Air Sensors 2018: Deliberating Performance Targets for Air Quality Sensors

Session 10: Ozone Focus - Perspectives on Data Quality Objectives

Andrea Polidori[^], Brandon Feenstra[^], and Geoff Henshaw[*]

[^]*South Coast Air Quality Management District, Diamond Bar, California*
[*] *Aeroqual Ltd, Auckland, New Zealand*

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

- Established in July 2014
- Initial investment: over $600,000
- Main Goals & Objectives
  - Provide guidance & clarity
  - Promote successful evolution and use of sensor technology
  - Minimize confusion
- Sensor Selection Criteria
  - Commercially available
    - *Optical*
    - *Electrochemical*
    - *Metal oxide*
  - Real- or near-real time
  - Criteria pollutants & air toxics

Field Testing

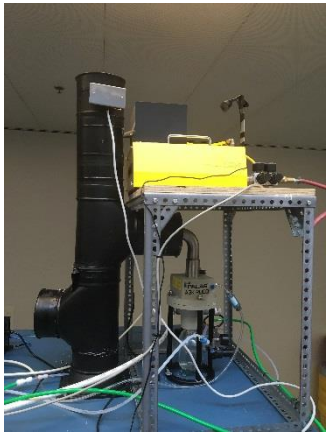
- Started in September, 2014
  - 40+ sensors evaluated
- Process
  - Sensor tested in triplicates
  - Two month deployment
  - < ~ $2,000: purchase
  - > ~ $2,000: lease or borrow
- Location
  - Rubidoux station (main)
    - Inland site
    - Fully instrumented

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Laboratory Testing

Aerosol Test



Gas Test

Laboratory Testing (cont.)

T and RH controlled: T (0-50 ^{0}C); RH (5-95%)

Particle testing

- Particle generation systems
- Particle monitors: mass concentration and size distribution

Gas testing

- Gas generation / dilution system
- Gas monitors: CO, NO_X, O_3, SO_2, H_2S, CH_4/NMHC, and **VOCs**

AQ-SPEC Ozone Testing Results

Ozone Sensors				
Manufacturer (Model)	**Type**	**Approx. Cost (USD)**	**Field R^2**	**Lab R^2**
2B Technologies (POM)	UV absorption (FEM)	~$4,500	R^2 ~ 1.00	R^2~ 0.99
Aeroqual (AQY v0.5)	Metal Oxide	~$3,000 (multi-sensor)	R^2 ~ 0.95	
Aeroqual (S-500)	Metal Oxide	~$500	R^2 ~ 0.85	R^2~ 0.99
Air Quality Egg (Ver. 1)	Metal Oxide	~$200 (multi-sensor)	R^2 ~ 0.85	
Air Quality Egg (Ver. 2)	Electrochem	~$240 (multi-sensor)	R^2 ~ 0.0 to 0.20	
AQMesh (Ver. 4.0)	Electrochem	~$10,000 (multi-sensor)	R^2 ~ 0.46 to 0.83	
Perkin Elmer (ELM)	Metal Oxide	~$5,200 (multi-sensor)	R^2 ~ 0.89 to 0.96	
Spec Sensors	Electrochem	~ $500 (multi-sensor)	R^2 ~ 0.0 to 0.24	
uHoo	Metal Oxide	~$300 (multi-sensor)	R^2 ~ 0.43 to 0.72	
UNITEC (SENS-IT)	Metal Oxide	~$2,200	R^2 ~ 0.72 to 0.83	R^2 ~ 0.82 to 0.90
Vaisala (AQT410)	Electrochemical	~$3,700 (multi-sensor)	R^2 ~ 0.40 to 0.58	

Most ozone sensors showed:

- Acceptable data recovery
- Wide intra-model variability range
- Wide range of correlation with reference methods
- Potential O_3/NO_2 interference

Ozone Sensor Applications

Crestline Ozone Study

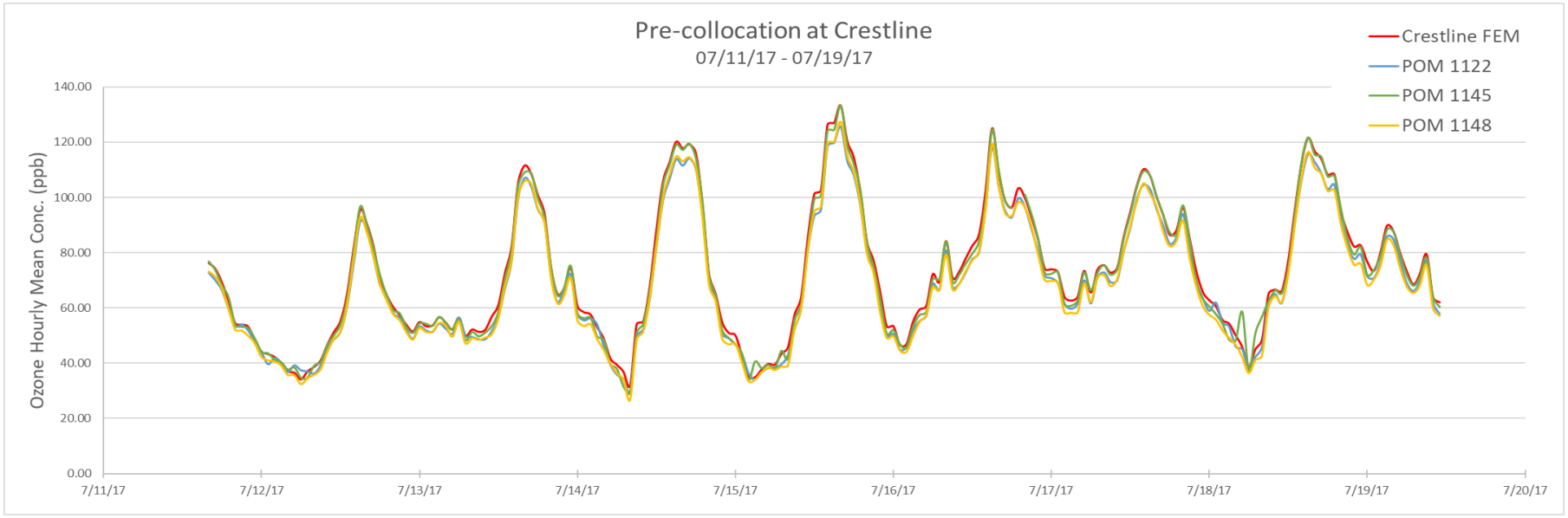
- Purpose: investigate spatial O_3 distribution across the San Bernardino mountains. Find potential replacement site for Crestline
- Need: sensors should be accurate, precise, and easy to deploy
- Solution: three 2B POMs outfitted with cellular data logger
- Note: All sensor units were collocated at our Crestline air monitoring station pre- and post-deployment

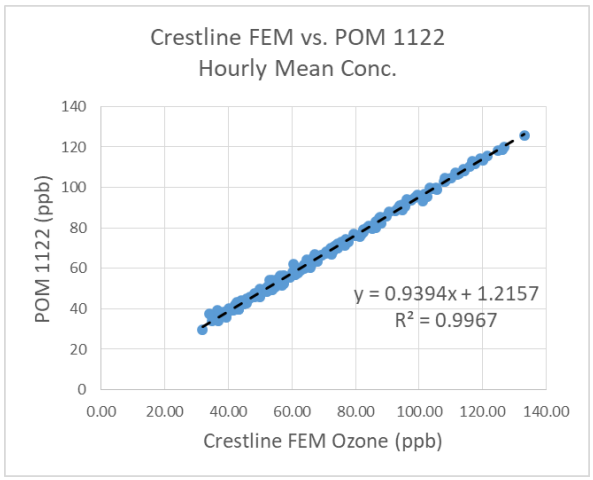
Period	Dates	# of Days
Pre-deployment collocation	6/30 to 7/19, (data from 7/11 to 7/19)	8
Deployment	7/19 to 9/19	62
Post-deployment collocation	9/19 to 10/4	15

