

Field Evaluation Spec Gaseous Sensors



Background

- From 11/23/2015 to 01/26/2016, four CO, four NO₂ and four Ozone **Spec Sensors** were deployed in Rubidoux, CA and ran side-by-side SCAQMD's Federal Reference Method (FRM) instruments measuring the same pollutants

	Type	Unit cost	Time Resolution	# tested: ID name
CO	Electrochemical	~\$500	1 min	4 sensors: B1-1, B1-1(T)*, B1-2, B1-2(T)*
NO ₂	Electrochemical	~\$500	1 min	4 sensors: B2-2, B2-2(T)*, B2-3, B2-3(T)*
Ozone	Electrochemical	~\$500	1 min	4 sensors: B2-2, B2-2(T)*, B2-3, B2-3(T)*

- SCAQMD FRM instruments:

- CO instrument; cost: ~\$10,000
 - Time resolution: 1-min
- NO_x instrument; cost: ~\$11,000
 - Time resolution: 1-min
- O₃ instrument; cost: ~\$13,000
 - Time resolution; 1-min



*These units are also provided with a temperature sensor and use a temperature compensated firmware algorithm to adjust/correct measured gas concentration readings

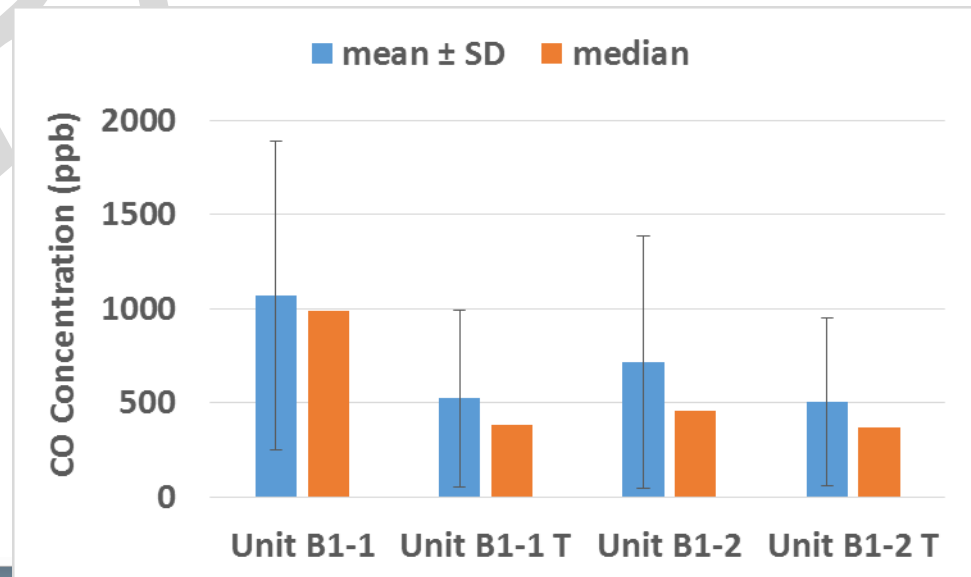
CO Spec Sensor: data validation & recovery

- 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 was variable and ranged between 5 and 89 %.

