Measuring Spatial Variability in Ozone Concentrations Using a Small-Sensor Network

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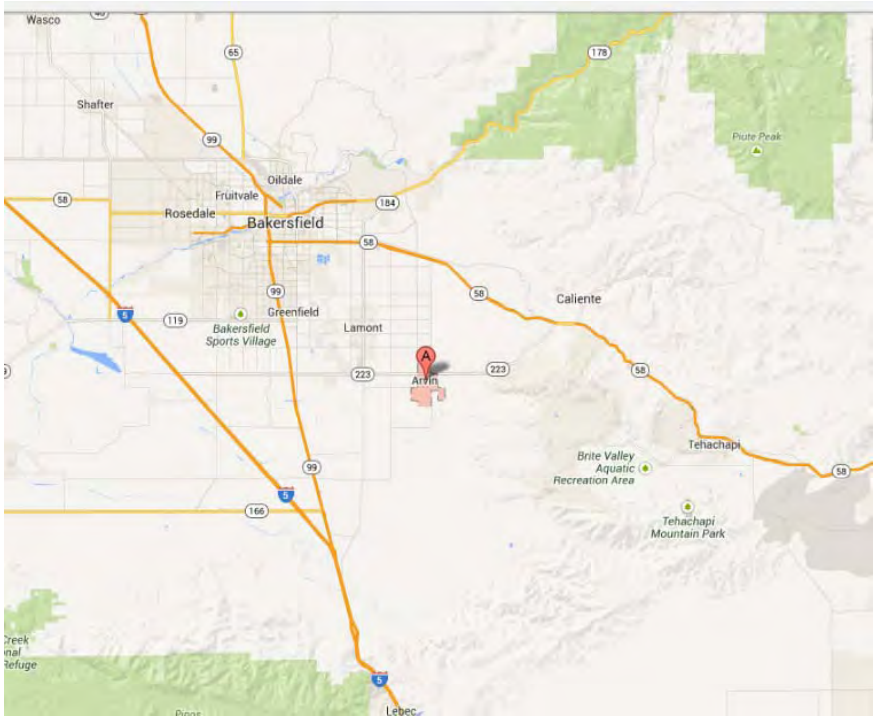
Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

Objectives

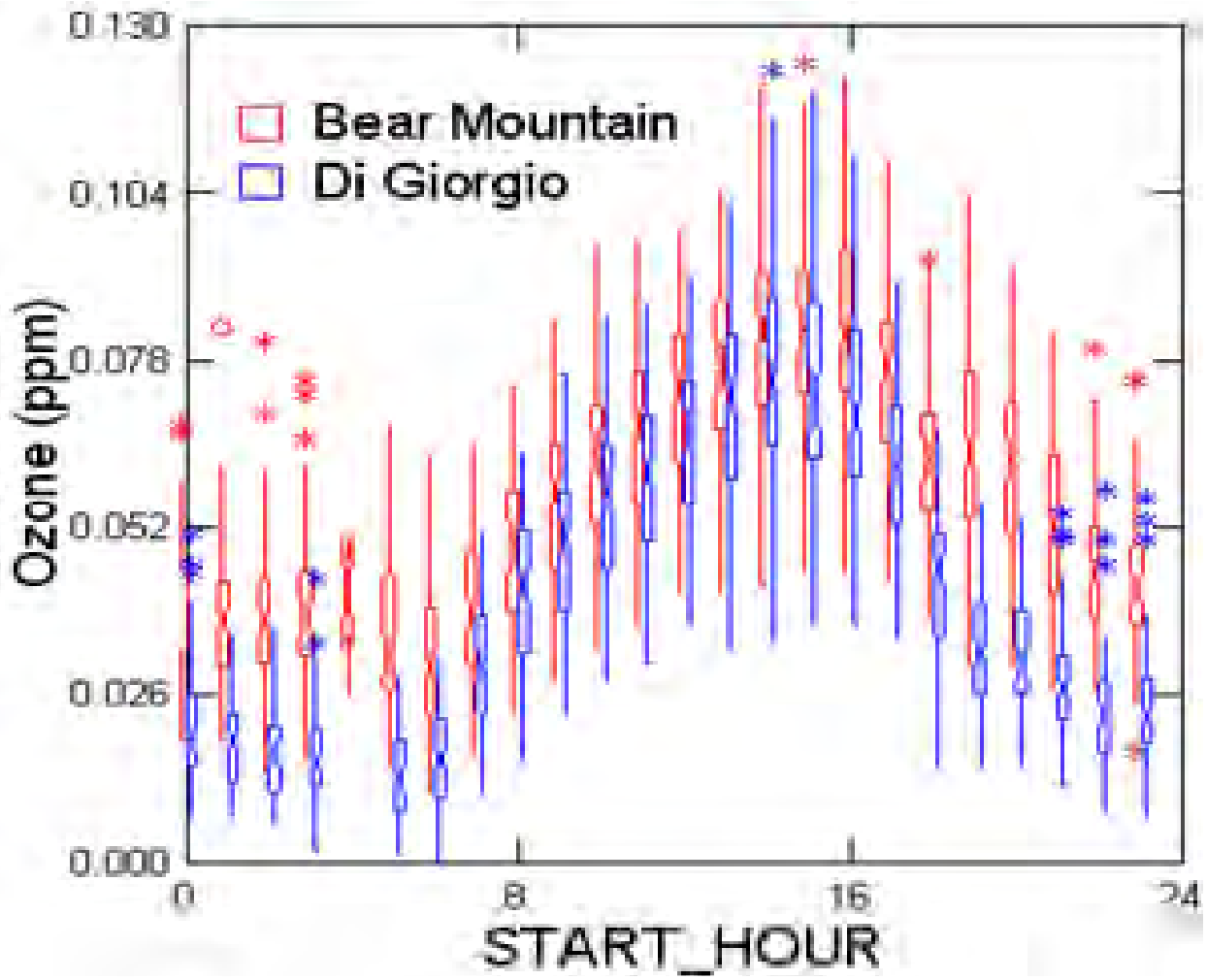
- Determine ozone gradients in and around Arvin
- Develop an algorithm to predict peak ozone concentrations within the City of Arvin



Motivation

- One of the sites with highest ozone concentrations, called Bear Mountain, operated from June 1989 through December 2010.
- In 2010, it was replaced with a site about two miles to the north, near Di Giorgio Elementary School.
- Sites were operated in parallel in 2010.
- During 2010, ozone concentrations at Di Giorgio were about 10% lower than at Bear Mountain.
- This issue raised concerns in the community, and the U.S. Environmental Protection Agency (EPA) has indicated that the differences may hinder EPA's ability to determine whether the region has reached attainment.

Bear Mountain vs. Di Giorgio



Box-notch whisker plot of August-September 2010 diurnal pattern of ozone concentrations (ppm) at Bear Mountain (red) and Di Giorgio (blue).

Notches show median concentrations, boxes indicate the interquartile range (25^{th}–75^{th} percentile), and asterisks and circles indicate outliers.