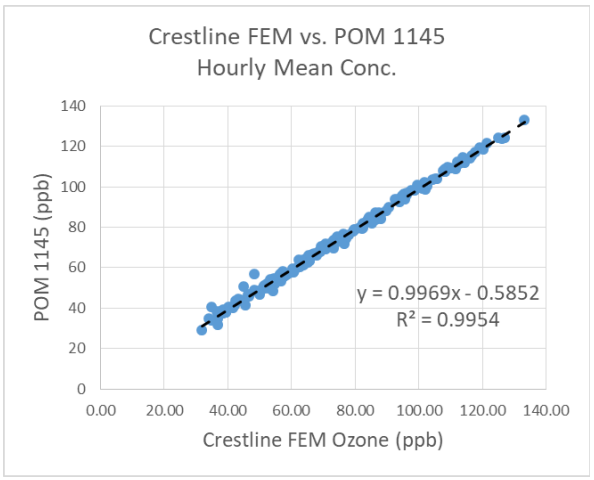
Crestline Ozone Study Locations

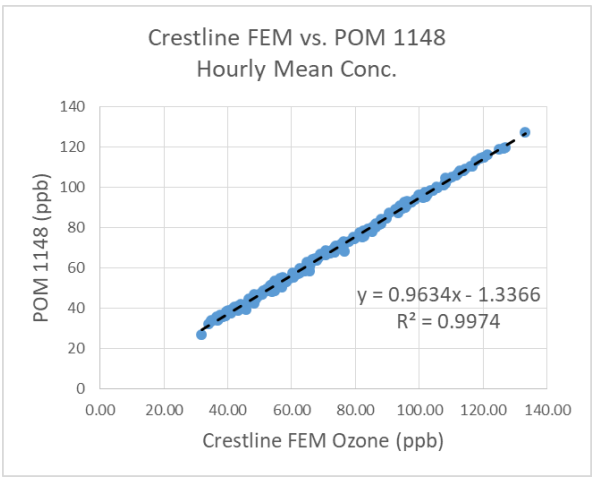
Location	City	Lat / Lon	Elevation	Instrument
Crestline Air Monitoring Station	Crestline, CA	34.24313, -117.27230	4,560’	FEM
1 - SkyPark at Santa’s Village	Skyforest, CA	34.233773, -117.169432	5,685’	POM 1122
2 - Rim of the World High School	Lake Arrowhead, CA	34.231669, -117.211283	5,750’	POM 1145
3 - Robert Hootman Community Center	Running Springs, CA	34.200729, -117.093298	6,095’	POM 1148

Crestline Ozone Study
Pre-deployment Collocation

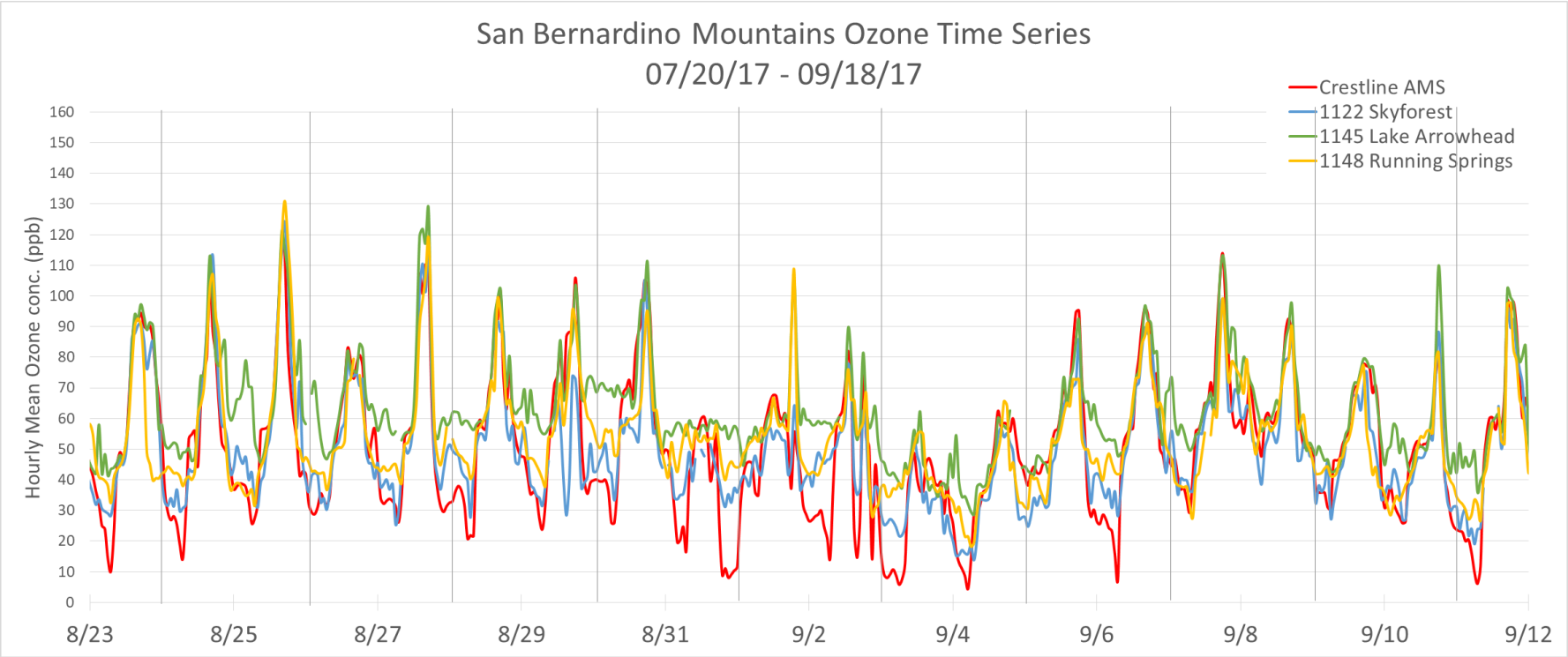








Crestline Ozone Study Deployment



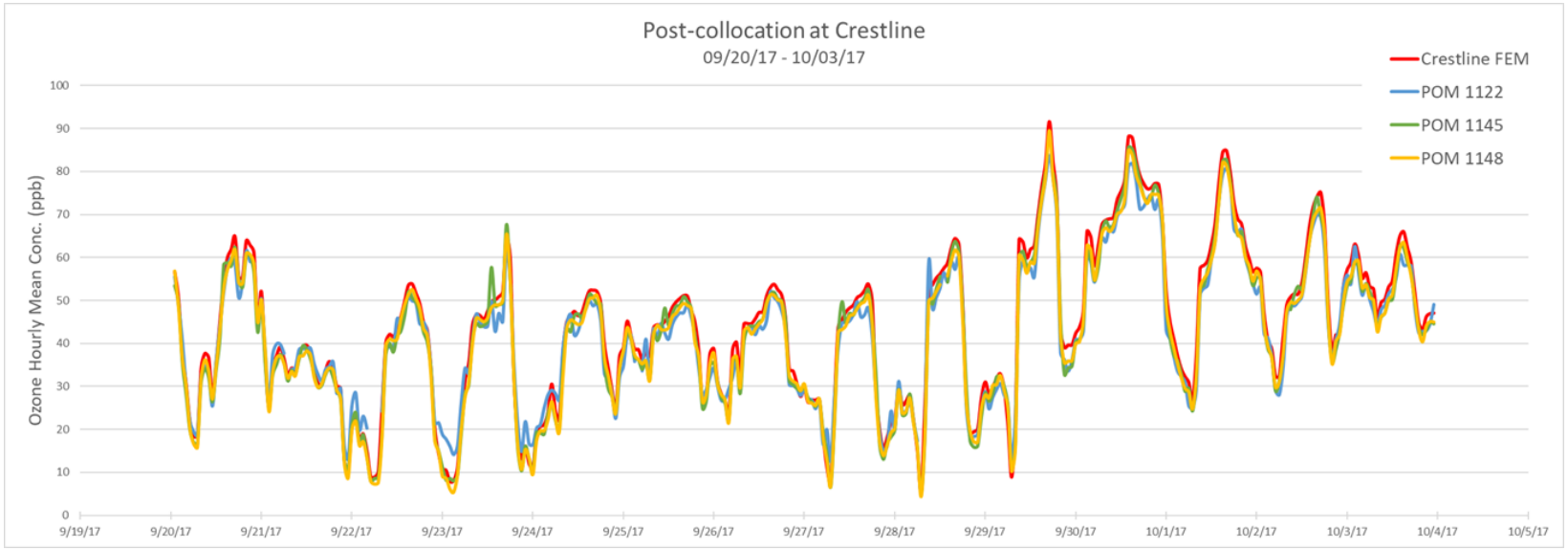
- Lower O_3 variability between locations during peak O_3 generating hours of the day
- Higher O_3 variability between locations at night-time (titration)