CO Spec Sensor	Data Recovery (%)
B1-1	5.5
B1-1(T)	77.3
B1-2	10.2
B1-2(T)	89.2

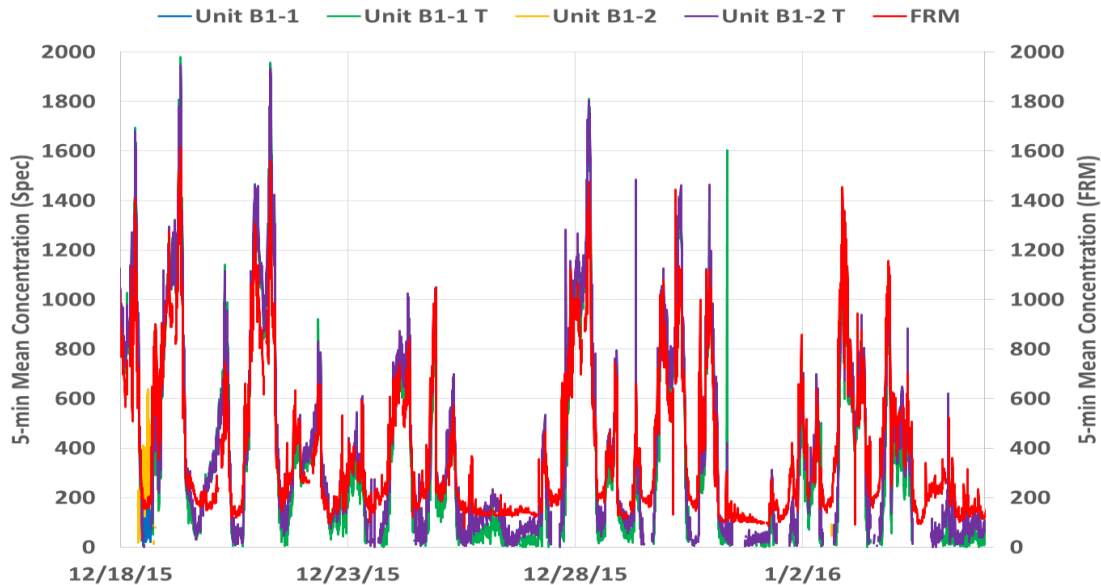
CO Spec Sensor: intra-model variability

- Substantial variation was only observed between the two sensor units that did not adjust the CO measurements for temperature variations



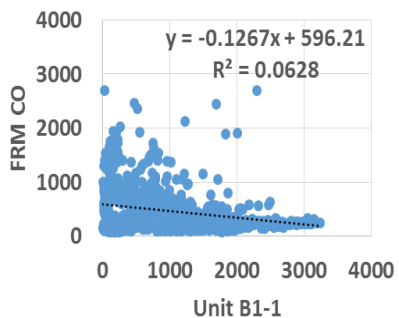
Spec Sensors vs FRM (CO; 5-min mean)

Spec Sensor vs FRM (CO; ppb)

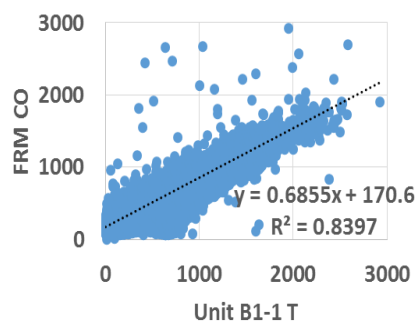


- The non-temperature compensated CO Spec sensors do not correlate with the corresponding FRM data
- The temperature compensated CO sensors correlate well ($R^2 > 0.83$) with the corresponding FRM readings
- Although these sensors tracked well the actual (FRM) diurnal CO variations, relatively high discrepancies between the sensors and FRM readings were observed at low CO concentrations

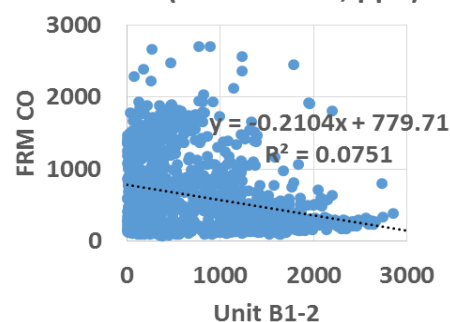
CO (5-min mean; ppb)



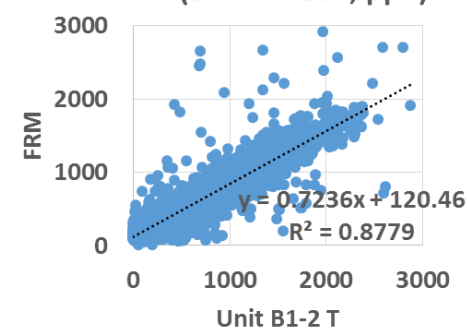
CO (5-min mean; ppb)



CO (5-min mean; ppb)

