Field Evaluation
Ecowitt WH41B Sensor

South Coast
AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 03/13/2019 to 05/14/2019, three **Ecowitt WH41B (hereinafter Ecowitt)** sensors were deployed at the South Coast AQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with three reference instruments measuring the same pollutants

- Ecowitt (*3 units tested*):
  - Particle sensor (optical; non-FEM)
  - PM sensor: Honeywell HPMA115S0-xxx
  - Each unit reports: $PM_{2.5}$ ($\mu g/m^3$), Temperature (F), Relative Humidity (%)
  - Unit cost: ~$100
  - Time resolution: 5 min
  - Units IDs: 54B2, 54E5, 5378

- MetOne BAM (*reference instrument*):
  - Beta-attenuation monitor (FEM $PM_{2.5}$ & PM_{10})
  - Measures $PM_{2.5}$ & PM_{10} ($\mu g/m^3$)
  - 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} ($\mu g/m^3$)
  - 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} ($\mu g/m^3$)
  - 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 for $PM_{2.5}$ mass conc. measurements from units 54B2, 54E5, and 5378 is 92.2%, 92.3% and 92.2 %, respectively.
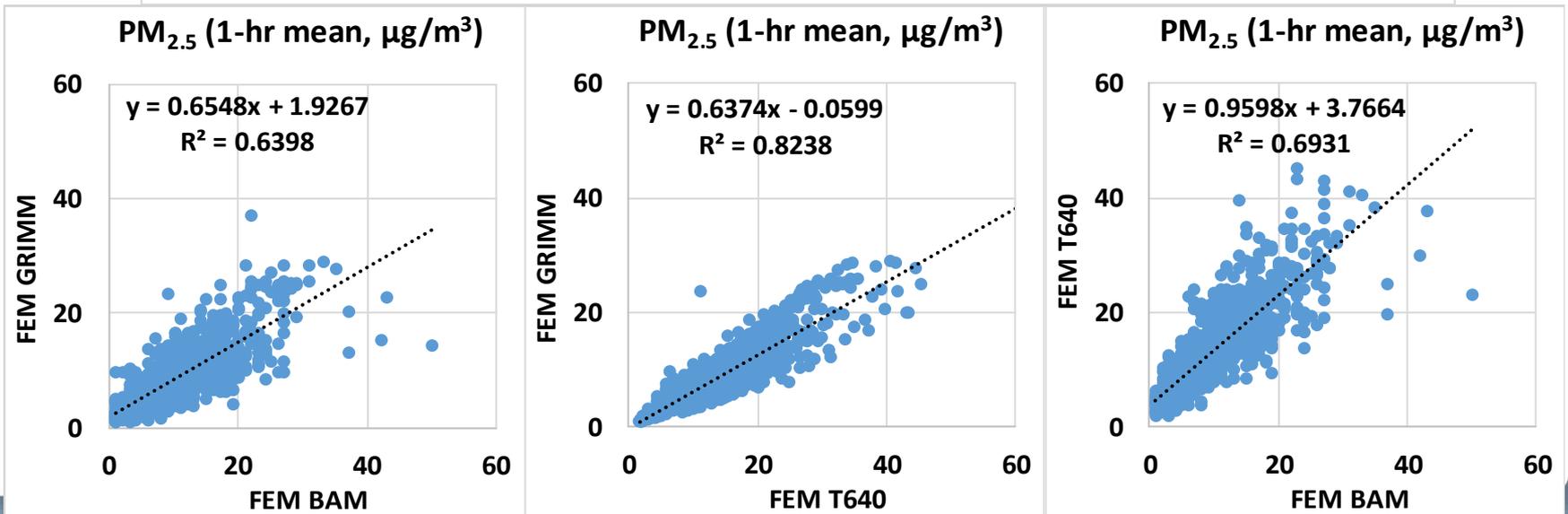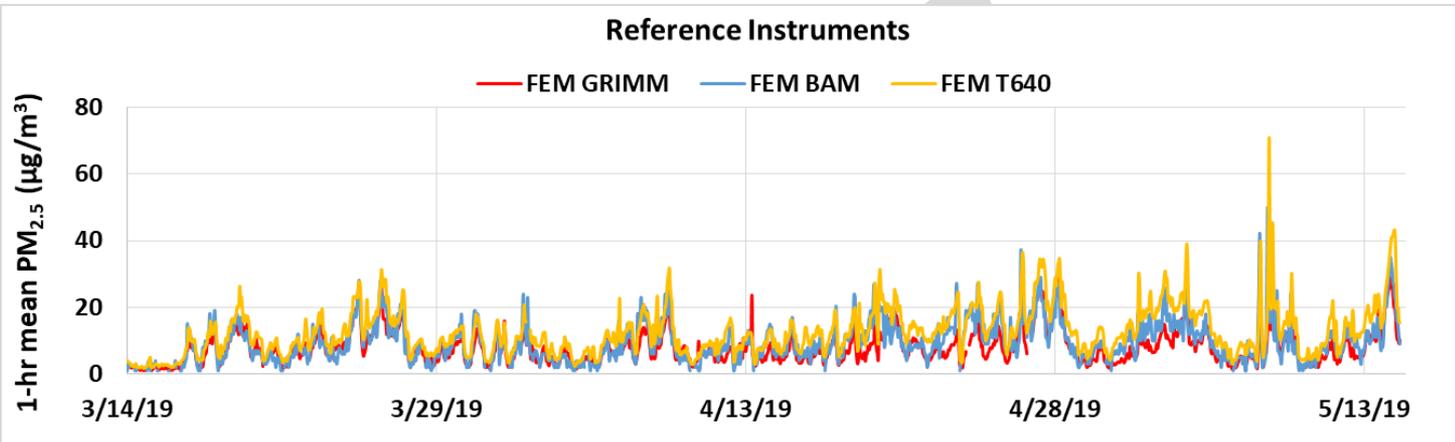
Ecowitt; intra-model variability

