



Webinar | Air Quality Networks and Smart Cities

aeroqual^{oo}
TM



CAMPBELL ASSOCIATES
SOUND, VIBRATION & AIR SOLUTIONS



Today's Panel



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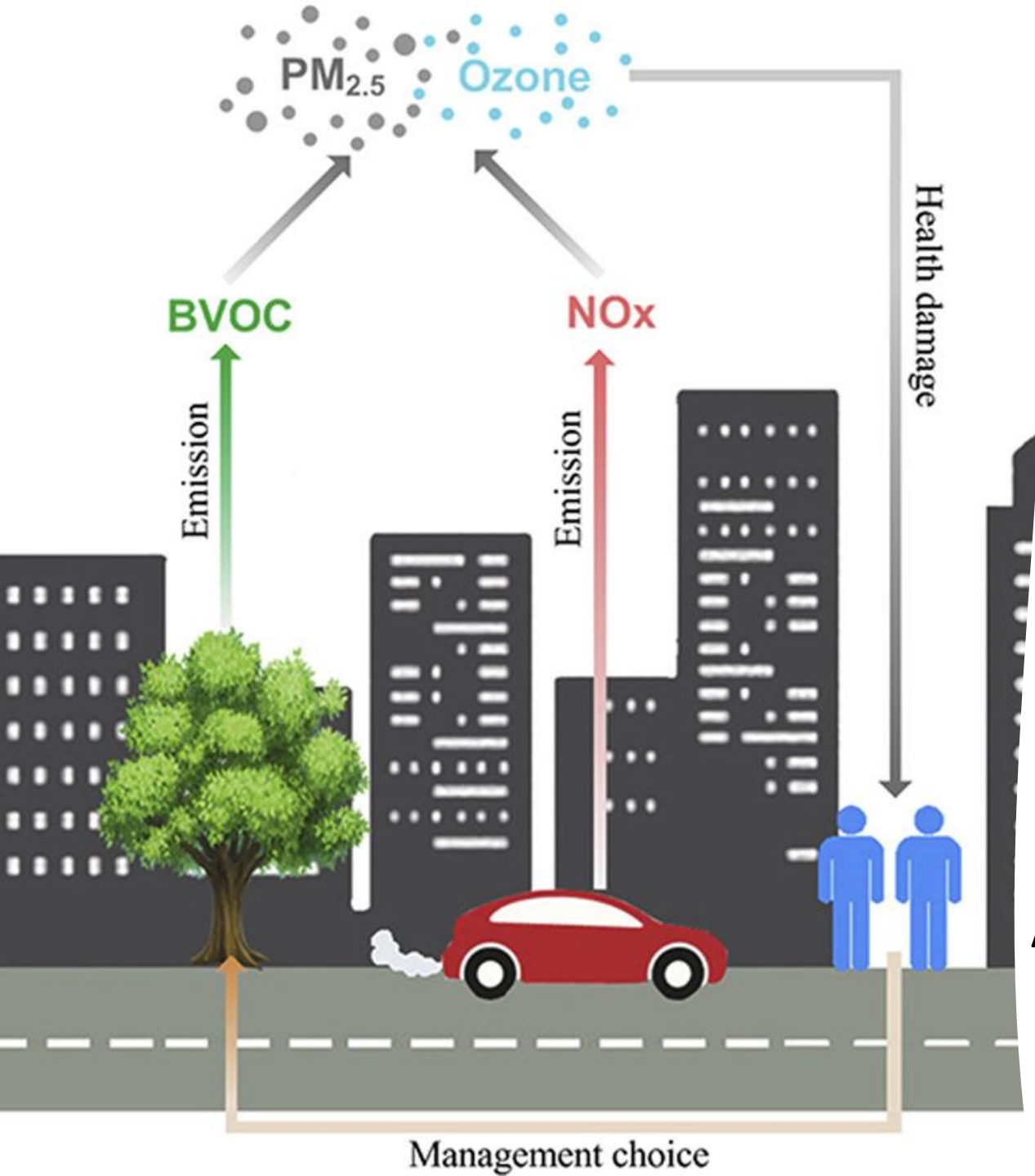
GEOFF HENSHAW
Chief Technology Officer

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Urban Areas

- **55%** of the world's population lives in **urban areas**
 - In the UK, approx. **84%** of the population





Air Pollution in Urban Areas

- Combustion of fossil fuels
 - Motor vehicles, heat and power generation
 - Industrial facilities, municipal waste incineration
 - Domestic cooking, heating, and lighting



Air pollution emission

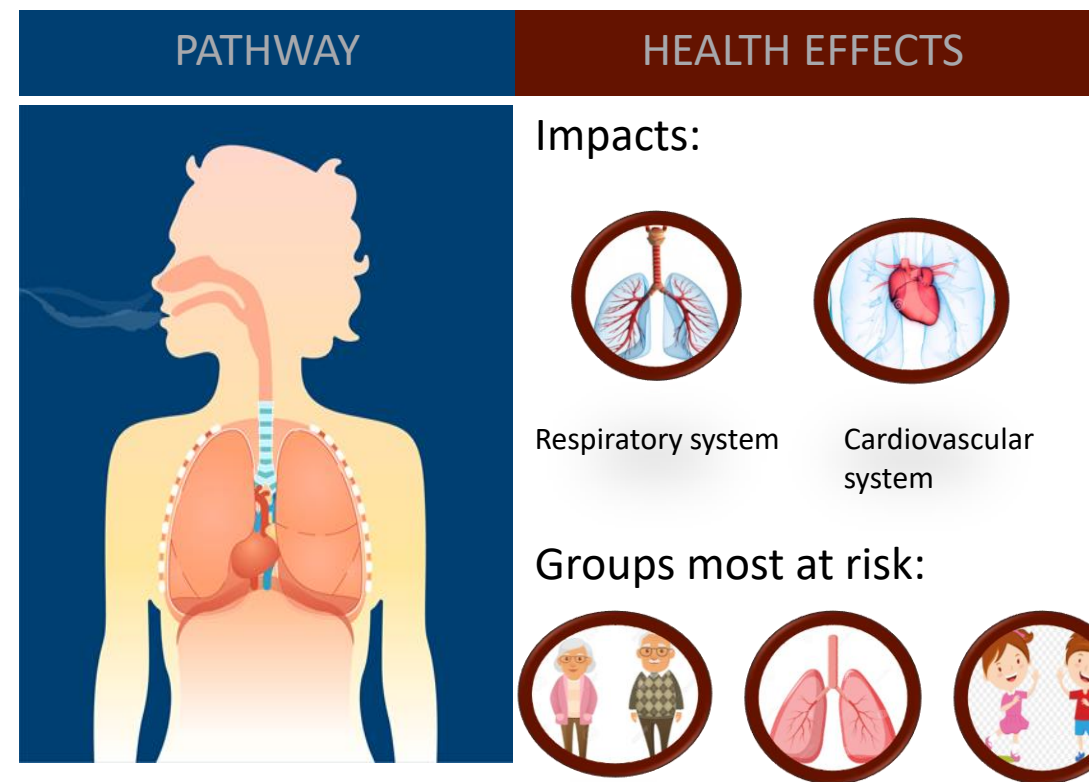
- Nitrogen oxides
- Particulate matter (PM₁₀ and PM_{2.5})
- Ozone

Health concerns associated with Air Pollution

Fraction of mortality attributable to particulate air pollution in 2018

Area	Value
England	5.2
London region	6.6
South East region	5.6
East of England region	5.5
West Midlands region	5.0
East Midlands region	4.9
Yorkshire and the Humber region	4.5
South West region	4.4
North West region	4.3
North East region	3.8

