Creating air quality intelligence from low cost sensors

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Outline

1. Summary of ambient air sensor projects
2. Drift
3. Field calibration
4. Temporal and spatial information examples
5. Future work
6. Conclusions

Ambient air sensor projects

Year	Network	Publication	Insights
2005	3 x O3 sensors collocated at regulatory sites, Houston, TX 3 months	http://airalliancehouston.org/wp-content/uploads/ghasp-monitoring-report-2008.pdf	1. O3 sensors vs FEM r2 >0.97 2. H2S interference
2009	4 x NO2/O3 sensors Auckland, NZ 5 months	1. ECS Transactions, 19 (6) (2009)	1. Thermal O3 scrubber for NO2. 2. Demonstrated spatial variation of pollutants at a road intersection.
2012	50 x O3 sensors Vancouver, Canada 3 months	1. Williams et al. Meas. Sci. Technol. **24** (2013) 2. Bart et al. Environ. Sci. Technol. 2014, 48, 3. Miskell et al., Environ. Sci. Technol. 2016, 50..	1. Practical challenges in sensor deployment. 2. Network calibration methods 3. Sensor drift detection 4. New environmental knowledge of O3 spatial variability.
2013	23 x O3 sensors, 6 weeks San Joachim Valley, CA	http://www.valleyair.org/air_quality_plans/docs/2013attainment/ozonesaturationstudy.pdf	1. Short project QA methodology 2, Sensor drift correction 3. Sensors answered the question on how to interpret FEM data !
2015	O3 and NO2 sensors	Lin et al. Atmospheric Environment 100 (2015) p111	1. Correct O3 interference on EC NO2 with GSS O3.
2017-	100 x PM2.5, NO2, O3, T, RH Los Angeles, CA	Williams et al. Geographical invariance of a calibration framework for low-cost air quality sensors in networks (in prep.)	1. Extreme weather events (hurricanes, wildfires) 2. Sensor drift reduction 3. Calibration methodology 4. New sensors – VOC

Sensor drift

- All air sensors exhibit drift.
- Drift increases the complexity of data analysis
- It occurs at different timescales and has different causes.

Timescale	Causes	Solution
Minutes/days	Interferences, temperature, RH, wind speed,	Instrument design
Weeks/months	dust accumulation, contamination of sensing surfaces, filters clogging, sensor degradation	Calibration
> Months	mechanical wearing of fans/pumps, corrosion, power interruptions, insect nests, seasonal influences, instrument damage	Calibration/maintenance

