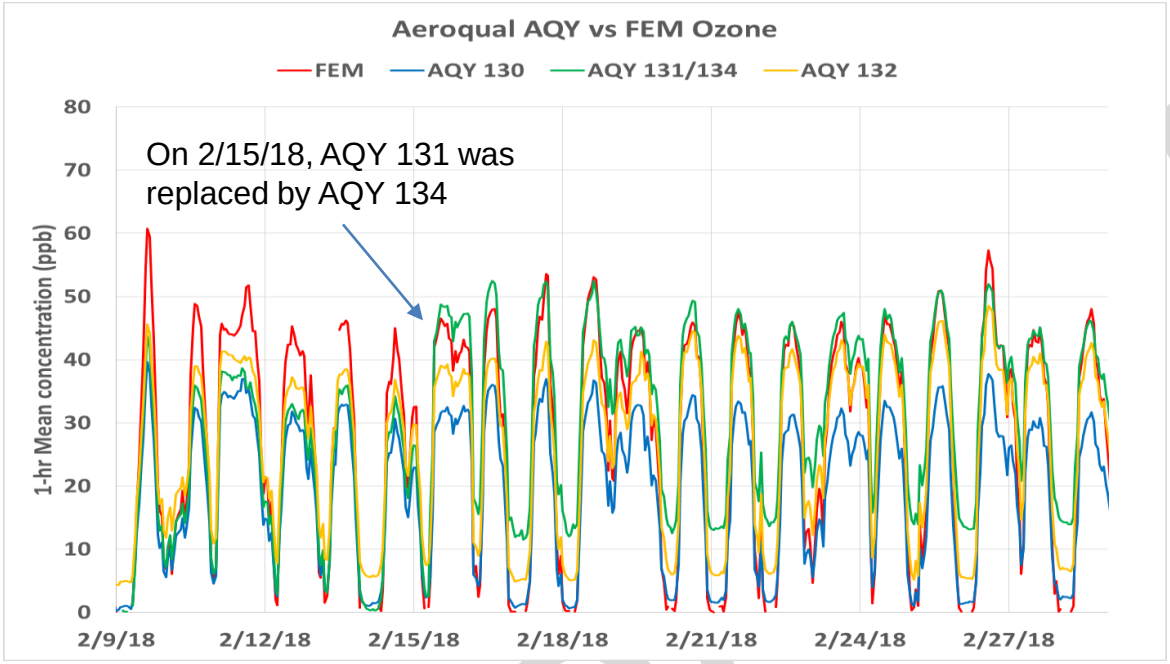




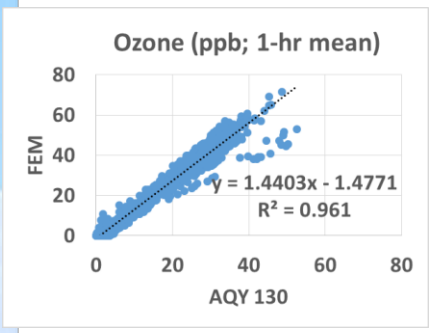


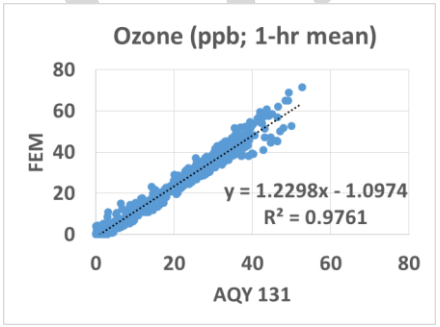


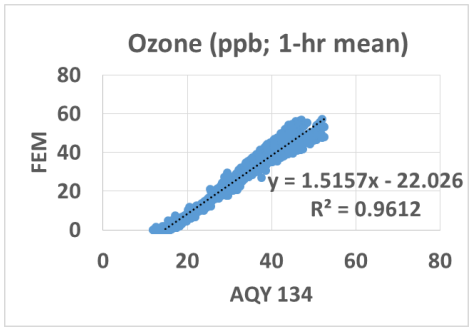
Aeroqual AQY vs FEM (Ozone; 1-hr mean)

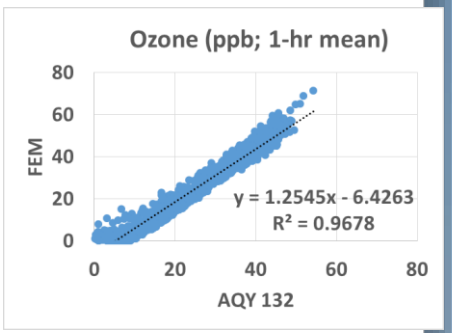


- AQY Ozone measurements showed very strong correlations with the corresponding FEM data (R^2 ~ 0.96)
- Overall, the AQY sensors underestimated ozone concentration as measured by the FEM instrument
- The AQYs seem to track well the diurnal ozone variations recorded by the FEM instrument

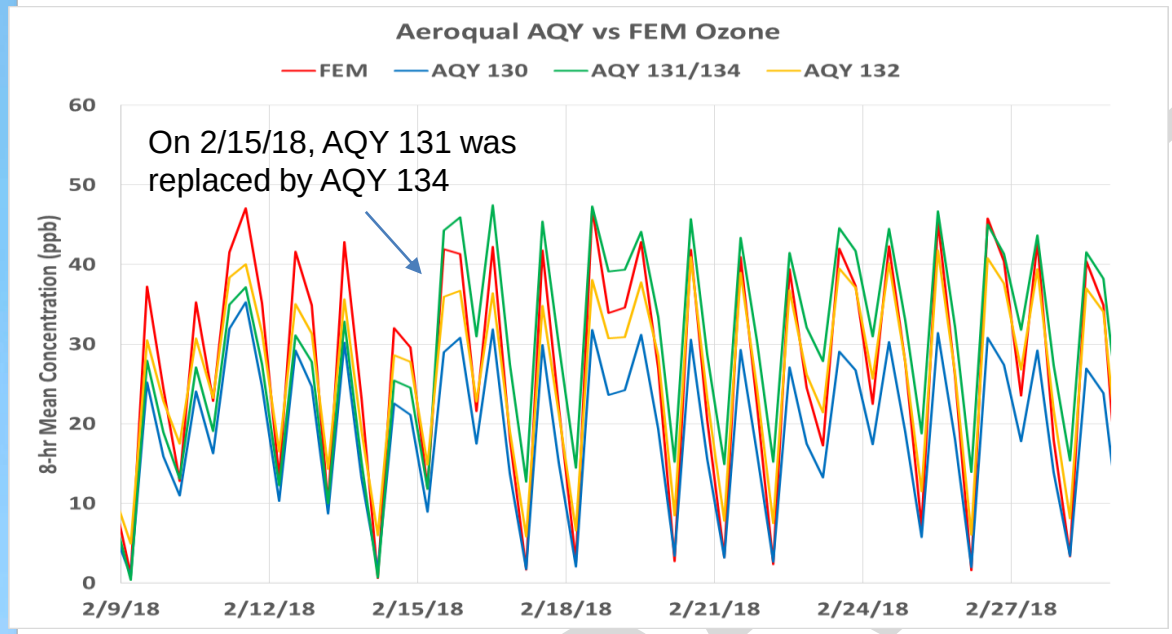




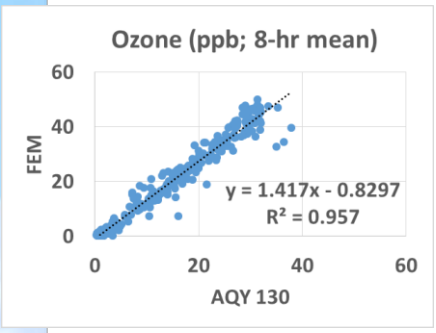


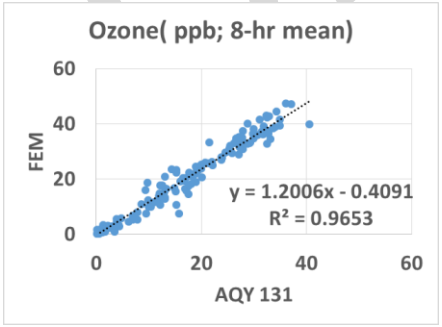


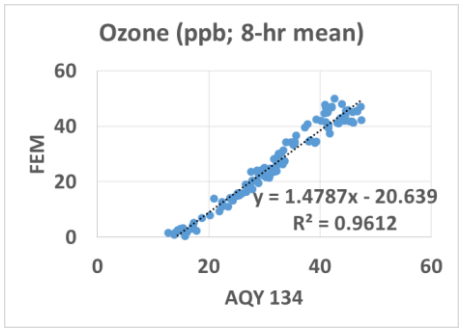
Aeroqual AQY vs FEM (Ozone; 8-hr mean)

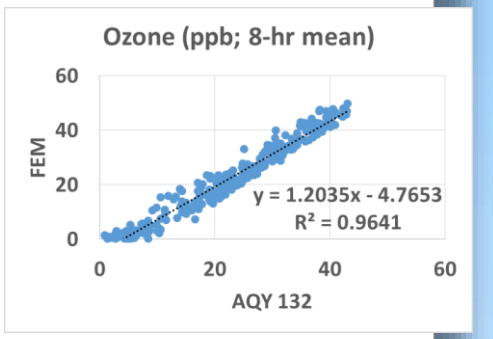


- AQY Ozone measurements showed very strong correlations with the corresponding FEM data (R^2 ~ 0.96)
- Overall, the AQY sensors underestimated ozone concentration as measured by the FEM instrument
- The AQYs seem to track well the diurnal ozone variations recorded by the FEM instrument









Nitrogen Dioxide (NO_2) in AQY

NO_2 Data Handling

During this AQ-SPEC field evaluation, Aeroqual corrected and calculated NO_2 in all four units, using two different approaches:

1st approach (in this report, pollutant referred to as NO_2):

- NO_2 with correction for O_3 bias using AQY ozone data in real-time
- Calculation by on-instrument Aeroqual algorithm