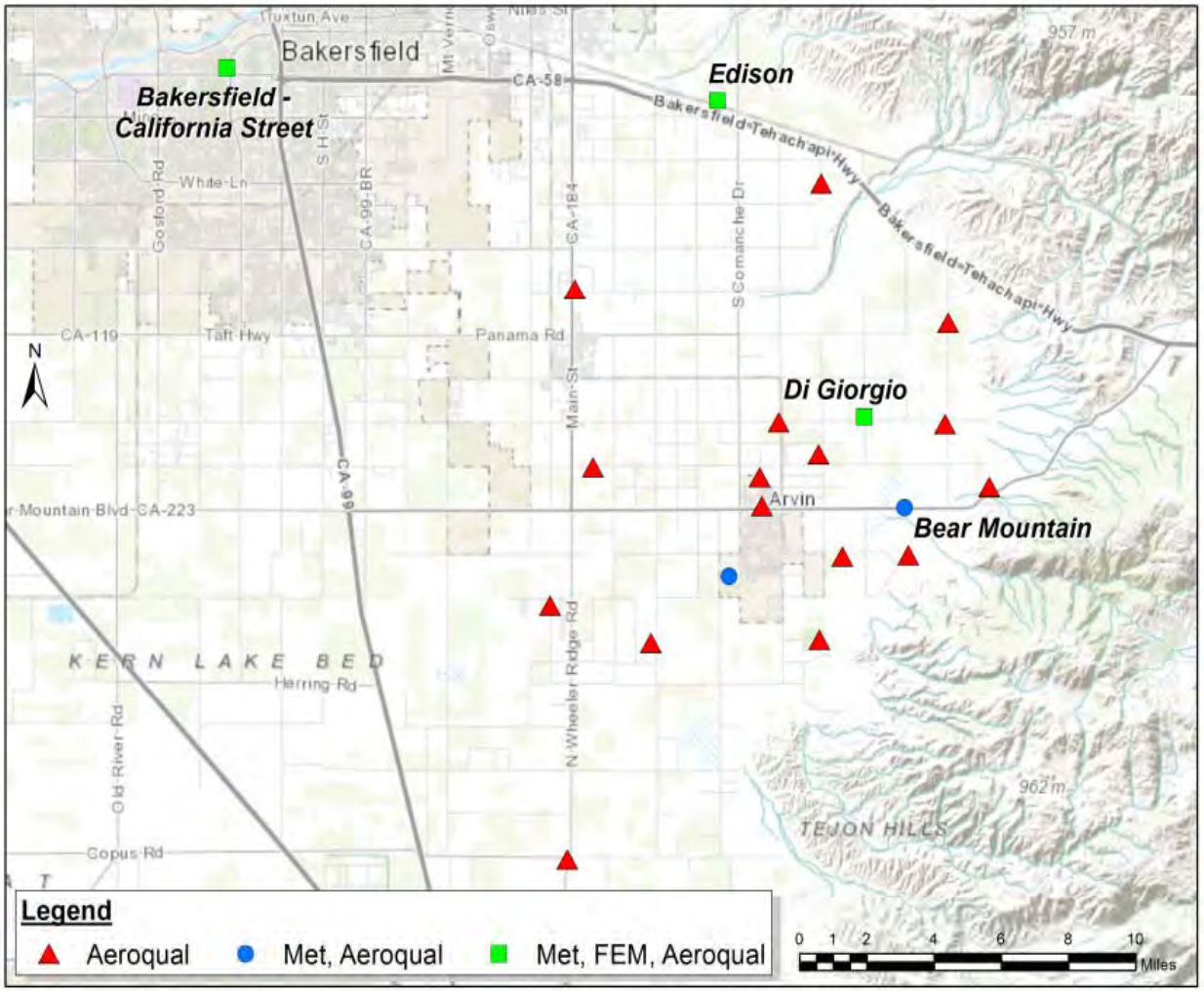
The Study

- Saturation ozone study with 21 sites
  - 3 FEM sites
  - 18 new sites
- August 10 though September 25, 2013
- Sub-hourly ozone data using low-cost, low-power, portable AeroQual S500 sensors
- Collocation study at beginning and end to calibrate sensors against a Federal Equivalent Method (FEM) monitor
- Data analysis

About Arvin

- 19,000 people
- Agricultural community
- Generally downwind of the rest of the San Joaquin Valley
- Ideal meteorology and topography for high concentrations of ozone in the summer

Sites

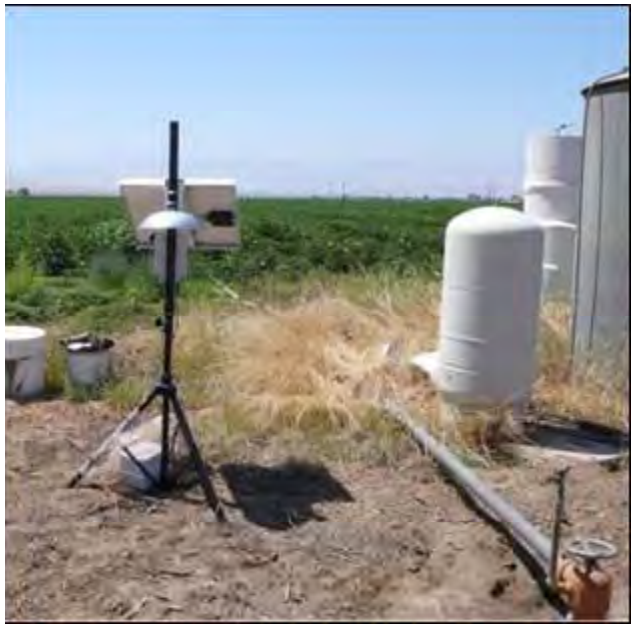

Bakersfield
Bakersfield - California Street
Edison
Di Giorgio
Bear Mountain
Arvin
CA-58
CA-99
CA-184
CA-119
CA-223
Taft Hwy
Panama Rd
Herring Rd
Copus Rd
White Ln
Gosford Rd
Main St
N Wheeler Ridge Rd
Old River Rd
S Comanche Dr
Bakersfield-Tehachapi-Hwy
KERN LAKE BED
TEJON HILLS
957 m
962 m
N
Legend
Aeroqual
Met, Aeroqual
Met, FEM, Aeroqual
0 1 2 4 6 8 10
Miles

Ozone Sensor Considerations

- **Ozone specificity** – The instrument chosen should measure ozone with limited interferences from other chemicals.
- **Precision** – Measurements should be sufficiently precise to ensure that the ozone concentrations provide statistically significant gradients.
- **Accuracy** – Measurements should be accurate enough to ensure that the ozone concentrations are accurate for gradients and ozone predictions.
- **Baseline drift** – The instrument's baseline drift should be low enough to ensure consistent ozone measurements during the study period.

About the AeroQual S500 Sensors

- Gas-sensitive semiconductor
- Uses heated tungstic oxide (WO_3); in the presence of ozone, conductance of WO_3 decreases. Changes in the conductance are calibrated to measure ozone.
- During the no-flow state, the high temperature of the sensor results in thermal decomposition of surrounding ozone, and the sensor measures a “zero ozone” conductance. During the “fan on” state, the sensor responds to incoming ozone, and the sensor conductance decreases.

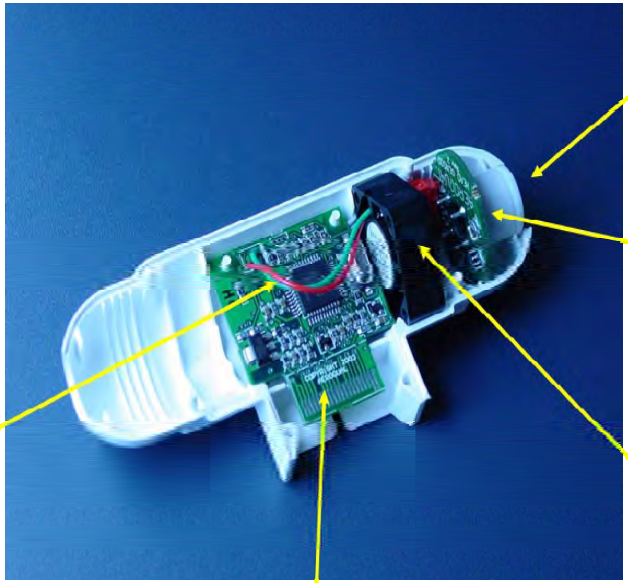


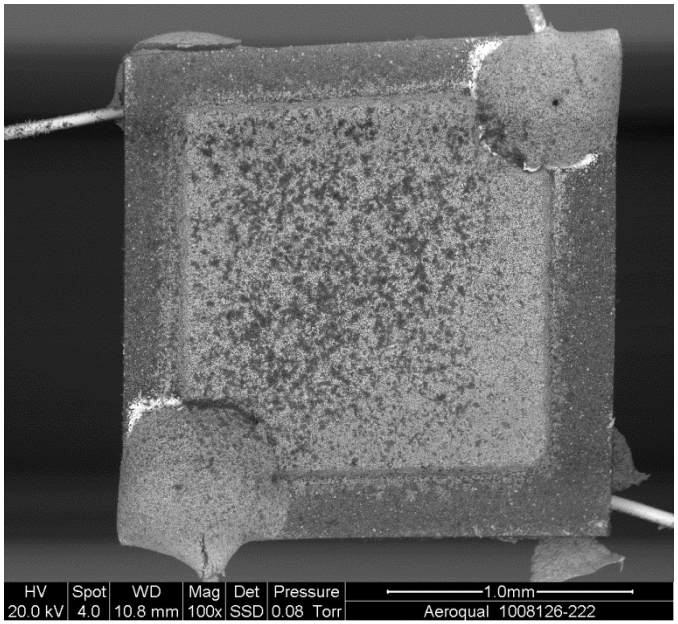
Manufacturer’s Specifications

Performance Characteristics	Value	Units
Linear range	0 - 0.15	ppm
Resolution	0.001	ppm
Accuracy of calibration	±0.005	ppm
Minimum detection limit	0.001	ppm