Source: Finger Tips, Public Health England - 2018



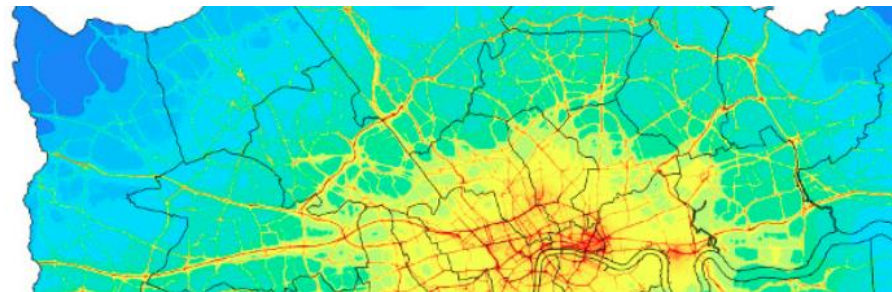
UK and EU Air Quality Limits

Pollutant	Highest Permissible Concentration	Averaging Period
Nitrogen dioxide (NO ₂)	200 µg/m ³ not to be exceeded more than 18 times a year	1 hour
	40 µg/m ³	1 year
PM ₁₀	50 µg/m ³ not to be exceeded more than 35 times a year	24 hour
	40 µg/m ³ 18 µg/m ³ (Scotland)	1 year
PM _{2.5}	25 µg/m ³ 10 µg/m ³ (Scotland)	1 year
Ozone (O ₃)	100 µg/m ³ not to be exceeded more than 10 times a year	8 hour mean

How do communities currently monitor Air Quality



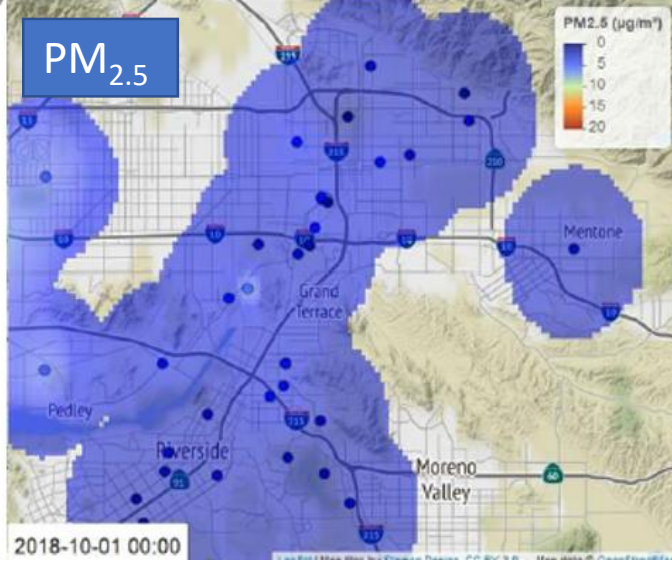
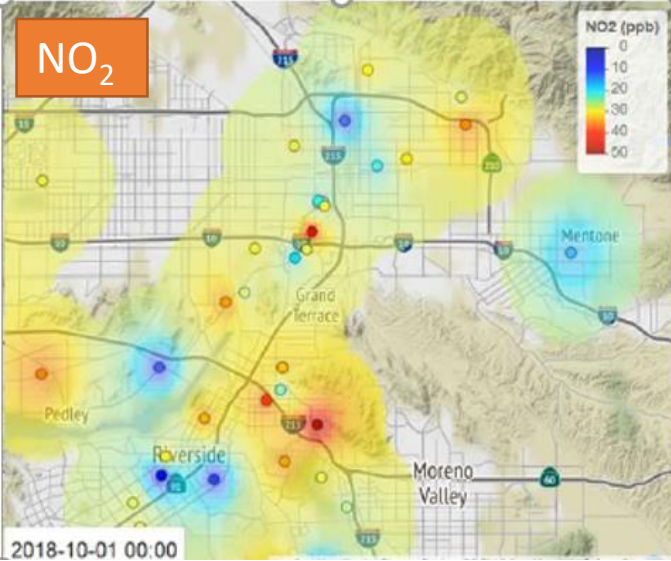
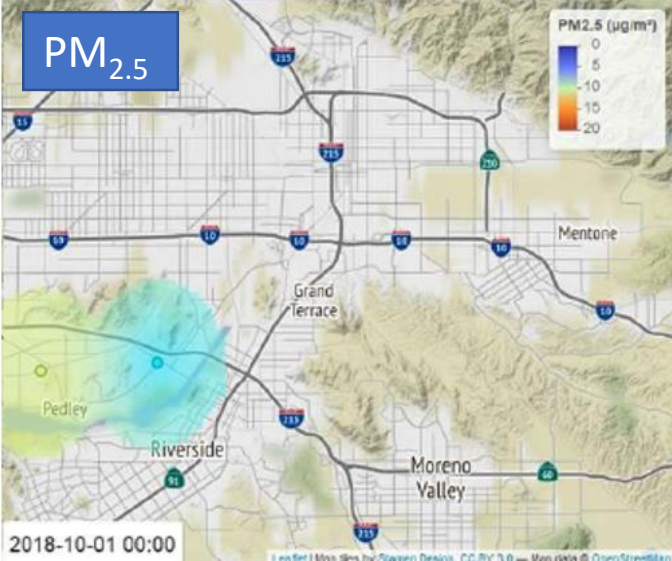
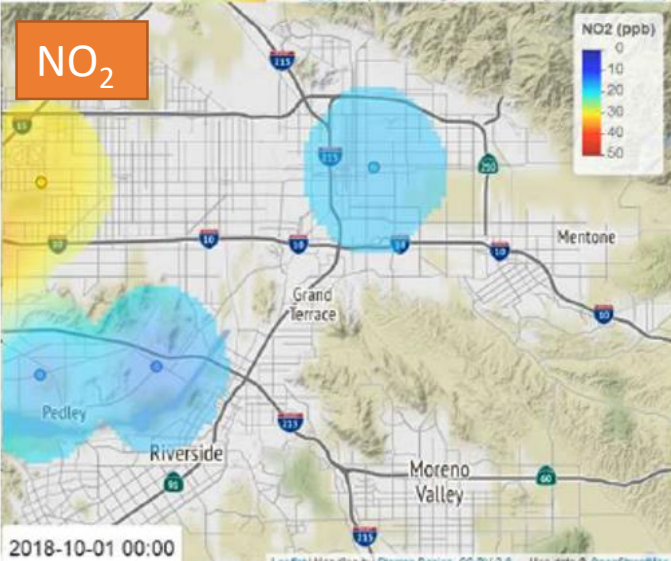
Poor spatial resolution
Poor temporal resolution



Higher resolution data

Reference monitors

AQY monitor network





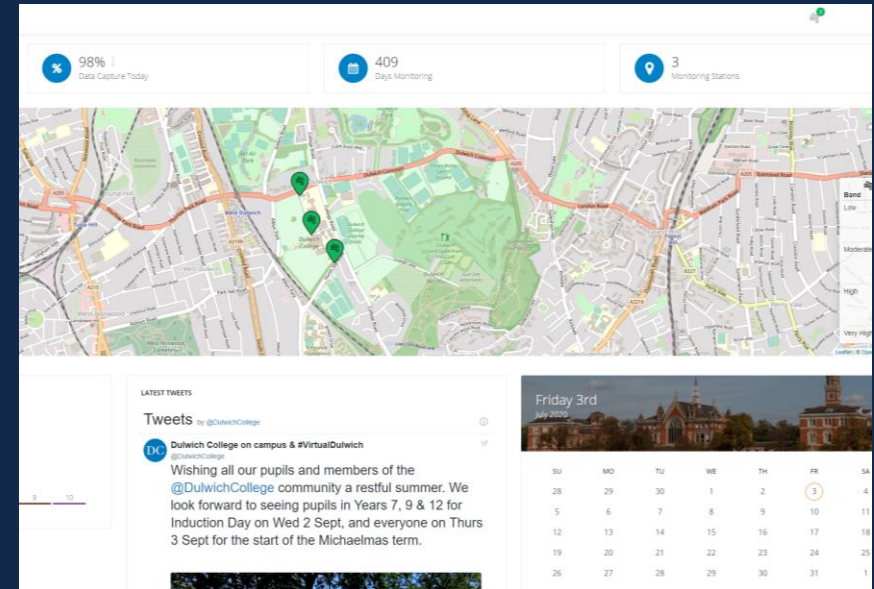
Aeroqual AQY – Micro Air Quality Station