2nd approach (in this report, pollutant referred to as NO_2 V2)

- NO_2 with correction for O_3 and RH bias using AQY ozone and AQY RH data in real-time
- Calculation by new on-instrument Aeroqual algorithm

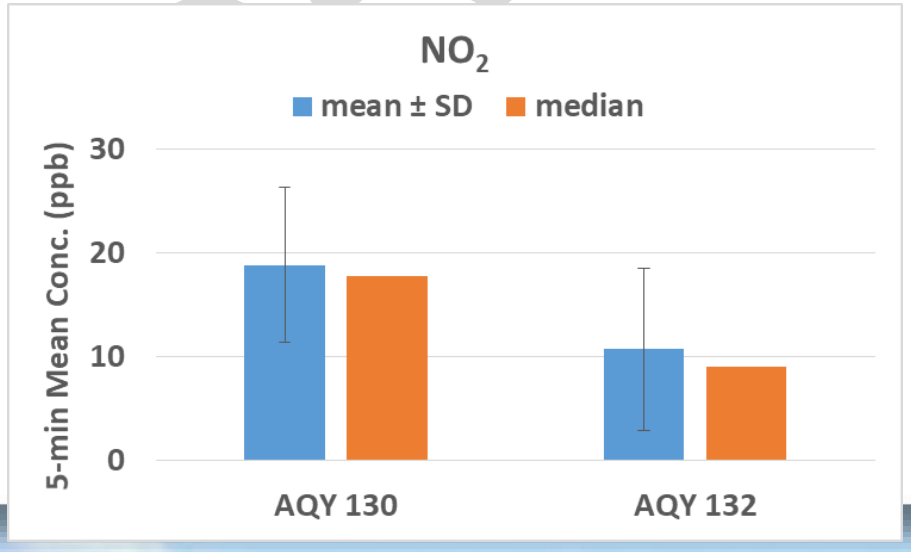
To better assist in understanding the procedures mentioned above, Aeroqual has shared all related proprietary information with AQ-SPEC

Data validation & recovery

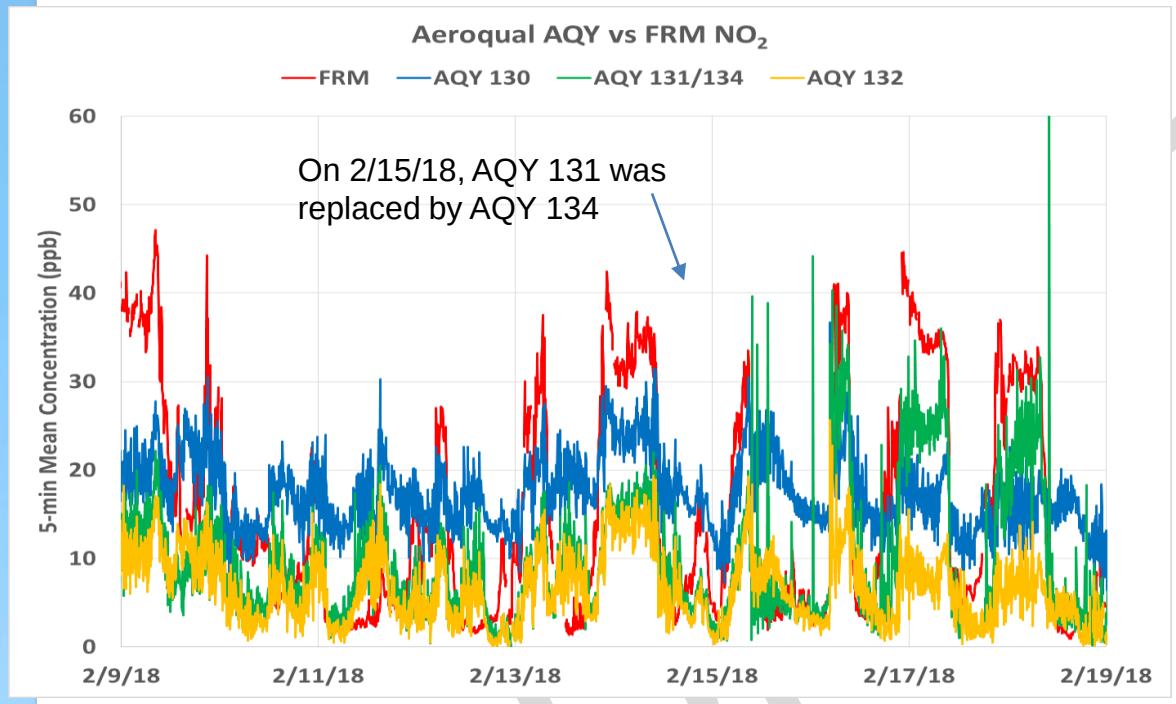
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for **NO_2** in the four AQYs was high (i.e., 98% for AQY 130; 95% for AQY 131; 85% for AQY 132 and 92% for AQY 134).

Aeroqual AQY; Intra-model variability

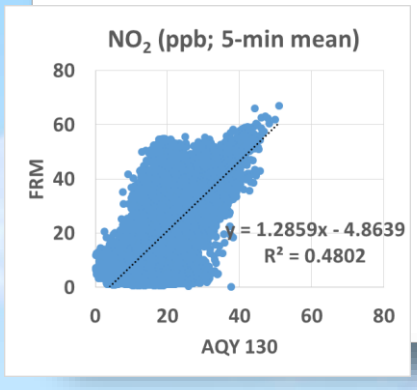
- Modearate measurement variability was observed between the two AQY units (130, 132) for nitrogen dioxide during the entire deployment period.

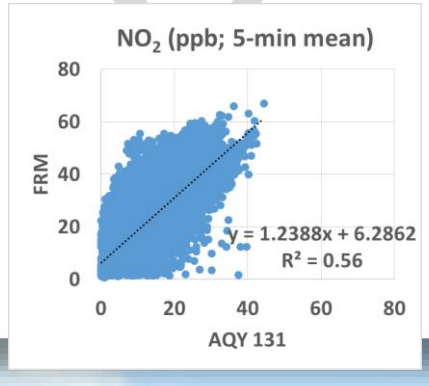


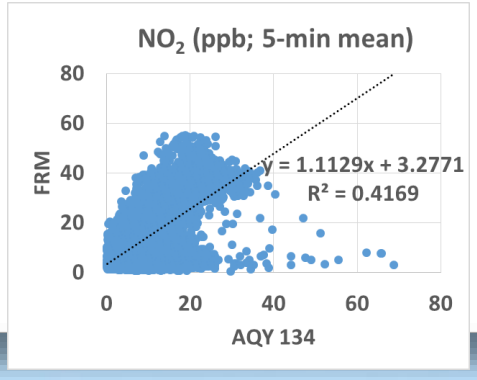
Aeroqual AQY vs FRM (NO_2; 5-min mean)

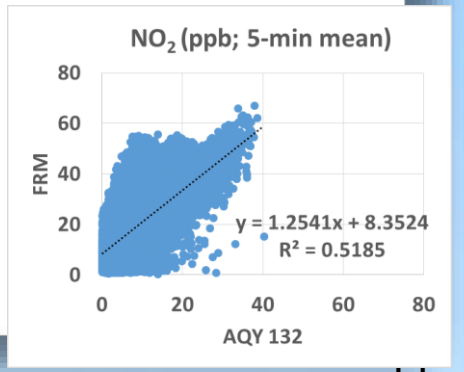


- AQY NO_2 measurements in AQYs 130 and 132 showed weak correlations with the corresponding FRM data (R^2 ~ 0.499)
- Overall, the AQY sensors underestimated NO_2 concentration as measured by the FRM instrument
- The AQYs seem to track the diurnal NO_2 variations recorded by the FRM instrument