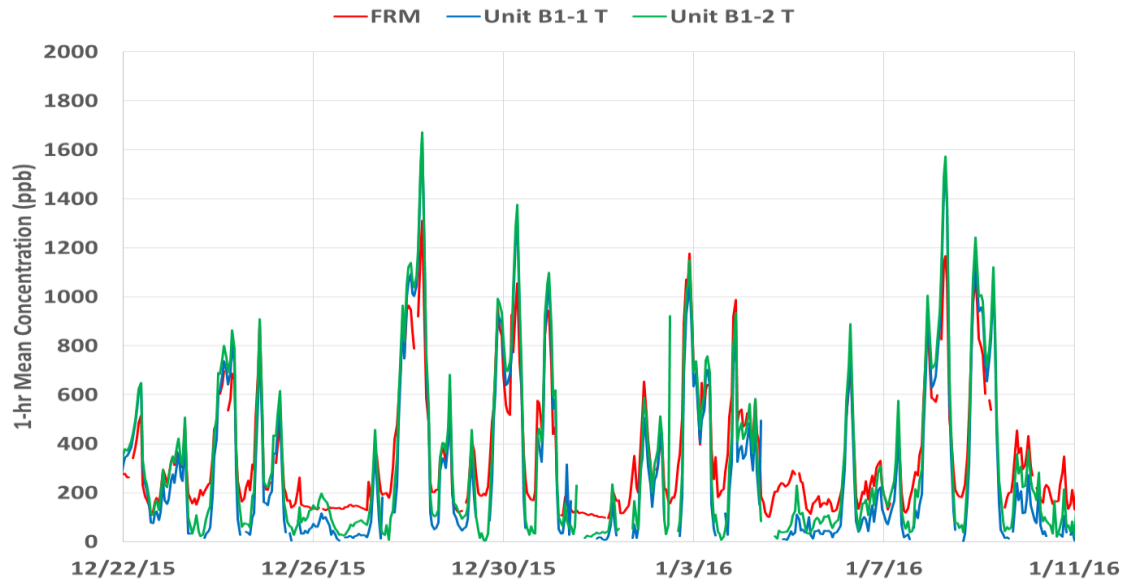


CO (5-min mean; ppb)

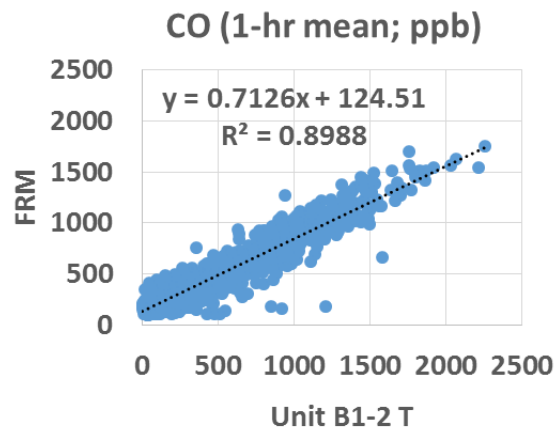
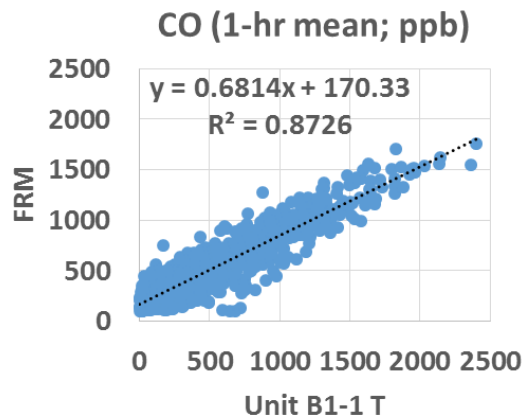


Spec Sensors vs FRM (CO; 1-hr mean)