- A ‘low cost’ micro air quality monitor that produces **real-time** and **scientifically credible data**
- **Simple** to set up and **easy** to use
- **Low cost** to purchase and service
- **Simple** to deploy as networks



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Aeroqual AQY – Micro Air Quality Station



Aeroqual AQY – Advanced Sensor Technology

PM sensor inlet



O_x Sensor O₃ Sensor

- O₃ sensor uses Aeroqual's patented gas sensitive semiconductor (GSS) for unrivalled sensitivity, stability and selectivity
- NO₂ concentration is the difference between O_x sensor with O₃ sensor
- Simple calculation, no need for web-based algorithm
- Performance best on market from independent studies

<http://www.aqmd.gov/aq-spec/evaluations/summary-gas>

Aeroqual AQY – Applications



Smart city grid networks



Roadside traffic emissions



Emergency response / event monitoring



Community groups / citizen science



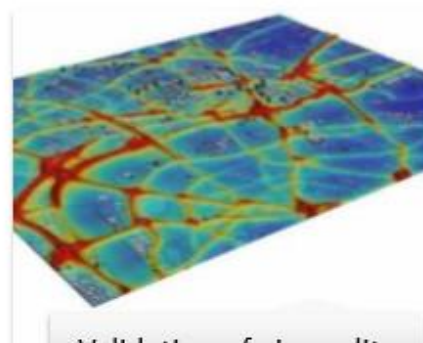
Schools and childcare health and safety



Community exposure studies



Mapping smog formation and distribution



Validation of air quality models

What is a Smart City?

- A **smart city** is one that is a technology-intensive city. This means highly efficient public services, thanks to information gathered in by thousands of interconnected devices coupled with software applications.
- In the air quality context this means hundreds of **air quality sensors** providing **real-time information** to government and citizens alike. This data can be turned into useful information, allowing us to make better decisions – whether to do with transport planning, or knowing what route is best to walk to work.
- **Air quality sensing** fits well with the vision of the smart city – providing information about a city that was not previously available, allowing people to make decisions that can improve the quality of their lives

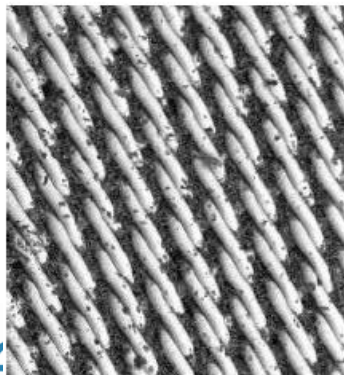
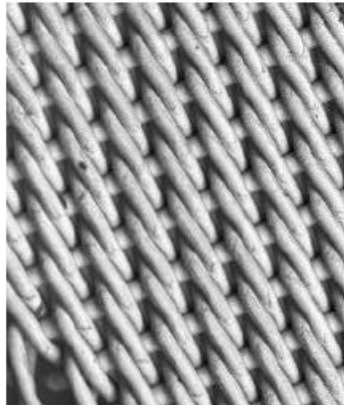
How do we know if the data is reliable?

- All air quality sensors exhibit drift (as do reference analysers)
- Sensor drift can be corrected by calibration however calibration by traceable standards is often not be possible due to instrument design.
- Large numbers of sensors in dense networks makes site calibration logistically difficult and expensive.
- Alternative methods of calibration are needed to understand the quality of the measurement.

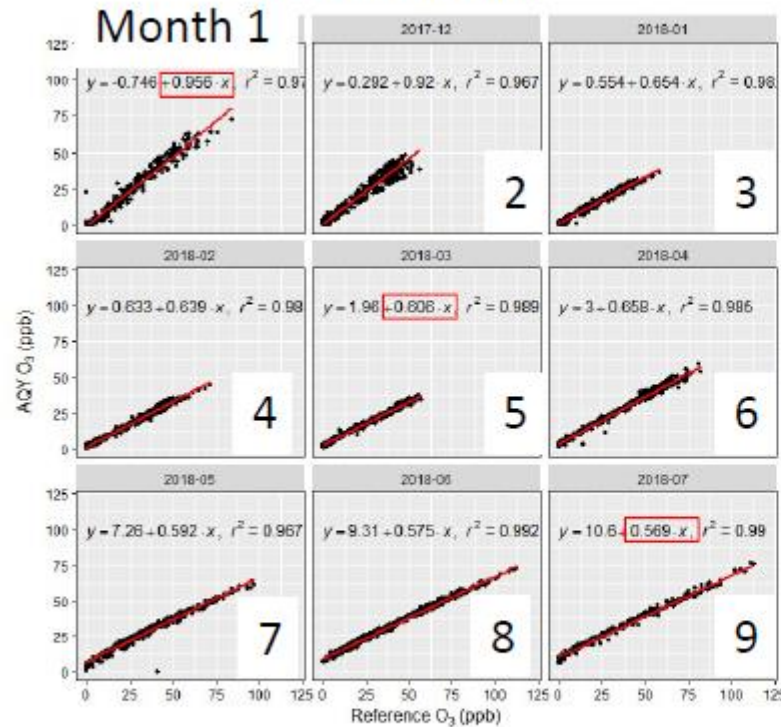
Sensor based systems - Drift

Timescale	Causes of drift	Solution
Minutes/days	Cross -interferences, temperature, RH, wind speed,	Instrument design, sensor selection, software
Weeks/months	dust accumulation, filters clogging, sensor degradation,	Calibration
Months/years	mechanical wearing of fans/pumps, corrosion, electrode poisoning, electrolyte changes, insect nests, instrument damage	Calibration/maintenance

Drift correction

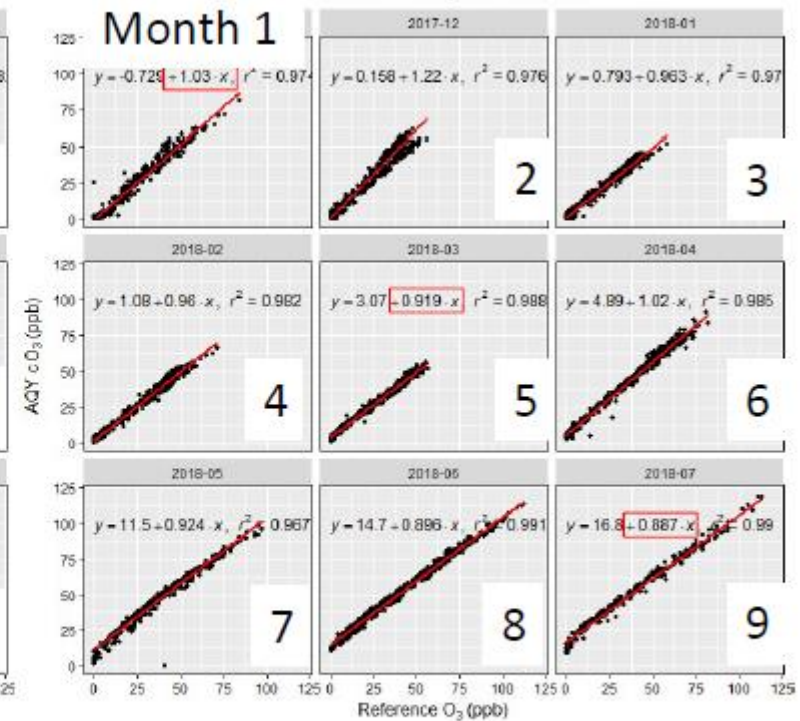


No correction



Sensor vs FEM slope decreased from 0.96 to 0.57 in 9 months

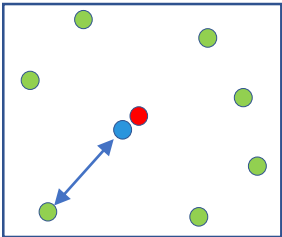
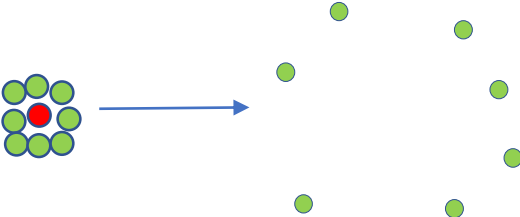
Flow corrected



Sensor vs FEM slope more stable. Slope = 0.89 at 9 months.