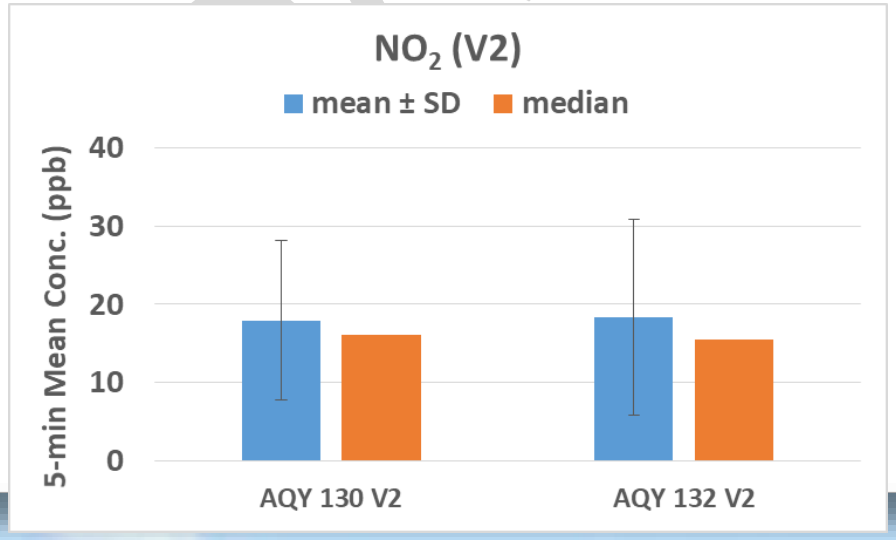


Data validation & recovery

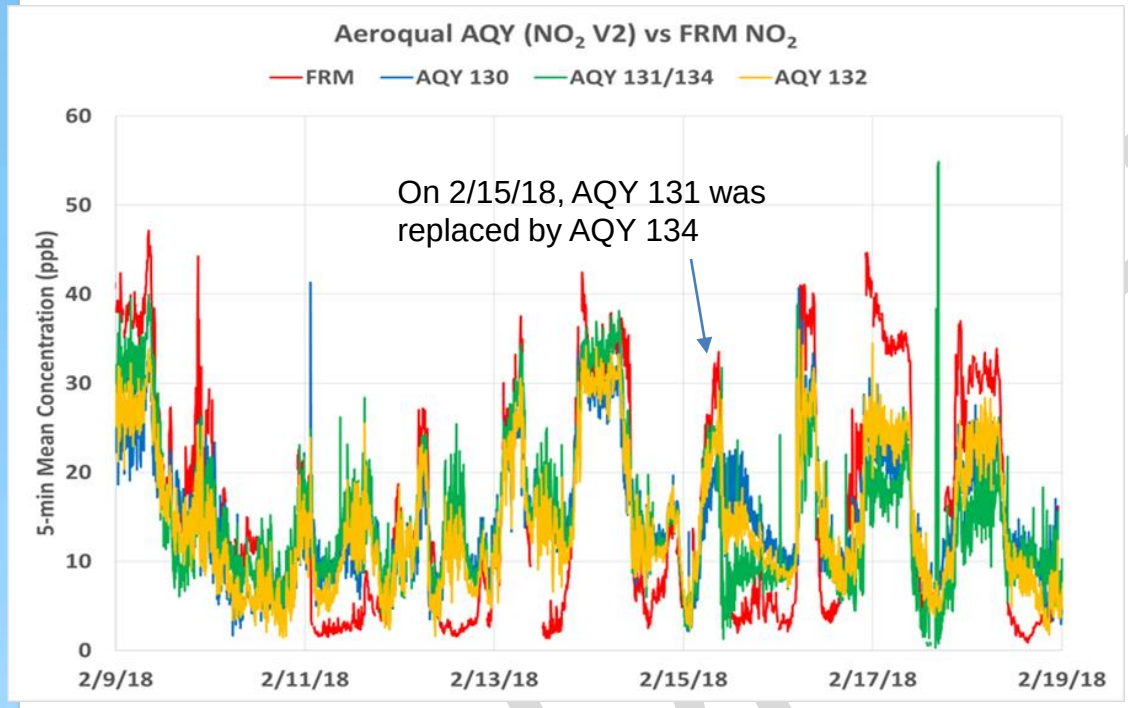
- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for **NO_2 V2** in the four AQYs was high (i.e., 98% for AQY 130; 99% for AQY 131; 97% for AQY 132 and 99% for AQY 134).

Aeroqual AQY; Intra-model variability

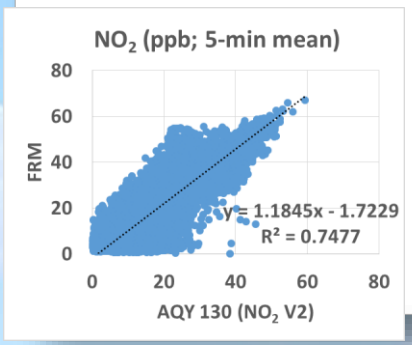
- Very low measurement variability was observed between the two AQY units (130, 132) for nitrogen dioxide (V2) during the entire deployment period.

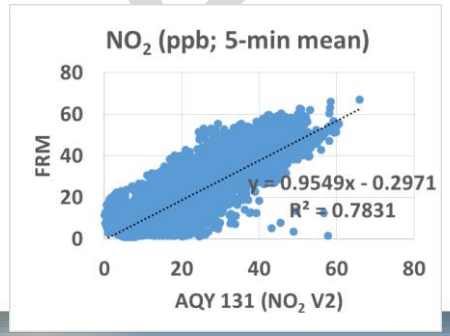


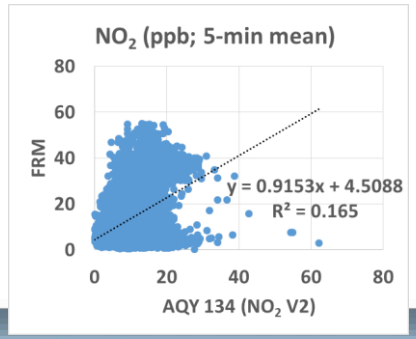
Aeroqual AQY vs FRM (NO_2; 5-min mean)

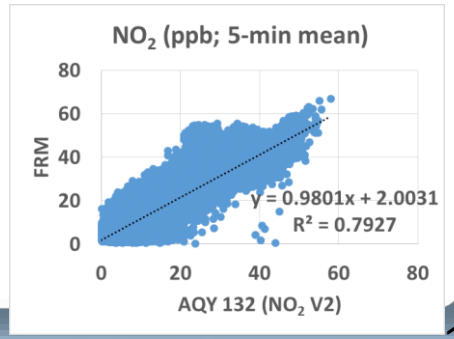


- AQY NO_2 measurements in AQYs 130 and 132 showed strong correlations with the corresponding FRM data (R^2 ~ 0.77)
- The two AQYs seem to track the diurnal NO_2 variations recorded by the FRM instrument

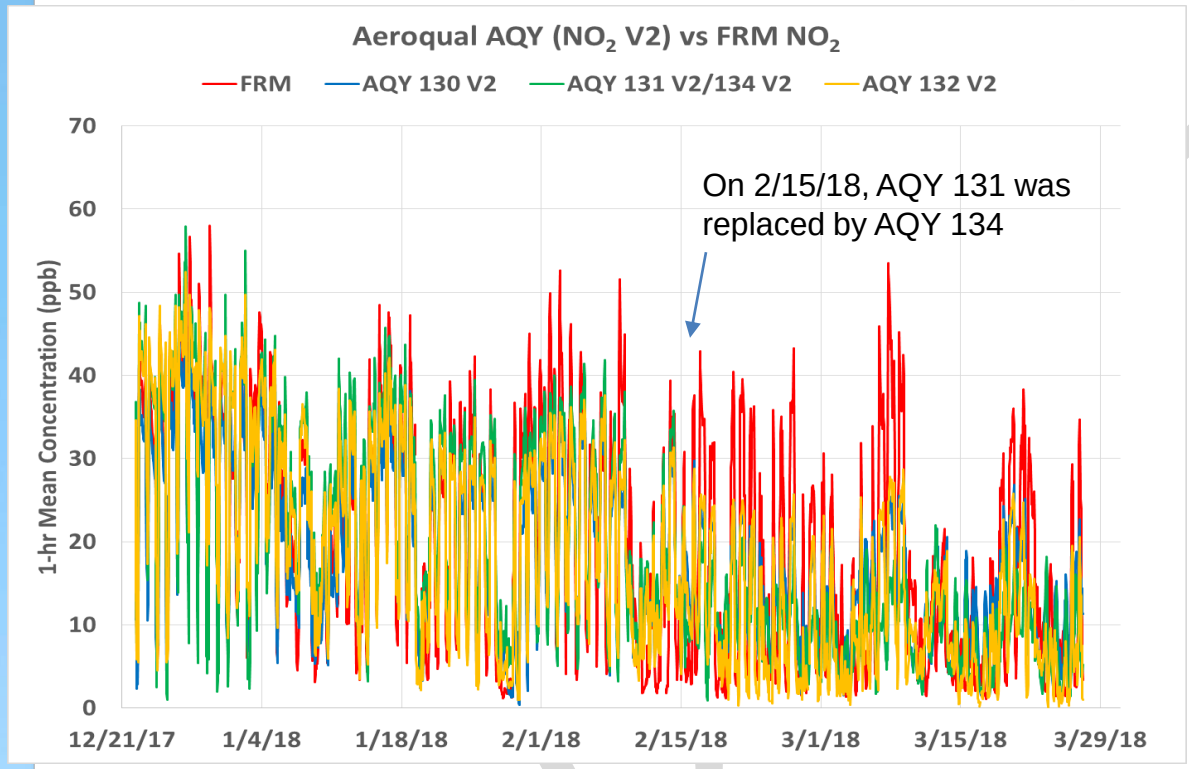




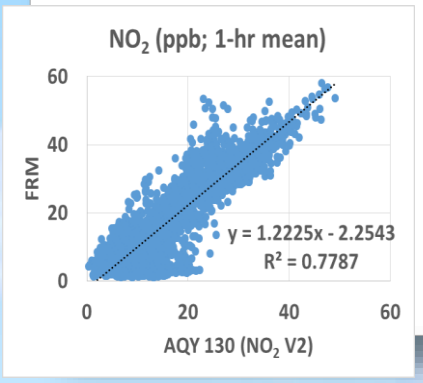


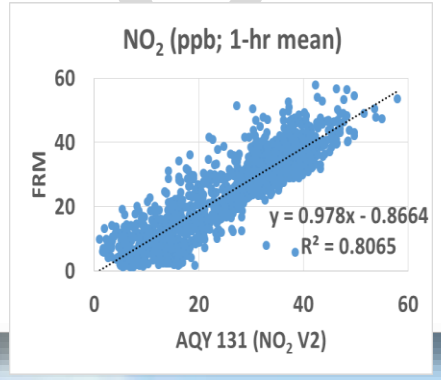


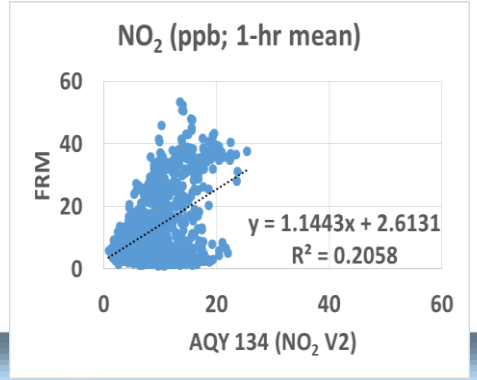
Aeroqual AQY vs FRM (NO_2; 1-hr mean)

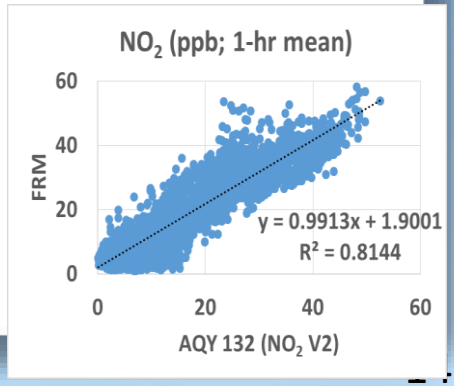


- AQY NO_2 measurements in AQYs 130 and 132 showed strong correlations with the corresponding FRM data (R^2 ~ 0.79)
- The two AQYs seem to track the diurnal NO_2 variations recorded by the FRM instrument