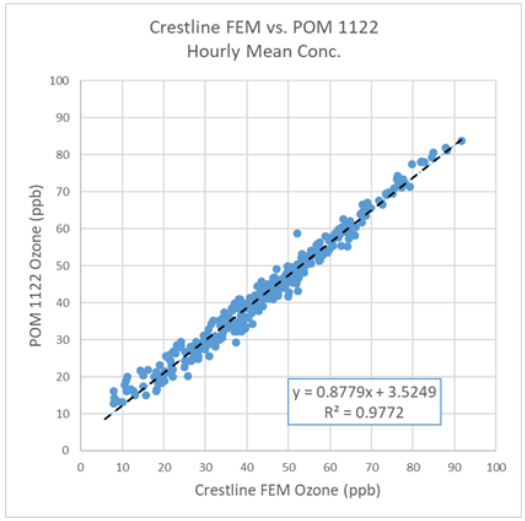
Crestline Ozone Study Deployment Stats

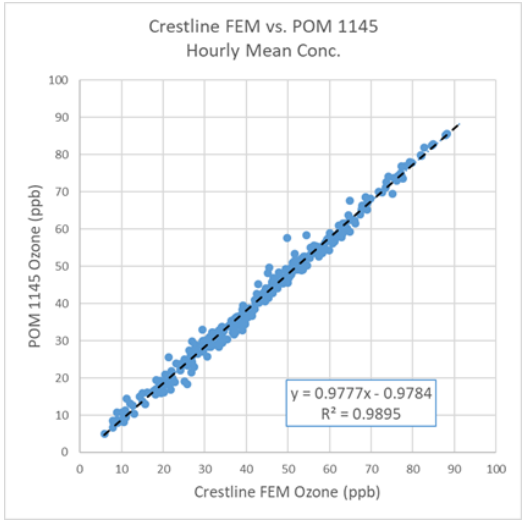
Statistics	Crestline AMS	POM 1122 Skyforrest	POM1145 (Lake Arrowhead)	POM 1148 (Running Springs)
Mean	54.88	52.84	63.74	53.77
Median	53.67	48.71	59.72	49.25
Standard Deviation	24.36	20.79	19.24	19.57
Minimum	4.45	13.81	20.79	13.63
Maximum	146.22	128.27	135.97	130.98
Count	1022	1022	1022	1022

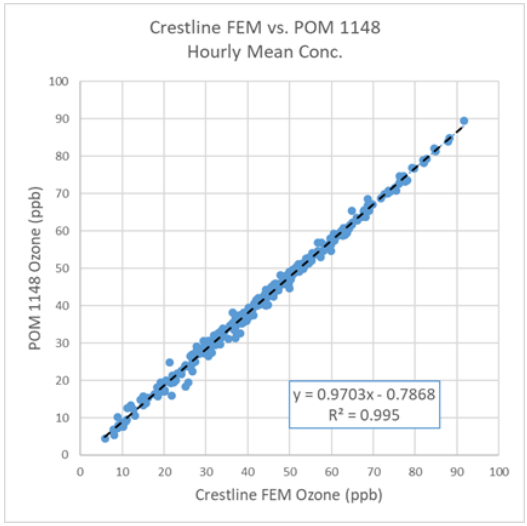
*All units are in ppb

Crestline Ozone Study
Post-deployment Collocation









U.S. EPA Science To Achieve Results (STAR) project

Engage, educate, and empower California communities on the use and applications of "low-cost" air monitoring sensors

- Provide communities with the knowledge necessary to select, use and maintain low-cost sensors and to correctly interpret the collected data
- Three year study:
  - SCAQMD (PI)
  - University of California Los Angeles (UCLA; Co-PI)
  - Sonoma Technology Inc. (STI; Co-PI)
  - BAAQMD
  - Santa Barbara County APCD
  - Other CAPCOA agencies
  - Community Groups
  - Leisure World (Seal Beach, CA)
  - Aeroqual Ltd, Auckland, New Zealand
  - University of Auckland (New Zealand)

South Coast AQMD

UCLA

STi Sonoma Technology, Inc.

U.S. EPA Science To Achieve Results (STAR) project

Engage, educate, and empower California communities on the use and applications of "low-cost" air monitoring sensors

- Four specific aims:
  1. Develop educational material for communities
  2. Evaluate / identify candidate sensors for deployment
  3. Deploy selected sensors in California communities
  4. Communicate the lessons learned to the public
- On-going activities:
  - Wide Spread Sensor Deployment across California
    - 300+ PM sensors
    - 100 Aeroqual (AQY) nodes (i.e., PM, O_3, NOx)
  - Cloud Based Platform Development
    - Data ingestion and storage
    - Data visualization and mapping
    - Data dissemination