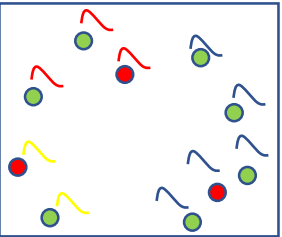
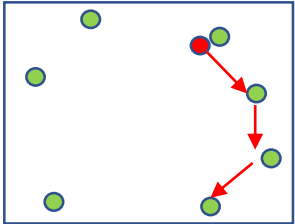
Calibration methods for AQY

Co-location with Reference: Good option especially if deployment sites are similar to the co-location site. Can be done before and after a project.



Transfer standard: standard moves between Reference station and network nodes. This is very labour intensive.

Mobile Reference standard: Reference standard visits network nodes for a period of time. Requires large variation in pollutant levels over short time. Not reliable.



MOMA calibration: identify proxy reference stations and match the sensor distribution to the distribution of the proxy reference. New process in development. Requires nearby reference station data for all pollutants



Co Location Before Installing Systems



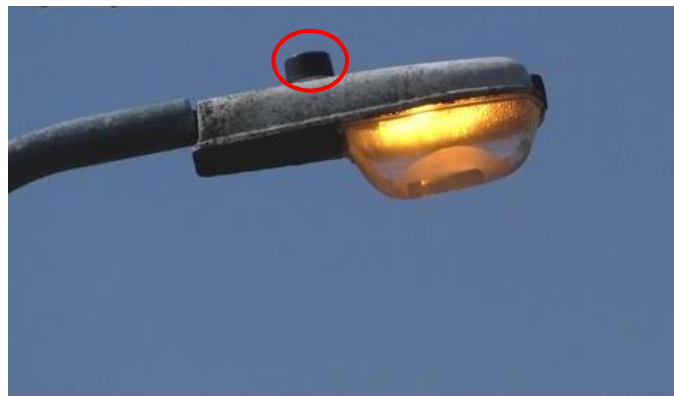
Installing Systems



Locating hardware – Street furniture



Locating hardware - Street Lighting



Street Lighting – Adaptor box



Stakeholders

- Instrumentation experts
- IT department,
- Budget holders,
- Politicians,
- Network provider,
- Integrators,
- Environmental Health departments
- Highways departments
- Citizens



Think BIG, start small

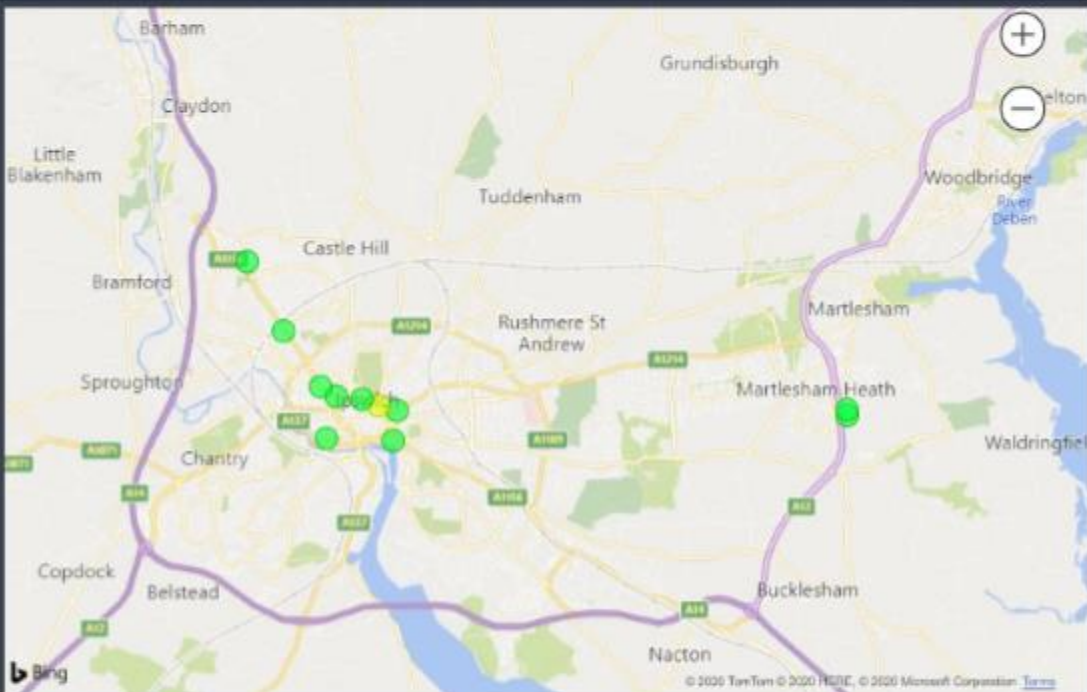
A pilot scale test network of 3-15 sensor devices to gain experience, and to make sure that the devices can actually deliver useful information



Suffolk - Urban & rural road network deployment



Pollution Analysis



WARNING LEVELS

Particulate <2.5µm

31



Particulate <10µm

25



Ozone (ppm)

48



Nitrogen Dioxide (ppm)