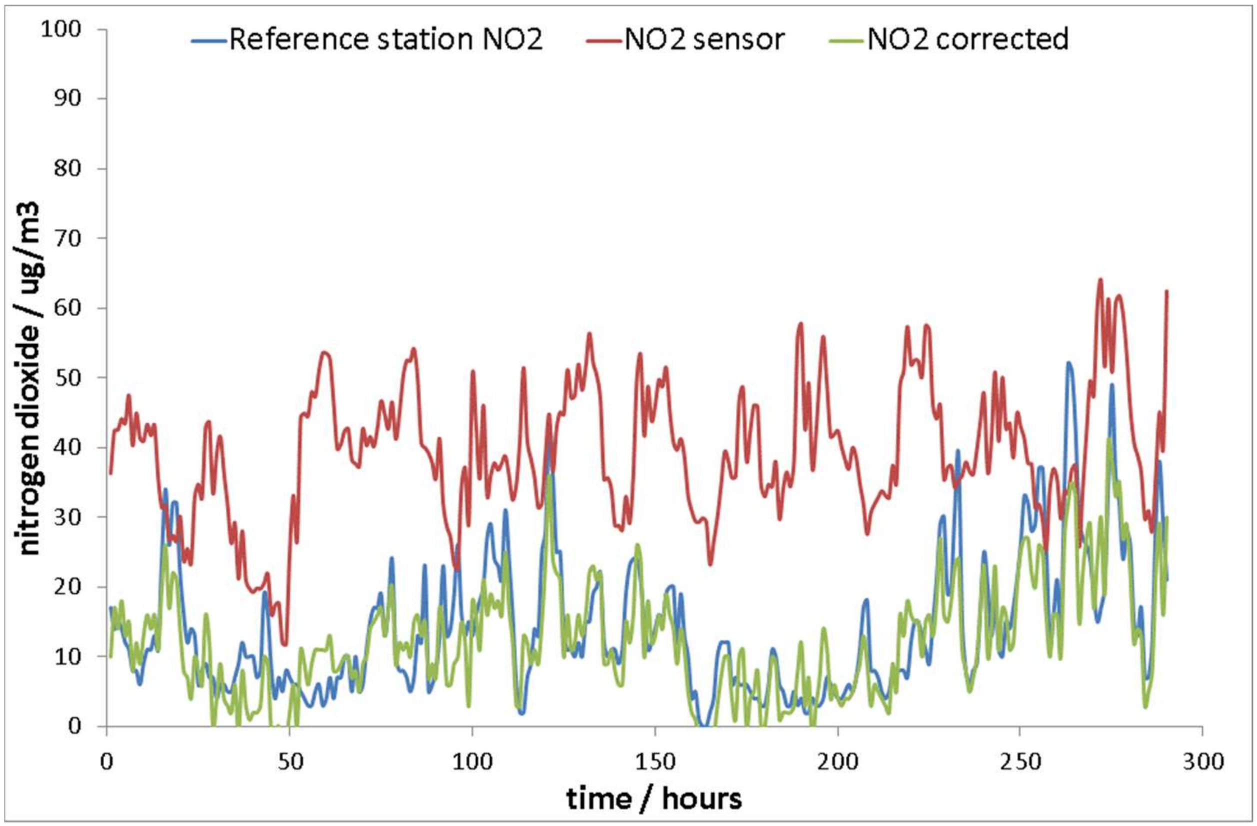
Cross-interferences

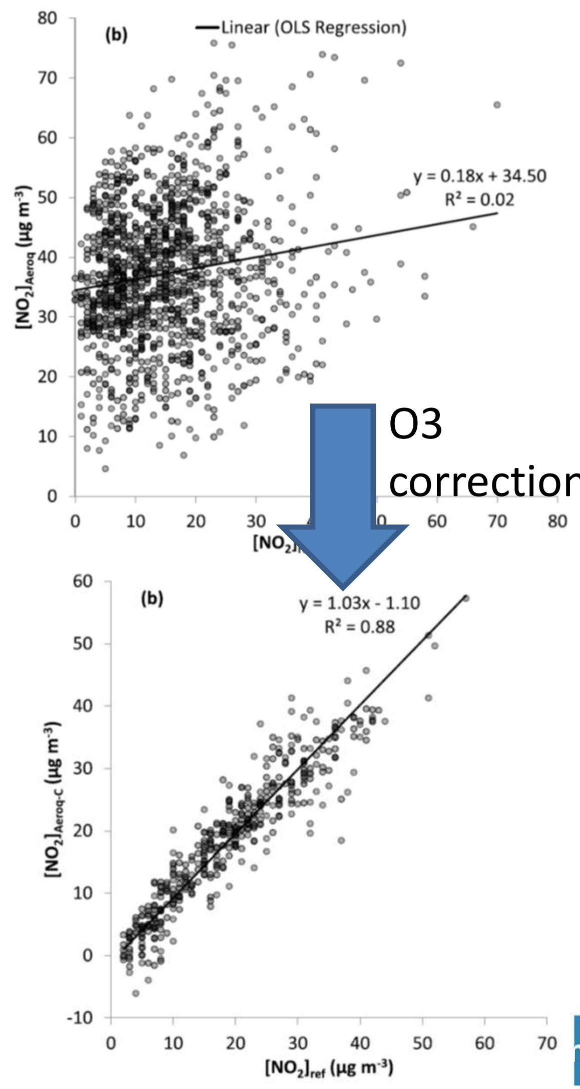
- Common interferences/confounders
  - T/RH effects on everything
  - MOS NO_2 / O_3
  - EC NO_2 / O_3
  - EC SO_2 / O_3
  - MOS O_3 / VOC, H_2S
  - PID / RH
  - MOS VOC / CO
  - $PM_{2.5}$ / RH