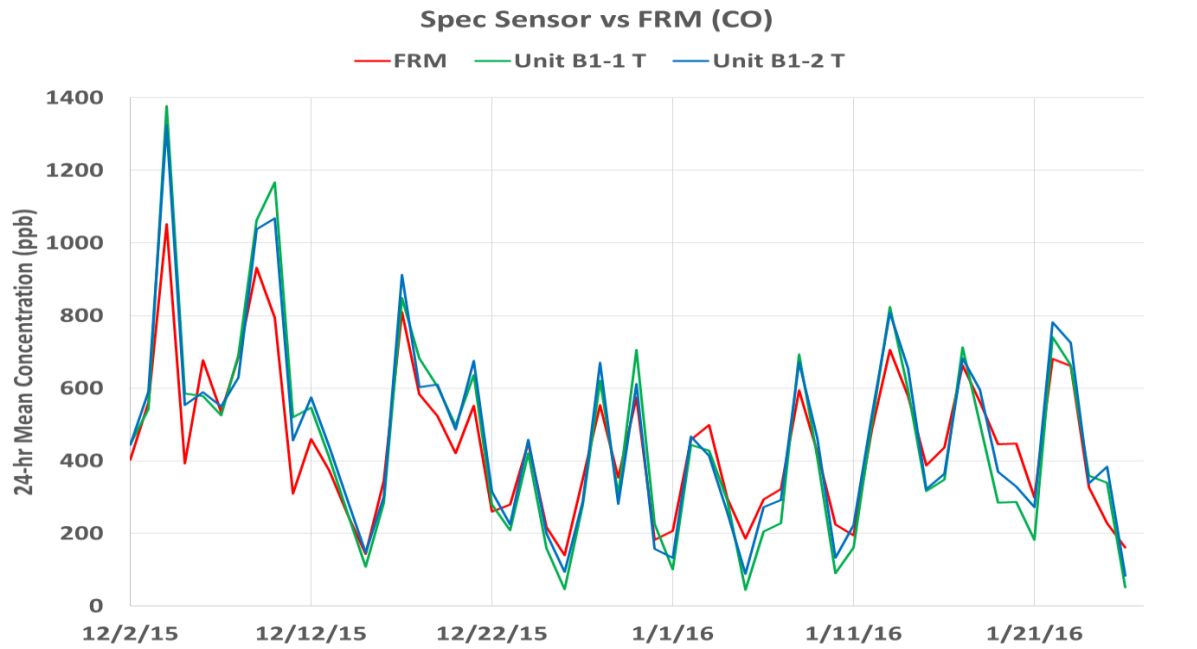
Spec Sensor vs FRM (CO)



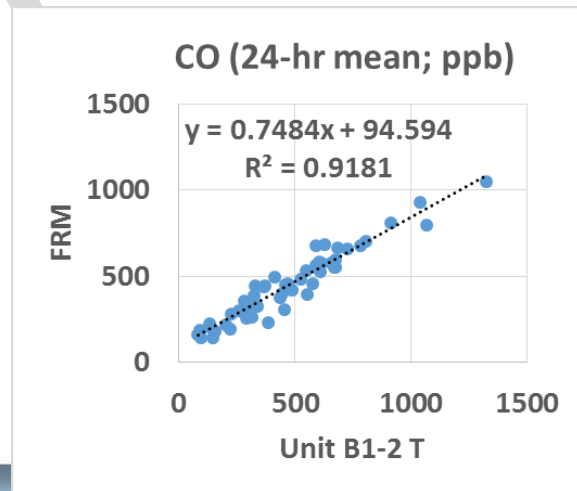
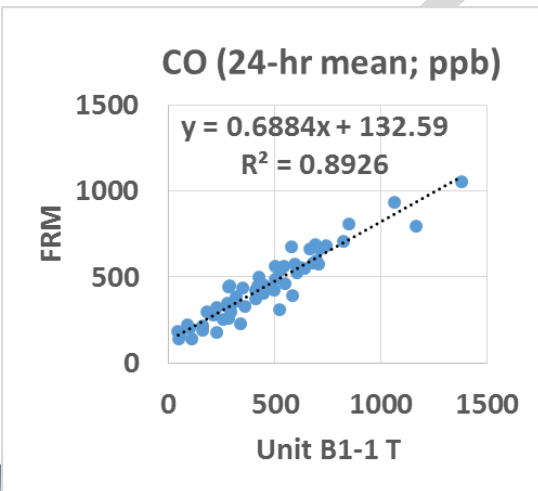
- The temperature compensated CO sensors correlate well ($R^2 > 0.87$) with the corresponding FRM readings
- Although these sensors tracked well the actual (FRM) diurnal CO variations, relatively high discrepancies between the sensors and FRM readings were observed at low CO concentrations
- Overall, all CO sensors overestimated the corresponding FRM measurements