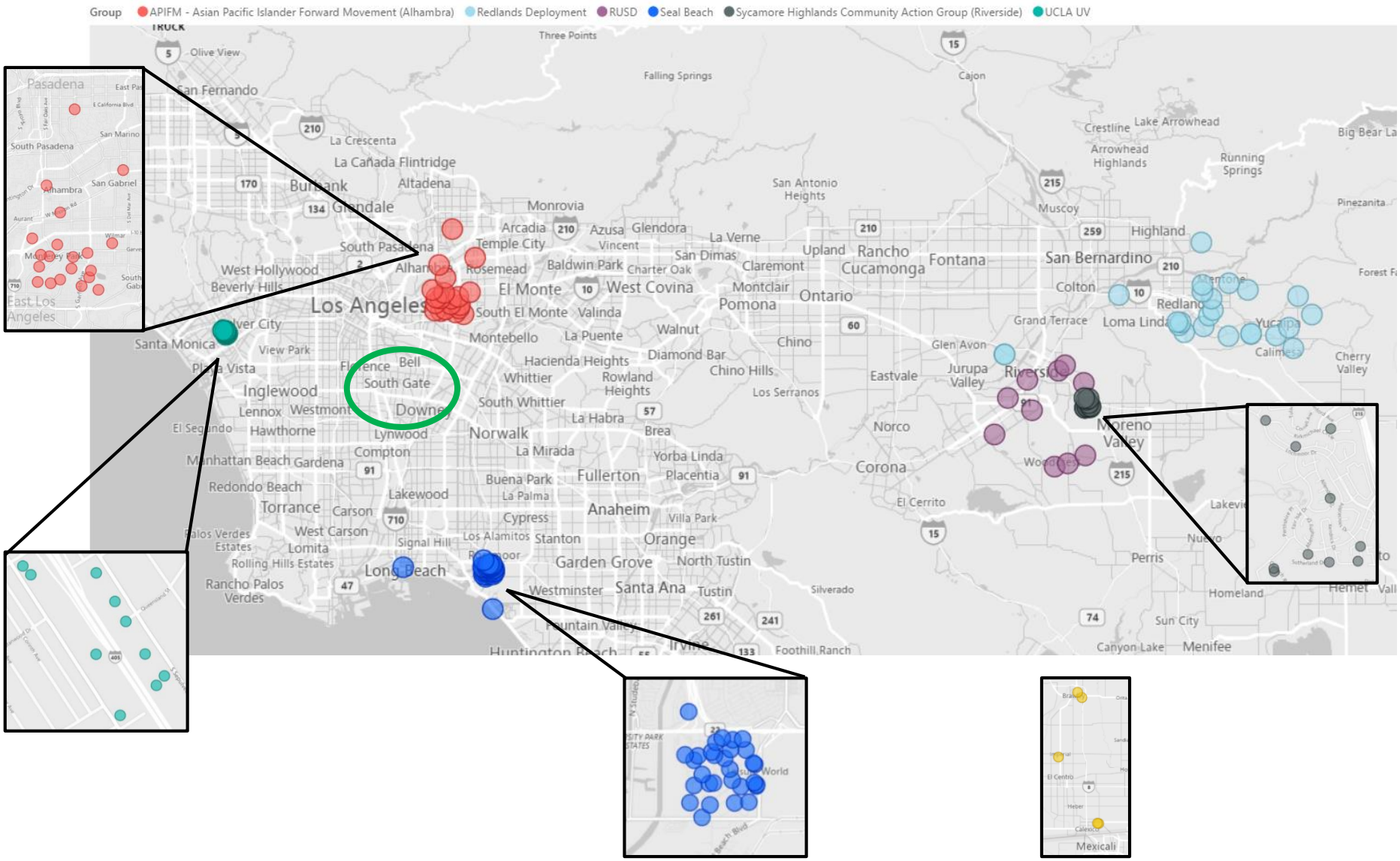
South Coast AQMD

UCLA

STi Sonoma Technology, Inc.