Performance Characteristics	Value	Units
Precision	±0.005	ppm
Baseline drift	< 0.004	ppm/ 1000 hrs
Operational range	0 to 40	deg C
Relative humidity	10 to 90	%

The Aeroqual Sensor



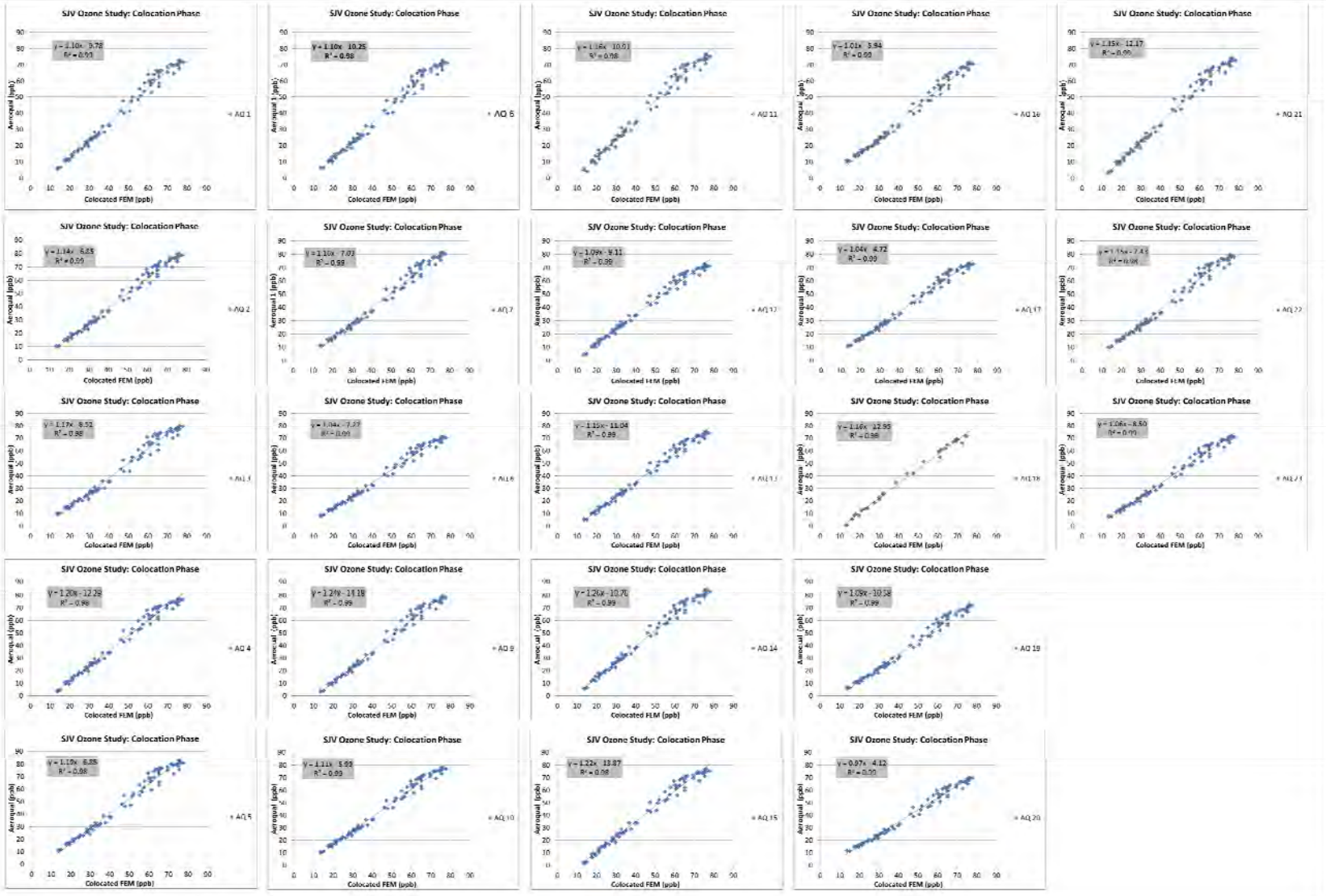


Sensor head after field study. The particle composition was mostly silicates with some carbonaceous content.

The Instruments During a Five-Day Collocation Study in Fresno

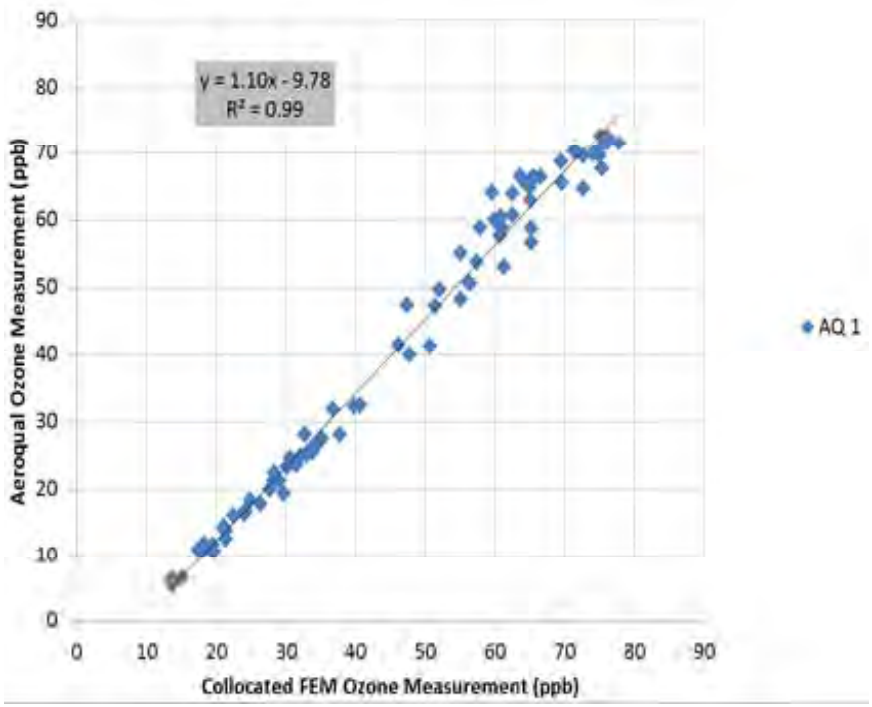
Collocated with a Transfer Standard Teledyne API Model T400 UV absorption ozone monitor