10



Air Quality

Excellent

Temperature

19.1

Humidity

50.7%

Particulate <2.5µm - Hourly average for all sensors



Particulate <10µm - Hourly average for all sensors



Ozone (ppm) - Hourly average for all sensors



Nitrogen Dioxide (ppm) - Hourly average for all sensors





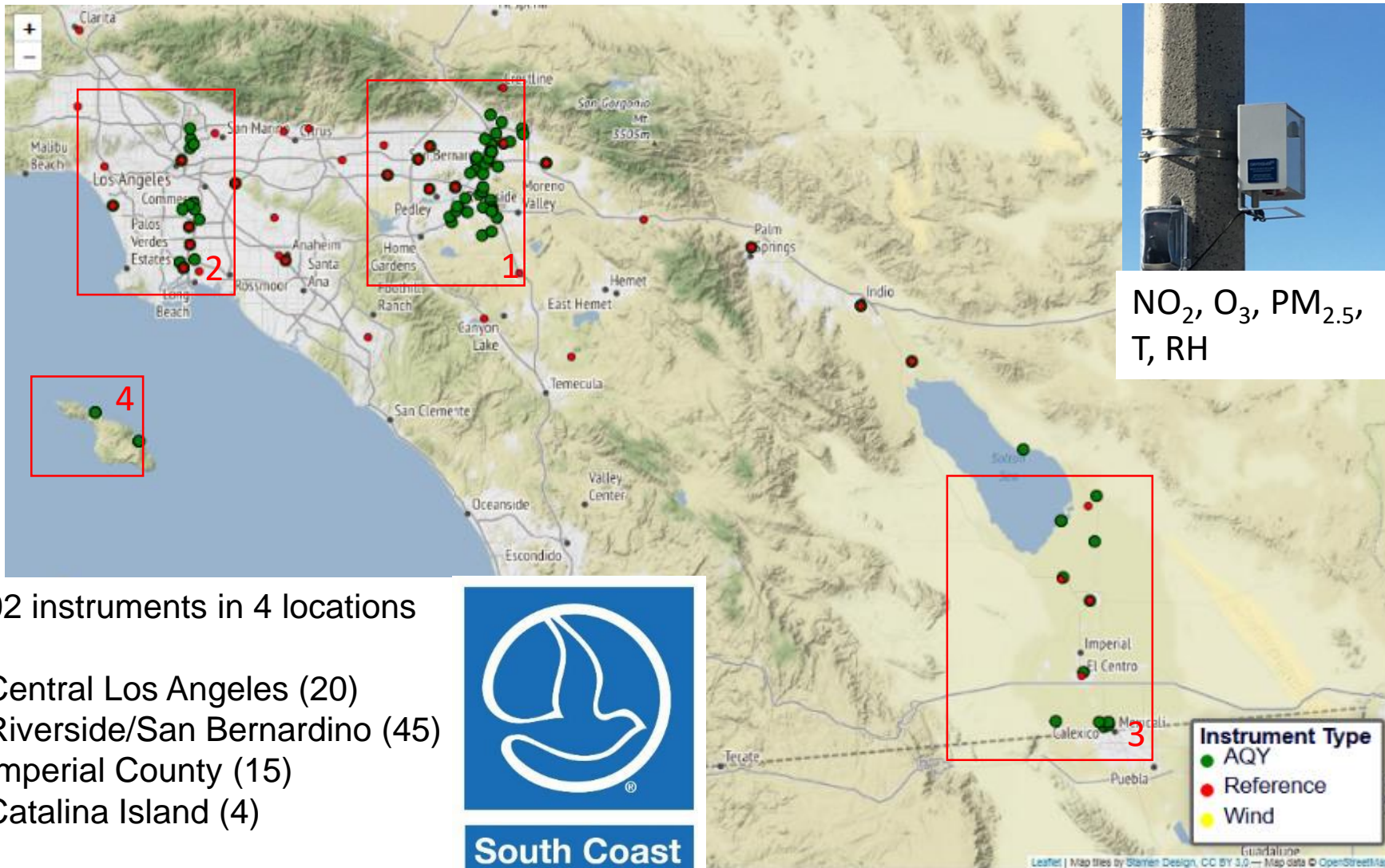
Reading at	Sensor ID	Particles <2.5µm	Particles <10µm	Ozone	Nitrogen Dioxide	Humidity	Temperature	Street	City	Postcode	Country	Latitude	Longitude
06/04/2020 14:35:00	AQY BC-1039	1.70	4.30	53.90	4.50	35.80	18.50	CHANCERY ROAD	Suffolk		UK	52.053369	1.145054
06/04/2020 14:35:00	AQY BC-1050	2.00	3.90	42.00	7.70	33.80	19.90	ST MATTHEWS STREET	Suffolk		UK	52.059999	1.147560
06/04/2020 14:35:00	AQY BC-1052	2.00	4.70	46.70	0.00	43.70	19.54	ADASTRAL PARK	Suffolk		UK	52.056994	1.278930
06/04/2020 14:35:00	AQY BC-1037	2.00	5.20	46.80	3.20	35.80	18.34	NORWICH ROAD	Suffolk		UK	52.081240	1.124712
06/04/2020 14:35:00	AQY BC-1043	2.60	5.10	41.90	6.60	34.40	18.36	NORWICH ROAD	Suffolk		UK	52.061511	1.143610
06/04/2020 14:35:00	AQY BC-1054	3.70	5.70	48.00	3.90	36.60	18.14	CROWN STREET	Suffolk		UK	52.059516	1.154193
06/04/2020 14:36:00	AQY BC-1039	1.80	4.80	50.20	4.60	35.80	18.50	CHANCERY ROAD	Suffolk		UK	52.053369	1.145054
06/04/2020 14:36:00	AQY BC-1050	1.90	4.10	41.50	7.60	34.20	20.14	ST MATTHEWS STREET	Suffolk		UK	52.059999	1.147560
06/04/2020 14:36:00	AQY BC-1052	2.10	5.40	47.50	0.00	41.90	19.38	ADASTRAL PARK	Suffolk		UK	52.056994	1.278930
06/04/2020 14:36:00	AQY BC-1043	2.40	5.20	41.30	6.40	34.30	18.65	NORWICH ROAD	Suffolk		UK	52.061511	1.143610
06/04/2020 14:36:00	AQY BC-1037	2.40	7.40	45.80	3.30	35.70	18.48	NORWICH ROAD	Suffolk		UK	52.081240	1.124712
06/04/2020 14:36:00	AQY BC-1054	3.60	6.90	44.40	5.60	36.80	18.30	CROWN STREET	Suffolk		UK	52.059516	1.154193
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06/04/2020 14:37:00	AQY BC-1037	2.10	6.40	42.40	4.70	35.30	18.55	NORWICH ROAD	Suffolk		UK	52.081240	1.124712
06/04/2020 14:37:00	AQY BC-1043	2.40	5.80	39.00	7.40	33.90	18.87	NORWICH ROAD	Suffolk		UK	52.061511	1.143610
06/04/2020 14:37:00	AQY BC-1050	2.70	6.20	40.70	7.50	34.00	20.62	ST MATTHEWS STREET	Suffolk		UK	52.059999	1.147560
06/04/2020 14:37:00	AQY BC-1054	3.70	6.00	41.10	7.90	36.80	18.56	CROWN STREET	Suffolk		UK	52.059516	1.154193
06/04/2020 14:38:00	AQY BC-1039	1.80	4.70	48.30	4.60	35.50	18.66	CHANCERY ROAD	Suffolk		UK	52.053369	1.145054
06/04/2020 14:38:00	AQY BC-1050	2.10	4.70	40.80	7.50	33.30	20.70	ST MATTHEWS STREET	Suffolk		UK	52.059999	1.147560
06/04/2020 14:38:00	AQY BC-1037	2.10	5.70	44.20	3.00	35.00	18.59	NORWICH ROAD	Suffolk		UK	52.081240	1.124712
06/04/2020 14:38:00	AQY BC-1052	2.20	6.00	48.80	0.00	40.70	19.96	ADASTRAL PARK	Suffolk		UK	52.056994	1.278930
06/04/2020 14:38:00	AQY BC-1043	2.30	6.90	36.40	7.70	33.70	19.05	NORWICH ROAD	Suffolk		UK	52.061511	1.143610
06/04/2020 14:38:00	AQY BC-1054	3.60	6.10	47.10	3.60	36.70	18.70	CROWN STREET	Suffolk		UK	52.059516	1.154193
06/04/2020 14:39:00	AQY BC-1052	1.80	4.70	48.00	0.00	40.30	20.19	ADASTRAL PARK	Suffolk		UK	52.056994	1.278930
06/04/2020 14:39:00	AQY BC-1039	1.90	4.70	48.20	4.60	35.60	18.79	CHANCERY ROAD	Suffolk		UK	52.053369	1.145054
06/04/2020 14:39:00	AQY BC-1043	2.00	4.50	41.90	3.50	33.50	19.18	NORWICH ROAD	Suffolk		UK	52.061511	1.143610
06/04/2020 14:39:00	AQY BC-1050	2.10	4.60	45.50	4.60	33.00	20.63	ST MATTHEWS STREET	Suffolk		UK	52.059999	1.147560
06/04/2020 14:39:00	AQY BC-1054	3.60	4.80	46.00	3.80	36.60	18.64	CROWN STREET	Suffolk		UK	52.059516	1.154193
06/04/2020 14:39:00	AQY BC-1037	5.50	8.20	44.70	2.90	35.00	18.58	NORWICH ROAD	Suffolk		UK	52.081240	1.124712
06/04/2020 14:40:00	AQY BC-1052	1.70	4.90	51.10	0.00	39.70	20.04	ADASTRAL PARK	Suffolk		UK	52.056994	1.278930
06/04/2020 14:40:00	AQY BC-1039	1.90	5.00	50.30	4.60	34.80	18.90	CHANCERY ROAD	Suffolk		UK	52.053369	1.145054
06/04/2020 14:40:00	AQY BC-1043	2.00	3.70	47.60	0.20	33.40	19.20	NORWICH ROAD	Suffolk		UK	52.061511	1.143610
06/04/2020 14:40:00	AQY BC-1050	2.30	4.70	45.10	4.40	33.10	20.42	ST MATTHEWS STREET	Suffolk		UK	52.059999	1.147560
06/04/2020 14:40:00	AQY BC-1054	3.80	5.20	45.40	3.80	36.10	18.43	CROWN STREET	Suffolk		UK	52.059516	1.154193
06/04/2020 14:40:00	AQY BC-1037	4.20	6.50	34.90	9.40	34.40	18.57	NORWICH ROAD	Suffolk		UK	52.081240	1.124712
06/04/2020 14:41:00	AQY BC-1052	1.60	3.30	54.30	0.00	39.60	19.75	ADASTRAL PARK	Suffolk		UK	52.056994	1.278930
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- Export data
- Show as a table
- Spotlight
- Sort descending
- Sort ascending
- Sort by