- Low measurement variability (~11%) was observed between the three Ecowitt units for $PM_{2.5}$ mass concentration measurements
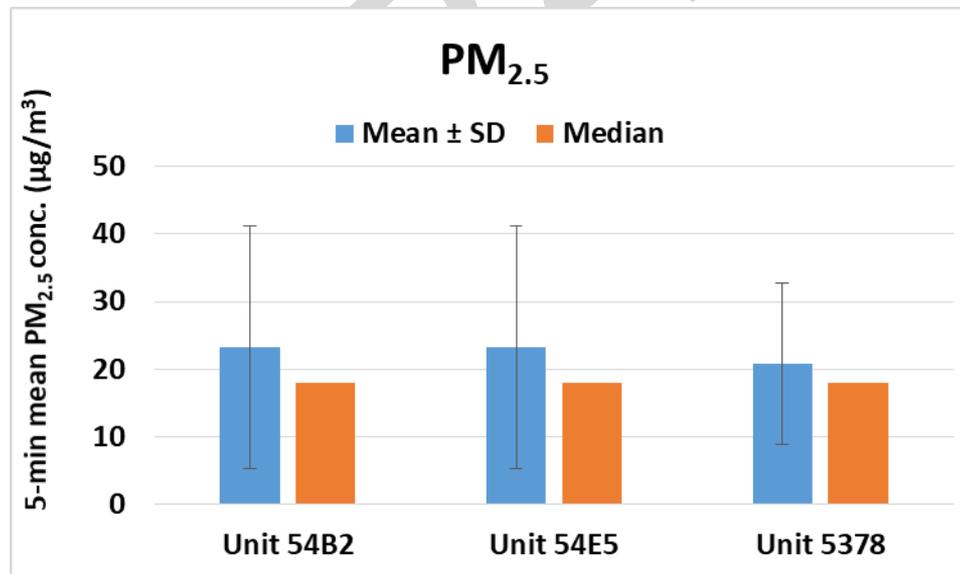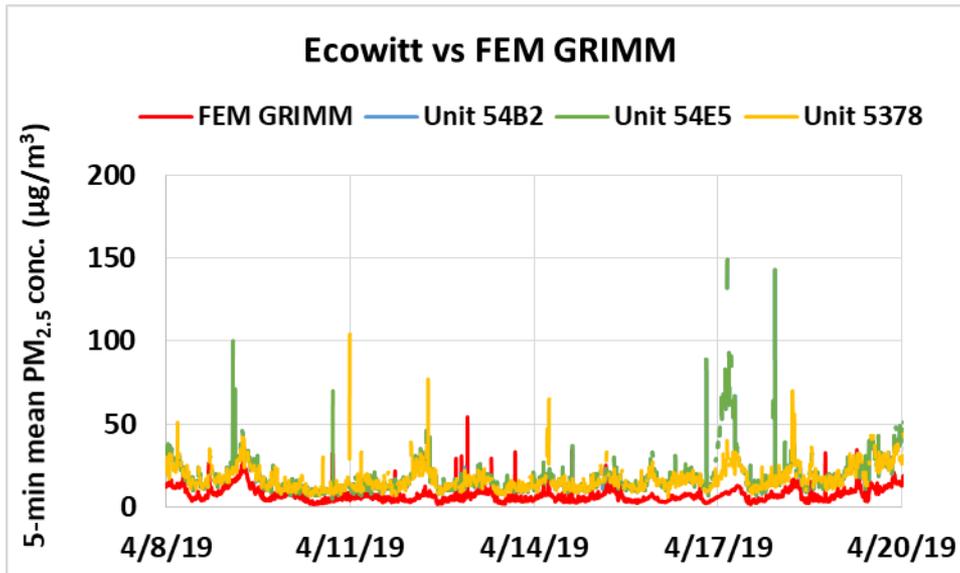
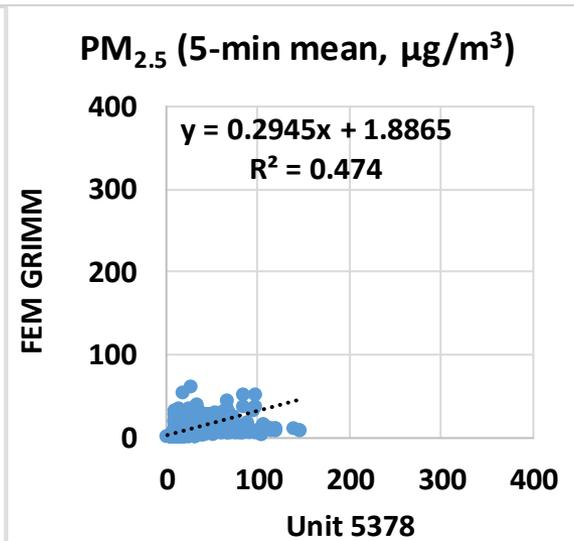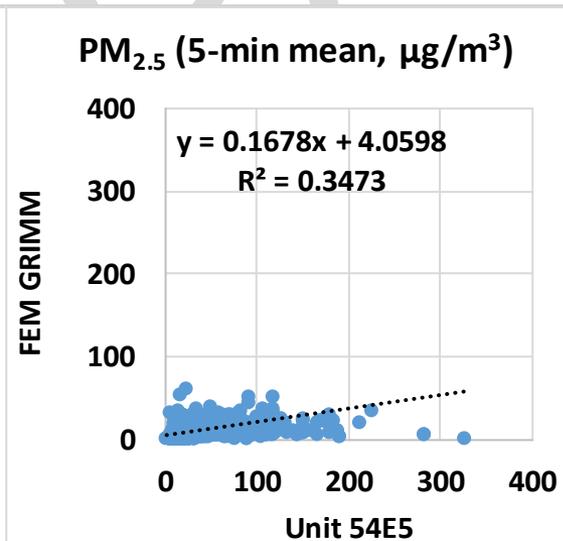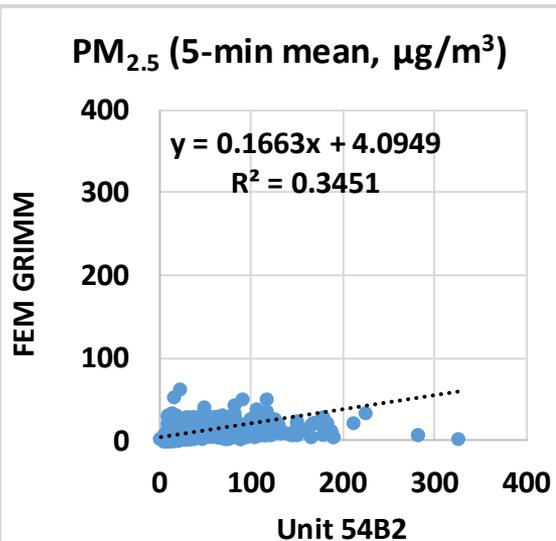# Reference Instruments: PM$_{2.5}$ GRIMM, BAM & T640

- Data recovery for PM$_{2.5}$ from FEM GRIMM, FEM BAM and FEM T640 is 99.4 %, 94.5 % and ~100 %, respectively.
- Good correlations between the three reference instruments for PM$_{2.5}$ measurements (0.63 < R^2 < 0.83) were observed.
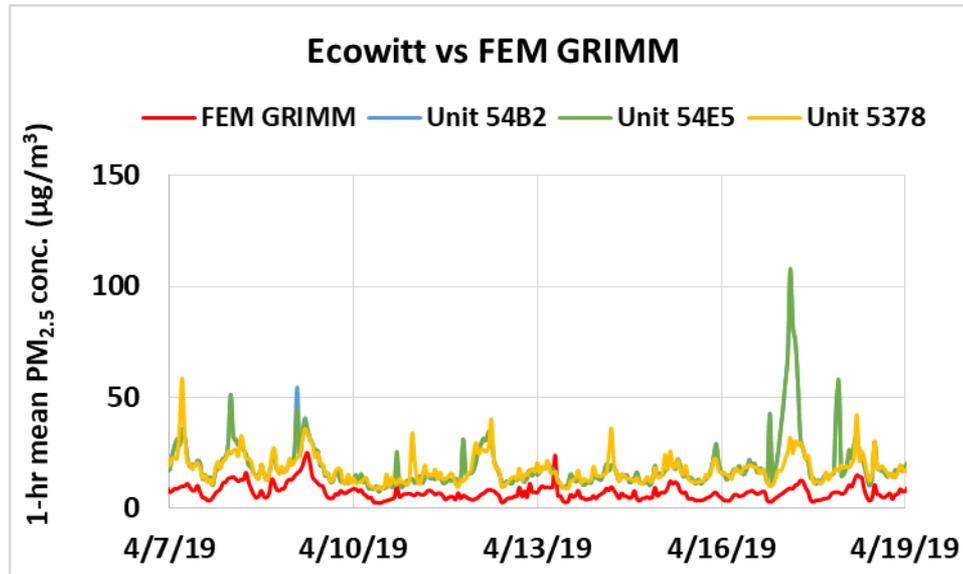

Reference Instruments

FEM GRIMM   FEM BAM   FEM T640

PM$_{2.5}$ (1-hr mean, µg/m^3)

y = 0.6548x + 1.9267
R² = 0.6398

PM$_{2.5}$ (1-hr mean, µg/m^3)

y = 0.6374x - 0.0599
R² = 0.8238

PM$_{2.5}$ (1-hr mean, µg/m^3)

y = 0.9598x + 3.7664
R² = 0.6931

Ecowitt vs FEM GRIMM (PM$_{2.5}$; 5-min mean)

Ecowitt vs FEM GRIMM

— FEM GRIMM — Unit 54B2 — Unit 54E5 — Unit 5378

5-min mean PM$_{2.5}$ conc. (µg/m³)