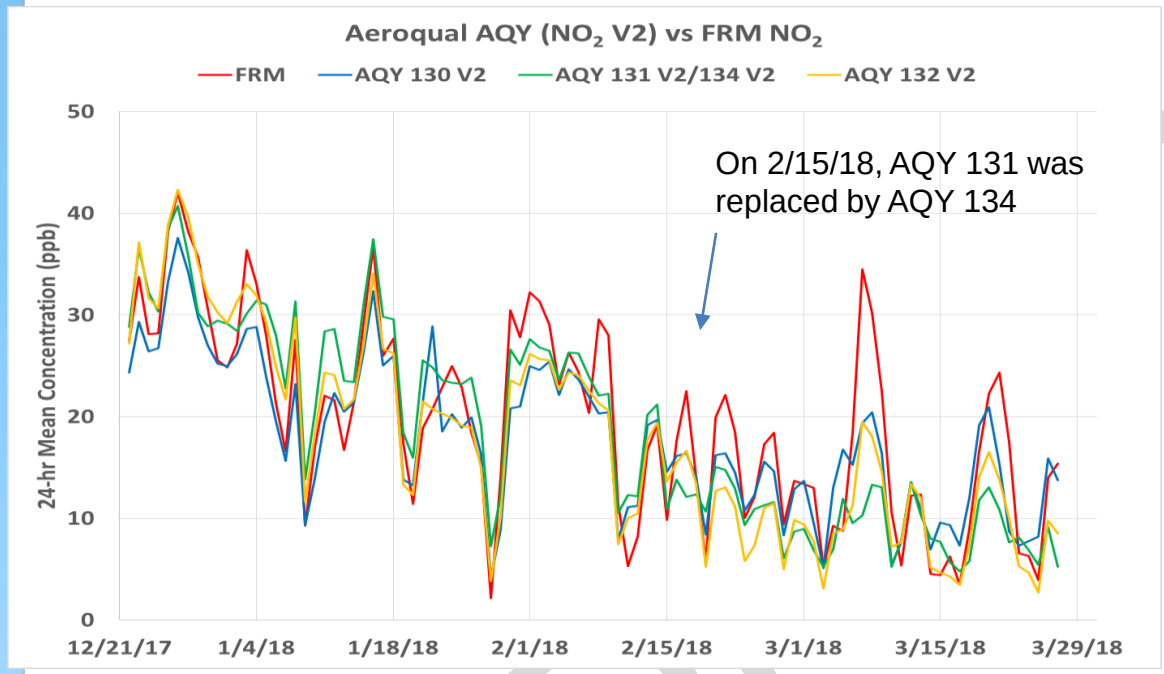




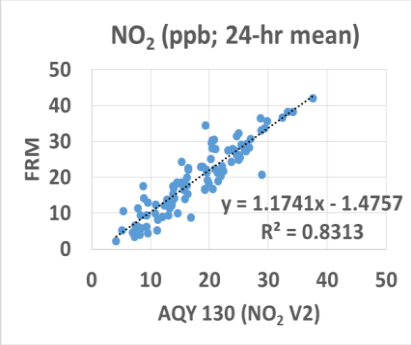


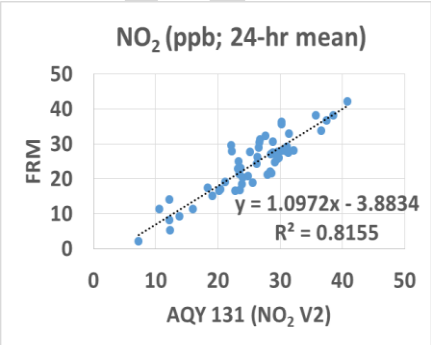


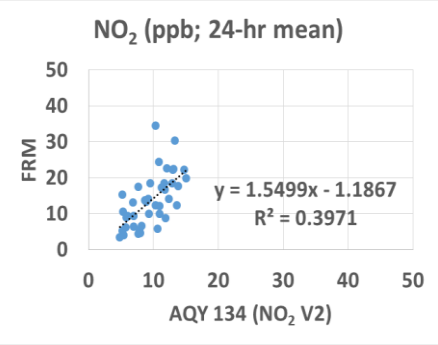
Aeroqual AQY vs FRM (NO_2; 24-hr mean)

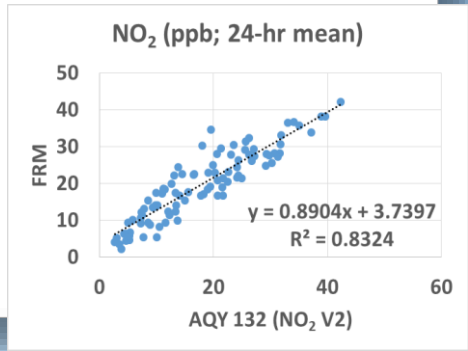


- AQY NO_2 measurements in AQYs 130 and 132 showed strong correlations with the corresponding FRM data (R^2 ~ 0.83)
- The two AQYs seem to track the diurnal NO_2 variations recorded by the FRM instrument









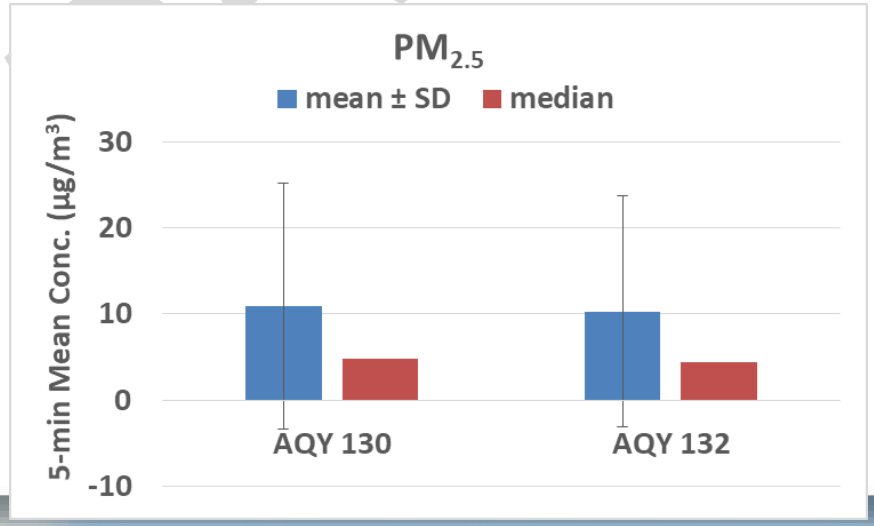
$PM_{2.5}$ in AQY

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)
- AQY $PM_{2.5}$ was corrected based on AQY RH data in real-time
- Data recovery for $PM_{2.5}$ in the four AQYs was excellent (i.e., 99% for AQY 130; 100% for AQY 131, AQY 132 and AQY 134).

Aeroqual AQY; Intra-model variability

- Very low measurement variability was observed between the two AQY units (130, 132) for $PM_{2.5}$ during the entire deployment period.

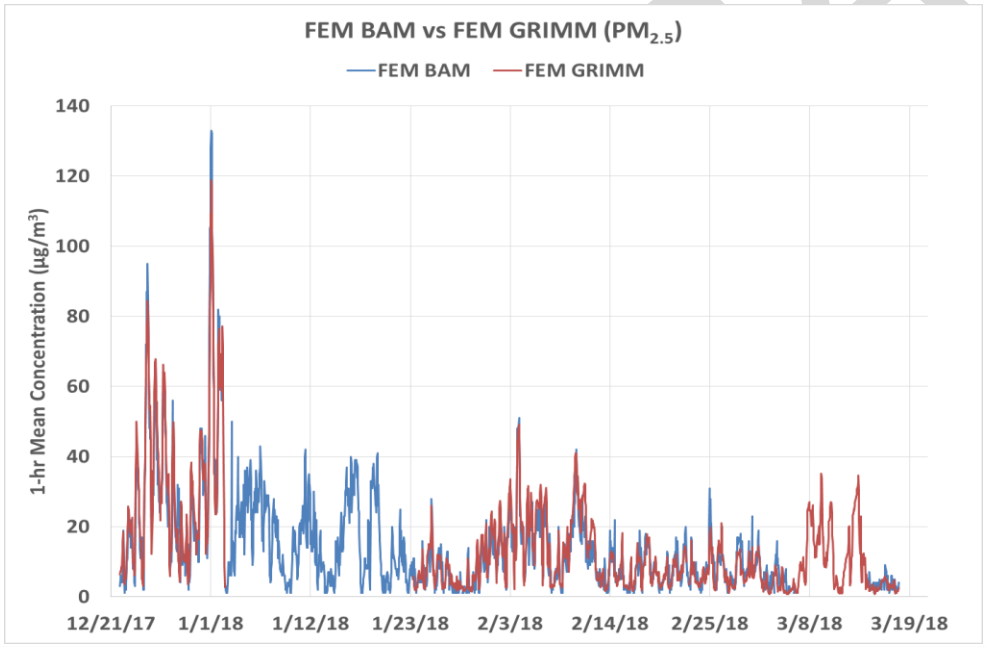


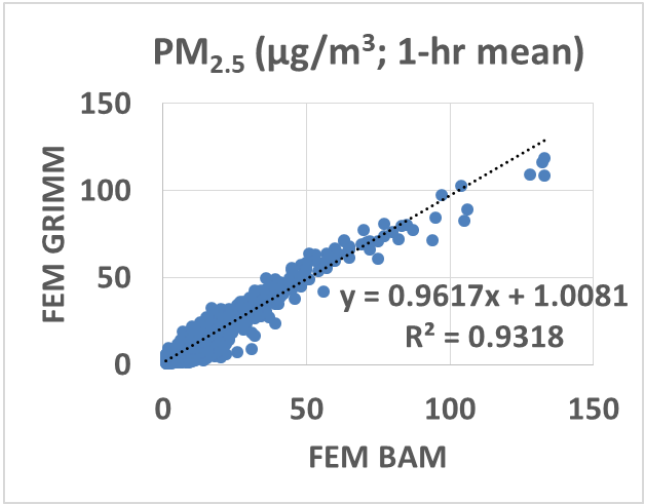
Data validation & recovery

- Basic QA/QC procedures were used to validate the collected FEM data (i.e. obvious outliers, negative values and invalid data-points were eliminated from data-set)
- $PM_{2.5}$ data recovery was 68 % for the GRIMM and 88 % for the BAM.