FEM vs. All Sensors During Collocation: All Look Good

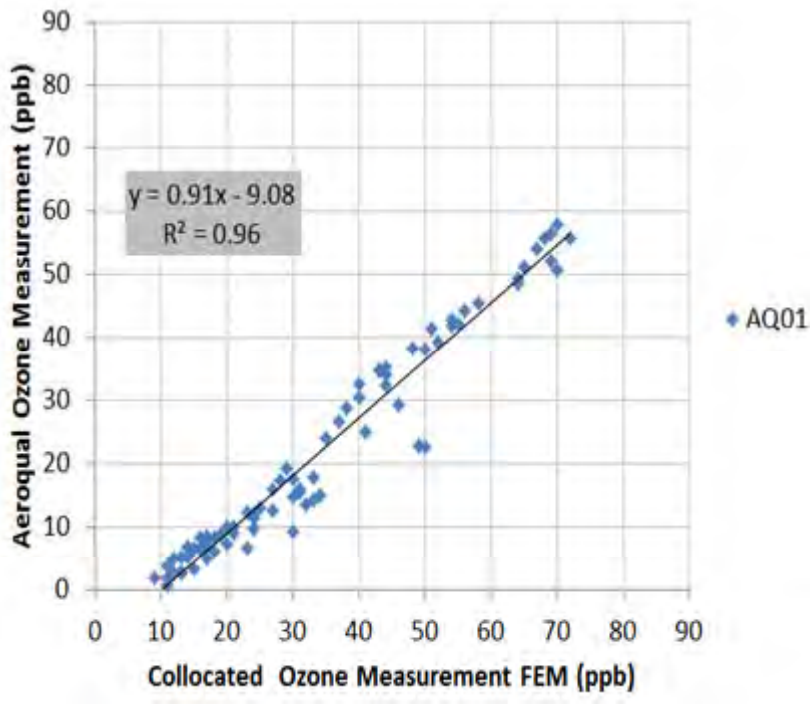


FEM vs. AQ 1 During Collocations

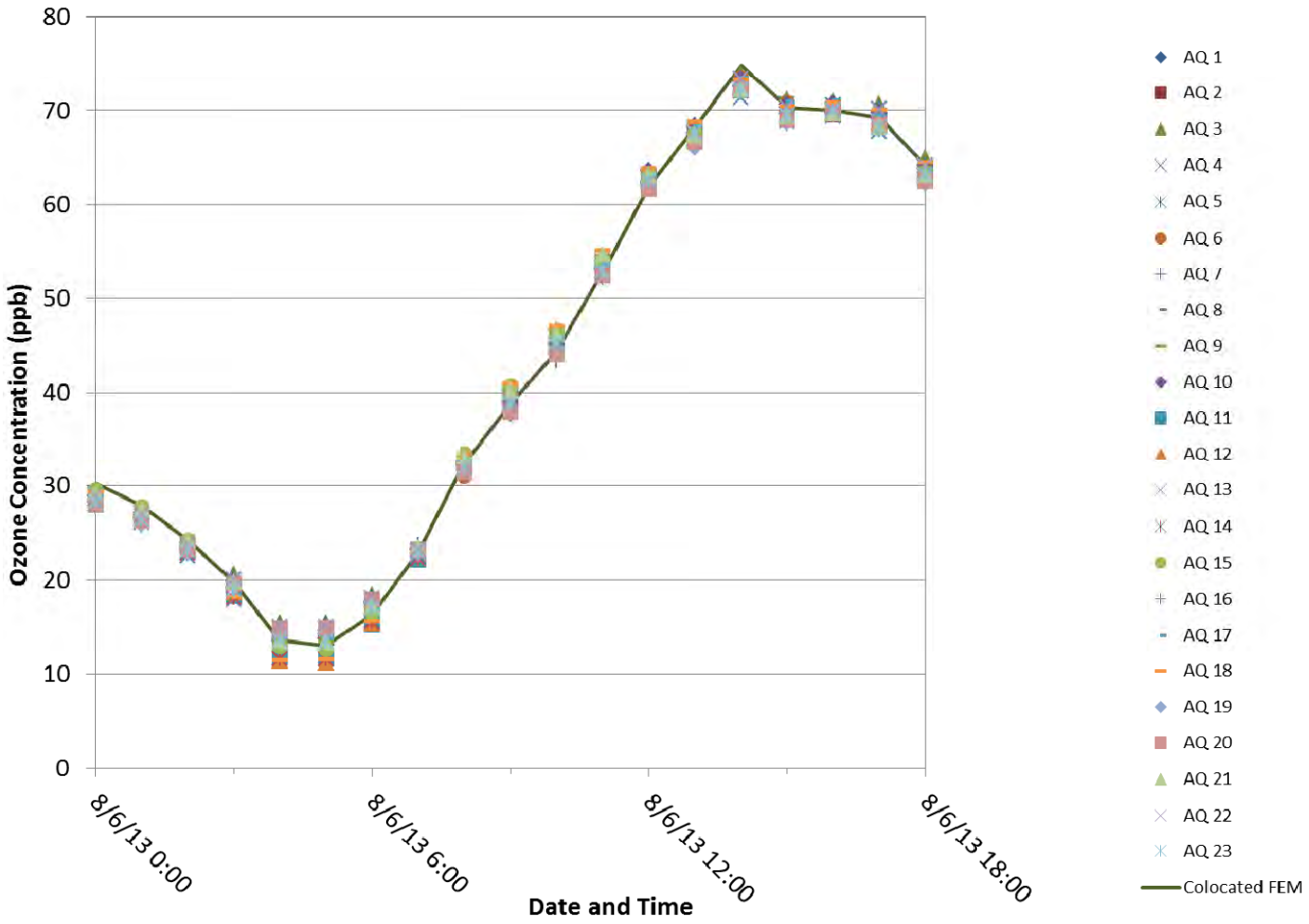
Initial Collocation



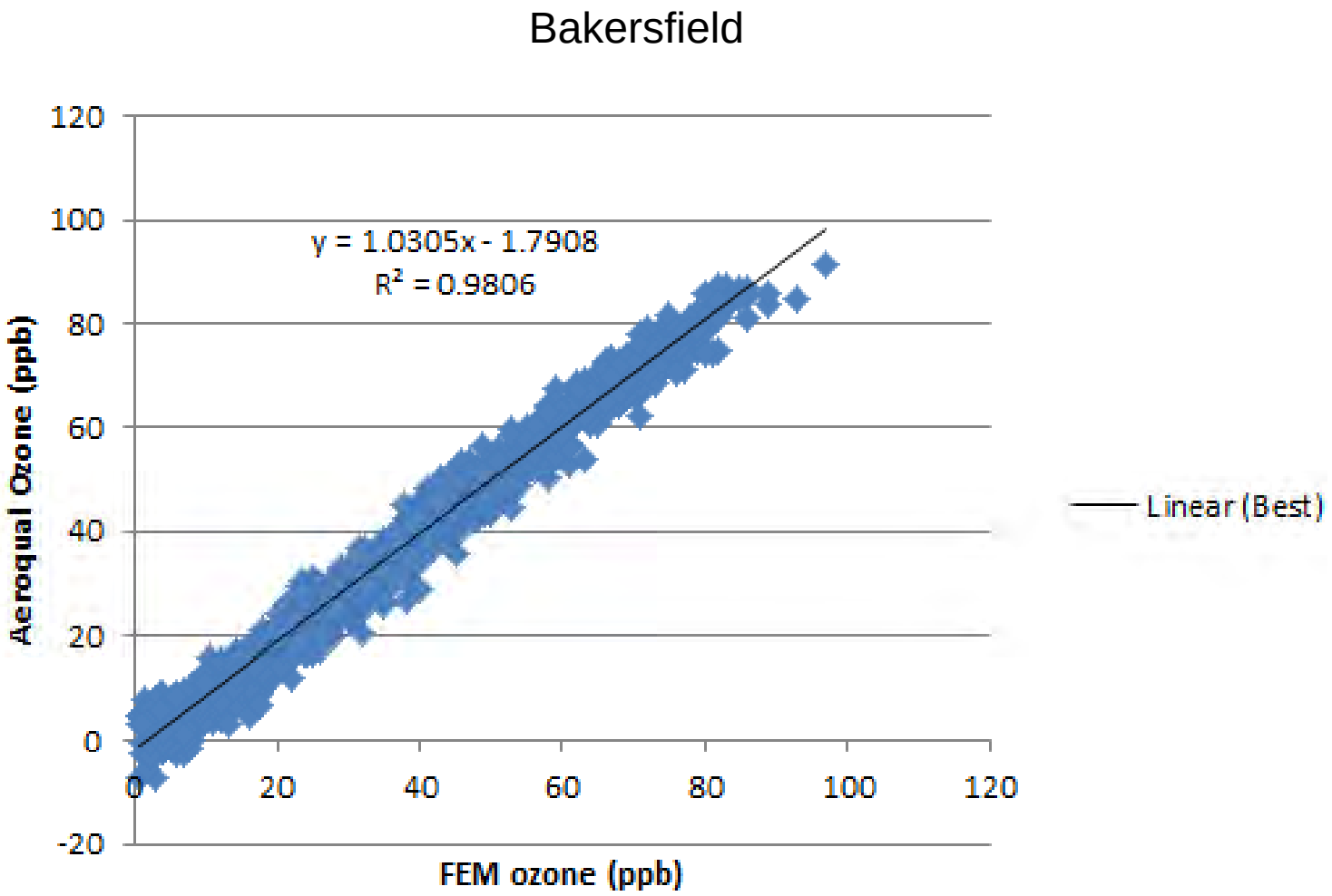
Ending Collocation



FEM vs. Calibrated Sensors



Final Corrected Data Compared to FEM



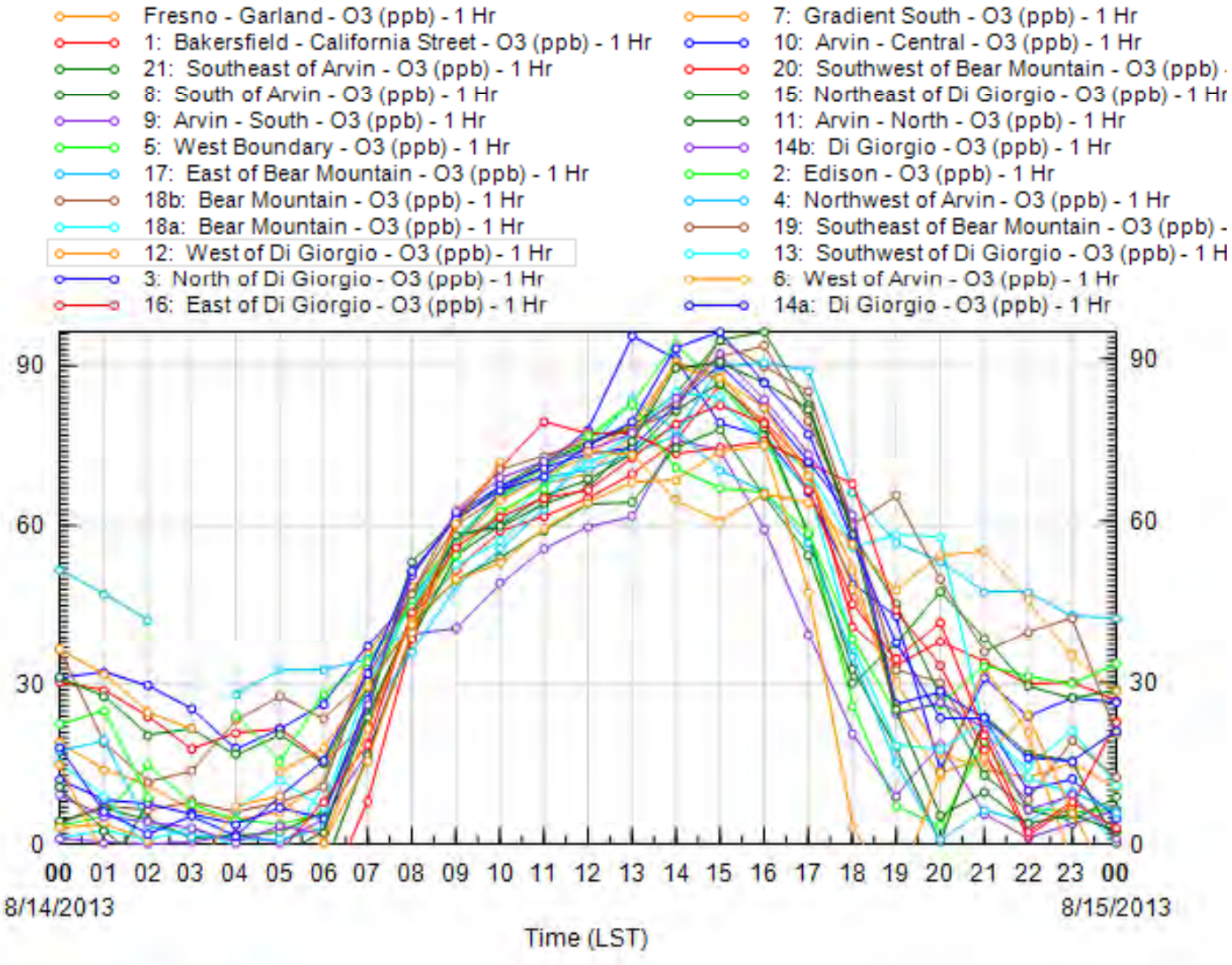
Collocation Results