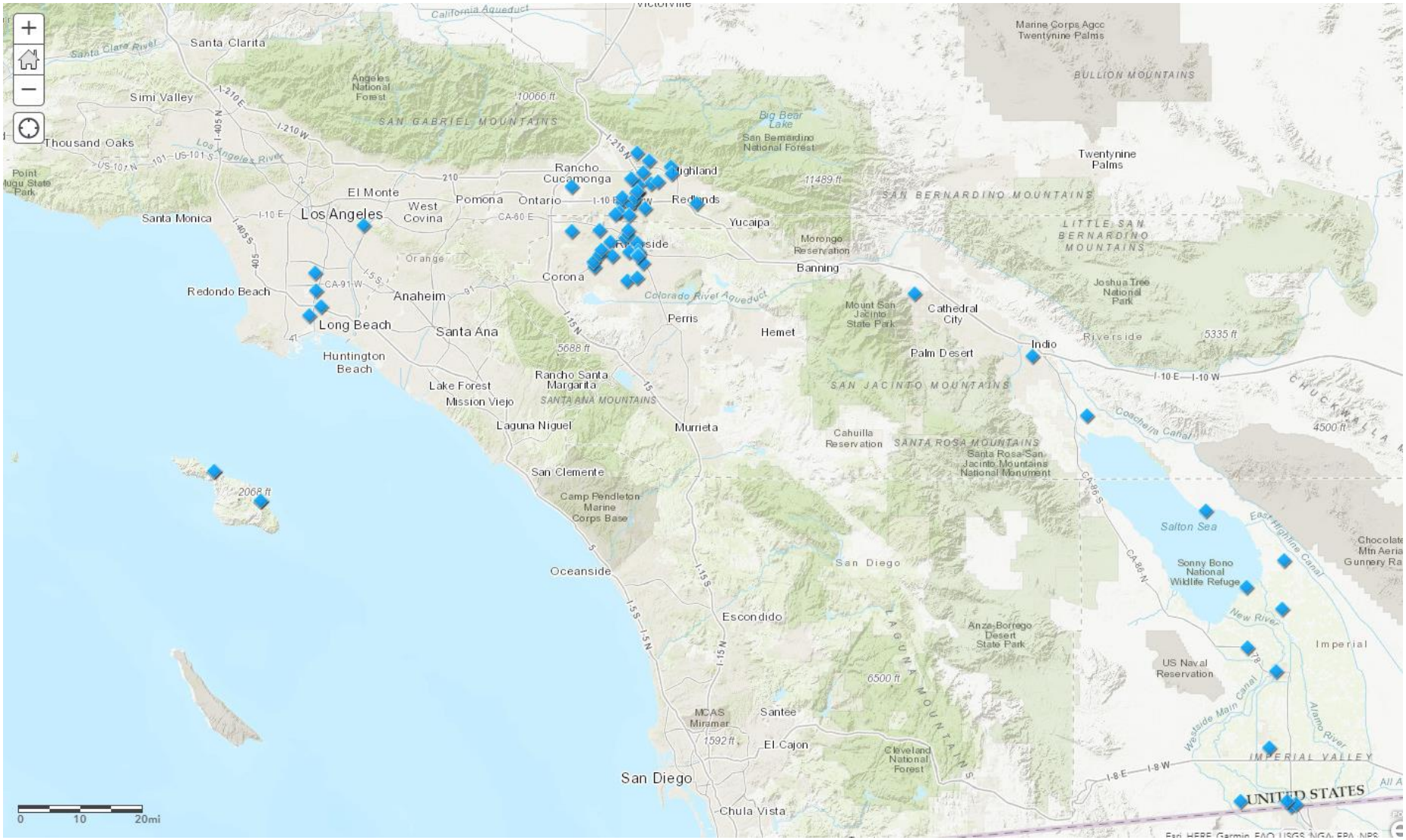
U.S. EPA STAR Project

$PM_{2.5}$ (PurpleAir) Sensors in SoCal Communities

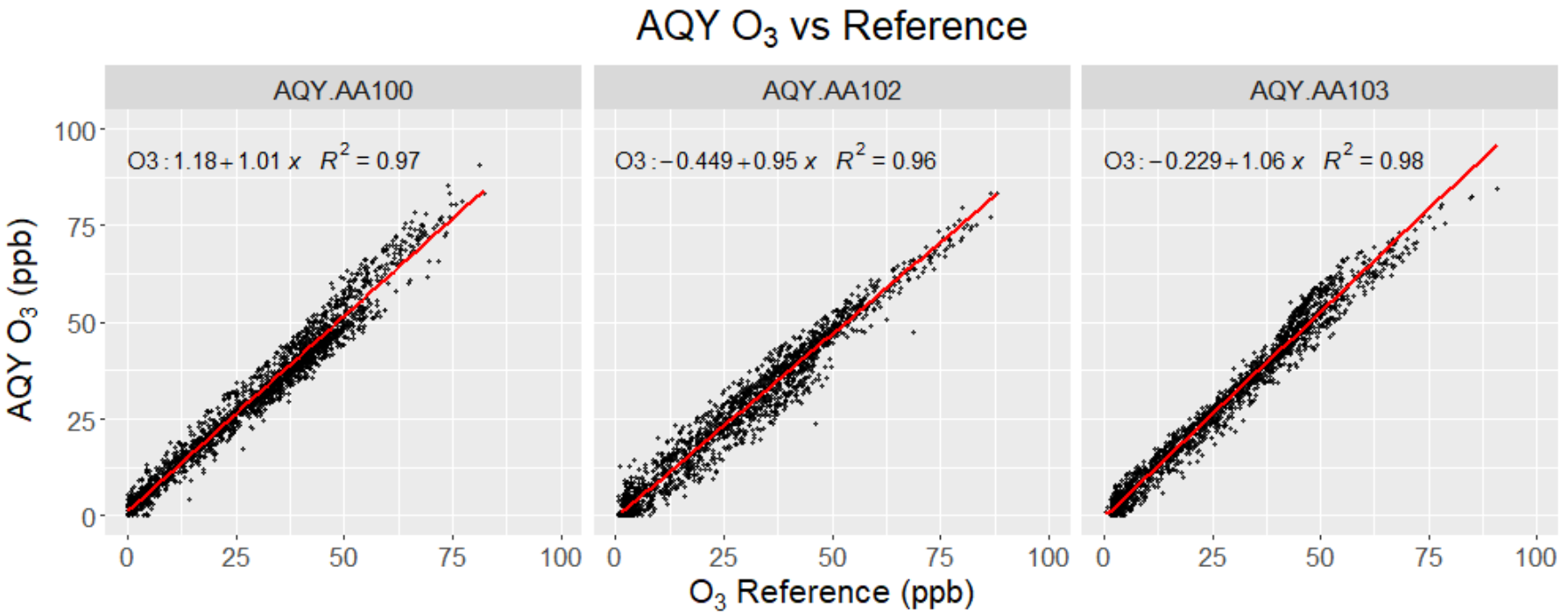


U.S. EPA STAR Project

$PM_{2.5}$, O_3, and NO_2 (Aeroqual AQY) Sensors in SoCal

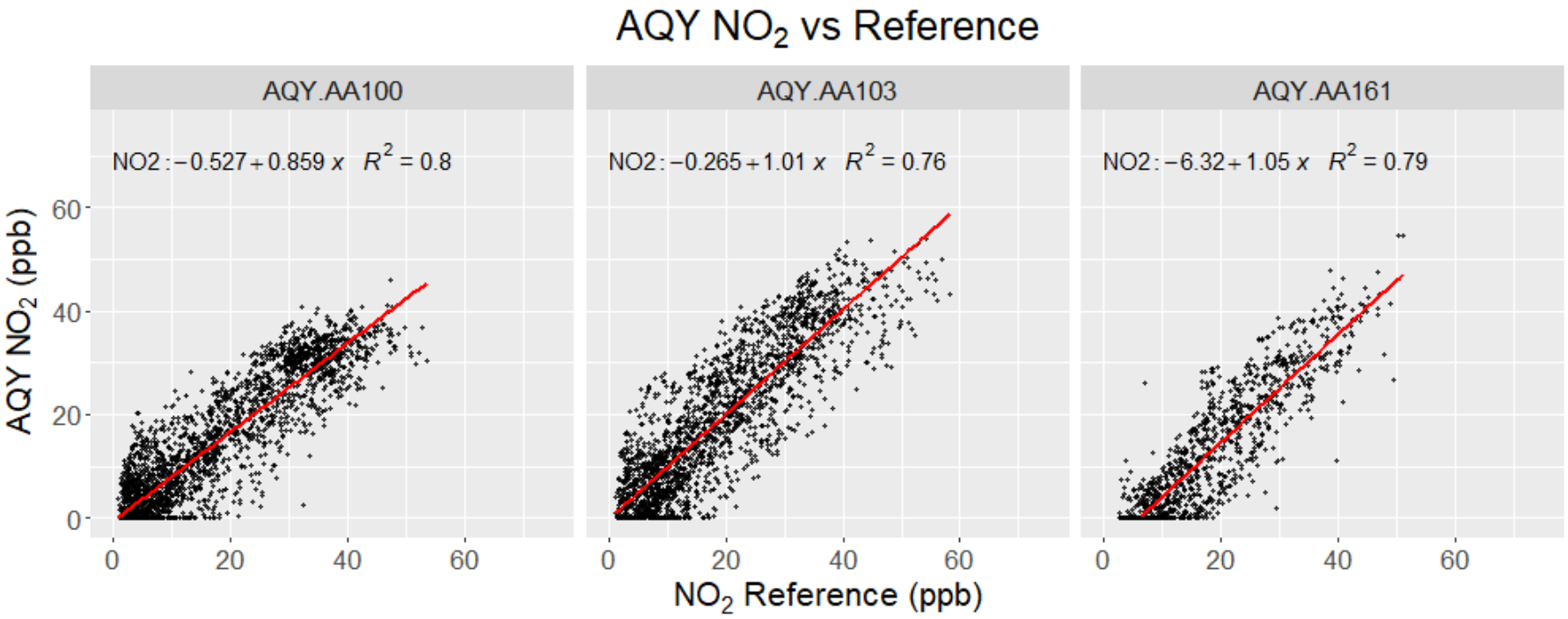


U.S. EPA STAR Project
AQY Ozone Collocation Data



- Hourly averaged data (Jan 1 – April 30, 2018)
- Collocation data collected at SCAQMD's Rubidoux station
- Fan degradation corrected data (active method)

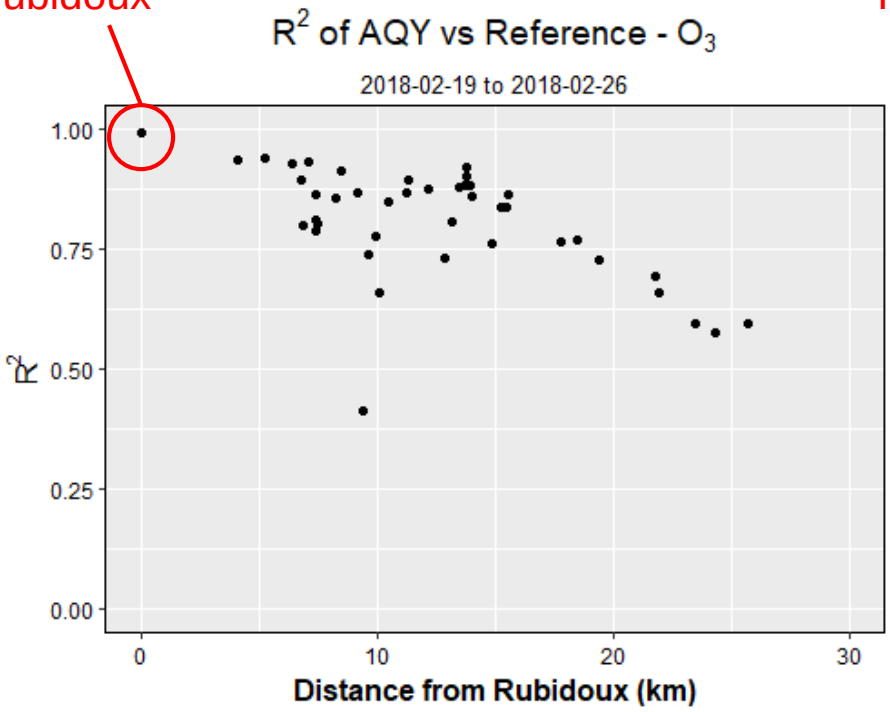
U.S. EPA STAR Project
AQY Nitrogen Dioxide Collocation Data