Electrochemical NO_2 sensor

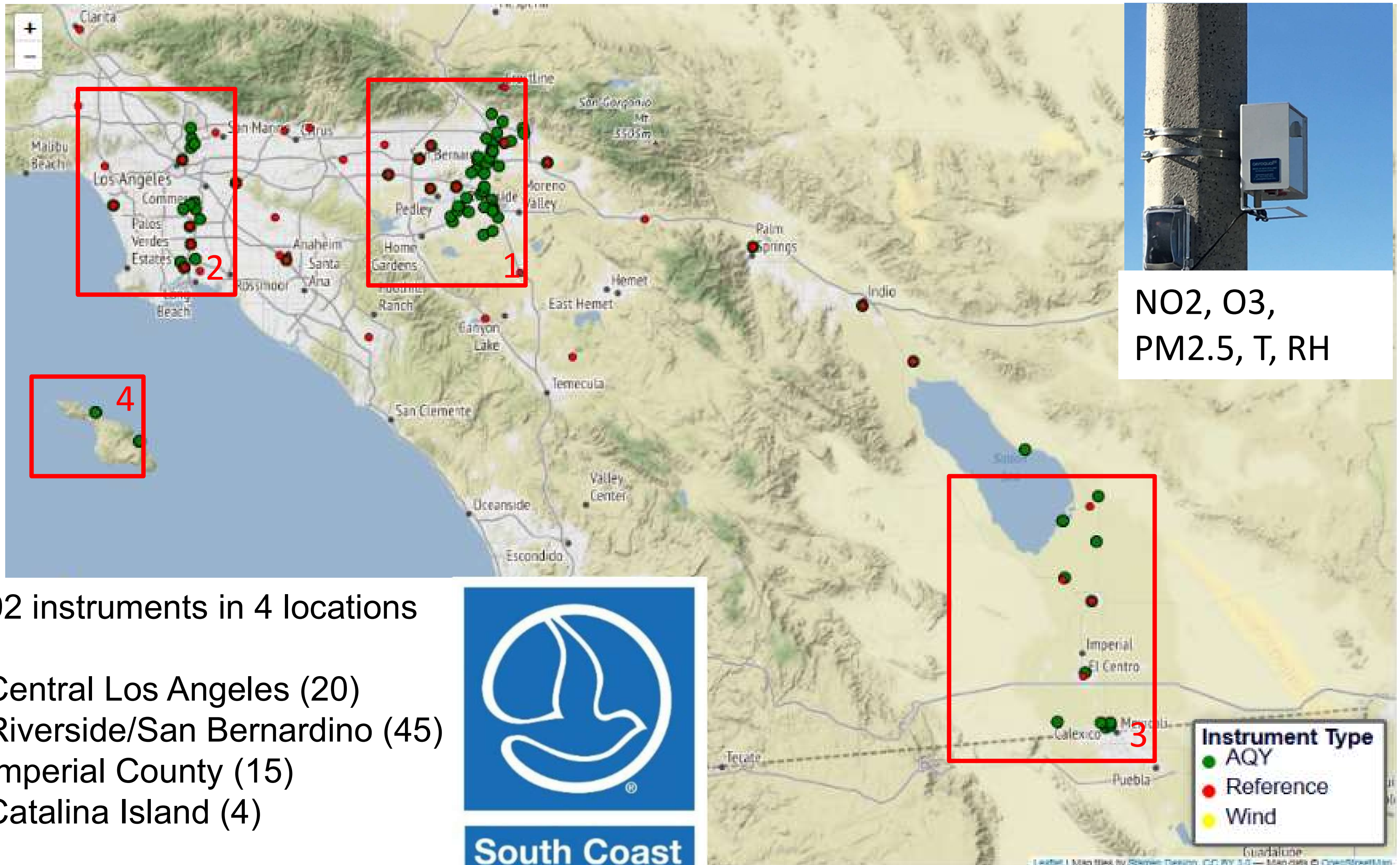
Most NO2 electrochemical sensors are also sensitive to ozone. GSS O3 selective sensor can be used to to correct for this cross-interference to get NO2 .

$$[NO2]_{corrected} = [NO2]_{sensor} - a[O3]_{GSS\ sensor}$$





AQY Los Angeles network NO_2, O_3, $PM_{2.5}$



NO2, O3, PM2.5, T, RH

92 instruments in 4 locations

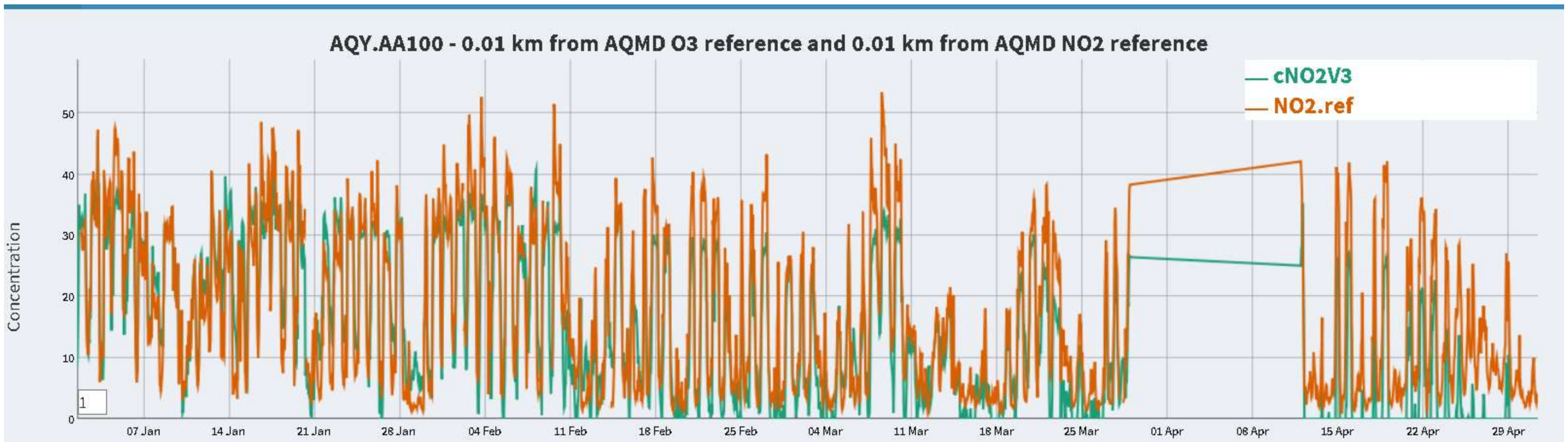
Central Los Angeles (20)
Riverside/San Bernardino (45)
Imperial County (15)
Catalina Island (4)