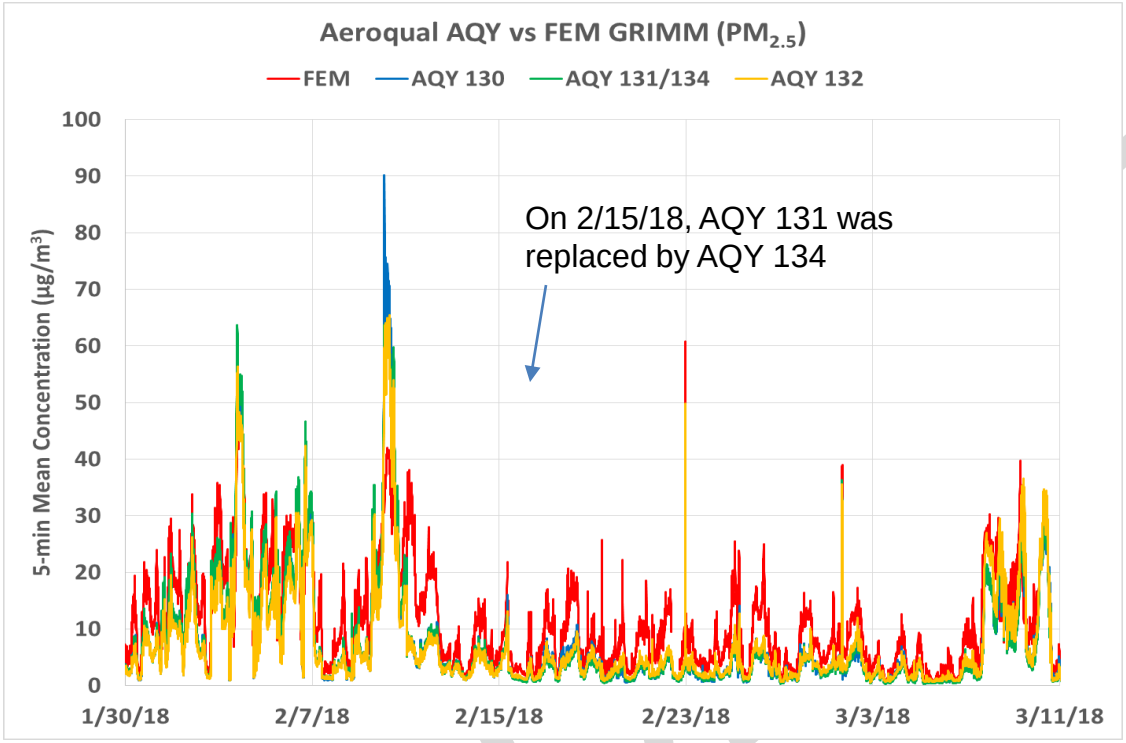
Equivalent methods: BAM vs GRIMM

- Excellent agreement between the two equivalent methods for $PM_{2.5}$

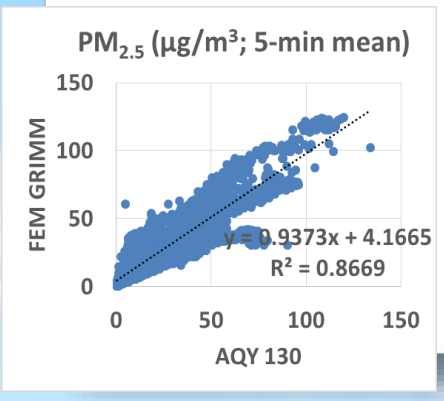


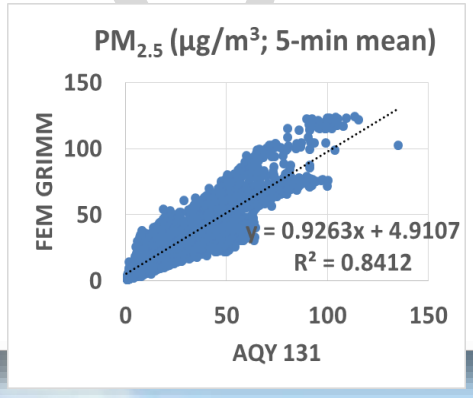


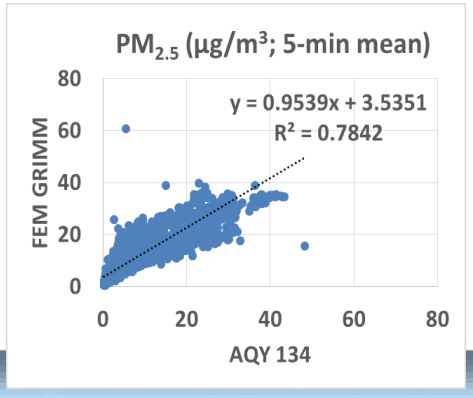
Aeroqual AQY vs FEM (GRIMM $PM_{2.5}$; 5-min mean)

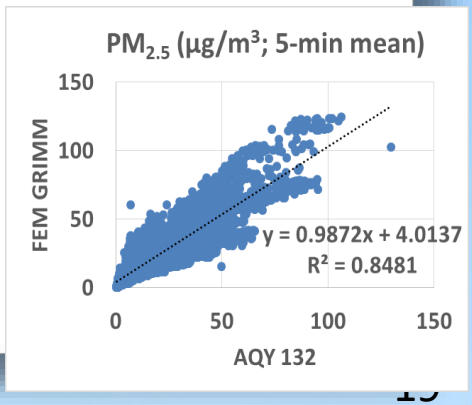


- AQY $PM_{2.5}$ measurements in AQYs 130 and 132 showed strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.86)
- Overall, the AQY sensors underestimated $PM_{2.5}$ concentration as measured by the FEM instrument
- The two AQYs seem to track well the diurnal $PM_{2.5}$ variations recorded by the FEM GRIMM instrument

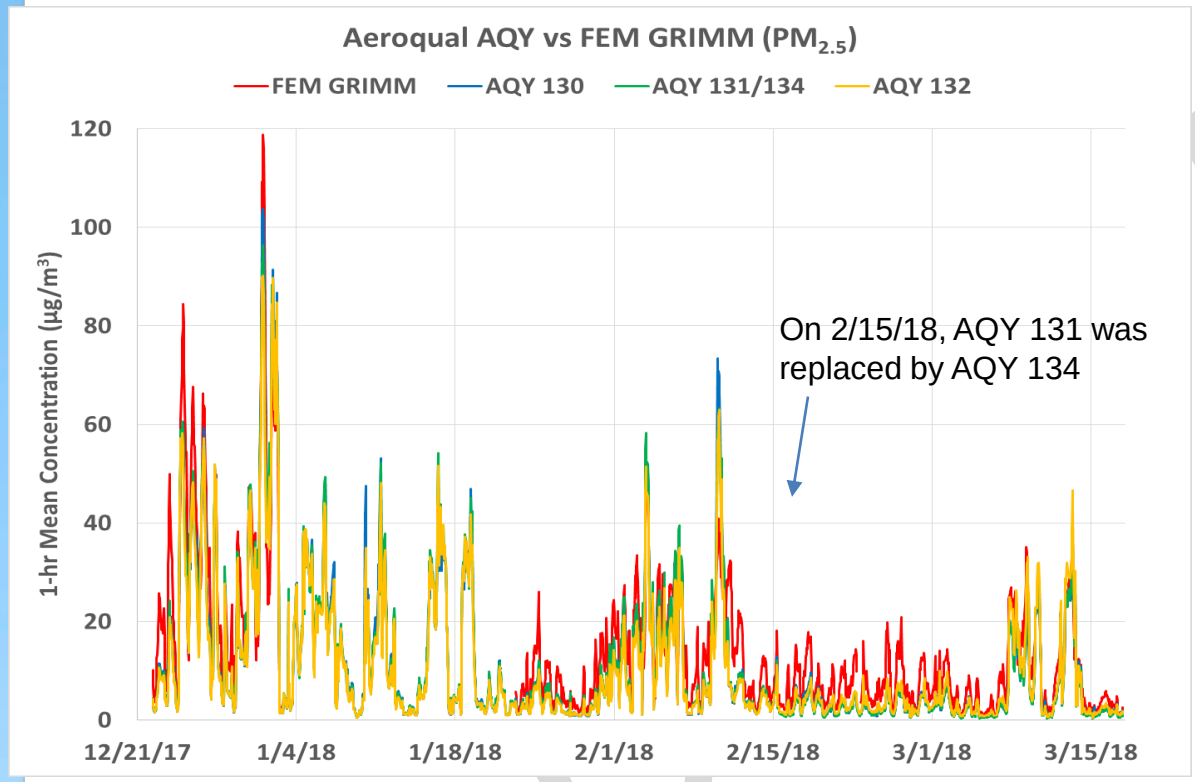




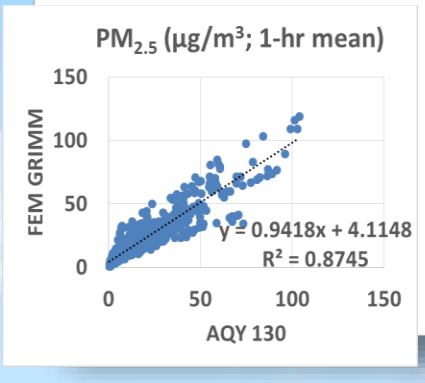


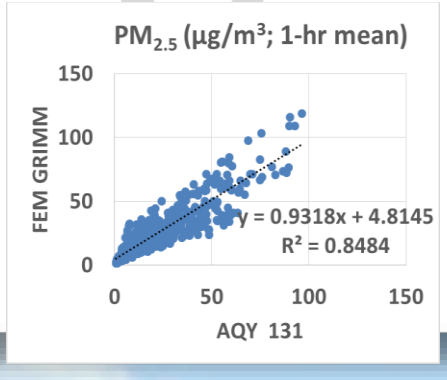


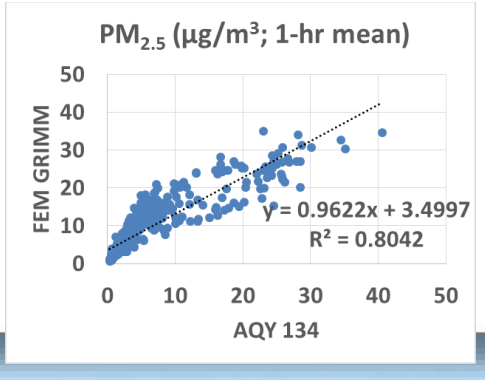
Aeroqual AQY vs FEM (GRIMM $PM_{2.5}$; 1-hr mean)