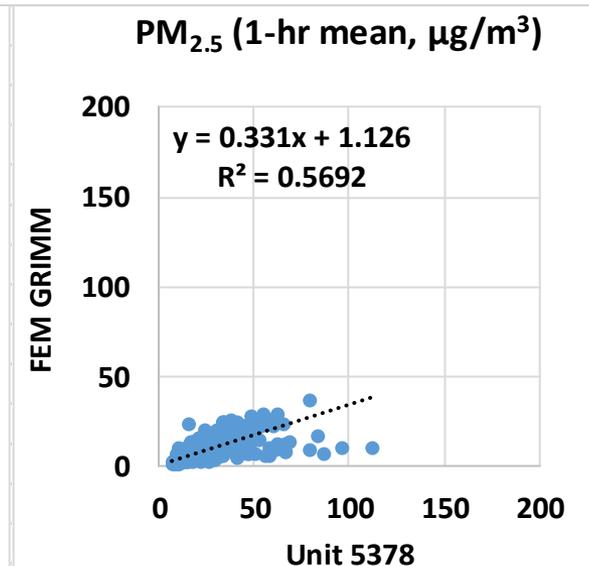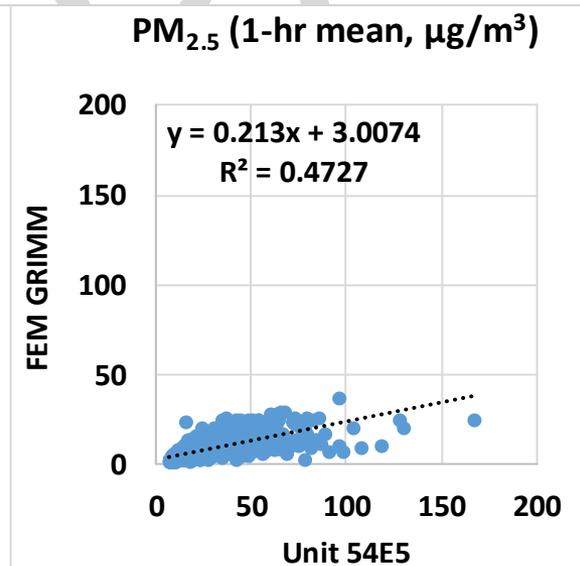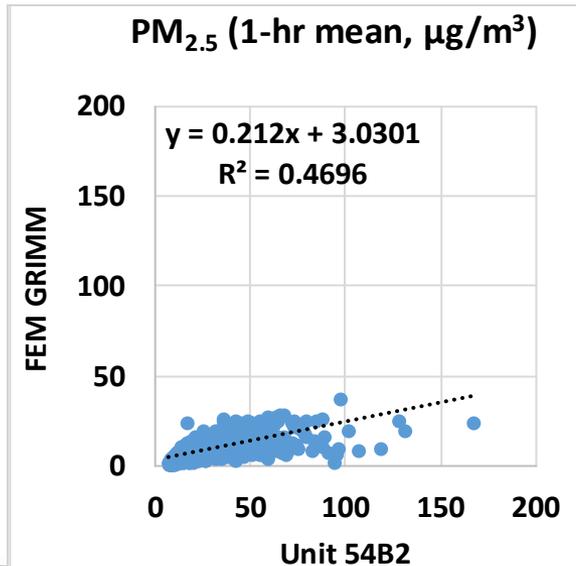200, 150, 100, 50, 0

4/8/19   4/11/19   4/14/19   4/17/19   4/20/19

- Ecowitt sensors did not correlate with the corresponding FEM GRIMM data (R^2 ~ 0.39)
- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM GRIMM
- The Ecowitt sensors seemed to moderately track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM
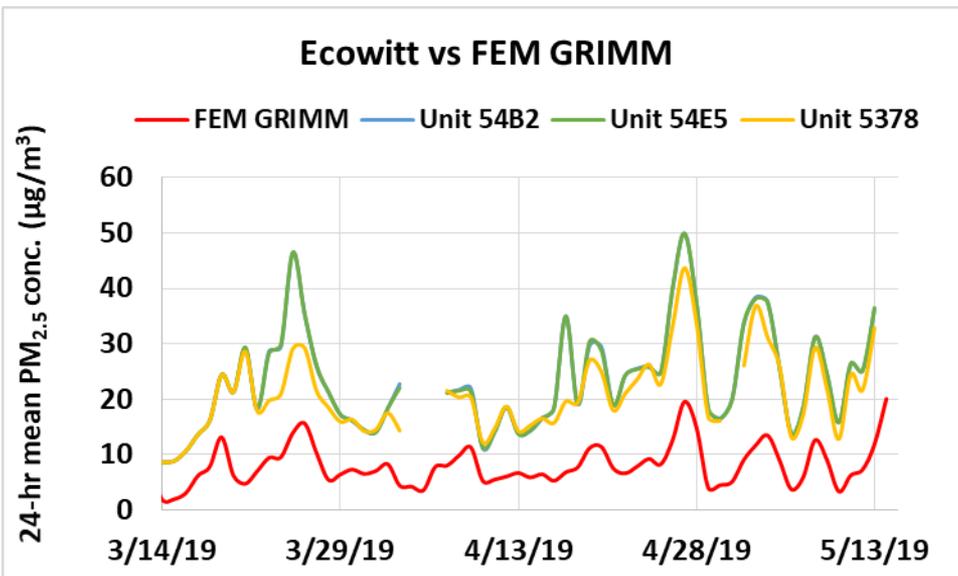
PM$_{2.5}$ (5-min mean, µg/m³)

y = 0.1663x + 4.0949
R^2 = 0.3451

FEM GRIMM

400, 300, 200, 100, 0

0   100   200   300   400

Unit 54B2

PM$_{2.5}$ (5-min mean, µg/m³)

y = 0.1678x + 4.0598
R^2 = 0.3473

FEM GRIMM

400, 300, 200, 100, 0

0   100   200   300   400

Unit 54E5

PM$_{2.5}$ (5-min mean, µg/m³)

y = 0.2945x + 1.8865
R^2 = 0.474

FEM GRIMM

400, 300, 200, 100, 0

0   100   200   300   400

Unit 5378

Ecowitt vs FEM GRIMM (PM$_{2.5}$; 1-hr mean)

Ecowitt vs FEM GRIMM

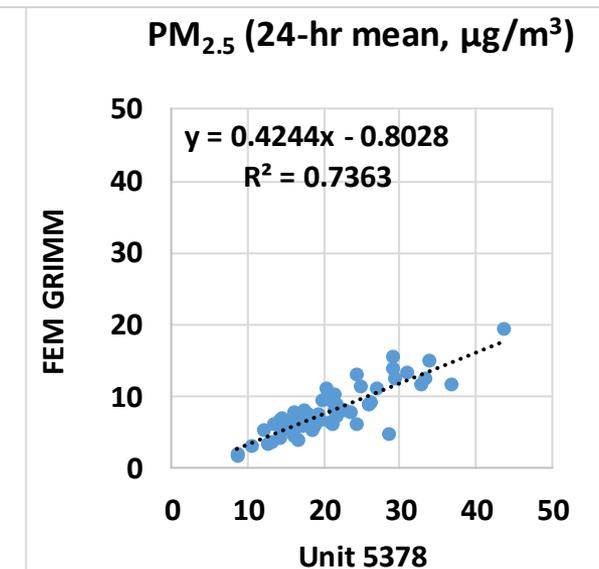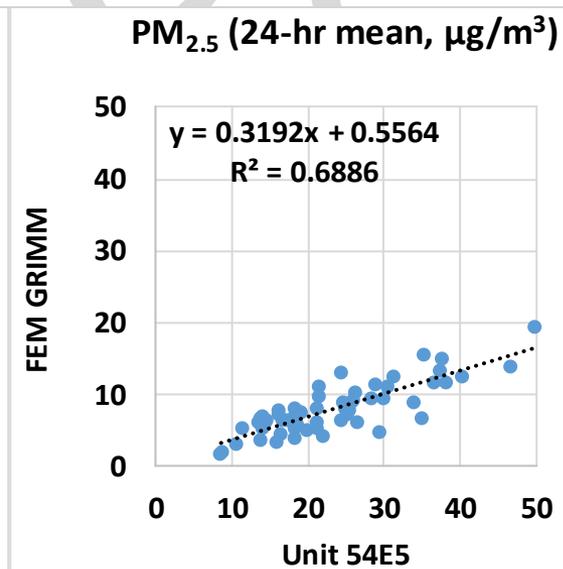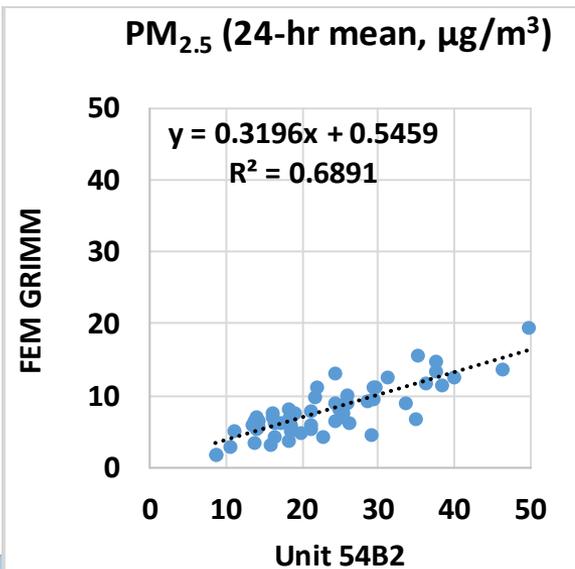FEM GRIMM — Unit 54B2 — Unit 54E5 — Unit 5378