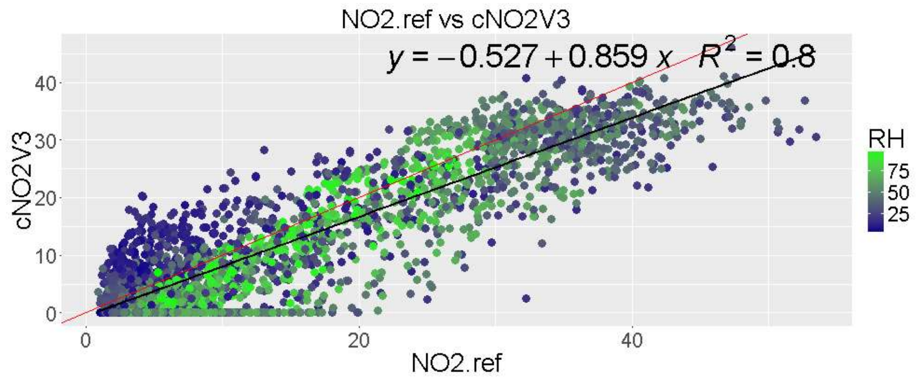
South Coast AQMD

aeroqual.com

NO_2 sensor co-located at SCAQMD regulatory site.

January to May 2018 hourly data





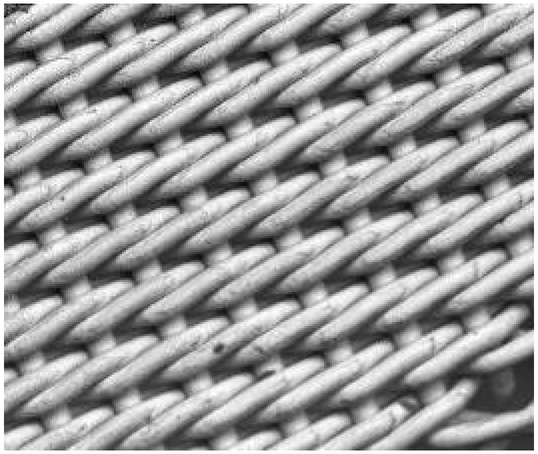
Reasonable r2 correlation of 0.8

Long term sensor drift: O_3 sensor

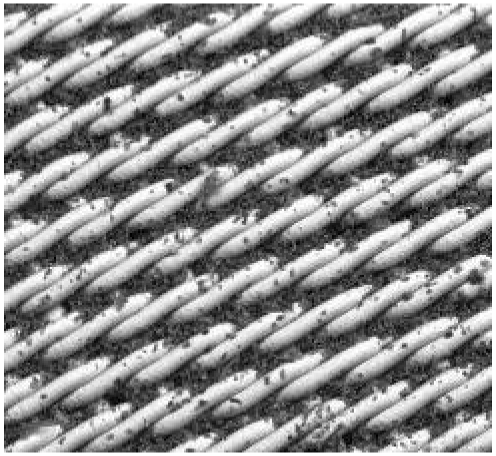
Problem: The project has shown particulate matter accumulates on the O_3 sensor inlet mesh over time reducing flow and sensitivity.