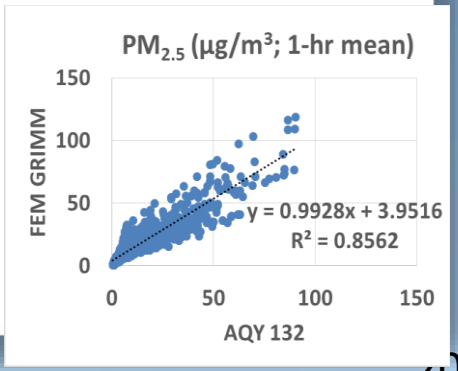


- AQY $PM_{2.5}$ measurements in AQYs 130 and 132 showed strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.86)
- Overall, the AQY sensors overestimated $PM_{2.5}$ concentration as measured by the FEM instrument
- The two AQYs seem to track well the diurnal $PM_{2.5}$ variations recorded by the FEM GRIMM instrument

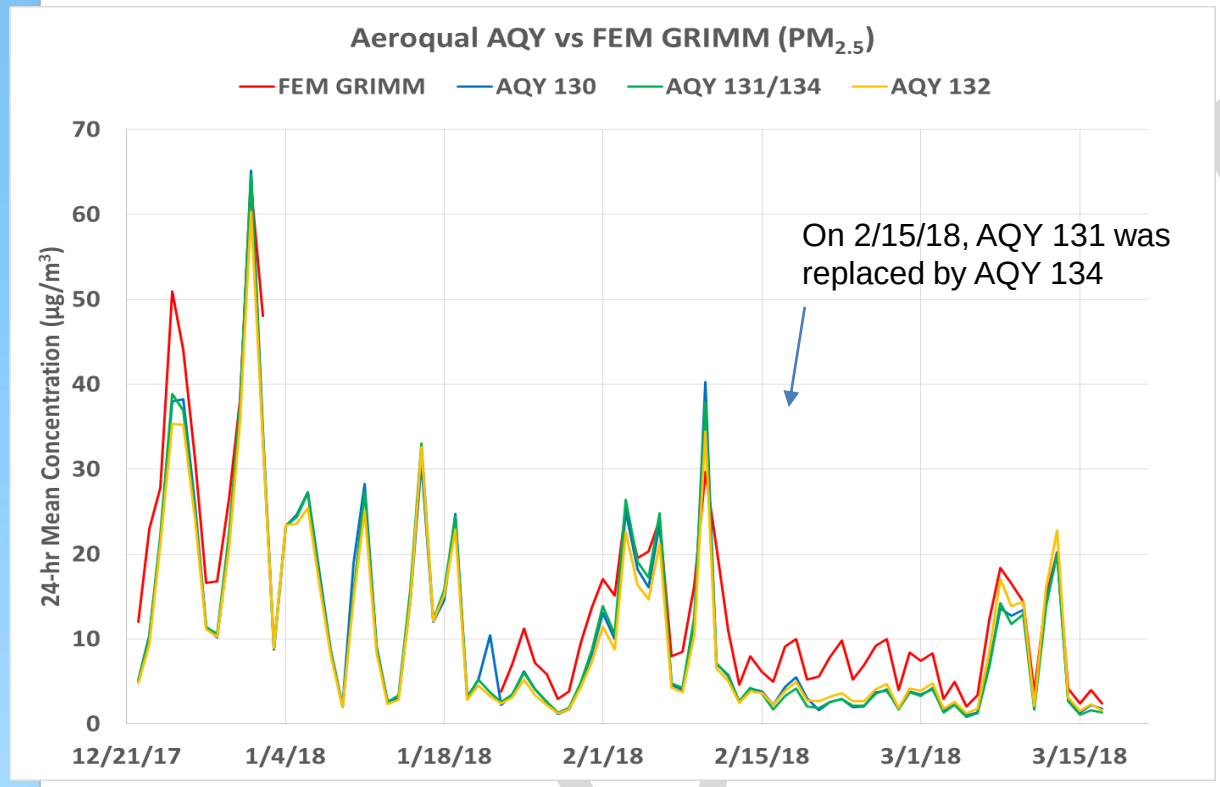




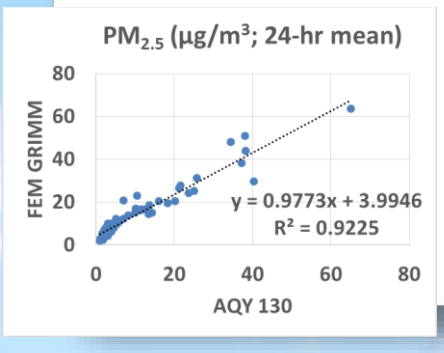


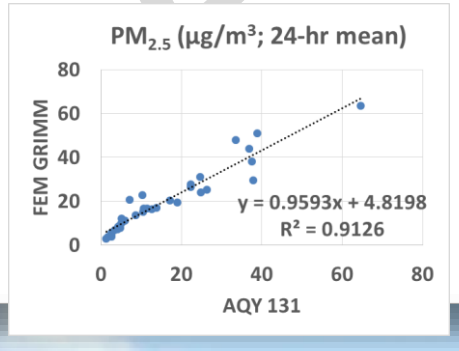


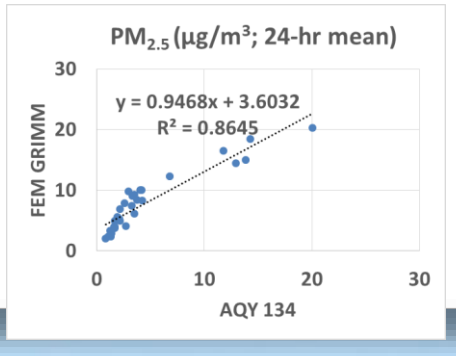
Aeroqual AQY vs FEM (GRIMM $PM_{2.5}$; 24-hr mean)

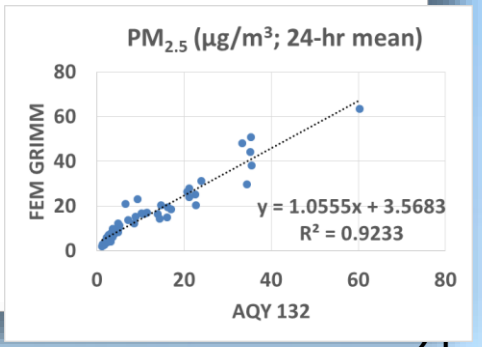


- AQY $PM_{2.5}$ measurements in AQYs 130 and 132 showed very strong correlations with the corresponding FEM GRIMM data (R^2 ~ 0.92)
- The two AQYs seem to track well the diurnal $PM_{2.5}$ variations recorded by the FEM GRIMM instrument