- The differences between the calibrated hourly AeroQual ozone measurements and the FEM were ±3 ppb.
- Data meet data accuracy requirements for understanding spatial gradients.
- Note: ozone concentrations did not exceed 77 ppb during either collocation study, and thus do not cover the full range of concentrations we have seen in and around Arvin in the field study.

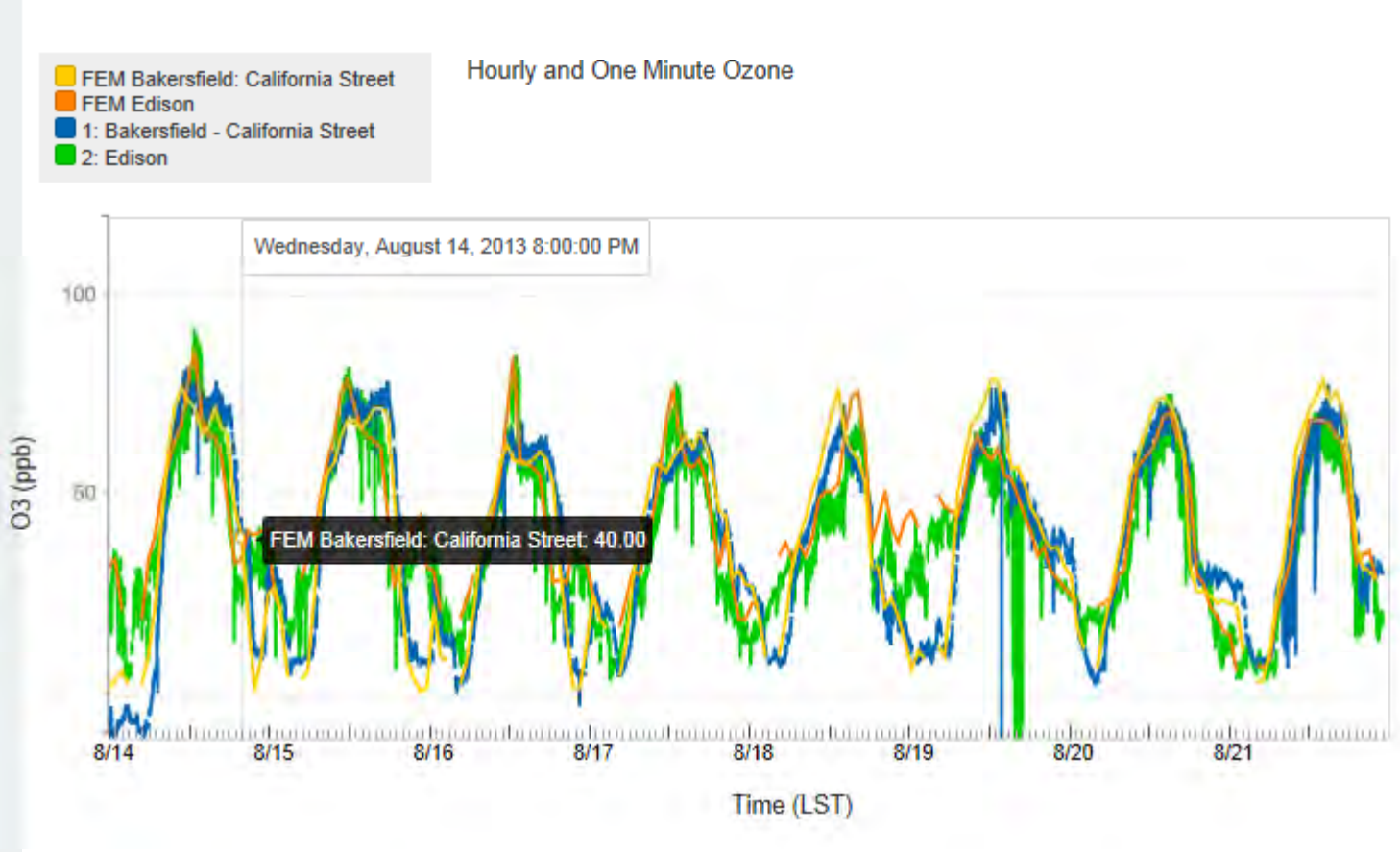
Installation and Operations: Mountain View Middle School