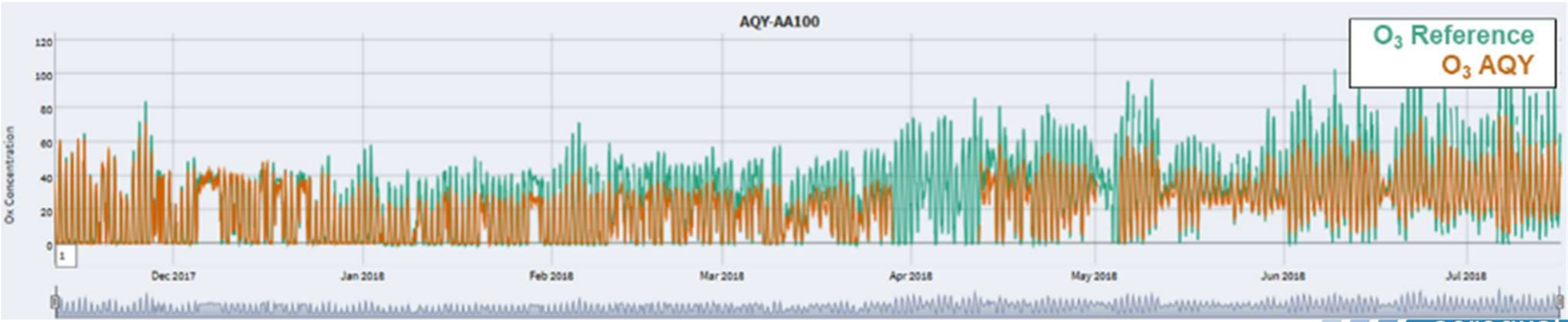
O3 sensor inlet

mesh at start



mesh after 6 months

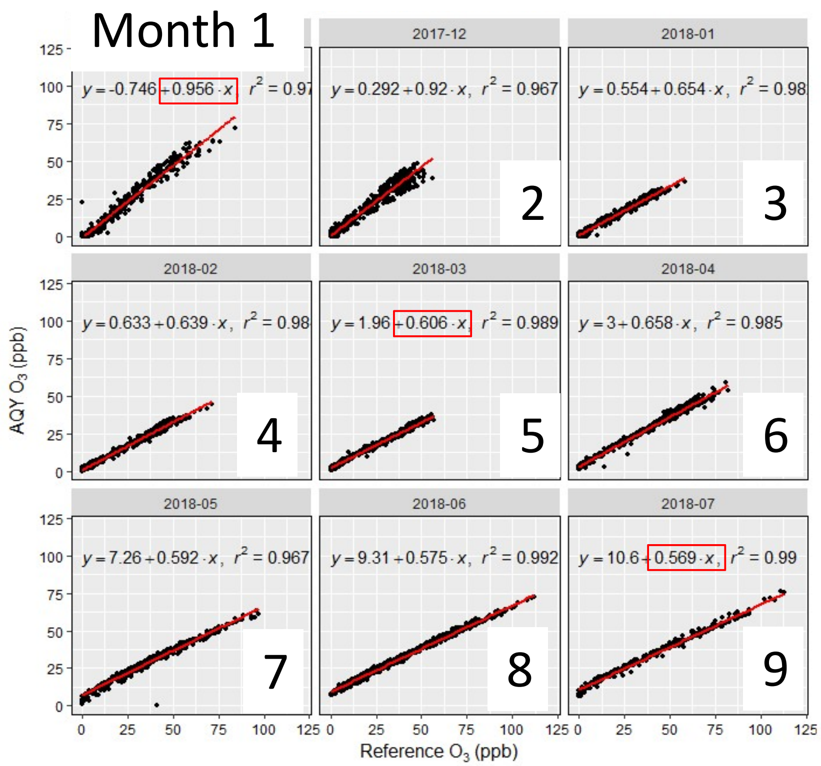




Solution: O_3 sensor flow correction

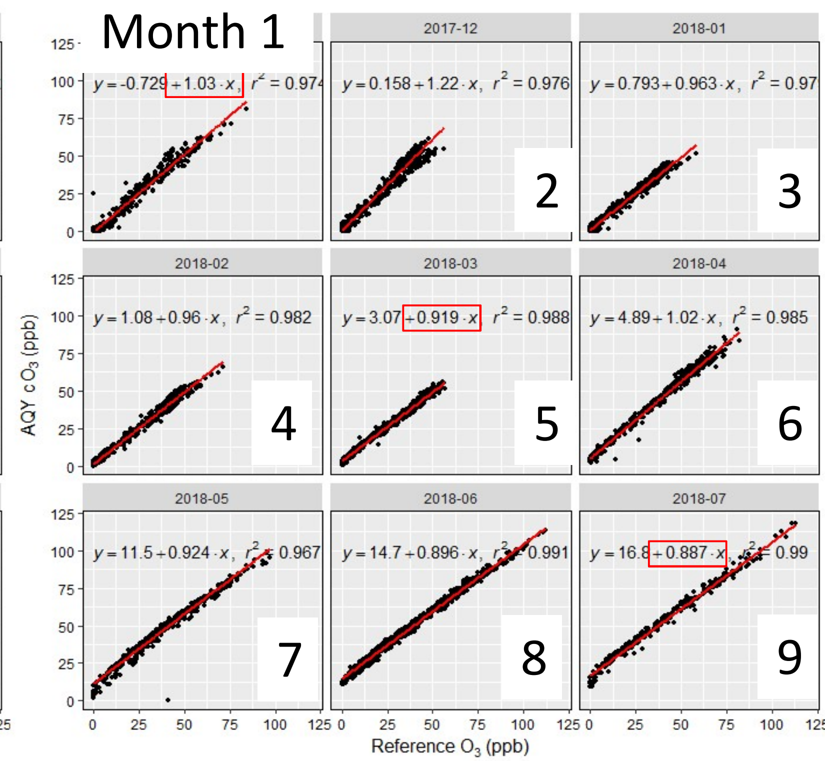
Measure O_3 sensor air flow and apply to O_3 slope. The graphs below show the effect is to stabilise drift and extend calibration interval 2 months to ~ 6 months.

O3 sensor vs FEM



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

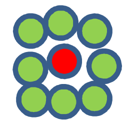
Flow corrected O3 sensor vs FEM

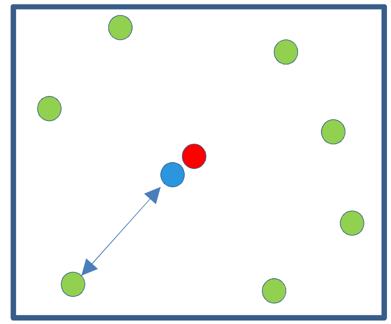


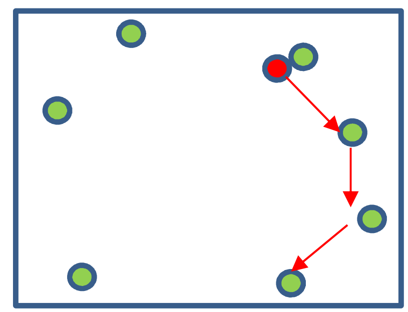
Sensor vs FEM slope more stable. Slope = 0.89 at 9 months.