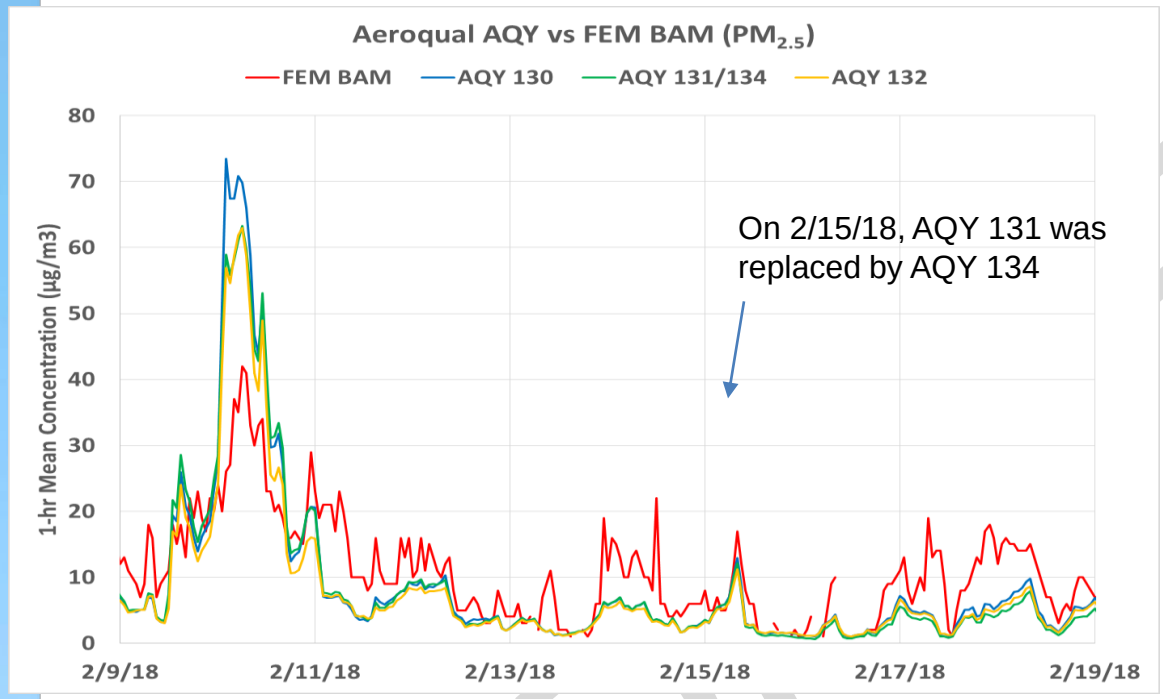




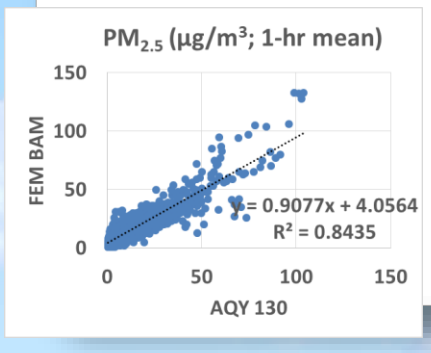


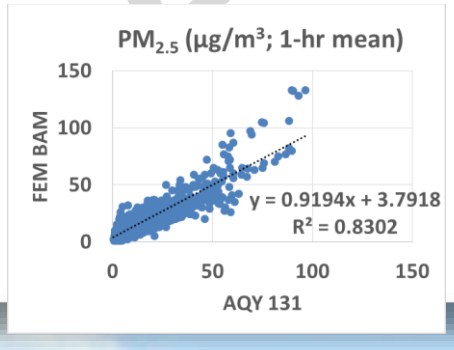


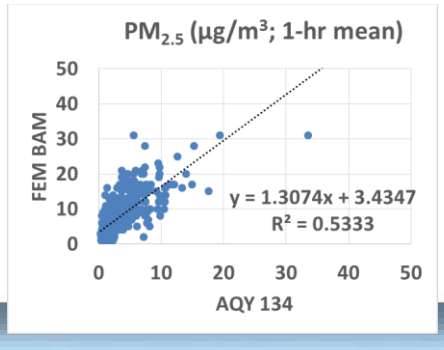
Aeroqual AQY vs FEM (BAM $PM_{2.5}$; 1-hr mean)

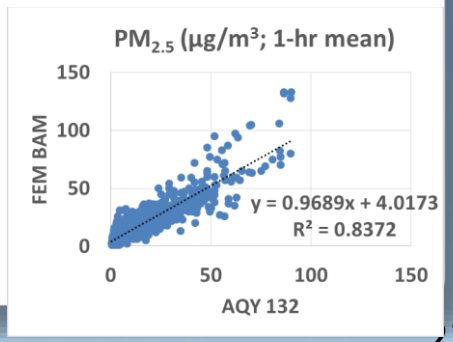


- AQY $PM_{2.5}$ measurements in AQYs 130 and 132 showed strong correlations with the corresponding FEM BAM data (R^2 ~ 0.84)
- Overall, the AQY sensors overestimated $PM_{2.5}$ concentration as measured by the FEM instrument
- The two AQYs seem to track the diurnal $PM_{2.5}$ variations recorded by the FEM BAM instrument

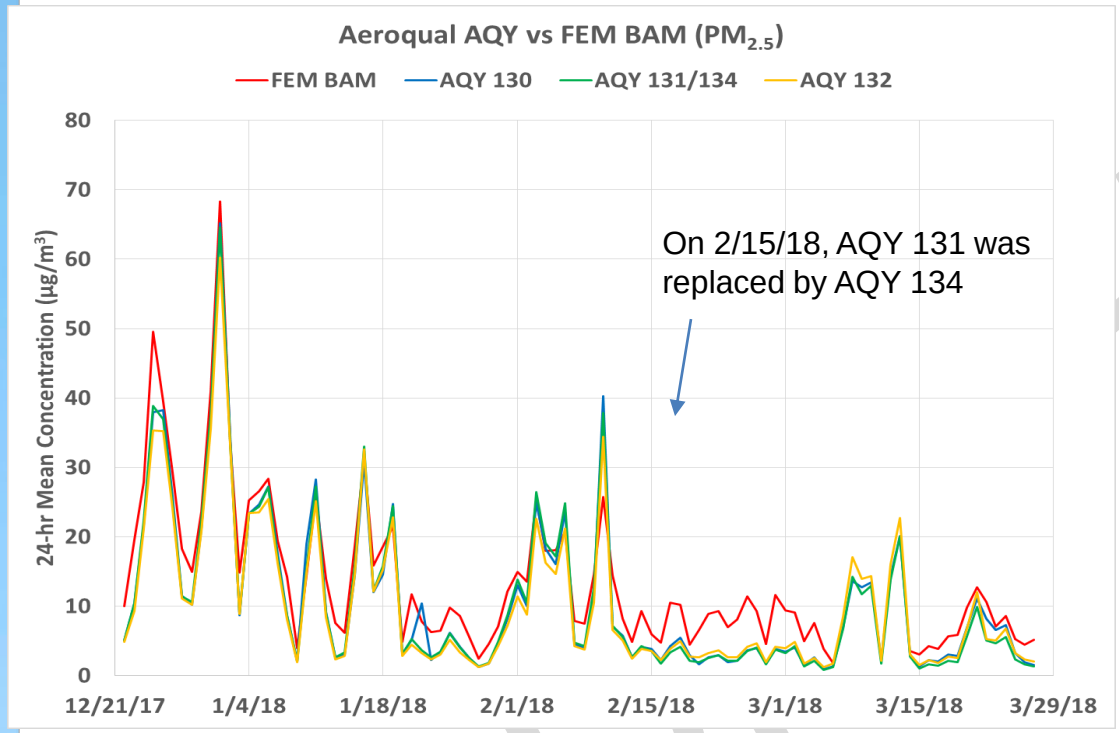




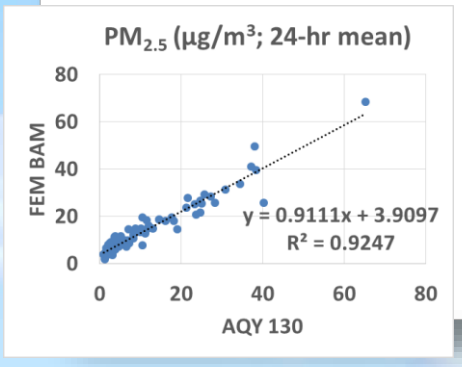


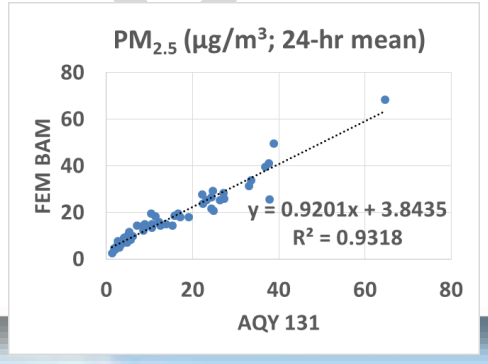


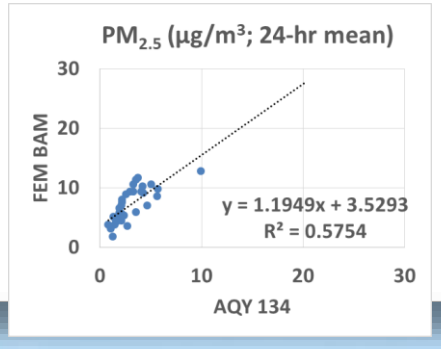
Aeroqual AQY vs FEM (BAM $PM_{2.5}$; 24-hr mean)

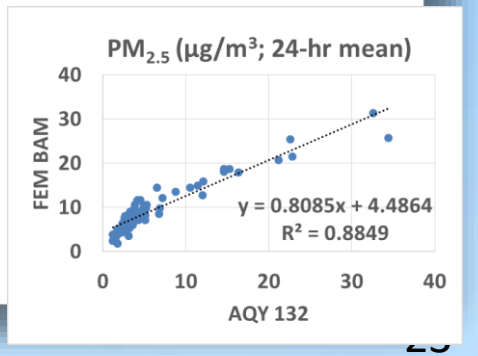


- AQY $PM_{2.5}$ measurements in AQYs 130 and 132 showed very strong correlations with the corresponding FEM BAM data (R^2 ~ 0.90)
- Overall, the AQY sensors overestimated $PM_{2.5}$ concentration as measured by the FEM instrument
- The two AQYs seem to track the diurnal $PM_{2.5}$ variations recorded by the FEM BAM instrument