- Ecowitt sensors showed moderate correlations with the corresponding FEM GRIMM data ($R^2 \sim$ 0.50)

- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM GRIMM

- The Ecowitt sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM

PM$_{2.5}$ (1-hr mean, µg/m^3)

$y = 0.212x + 3.0301$
$R^2 = 0.4696$

FEM GRIMM vs Unit 54B2

PM$_{2.5}$ (1-hr mean, µg/m^3)

$y = 0.213x + 3.0074$
$R^2 = 0.4727$

FEM GRIMM vs Unit 54E5

PM$_{2.5}$ (1-hr mean, µg/m^3)

$y = 0.331x + 1.126$
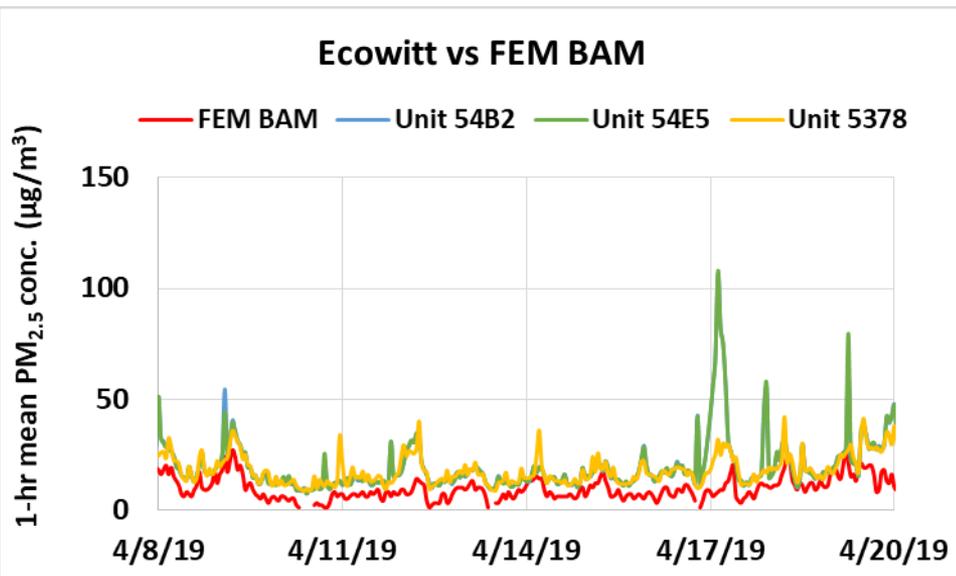$R^2 = 0.5692$

FEM GRIMM vs Unit 5378
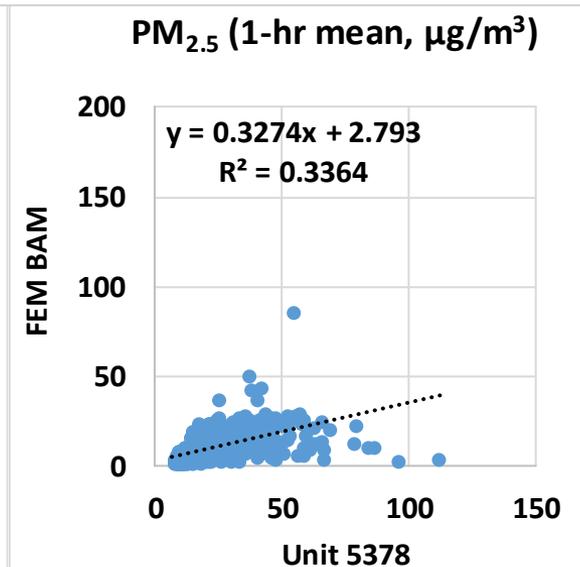
Ecowitt vs FEM GRIMM (PM$_{2.5}$; 24-hr mean)

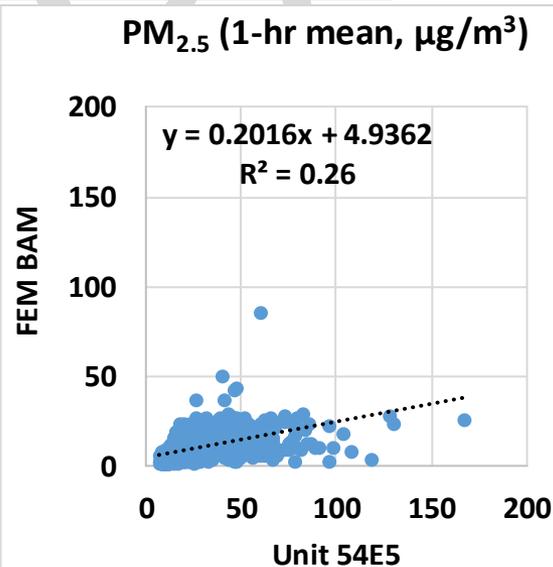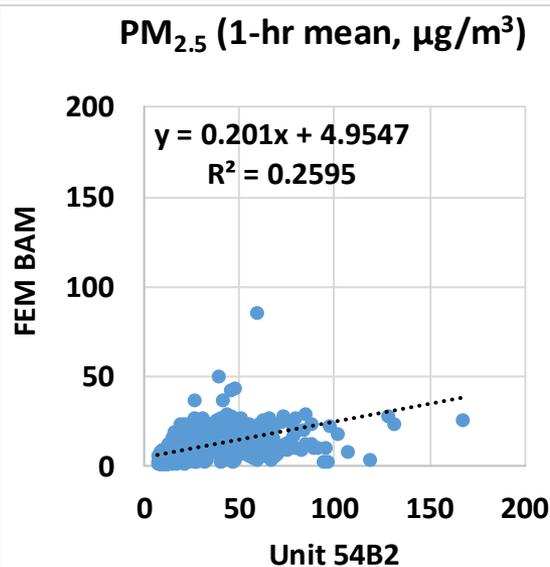- Ecowitt sensors showed good correlations with the corresponding FEM GRIMM data (R^2 ~ 0.70)

- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM GRIMM

- The Ecowitt sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM GRIMM

PM$_{2.5}$ (24-hr mean, µg/m^3)

y = 0.3196x + 0.5459
R^2 = 0.6891

Unit 54B2

PM$_{2.5}$ (24-hr mean, µg/m^3)

y = 0.3192x + 0.5564
R^2 = 0.6886

Unit 54E5

PM$_{2.5}$ (24-hr mean, µg/m^3)
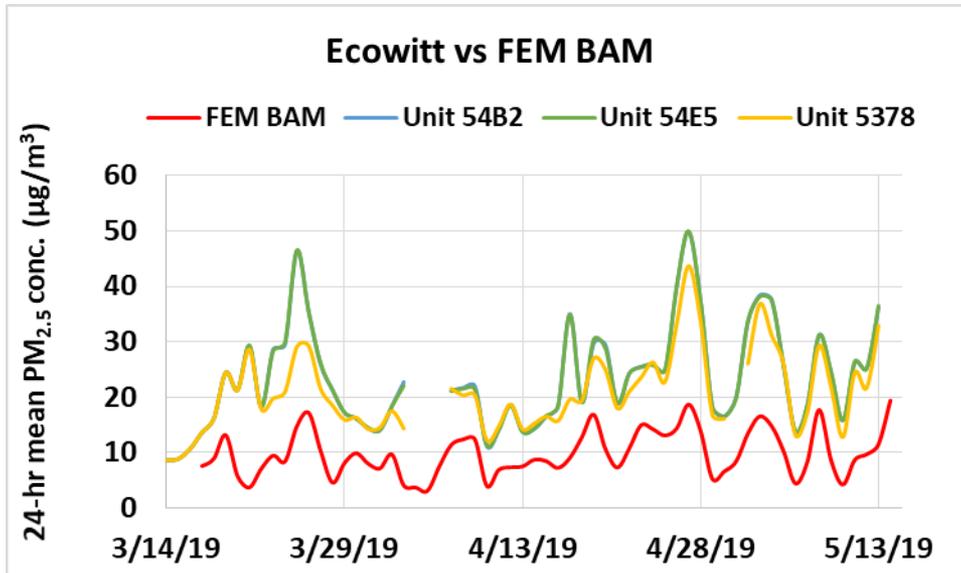
y = 0.4244x - 0.8028
R^2 = 0.7363