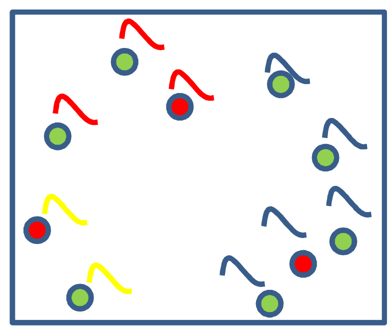
Field calibration

- **Co-location with FEM:** viable for short term projects.
- **Transfer standard:** sensor standard moves between FEM station and network nodes.
- **Mobile FEM standard:** FEM standard visits network nodes for a period of time.
- **Network calibration:** match the sensor distribution to the distribution of a valid reference proxy.
- **Satellite calibration:** future potential. NASA, EPA missions Discover-AQ, KORUS contributing to understanding.



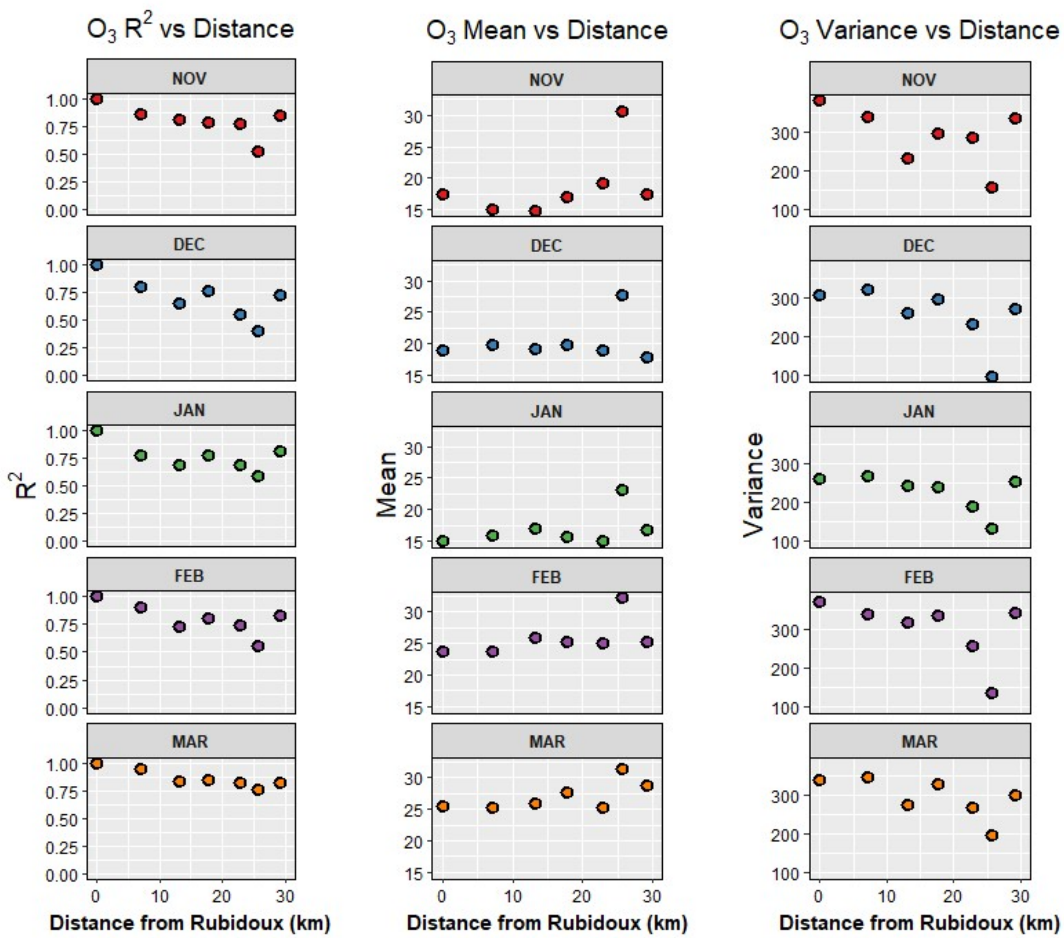






Regulatory monitor O_3 statistics – how well do they predict each other ?