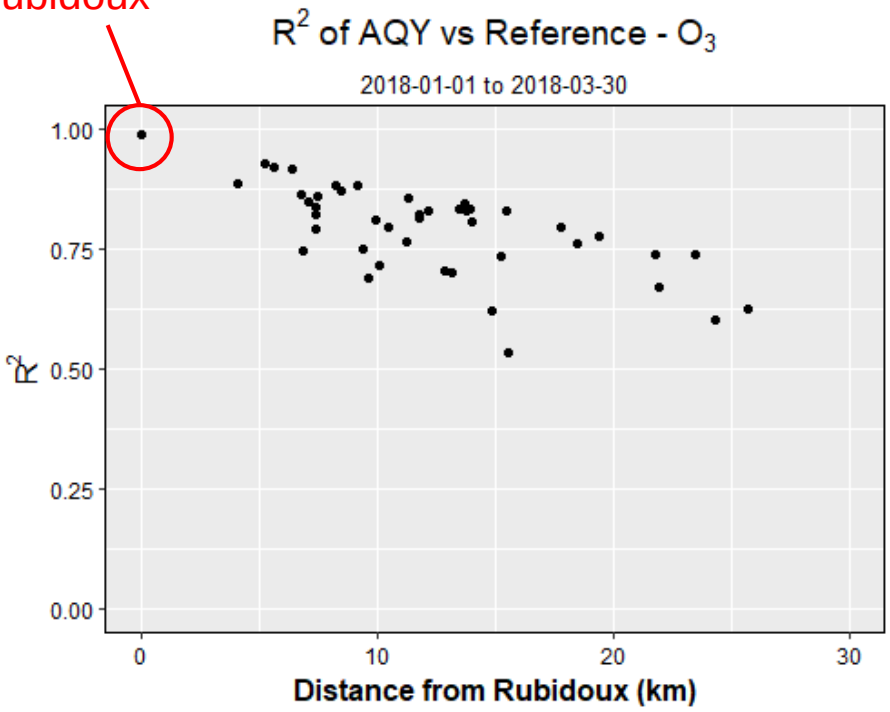
- Hourly averaged data (Jan 1 – April 30, 2018)
- Collocation data collected at SCAQMD's Rubidoux station
- NO_2 data corrected for O_3 interference

U.S. EPA STAR Project
R^2 (AQY vs Reference) vs Distance: Ozone

Rubidoux

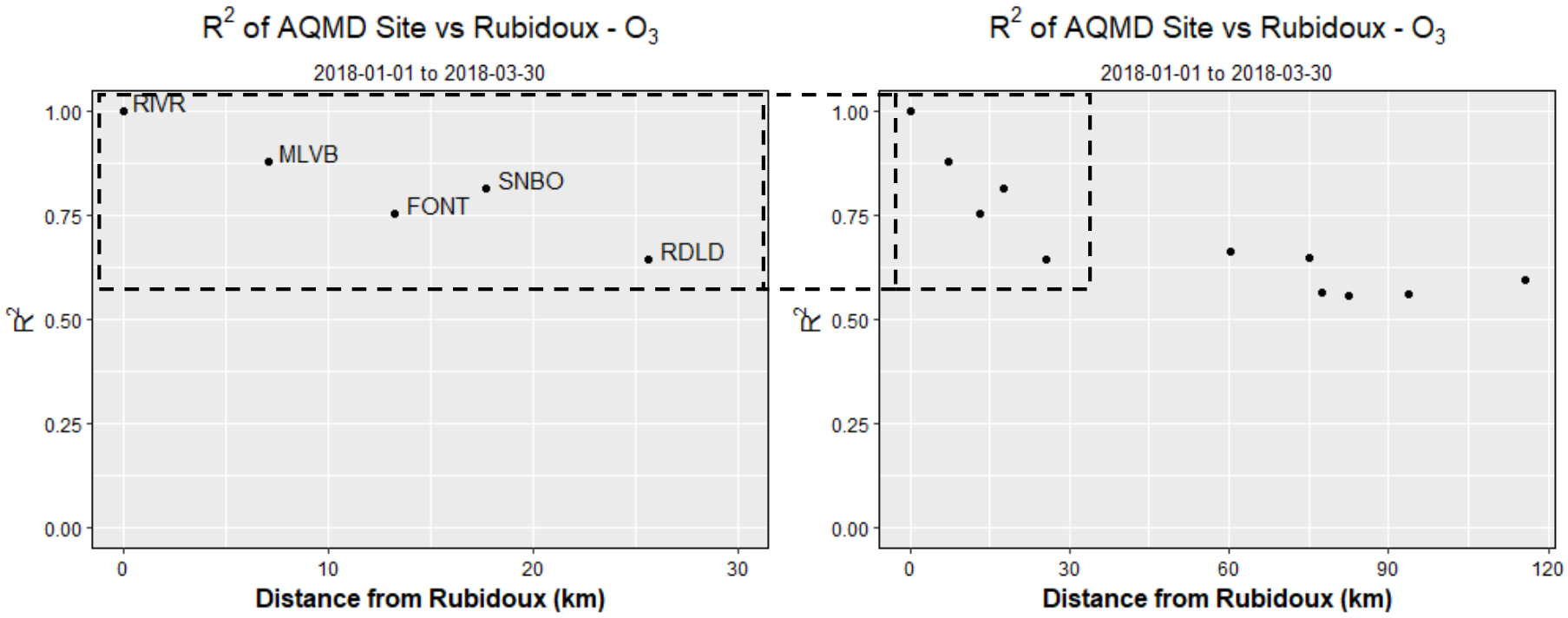


Rubidoux



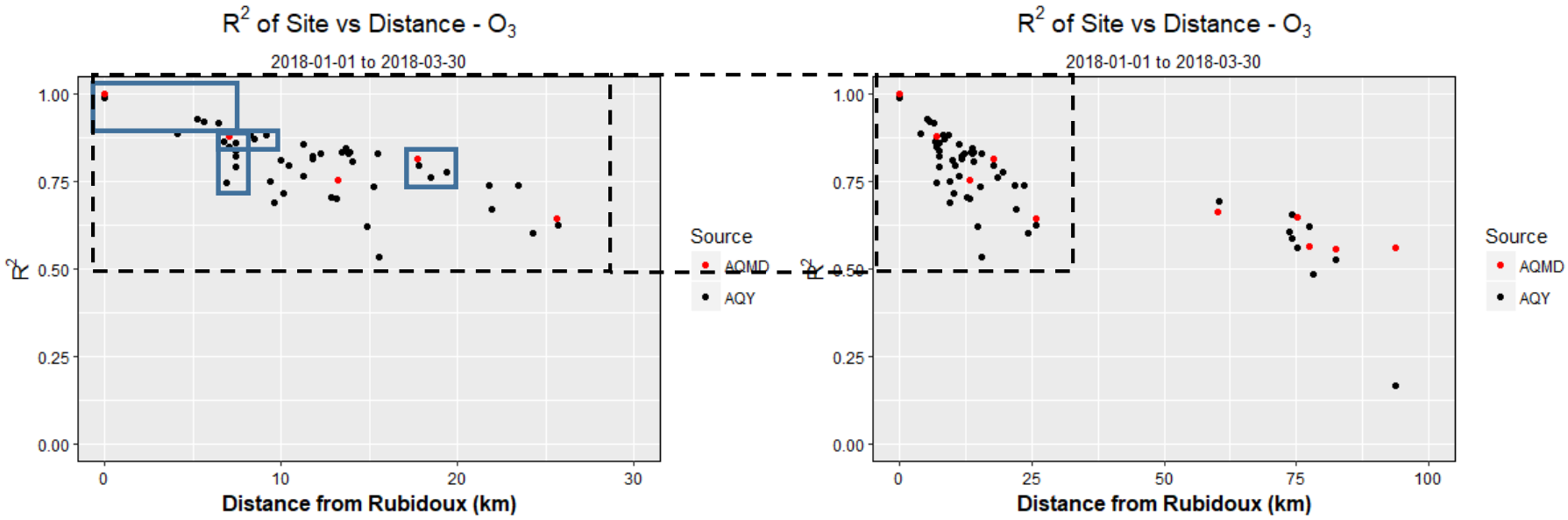
- A one week ‘snapshot’ is similar to the 3 month period