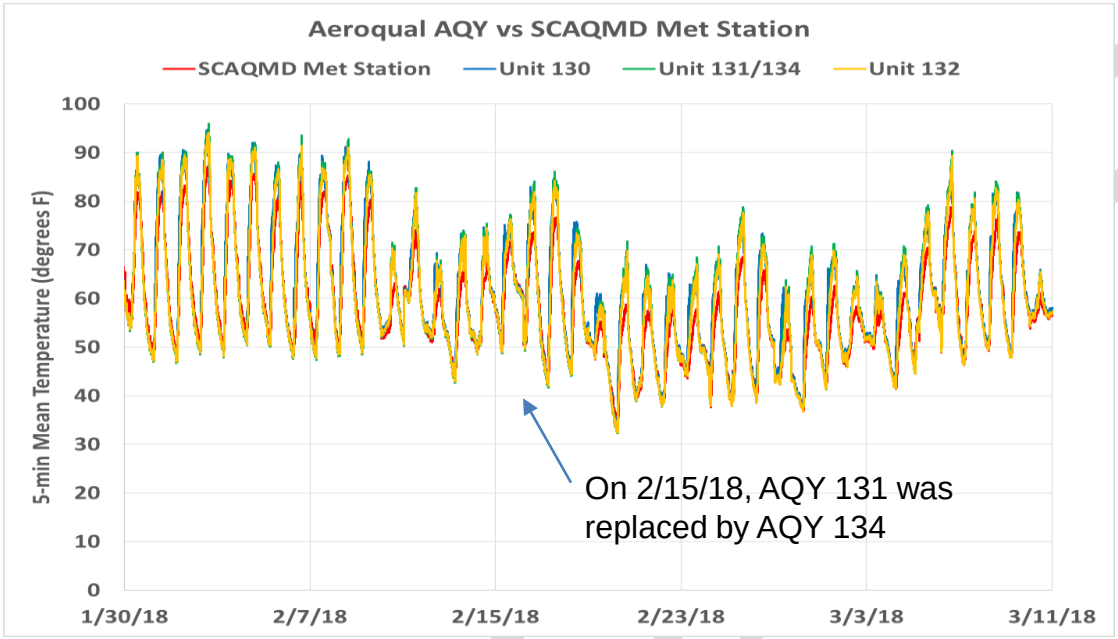




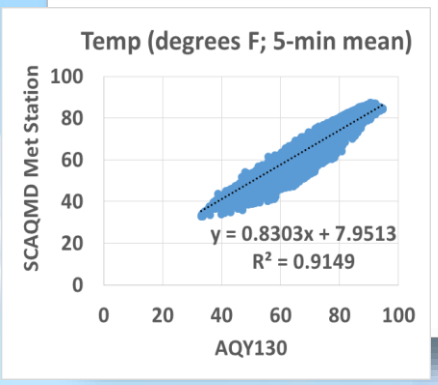


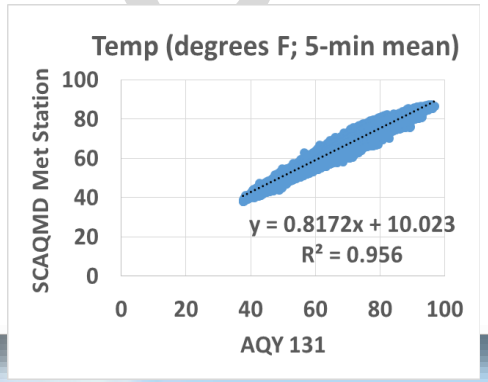


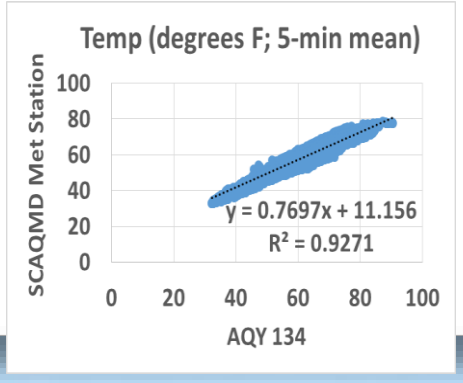
Aeroqual AQY vs South Coast AQMD Met Station (Temp; 5-min mean)

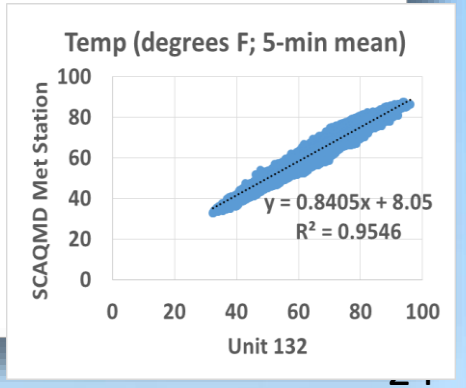


- AQY Temp measurements in AQYs 130 and 132 showed very strong correlations with the corresponding South Coast AQMD Met Station sensor (R^2 ~ 0.93)
- Overall, the AQY sensors overestimated ambient Temp as measured by the South Coast AQMD Met Station sensor
- The two AQYs seem to track the diurnal Temp variations recorded by the South Coast AQMD Met station sensor

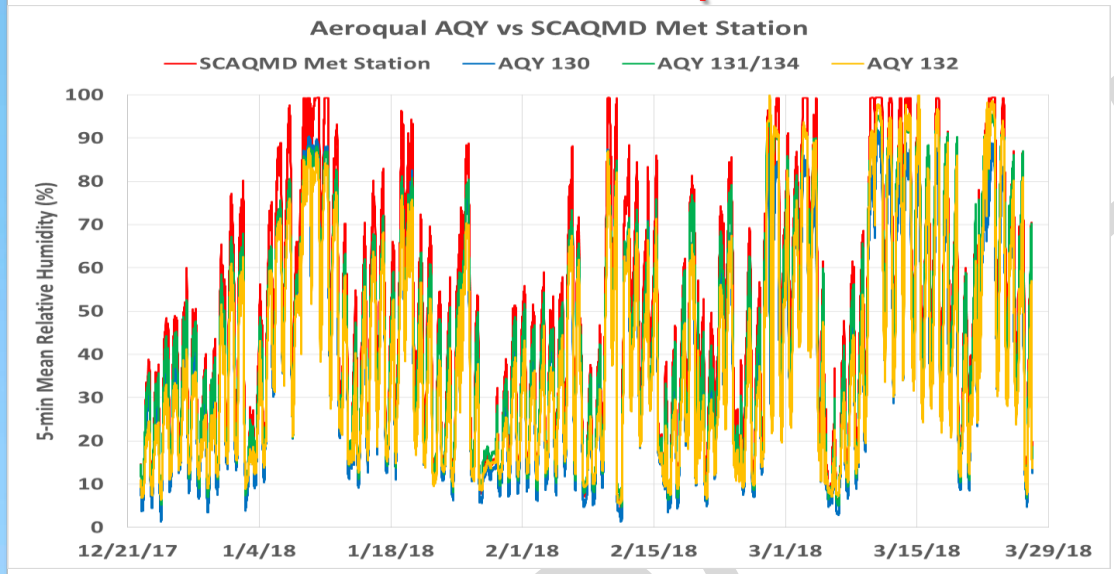






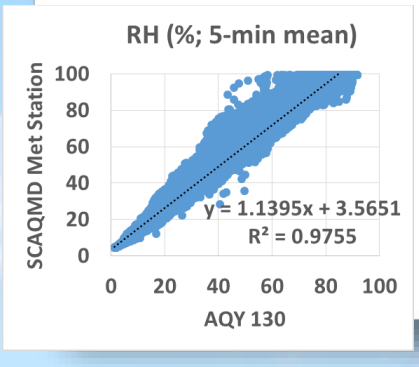


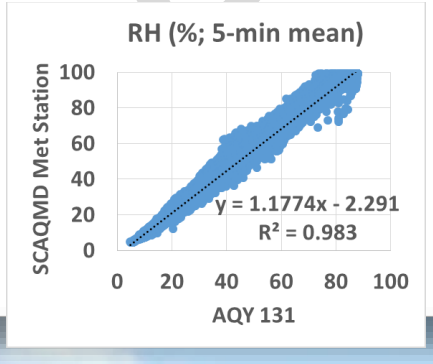
Aeroqual AQY vs South Coast AQMD Met Station (RH; 5-min mean)

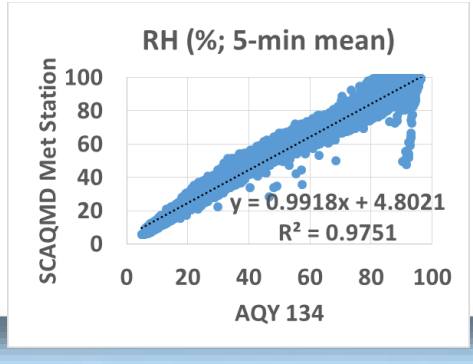


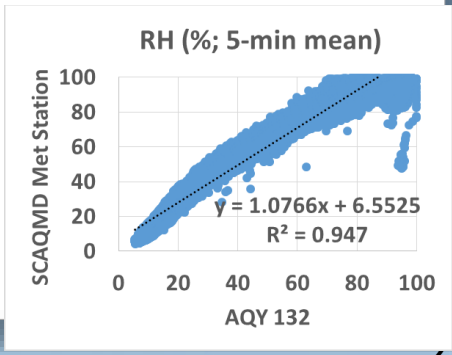
On 2/15/18, AQY 131 was replaced by AQY 134

- AQY RH measurements in AQYs 130 and 132 showed very strong correlations with the corresponding South Coast AQMD Met Station sensor (R^2 ~ 0.96)
- Overall, the AQY sensors underestimated RH as measured by the South Coast AQMD Met Station sensor
- The two AQYs seem to track the diurnal RH variations recorded by the South Coast AQMD Met station sensor









Discussion

- With the exception of a faulty NO_2 sensor in one of the three units (AQY 131), the **Aeroqual AQY v0.5** multi-sensor units (AQY 130 and 132) showed:
  - Minimal down-time: data recovery from each unit was higher than 90%
  - Low intra-model variability for all measured pollutants
- During the entire field deployment testing period:
  - Ozone sensors showed very strong correlations (R^2 ~ 0.96, 5-min mean) with the reference instrument and underestimated the corresponding FEM Ozone data
  - NO_2 V2 sensors showed strong correlations (R^2 ~ 0.77, 5-min mean) with the reference instrument
  - $PM_{2.5}$ sensors showed strong correlations (GRIMM: R^2 ~ 0.86, 5-min mean and BAM: R^2 ~ 0.84, 1-hr mean)with the reference instrument, underestimated the corresponding FEM GRIMM $PM_{2.5}$ data and overestimated the FEM BAM $PM_{2.5}$ data
  - Temp and RH sensors showed very strong correlations (T: R^2 ~0.93, 5-min mean and RH: R^2 ~0.96, 5-min mean) with the South Coast AQMD Met Station sensors, overestimated and underestimated the corresponding South Coast AQMD Met Station Temp and RH sensors, respectively
  - No sensor calibration was performed by AQ-SPEC prior to the beginning of this field testing
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under controlled T and RH conditions, and known target and interferent pollutants concentrations.
- These results are still preliminary