Spec Sensors vs FRM (CO; 24-hr mean)



- The temperature compensated CO sensors correlate well ($R^2 > 0.89$) with the corresponding FRM CO readings
- Although these sensors tracked well with the actual (FRM) diurnal CO variations, relatively high discrepancies between the sensors and FRM readings were observed at low CO concentrations



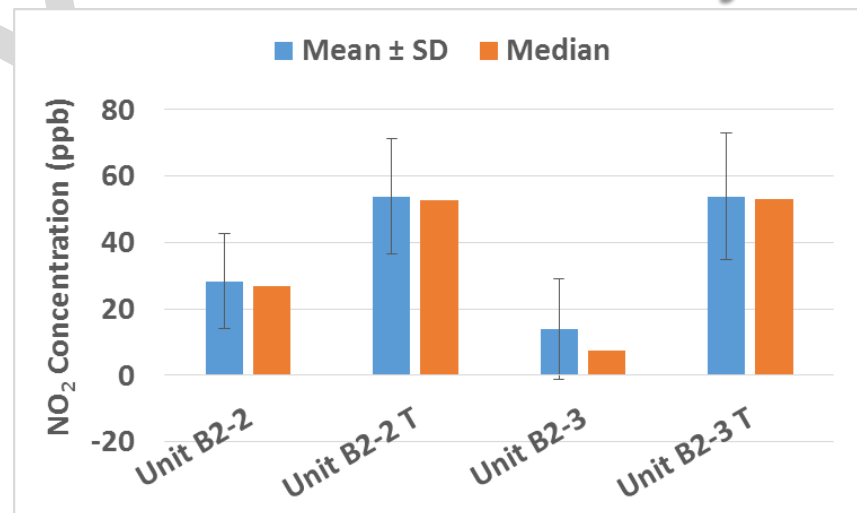
NO₂ Spec Sensor: data validation & recovery

- 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 dataset). Data recovery was variable and ranged between 0 and 100 %

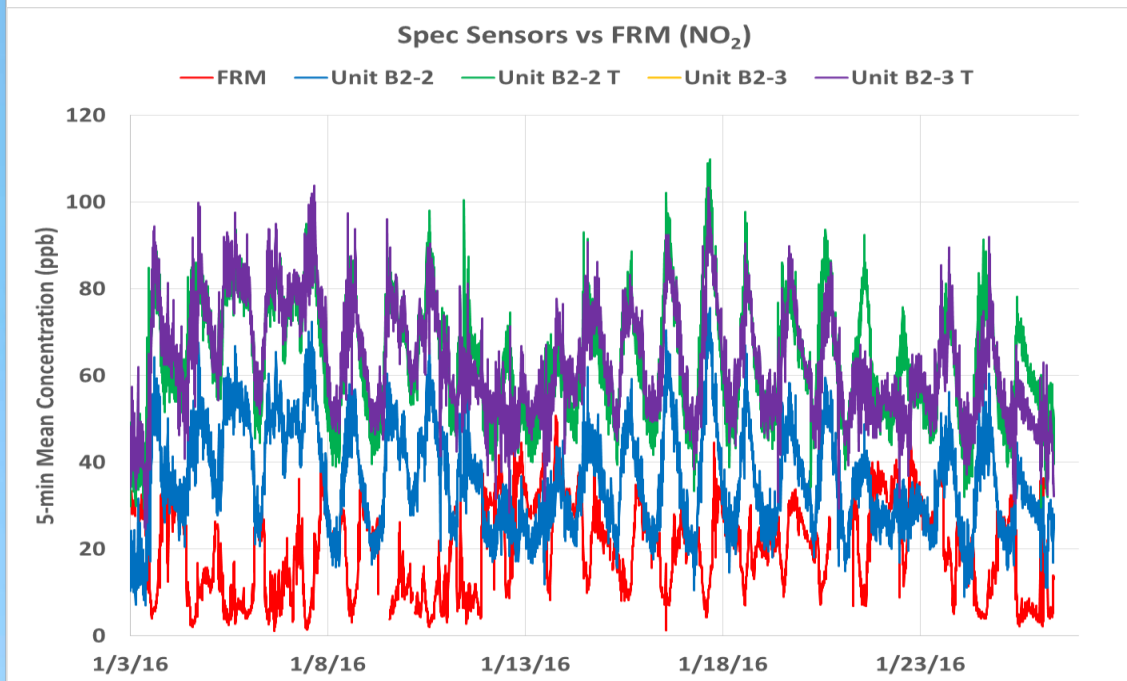
NO ₂ SpecSensor	Data Recovery (%)
B2-2	96.7
B2-2(T)	99.5
B2-3	0.4
B2-3(T)	98.5