U.S. EPA STAR Project
R^2 (AQY vs Reference) vs Distance: Ozone



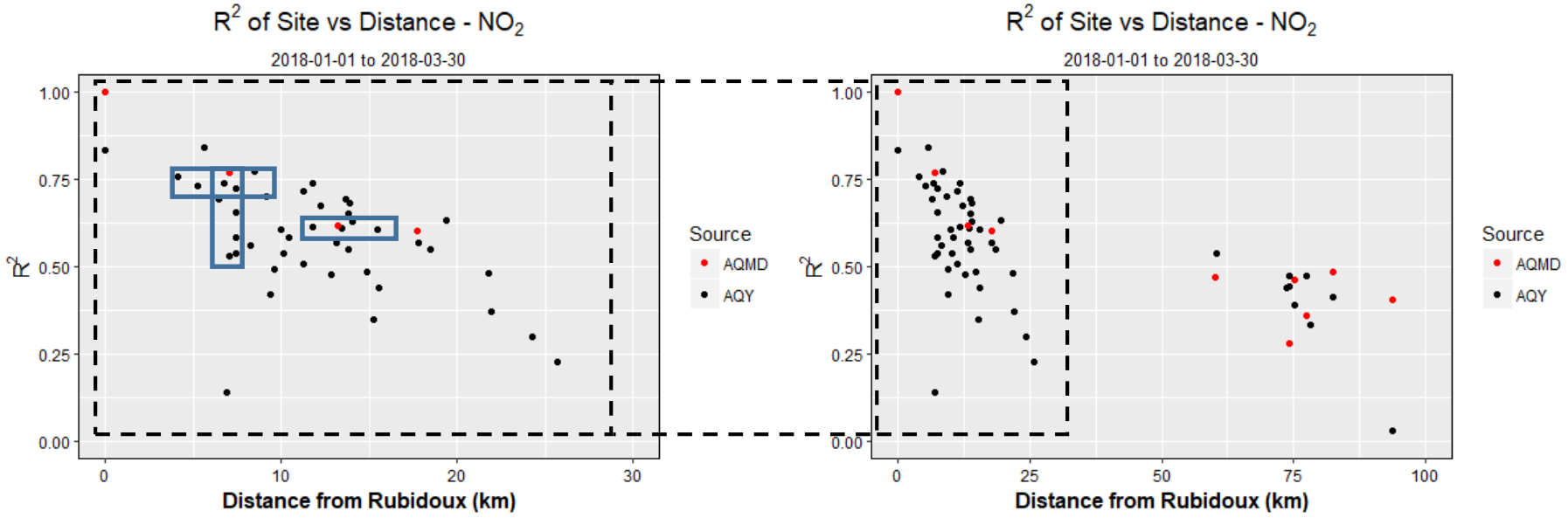
- Similar trends when using O_3 measurements at other SCAQMD fixed stations rather than AQY data

U.S. EPA STAR Project
R^2 (AQY vs Reference) vs Distance: Ozone



- DQO = 90% (R^2)
- Correlation not always linear with distance; site location and characteristics also a factor
- How often should the sensor data be corrected using this procedure? Quarterly so far

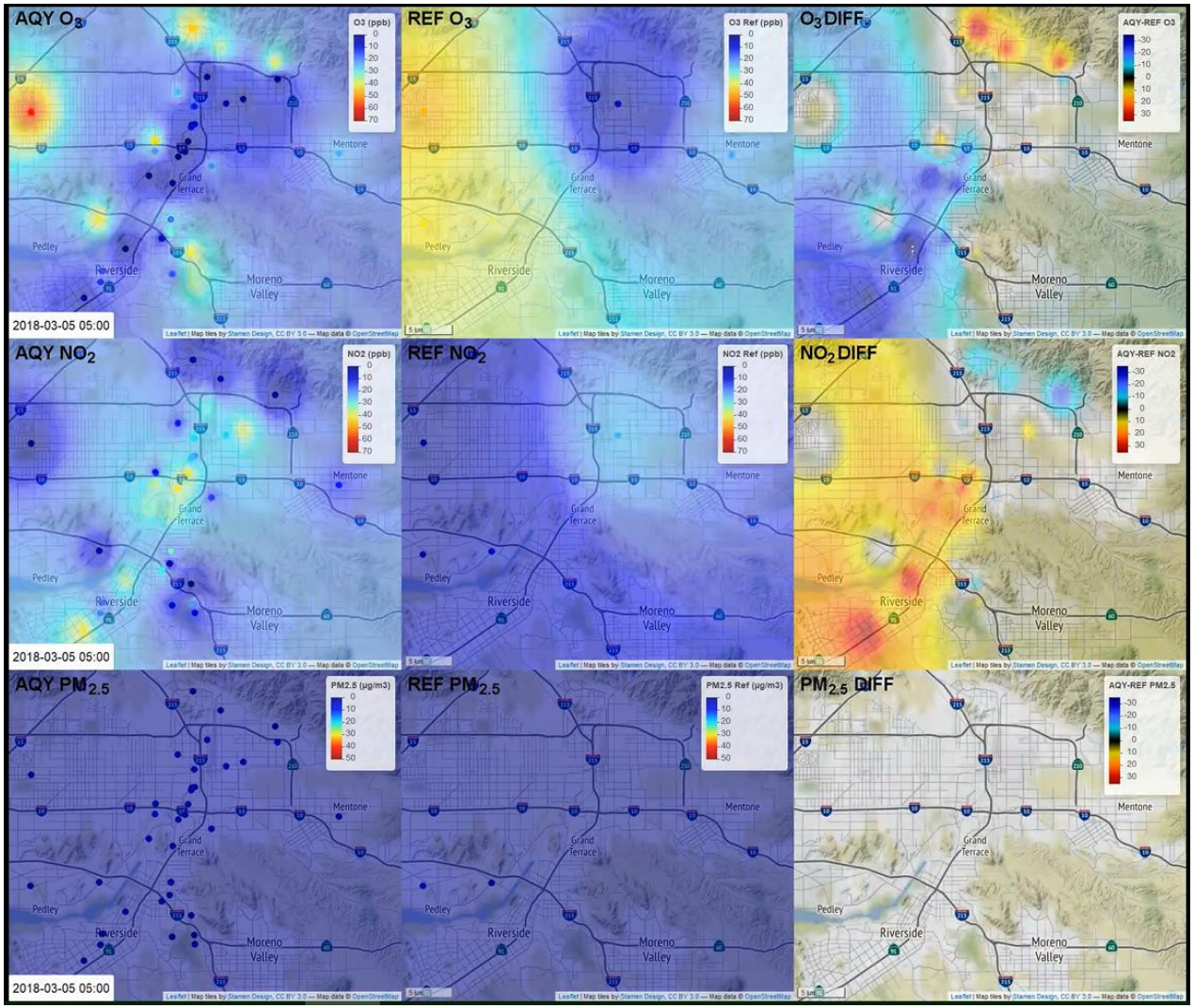
U.S. EPA STAR Project
R^2 (AQY vs Reference) vs Distance: Nitrogen Dioxide



- DQO = 90% (R^2)
- R^2 drops more rapidly with distance (compared to O_3 plot)
- Greater site variation than O3 due to various sources in the area