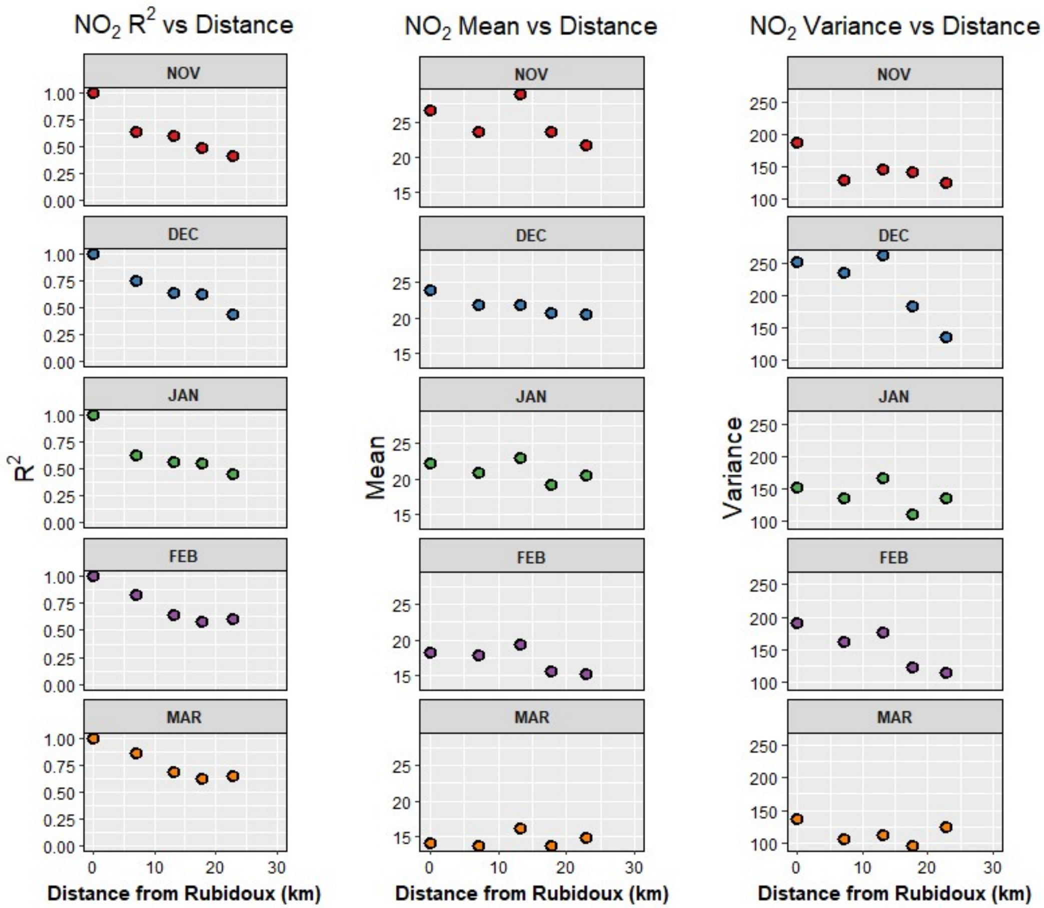
r2 defined by Rubidoux site vs others



- r2 correlations drop to 0.75 over 10-15 km
- mean looks more uniform (apart from site at 25 km)
- variance looks uniform for some months (apart from from site 25 km)

Regulatory monitor NO_2 statistics – how well do they predict each other ?

r2 defined by Rubidoux site vs others



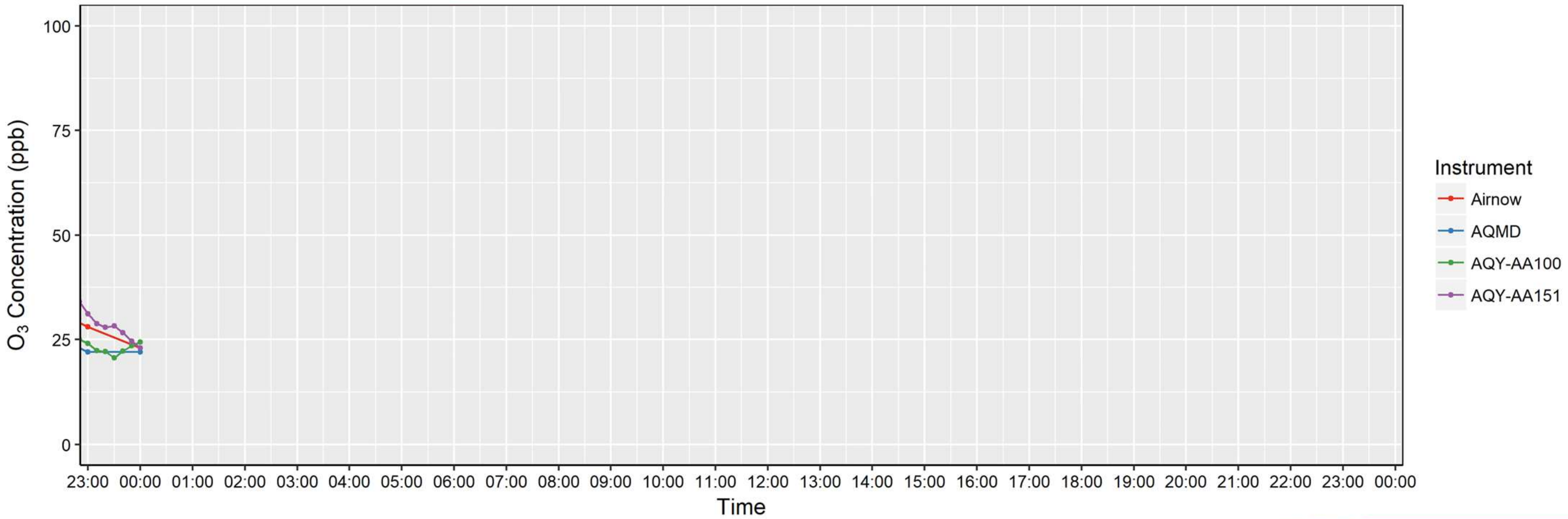
- r2 correlations drop faster than O3 r2 <0.75 beyond 5 km
- mean appears more uniform
- variance looks uniform for some months