NO₂ Spec Sensor: intra-model variability

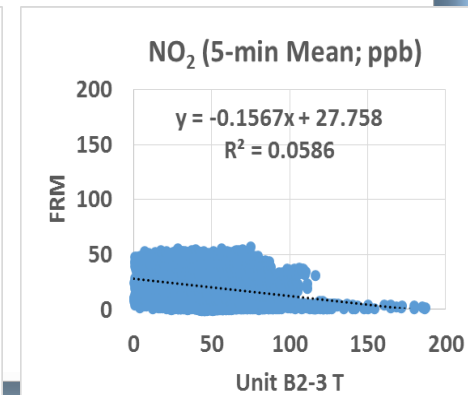
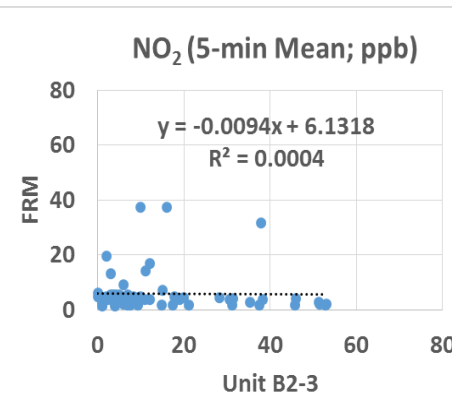
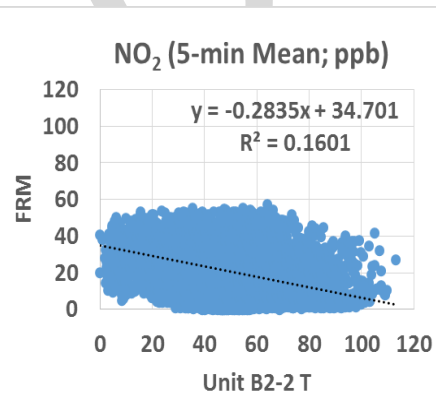
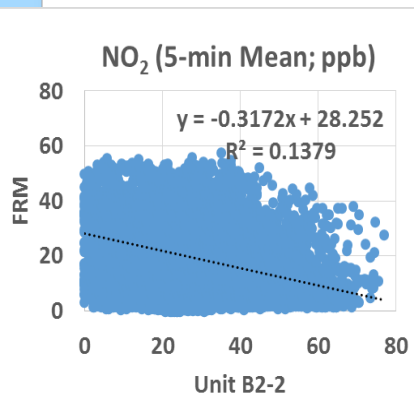
- Substantial variation was only observed between the two sensor units that did not adjust the NO₂ measurements for temperature variations



Spec Sensors vs FRM (NO₂; 5-min mean)



- None of the four sensors tested during this evaluation correlate well with our FRM NO₂ instrument ($R^2 \sim 0.00-0.16$)
- All Spec sensors overestimated actual (FRM) NO₂ concentrations