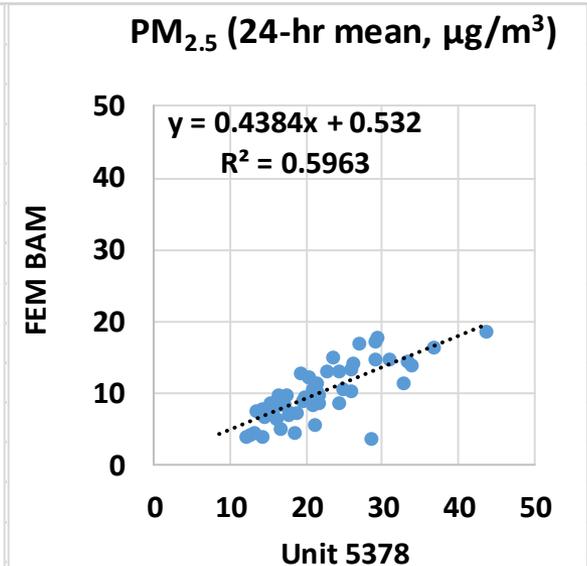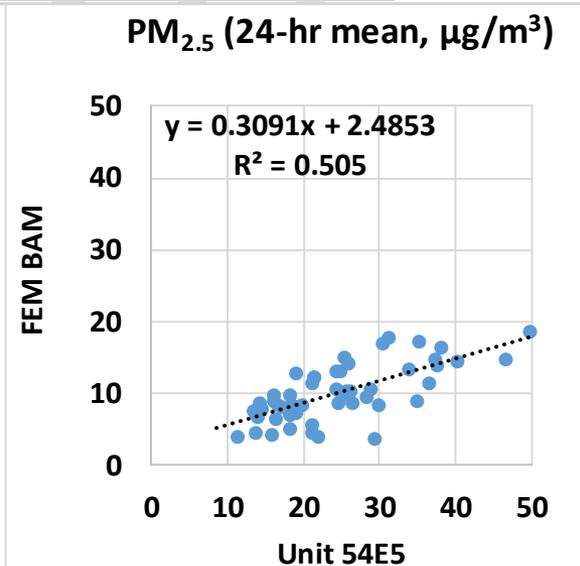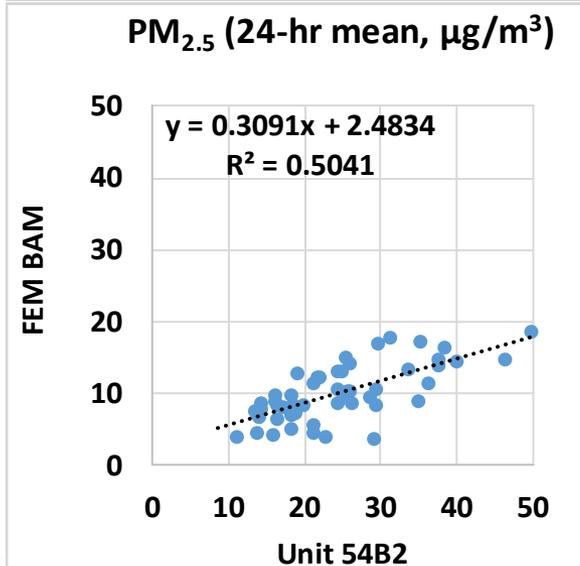Unit 5378

Ecowitt vs FEM BAM (PM$_{2.5}$; 1-hr mean)

- Ecowitt sensors did not correlate with the corresponding FEM BAM data ($R^2 \sim 0.29$)
- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM BAM
- The Ecowitt sensors seemed to moderately track the PM$_{2.5}$ diurnal variations as recorded by FEM BAM
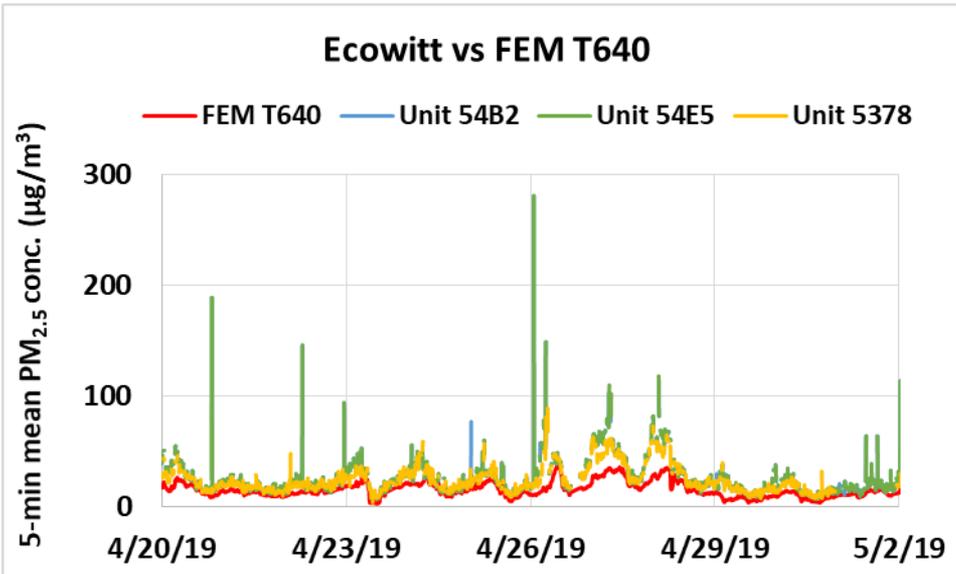
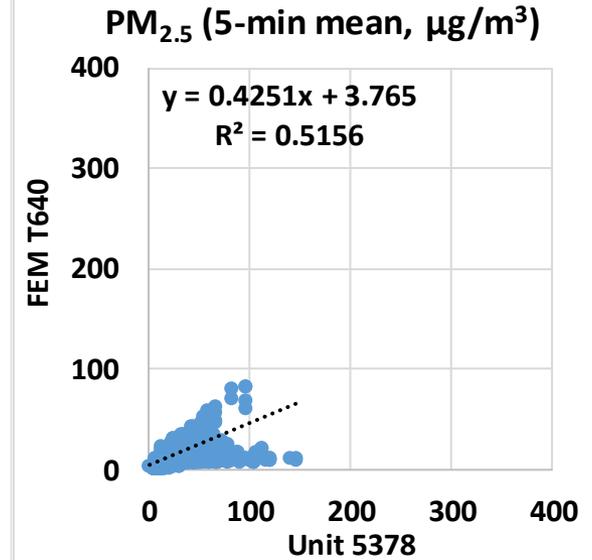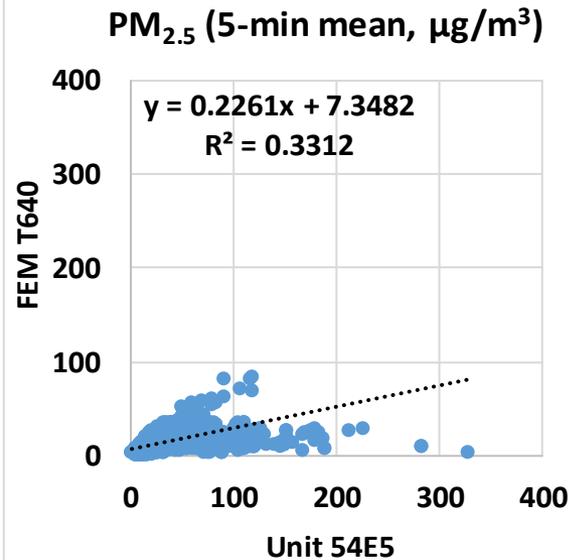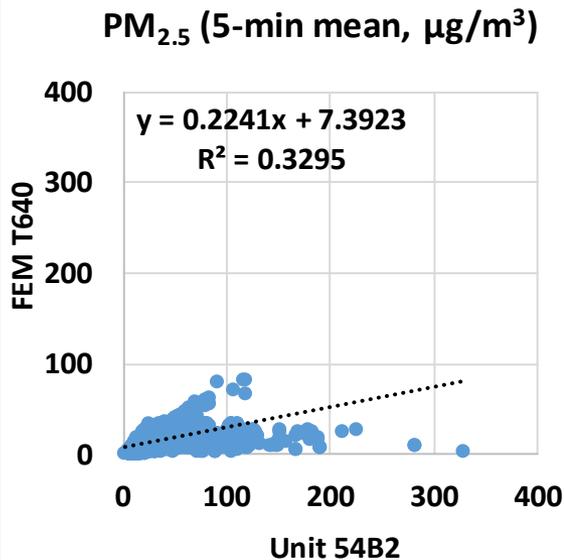# Ecowitt vs FEM BAM (PM$_{2.5}$; 24-hr mean)