AQY temporal information

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

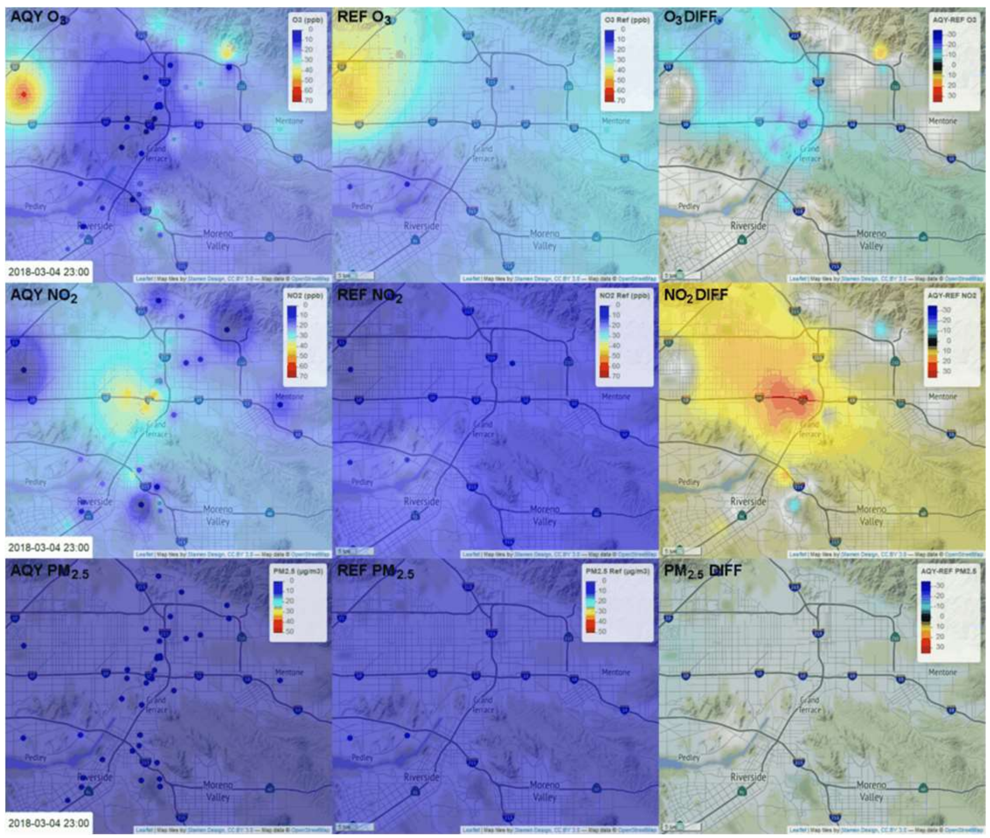
Comparison of real-time data from

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



AQY spatial information

- Sensor map shows higher granularity than regional stations
- Elevated NO_2 and O_3 titration along freeways
- Demonstrate the complex transport and dispersion of pollutants
- $PM_{2.5}$ relatively homogeneous across area



Future activities

- Operationalise the network calibration methodology
- EPA CRADA community monitoring projects in Kansas City and Denver.
- ppb VOC sensor in development and test
- ASTM working group established to develop a test method for evaluating air sensors. (*1st draft completed*) and keen to discuss with other sensor vendors.

ASTM INTERNATIONAL

WK64899 - Performance Evaluation of Ambient Air Quality Sensors and Other Sensor-based Instruments

Collaboration Area | Drafts | Polls | Discussions | Files

» Overview | Members | Email Collaboration Area Members | History | Edit Collaboration Area | Schedule Online Meeting

Conclusions

- Gas sensors now exist to measure CO, NO_2 and O_3 with sufficient sensitivity for ambient applications.
- Sensor drift and selectivity remain challenging and calibration methodologies appropriate for applications still need to be developed and demonstrated for long term networks.
- Low cost sensors can deliver unique air quality information and insights.

Acknowledgements

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South Coast AQMD

THE UNIVERSITY OF AUCKLAND Te Whare Wānanga o Tāmaki Makaurau NEW ZEALAND