Installation and Operations: Di Giorgio

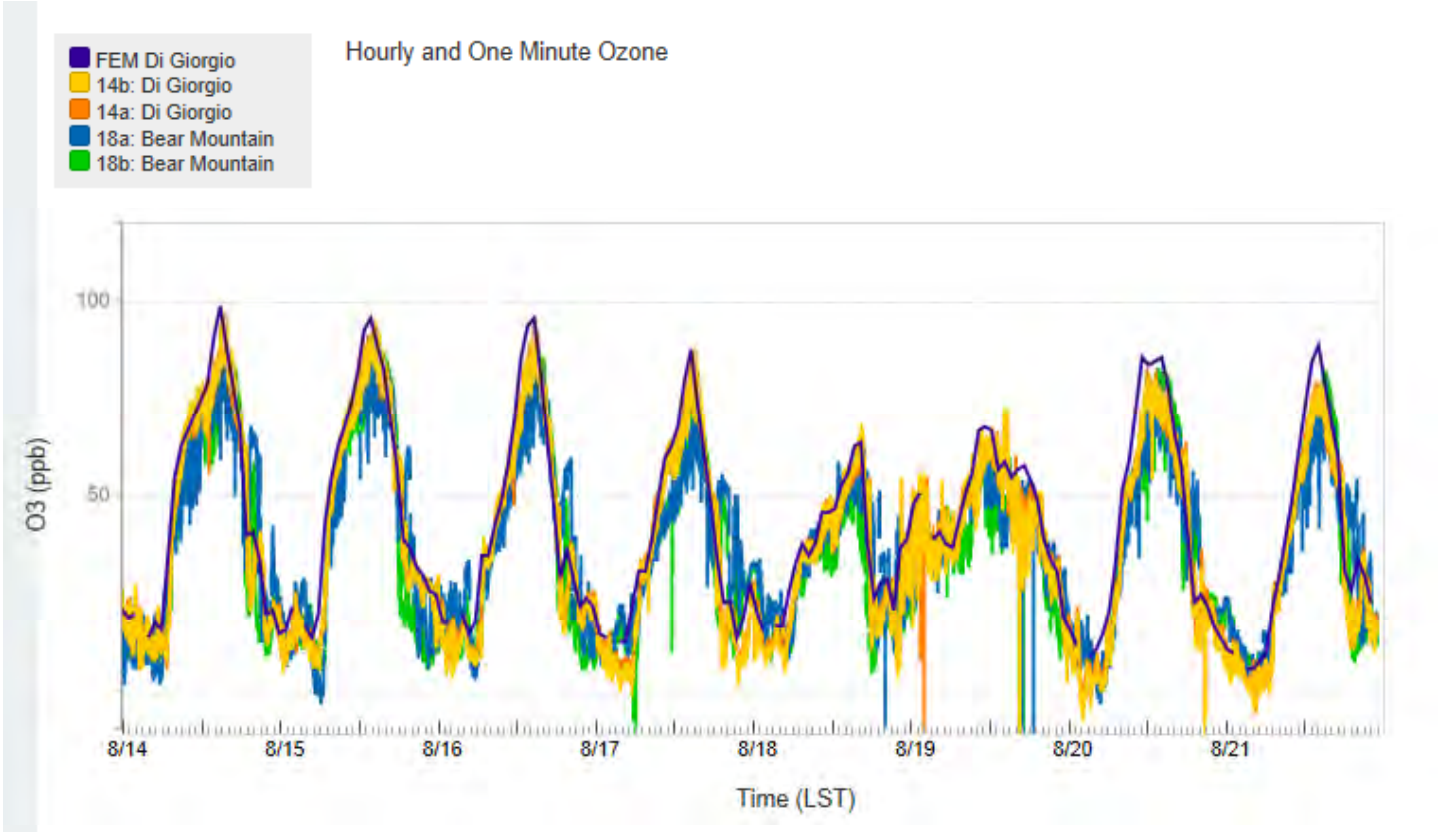
Raw Data Example From DMS



Real-Time Raw Data – Example 1

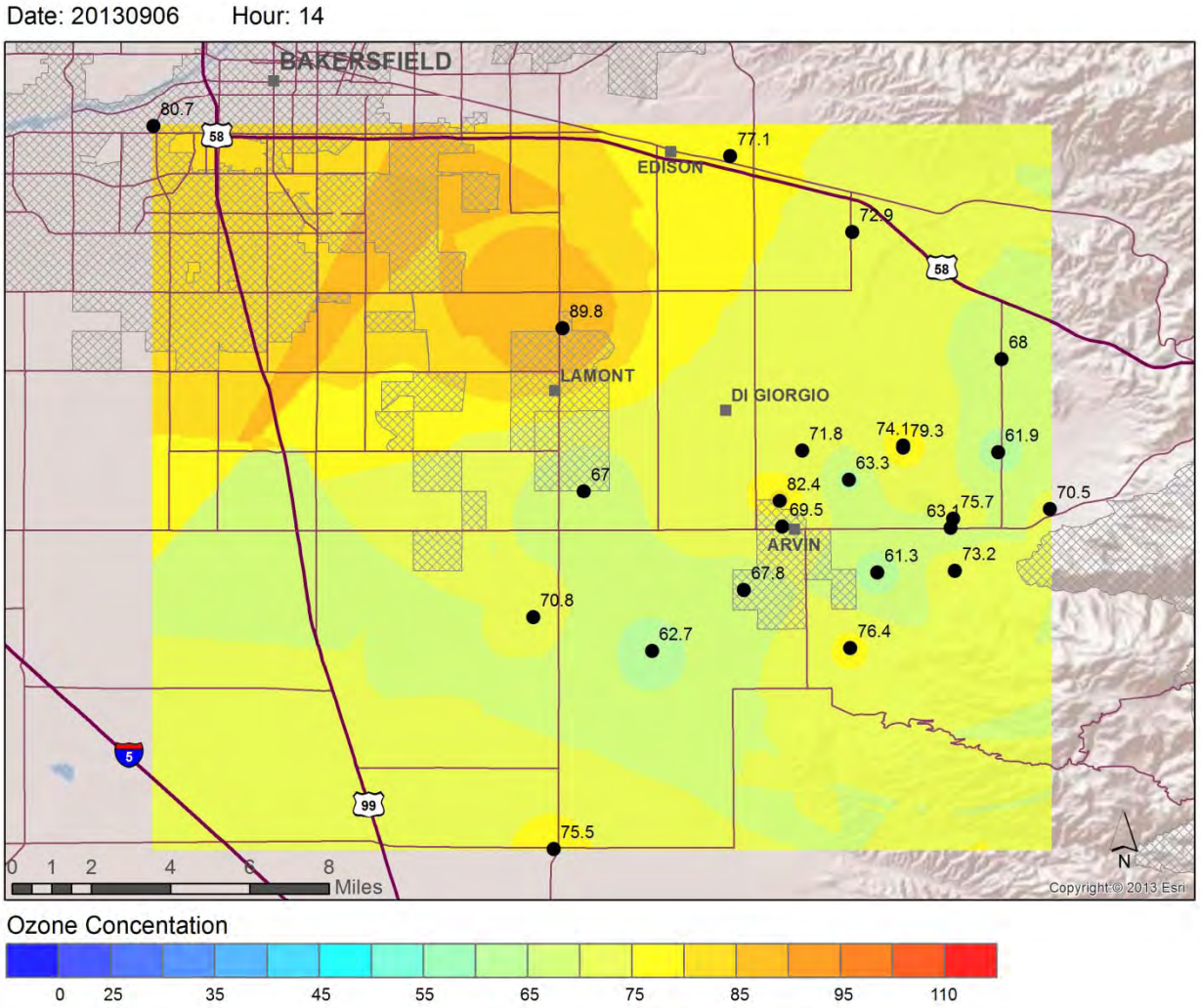


Real-Time Raw Data – Example 2

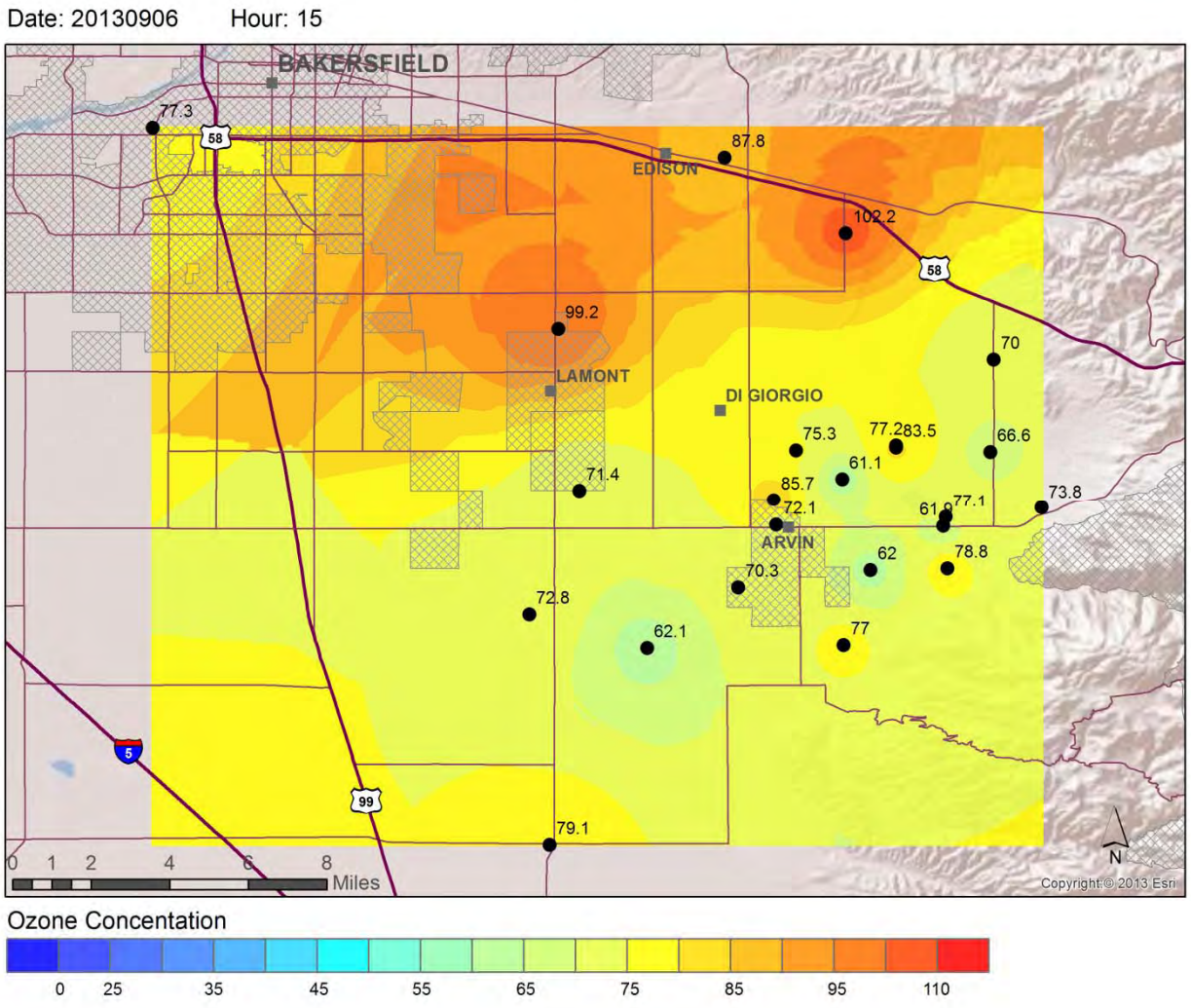


Real-Time Raw Data – Example 3

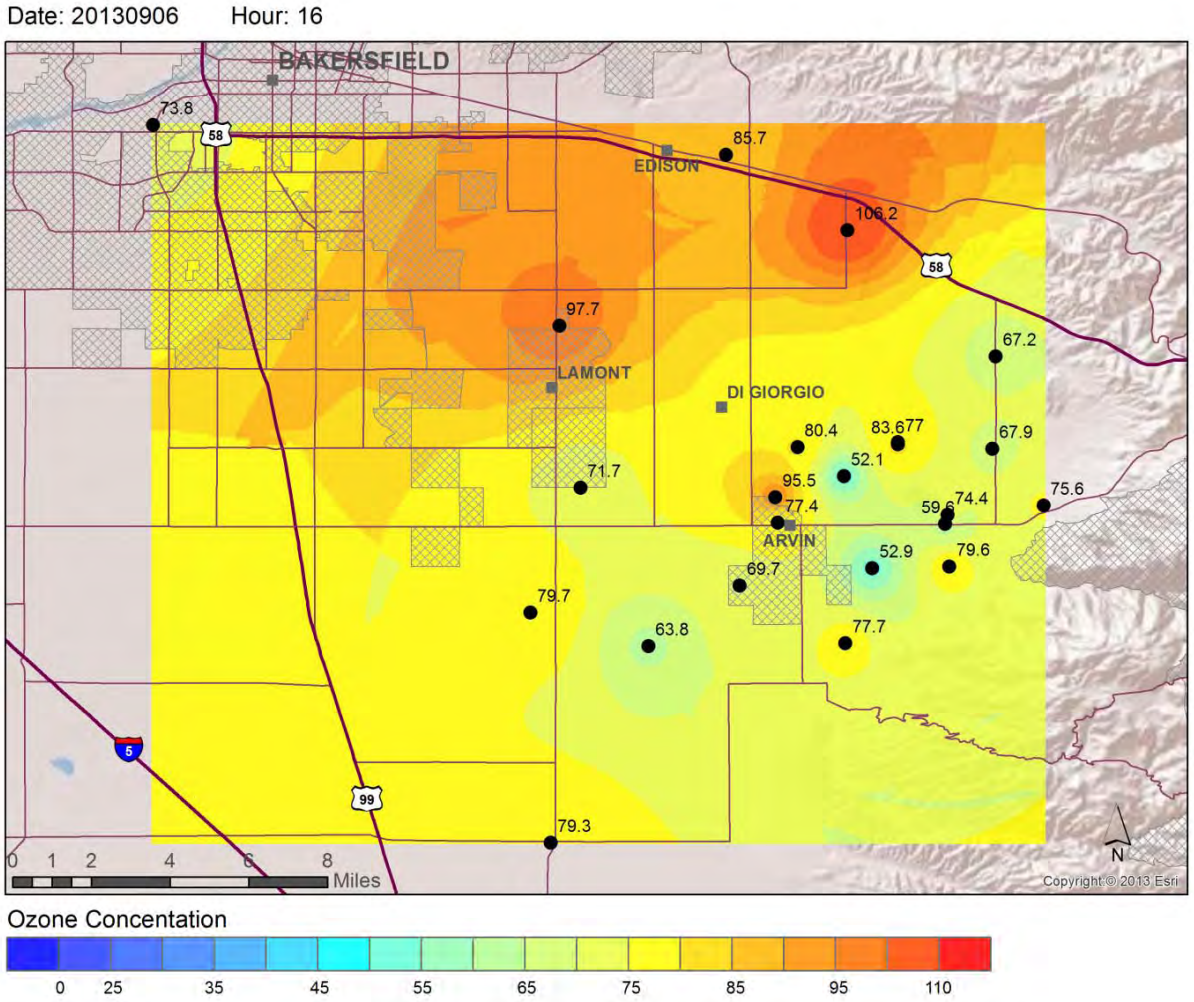