- Ecowitt sensors showed moderate correlations with the corresponding FEM BAM data ($R^2 \sim 0.54$)
- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM BAM
- The Ecowitt sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM BAM
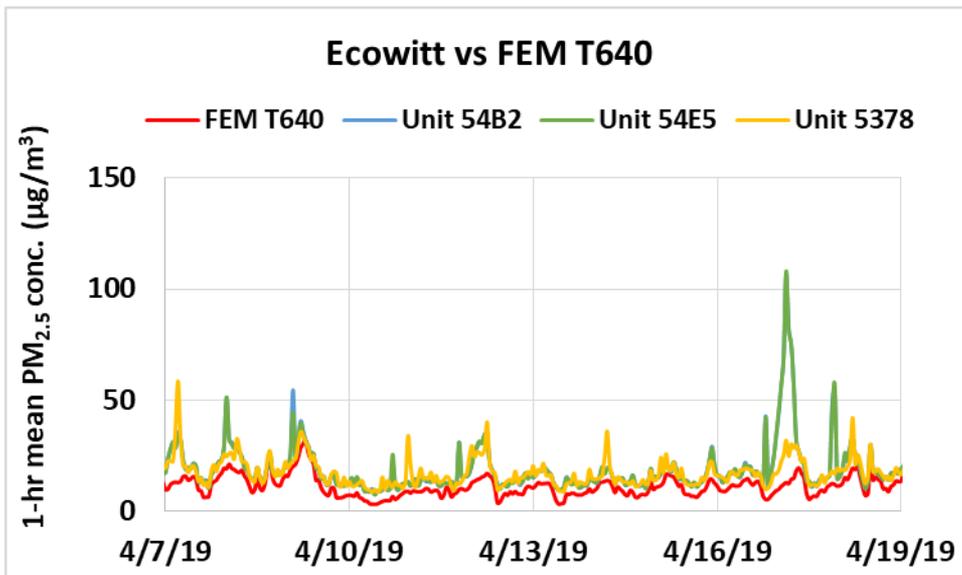
Ecowitt vs FEM T640 (PM$_{2.5}$; 5-min mean)

Ecowitt vs FEM T640

Legend: FEM T640 — Unit 54B2 — Unit 54E5 — Unit 5378

Y-axis: 5-min mean PM$_{2.5}$ conc. (µg/m^3), ranging 0 to 300
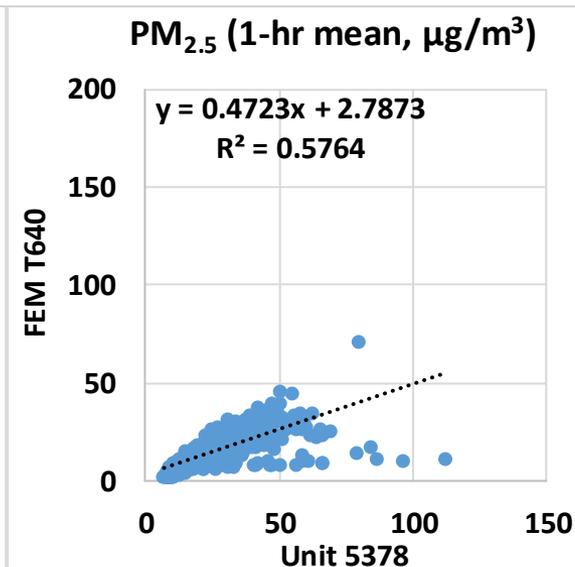
X-axis: 4/20/19, 4/23/19, 4/26/19, 4/29/19, 5/2/19

- Ecowitt sensors did not correlate with the corresponding FEM T640 data (R^2 ~ 0.39)

- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM T640

- The Ecowitt sensors seemed to moderately track the PM$_{2.5}$ diurnal variations as recorded by FEM T640

PM$_{2.5}$ (5-min mean, µg/m^3)

y = 0.2241x + 7.3923
R^2 = 0.3295

Y-axis: FEM T640 (0–400)
X-axis: Unit 54B2 (0–400)

PM$_{2.5}$ (5-min mean, µg/m^3)

y = 0.2261x + 7.3482
R^2 = 0.3312

Y-axis: FEM T640 (0–400)
X-axis: Unit 54E5 (0–400)

PM$_{2.5}$ (5-min mean, µg/m^3)

y = 0.4251x + 3.765
R^2 = 0.5156

Y-axis: FEM T640 (0–400)
X-axis: Unit 5378 (0–400)

Ecowitt vs FEM T640 (PM$_{2.5}$; 1-hr mean)

Ecowitt vs FEM T640

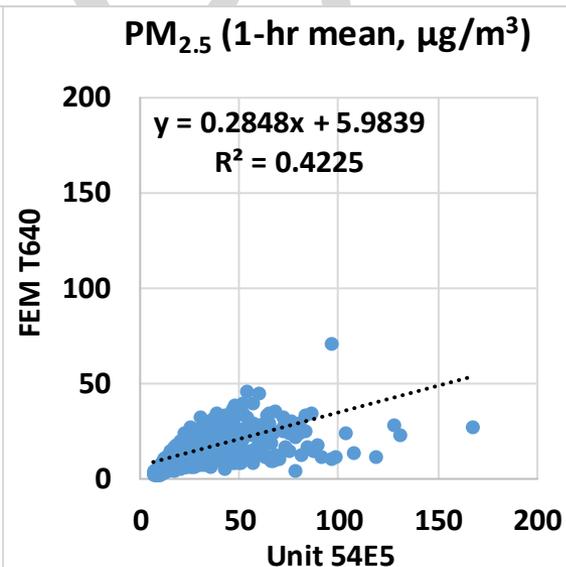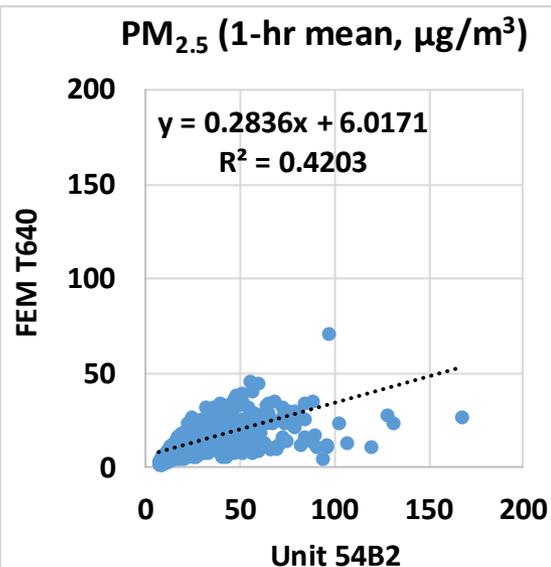Legend: FEM T640 — Unit 54B2 — Unit 54E5 — Unit 5378

- Ecowitt sensors showed moderate correlations with the corresponding FEM T640 data (R^2 ~ 0.47)

- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM T640

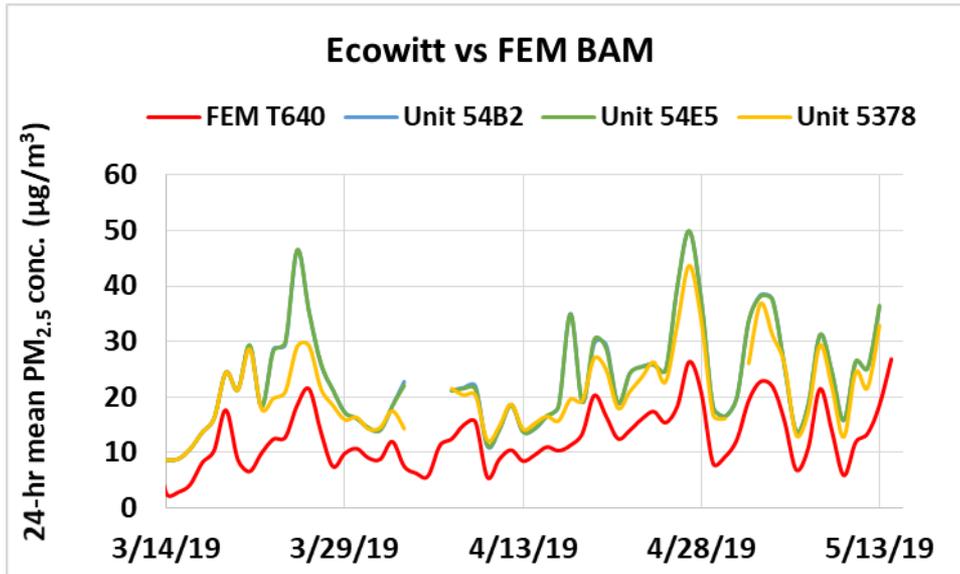- The Ecowitt sensors seemed to moderately track the PM$_{2.5}$ diurnal variations as recorded by FEM T640