- Reading at
- Sensor ID
- Particles <2.5µm
- Particles <10µm
- Ozone
- Nitrogen Dioxide
- Humidity
- Temperature
- Street
- City
- Postcode
- Country
- Latitude
- Longitude

AQY Los Angeles Network

AQY Los Angeles network NO₂, O₃, PM_{2.5}



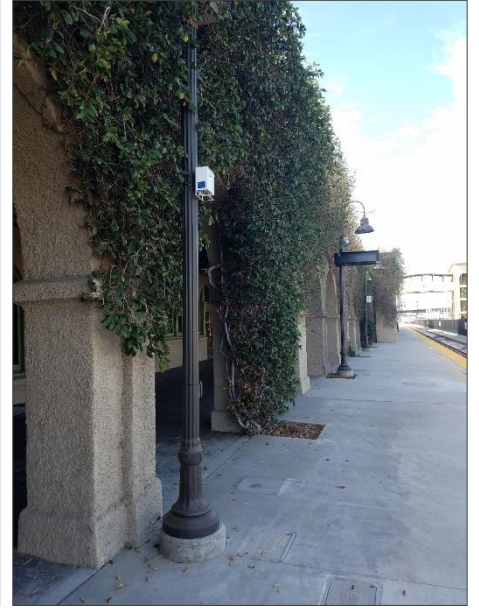
92 instruments in 4 locations

- Central Los Angeles (20)
- Riverside/San Bernardino (45)
- Imperial County (15)
- Catalina Island (4)