September 6, 2013, at 1400 LST



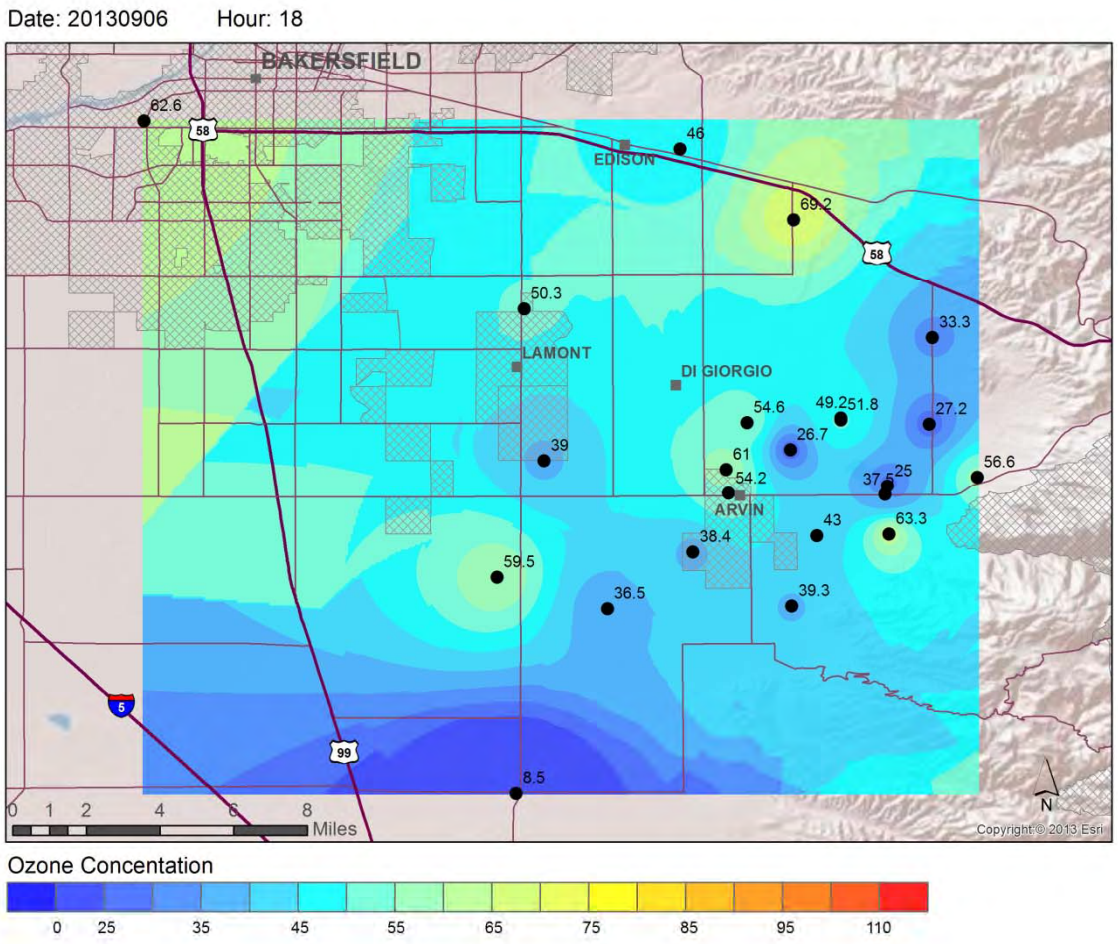
September 6, 2013, at 1500 LST



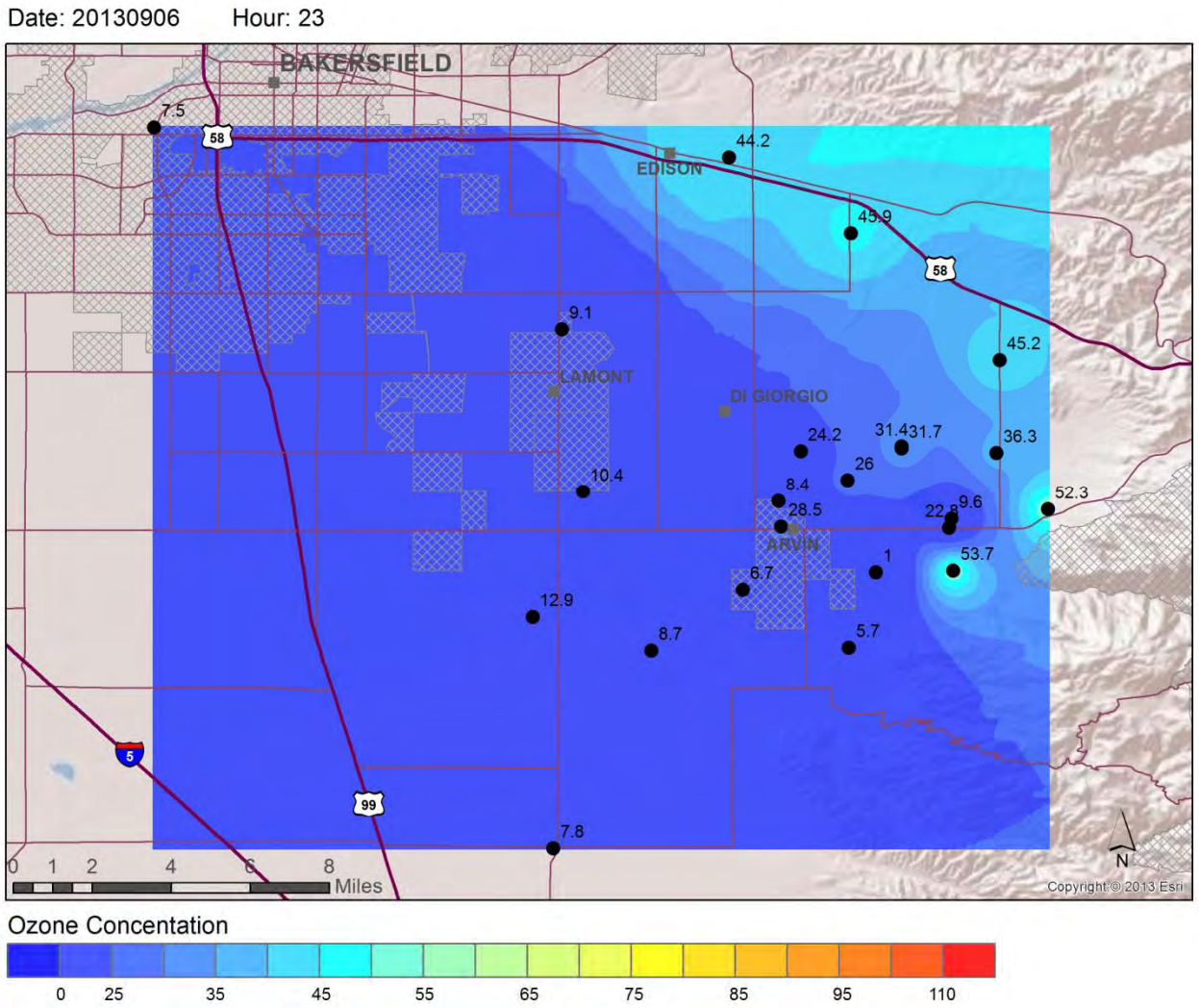
September 6, 2013, at 1600 LST



September 6, 2013, at 1800 LST



September 6, 2013, at 2300 LST



Summary and Next Steps

- The Aeroqual ozone sensors appear to be very useful for detecting spatial ozone gradients.
- Sensor drift does occur; collocation of instruments is key.
- Strong spatial gradients in ozone over short distances exist in the Arvin area, even in rural areas.
- Titration and local flows likely have strong impact on ozone gradients.
- Final results expected in January.