PM$_{2.5}$ (1-hr mean, µg/m³)

$y = 0.2836x + 6.0171$
$R^2 = 0.4203$

PM$_{2.5}$ (1-hr mean, µg/m³)

$y = 0.2848x + 5.9839$
$R^2 = 0.4225$

PM$_{2.5}$ (1-hr mean, µg/m³)

$y = 0.4723x + 2.7873$
$R^2 = 0.5764$

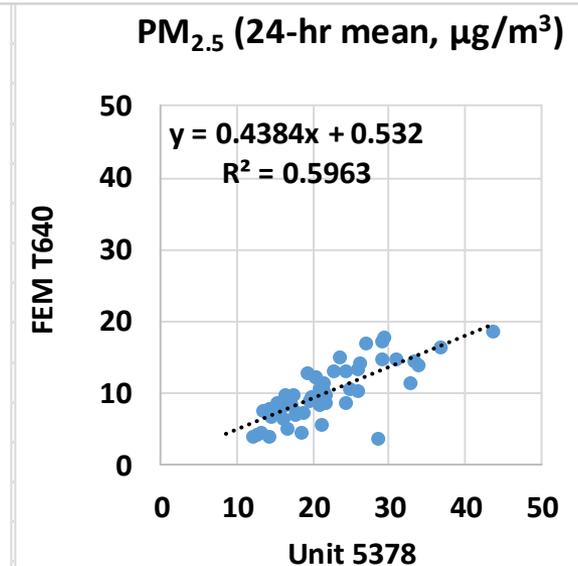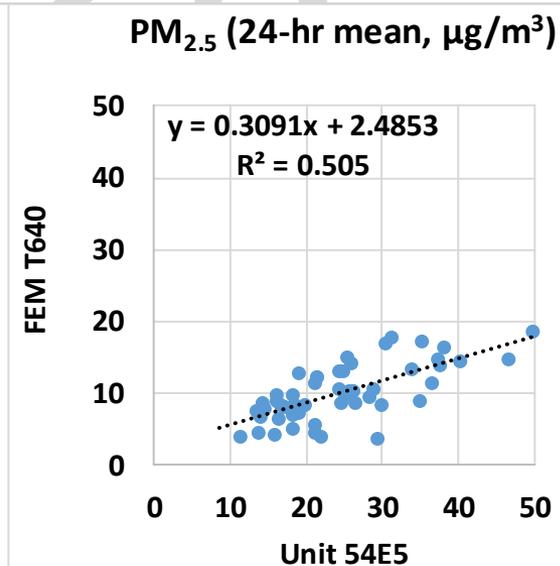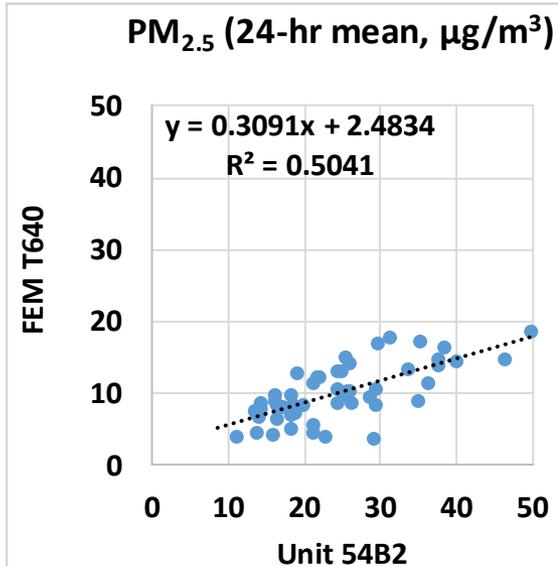# Ecowitt vs FEM T640 (PM$_{2.5}$; 24-hr mean)

Ecowitt vs FEM BAM

- Ecowitt sensors showed moderate correlations with the corresponding FEM T640 data (R$^2 \sim$ 0.53)

- Overall, the Ecowitt sensors overestimated the PM$_{2.5}$ mass concentrations measured by FEM T640

- The Ecowitt sensors seemed to track the PM$_{2.5}$ diurnal variations as recorded by FEM T640

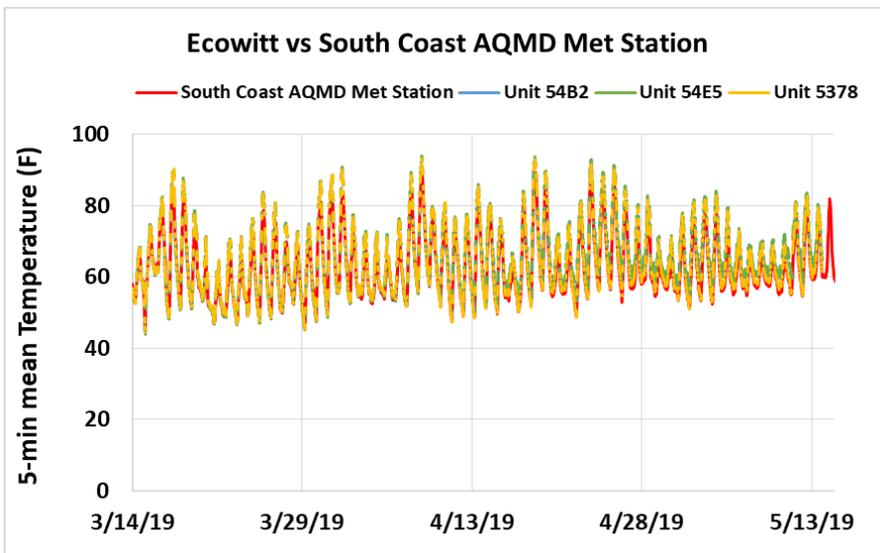**PM$_{2.5}$ (24-hr mean, μg/m^3)**

$y = 0.3091x + 2.4834$
$R^2 = 0.5041$

PM$_{2.5}$ (24-hr mean, μg/m^3)

$y = 0.3091x + 2.4853$
$R^2 = 0.505$

PM$_{2.5}$ (24-hr mean, μg/m^3)

$y = 0.4384x + 0.532$
$R^2 = 0.5963$

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

- Ecowitt temperature measurements correlated very well with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$)

- Overall, the Ecowitt temperature measurements slightly overestimated the corresponding South Coast AQMD Met Station data

- The Ecowitt sensors seemed to track well the temperature diurnal variations as recorded by South Coast AQMD Met Station

Temp (5-min mean, F)

$y = 0.8606x + 6.2658$
$R^2 = 0.9527$

Temp (5-min mean, F)

$y = 0.8655x + 6.9047$
$R^2 = 0.9773$

Temp (5-min mean, F)