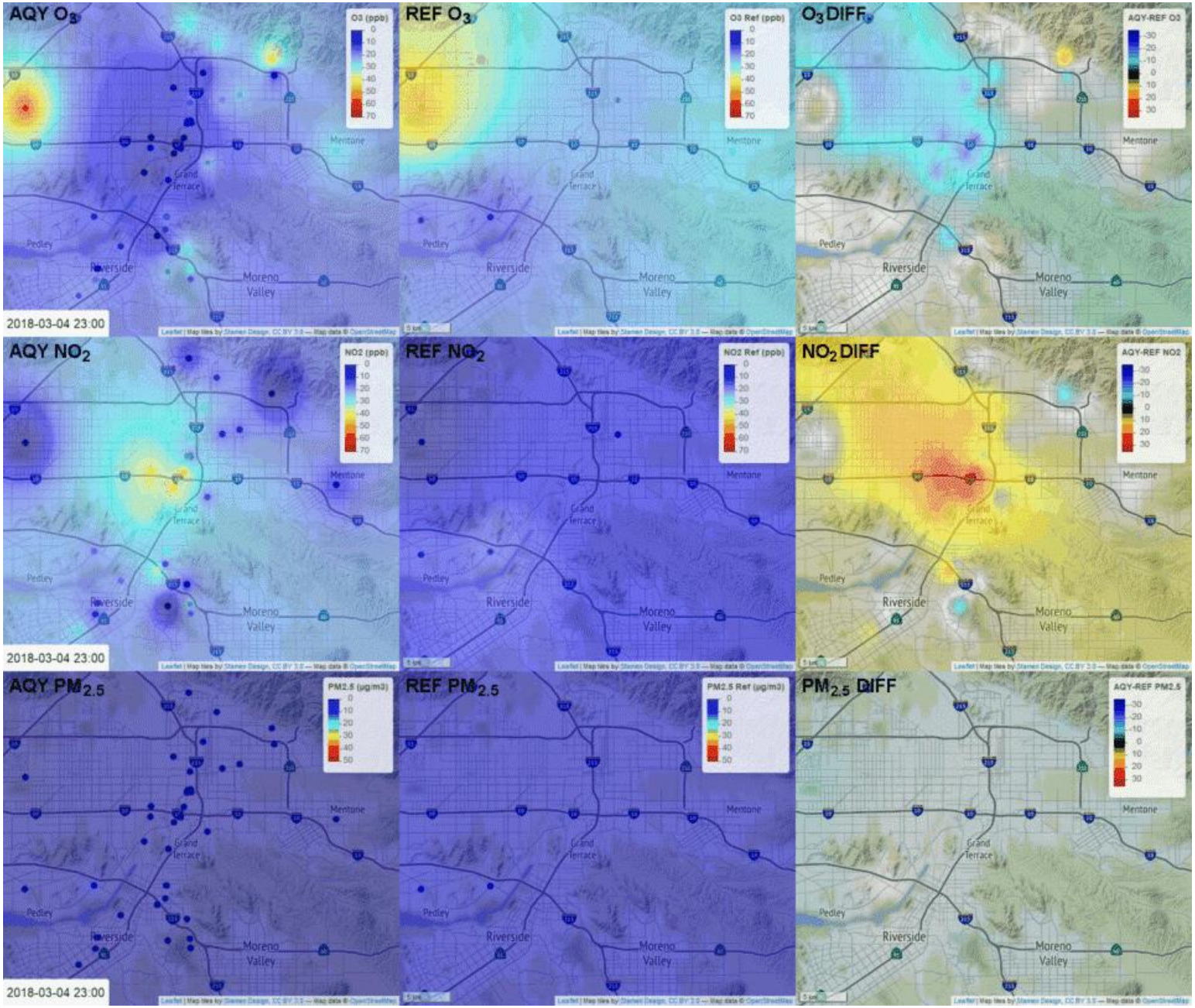
U.S. EPA STAR Project
Ozone, Nitrogen Dioxide and $PM_{2.5}$ Maps*

- Higher granularity for maps obtained using sensor data
- Elevated NO_2 along the freeway
- $PM_{2.5}$ is more homogeneously distributed throughout the Basin

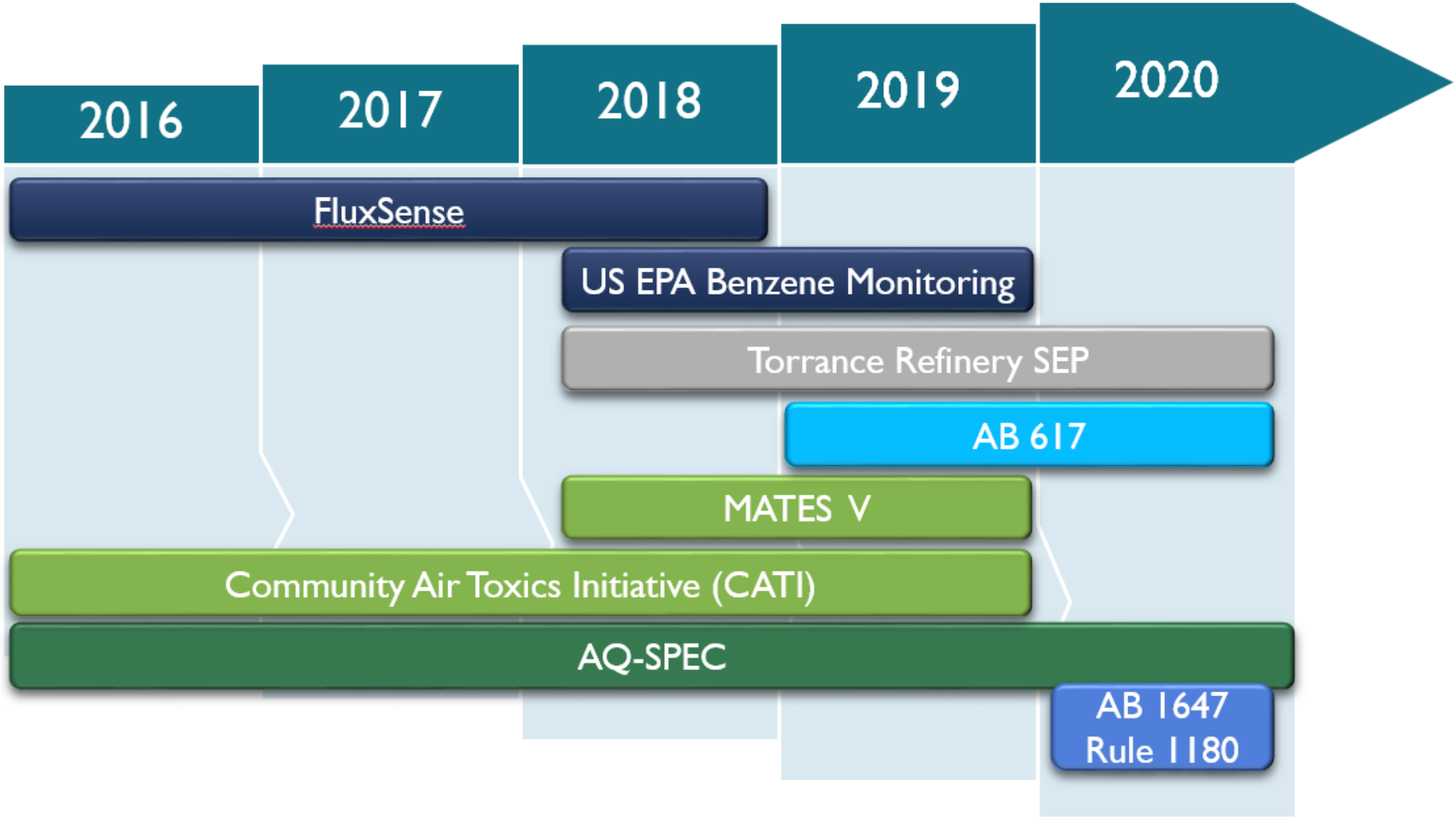


- $PM_{2.5}$ and NO_2 are corrected for T and RH….(O_3 is not)
- Can this type of correction be applied in real-time?

*Inverse distance weighted interpolation


AQY O_3
O3 (ppb)
0
10
20
30
40
50
60
70
2018-03-04 23:00
REF O_3
O3 Ref (ppb)
O_3 DIFF
AQY-REF O3
-30
-20
-10
0
10
20
30
AQY NO_2
NO2 (ppb)
REF NO_2
NO2 Ref (ppb)
NO_2 DIFF
AQY-REF NO2
AQY $PM_{2.5}$
PM2.5 (µg/m3)
REF $PM_{2.5}$
PM2.5 Ref (µg/m3)
$PM_{2.5}$ DIFF
AQY-REF PM2.5
Mentone
Grand Terrace
Pedley
Riverside
Moreno Valley

Current and Upcoming Air Monitoring Initiatives



Thanks!

The AQ-SPEC Team

- *Dr. Andrea Polidori*
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- *Brandon Feenstra*
- *Dr. Hang Zhang*
- *Berj Der Boghossian*
- *Dr. Michelle Kuang*