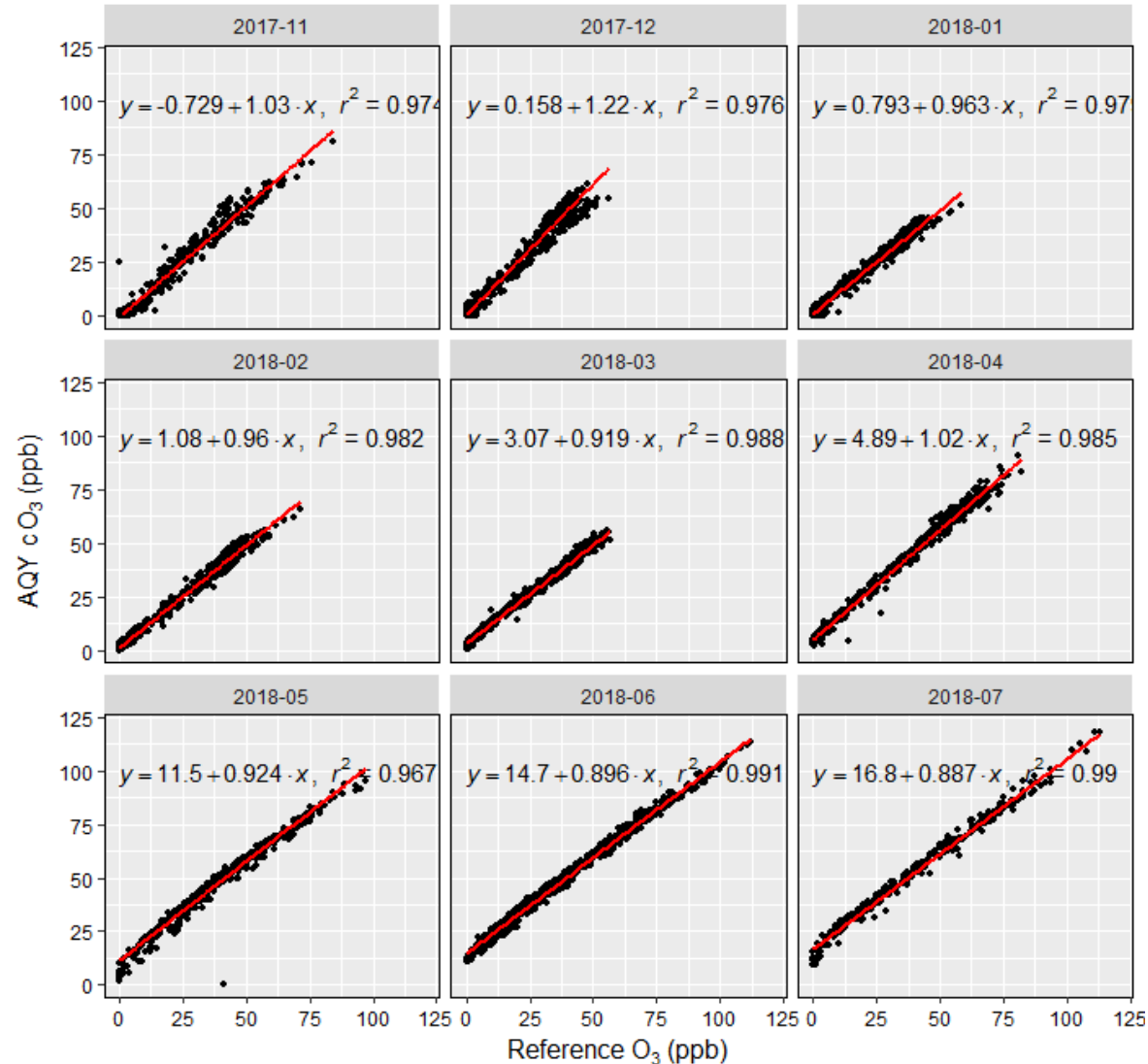
South Coast
AQMD

Site Photos



AQY – O₃

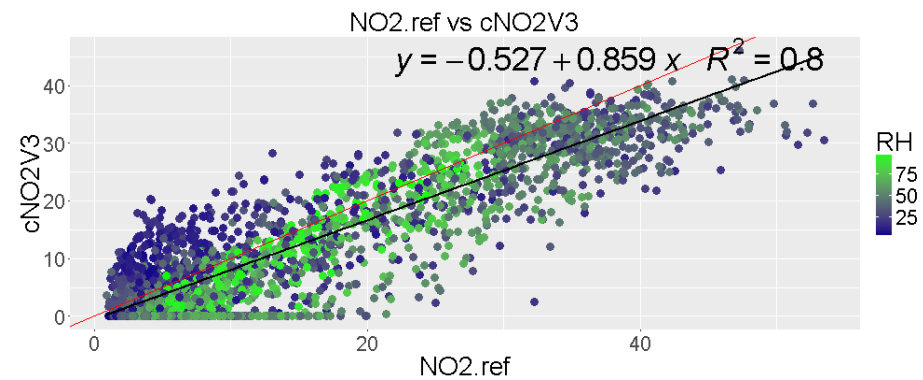
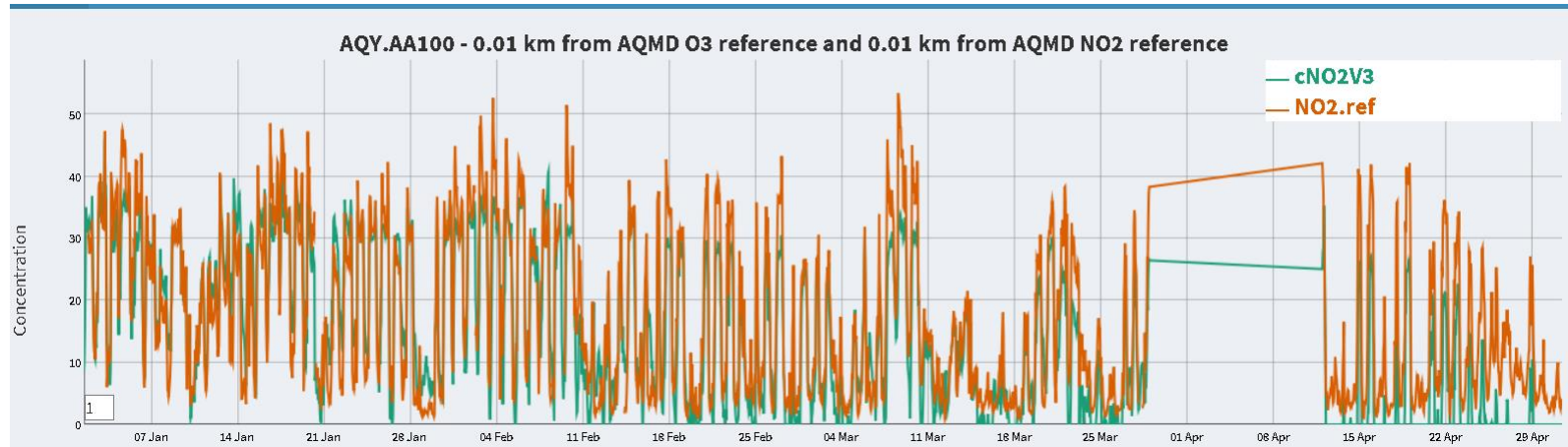
Co-located AQY instrument showing 9 month ozone data. $r^2 > 0.97$.



AQY - NO₂

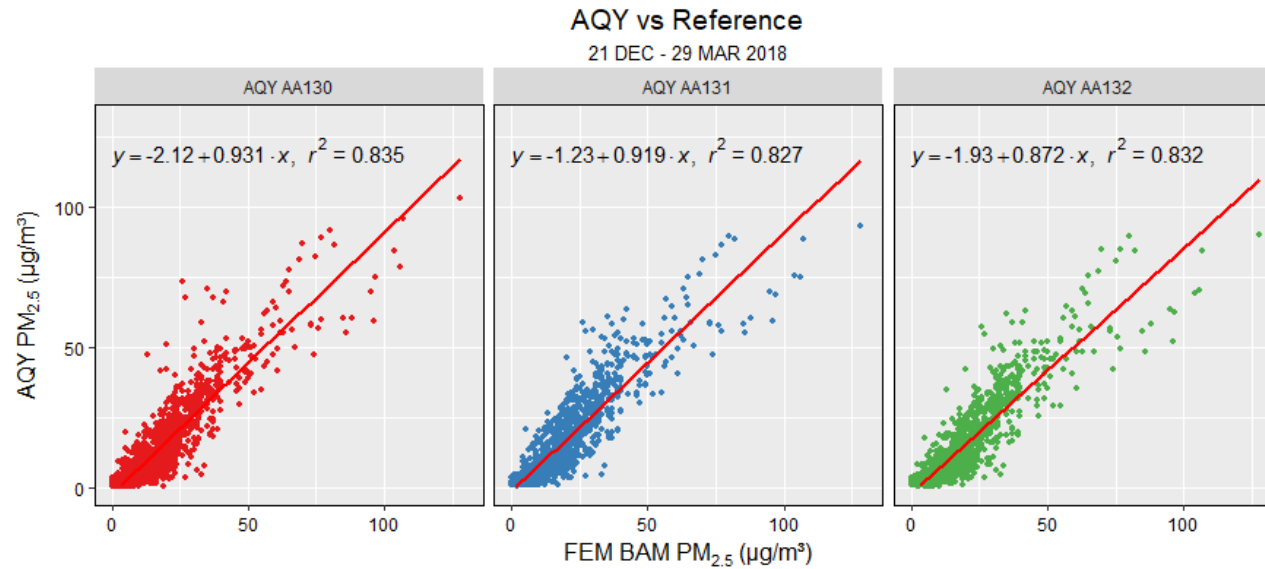
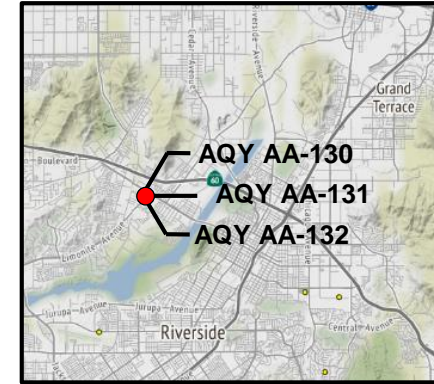
- Hourly-averaged data over a period of 5 months

January to May 2018 hourly data



AQY – PM_{2.5}

- Three instruments co-located at the same reference site
- Hourly-averaged data over a period of 3 months



Serial

- AQY AA130
- AQY AA131
- AQY AA132

	R ²	Slope	Intercept
vs Reference	0.831	0.91	-1.76
Between Instruments	0.987	0.99	0.27

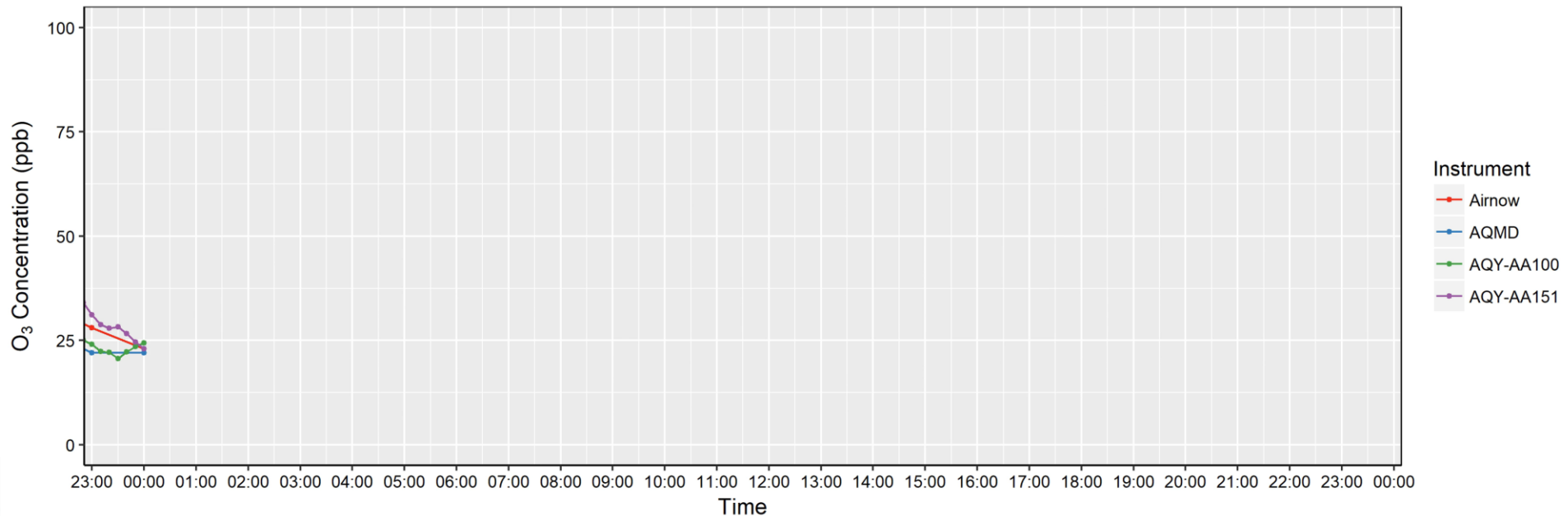
AQY temporal information



AQY-AA151 located at Sierra Middle School about 4 miles from SCAQMD Rubidoux station