$y = 0.8454x + 8.3182$
$R^2 = 0.9729$

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

Ecowitt vs South Coast AQMD Met Station

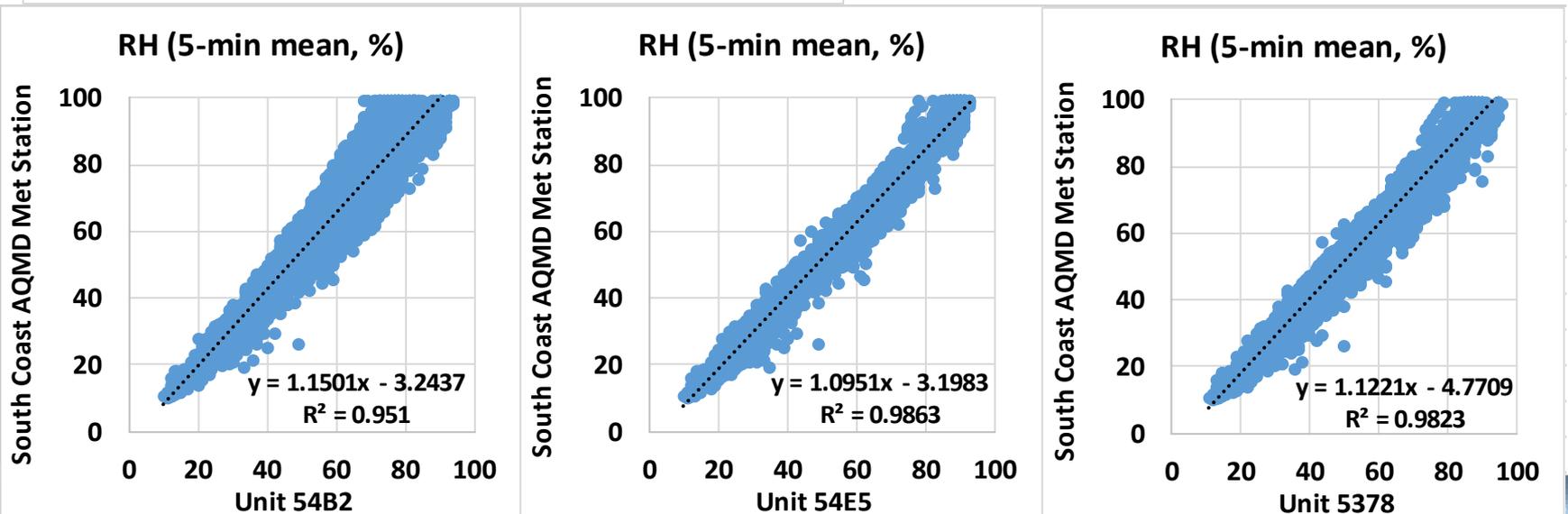Legend: South Coast AQMD Met Station — Unit 54B2 — Unit 54E5 — Unit 5378
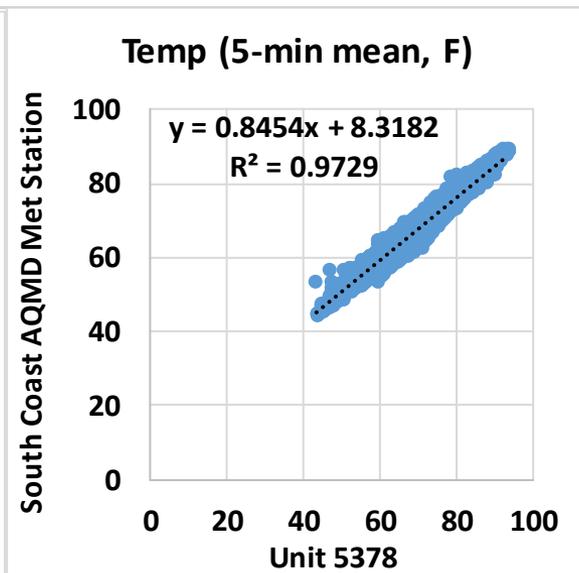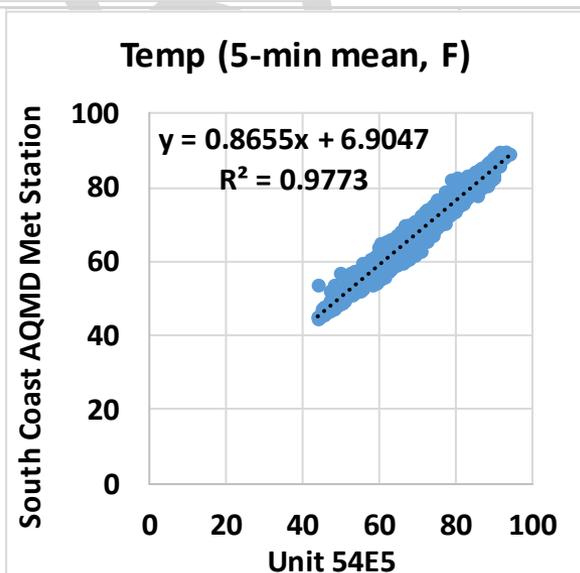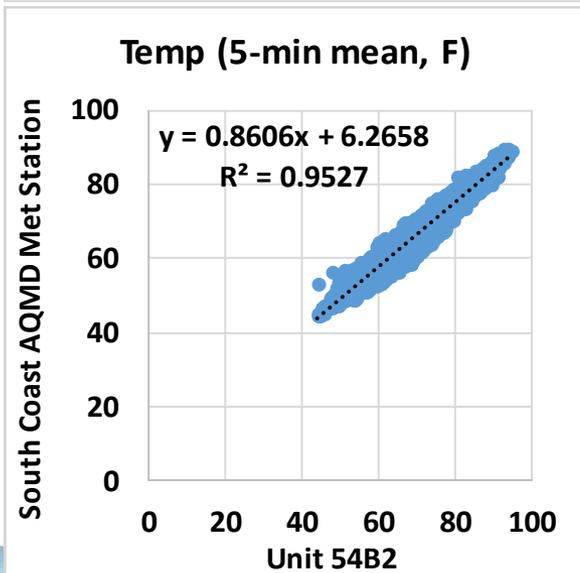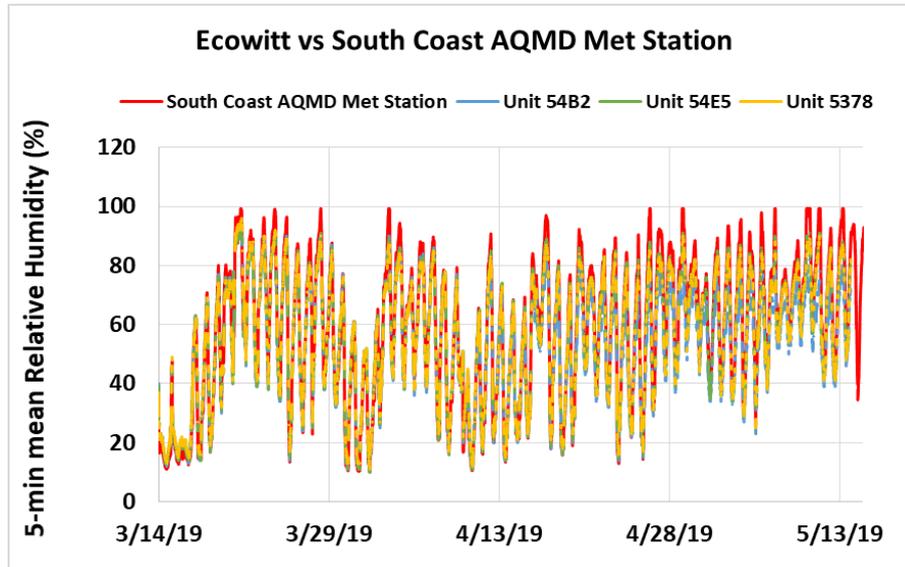
- The Ecowitt RH measurements correlated very well with the corresponding South Coast AQMD Met Station data ($R^2 \sim 0.97$)

- Overall, the Ecowitt slightly underestimated RH measurements as recorded by the South Coast AQMD Met Station

- The Ecowitt sensors seemed to track well the RH diurnal variations as recorded by South Coast AQMD Met Station

RH (5-min mean, %) — Unit 54B2
$y = 1.1501x - 3.2437$
$R^2 = 0.951$

RH (5-min mean, %) — Unit 54E5
$y = 1.0951x - 3.1983$
$R^2 = 0.9863$

RH (5-min mean, %) — Unit 5378
$y = 1.1221x - 4.7709$
$R^2 = 0.9823$

Discussion

- The three **Ecowitt** sensors' data recovery for $PM_{2.5}$ mass conc. measurements from units 54B2, 54E5, and 5378 was 92.2%, 92.3% and 92.2 %, respectively.

- The three sensors showed low intra-model variability (~ 11%)

- The reference instruments (GRIMM, BAM and T640) showed good correlations with each other for $PM_{2.5}$ (R^2 ~ 0.72) mass concentration measurements (1-hr mean)

- $PM_{2.5}$ mass concentration measurements measured by Ecowitt sensors showed poor to moderate correlations with the corresponding FEM GRIMM, FEM BAM and FEM T640 (R^2 ~ 0.50, 0.29 and 0.47, respectively, 1-hr mean) and overestimated $PM_{2.5}$ mass concentration measured by the FEM GRIMM, FEM BAM and FEM T640

- 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