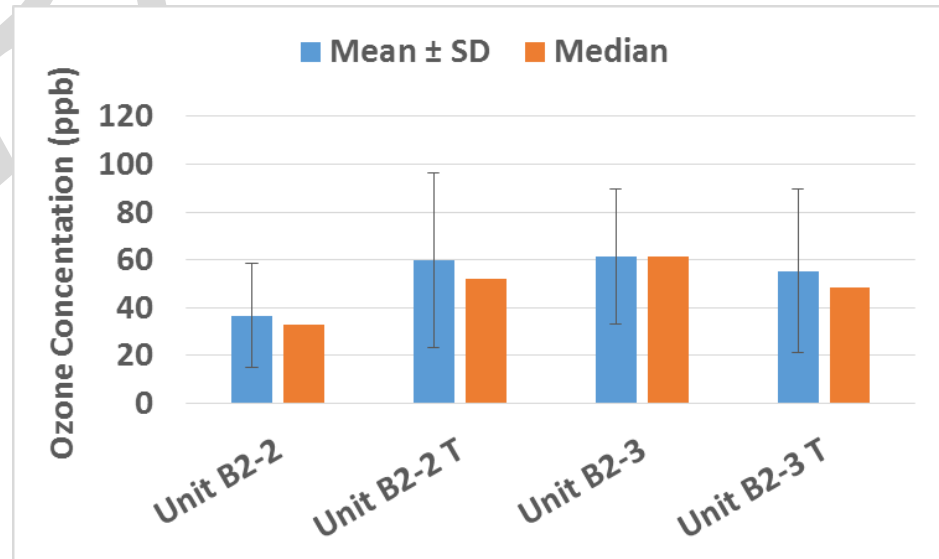
Ozone Spec Sensor: data validation & recovery

- 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 was variable and ranged between 86 and 97%.

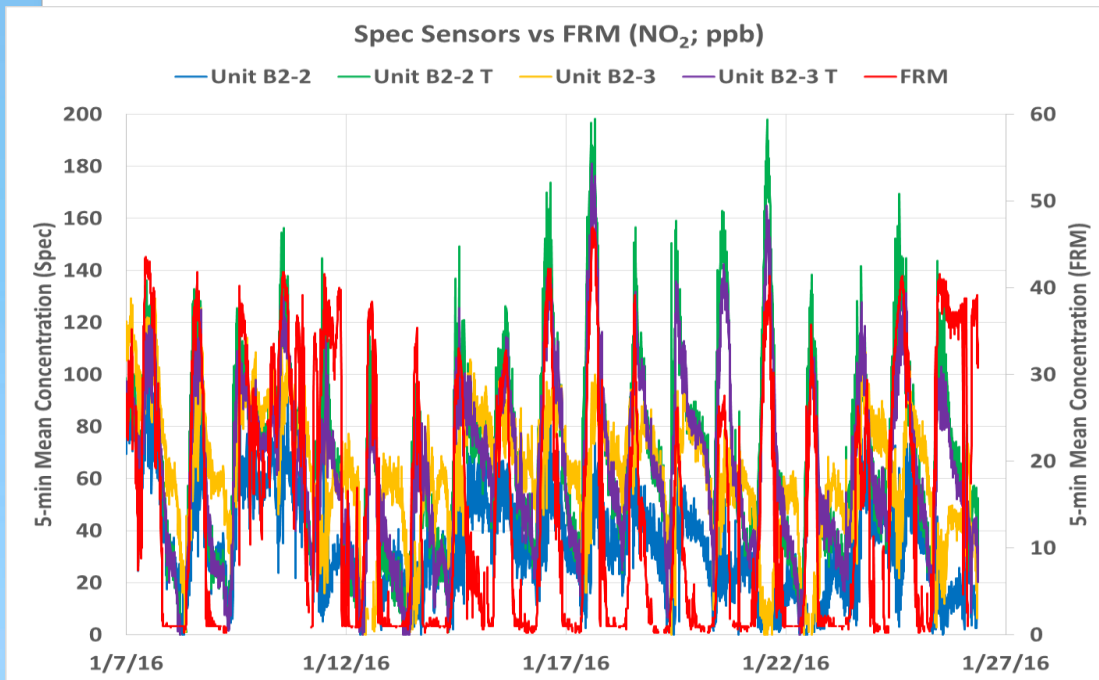
Ozone Spec Sensor	Data Recovery (%)
B2-2	85.9
B2-2 T	97.0
B2-3	90.3
B2-3 T	95.0