Comparison of real-time data from

- Airnow (hourly)
- SCAQMD (hourly)
- AQY sensor (10 minute)

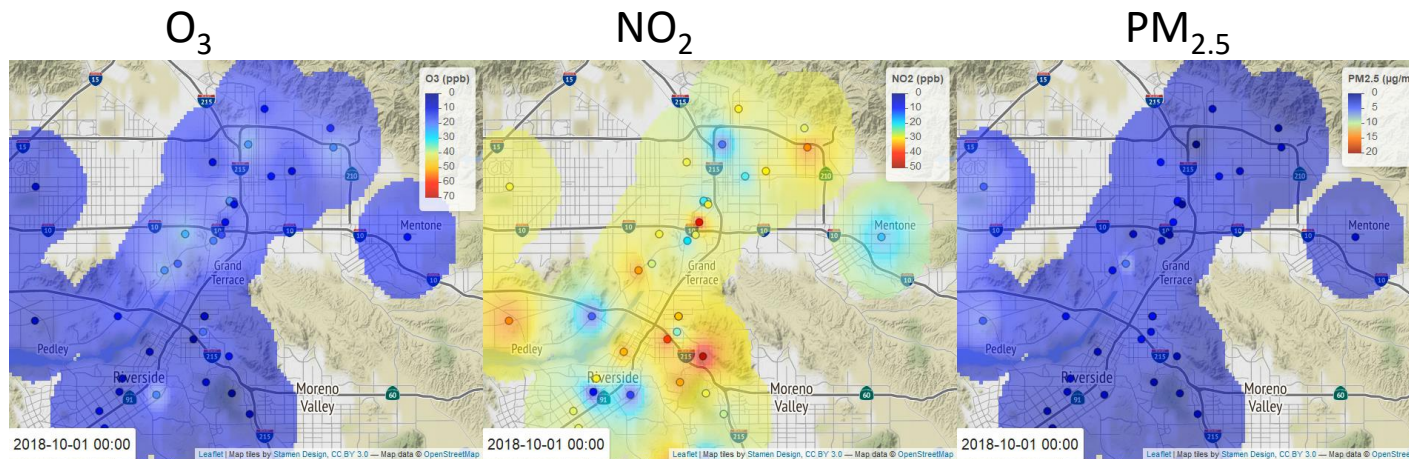


Sensor network vs regulatory network

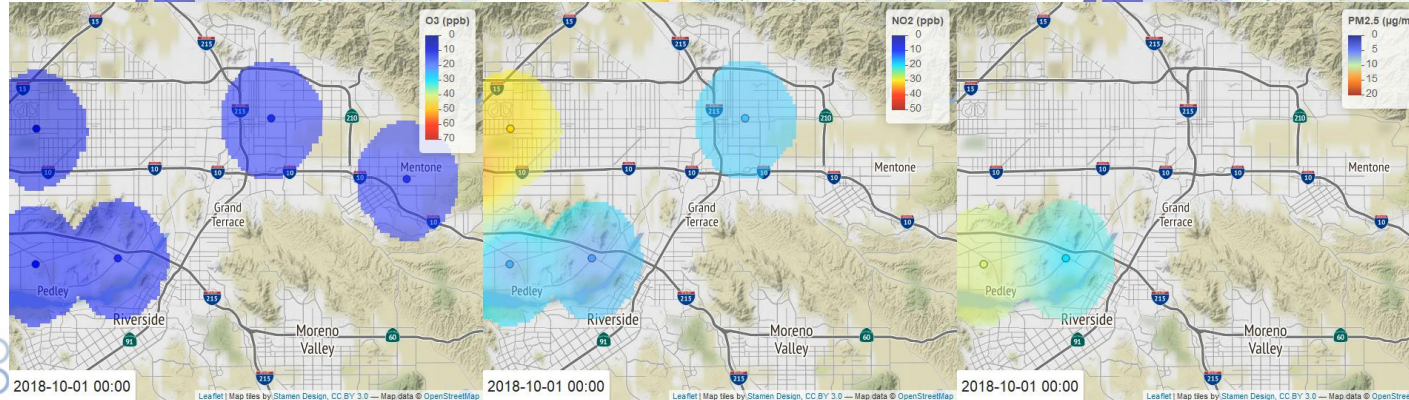
The spatially dense AQY network identified local hotspots and issues more easily than the regulatory network.

Heatmap generated using inverse-distance weighted interpolation in R.
Hourly maps stitched together into a video

Sensor



Regulatory



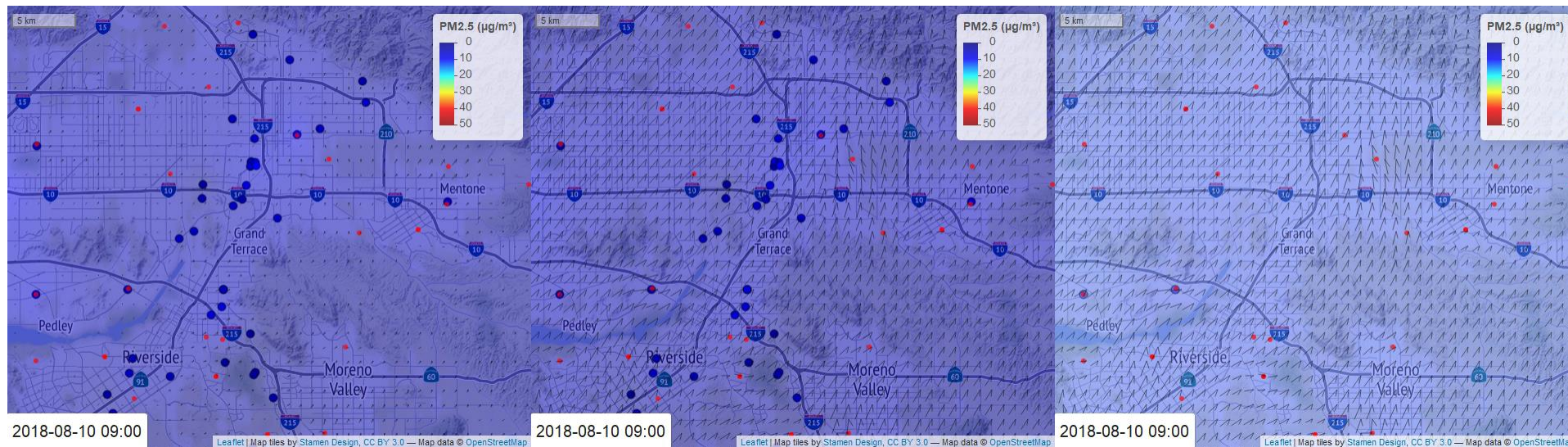
PM_{2.5} event detection

- PM_{2.5} event on 10 Aug 2018. Starts 11.30am, finishes 1.30 pm. Very localised.
- Higher time resolution provides more information about the event and transport of pollutants
- Higher density detects more isolated events – not picked up by reference network.

AQY 10-minute data

AQY - hourly data

Reference - hourly



Q&A



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