Ozone Spec Sensor: intra-model variability

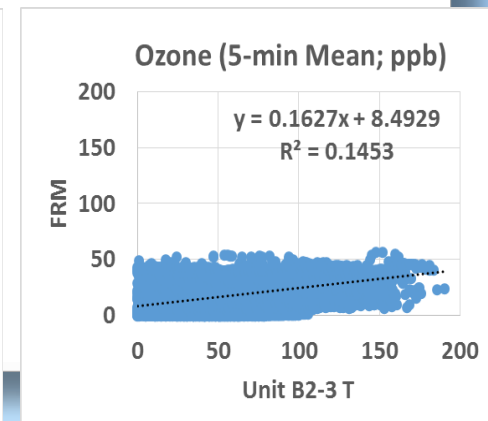
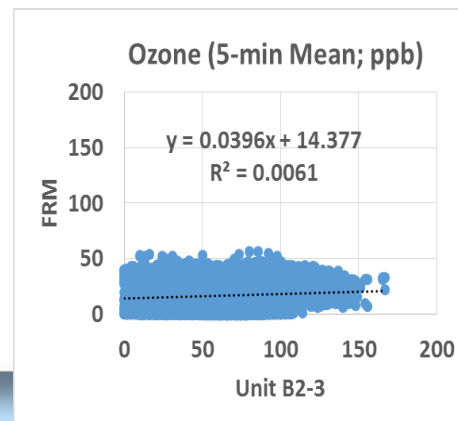
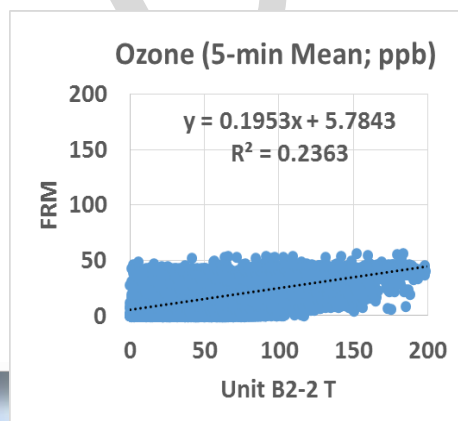
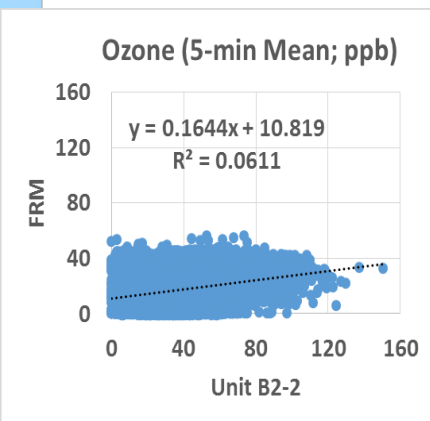
- Moderate measurement variations were observed between three of the four Ozone Spec Sensors tested



Spec Sensors vs FRM (Ozone; 5-min)



- None of the four sensors tested during this evaluation correlate well with our FRM ozone instrument ($R^2 \sim 0.01-0.24$)
- All Spec sensors overestimated actual (FRM) ozone concentrations



Summary

- CO Sensors:
 - Only the temperature compensated sensors correlated well ($R^2 > 0.83$) with the corresponding FRM CO data
 - Overall, all Spec sensors overestimated actual (FRM) CO concentrations
- NO₂ Sensors:
 - None of the NO₂ sensors tested correlated well with the corresponding FRM instrument ($R^2 < 0.16$)
 - All Spec sensors overestimated actual (FRM) NO₂ concentrations
- O₃ sensors:
 - None of the ozone sensors tested correlated well with the corresponding FRM instrument ($R^2 < 0.24$)
 - All Spec sensors overestimated actual (FRM) ozone concentrations
- Data reliability may be an issue due to significant intra-model variability between sensor units
- Chamber testing is necessary to fully evaluate the performance of the Spec Sensors under controlled temperature and relative humidity conditions and known target gas/gas mixture concentrations
- All results are still preliminary