

Evaluating low cost chemical sensors for air pollution measurement

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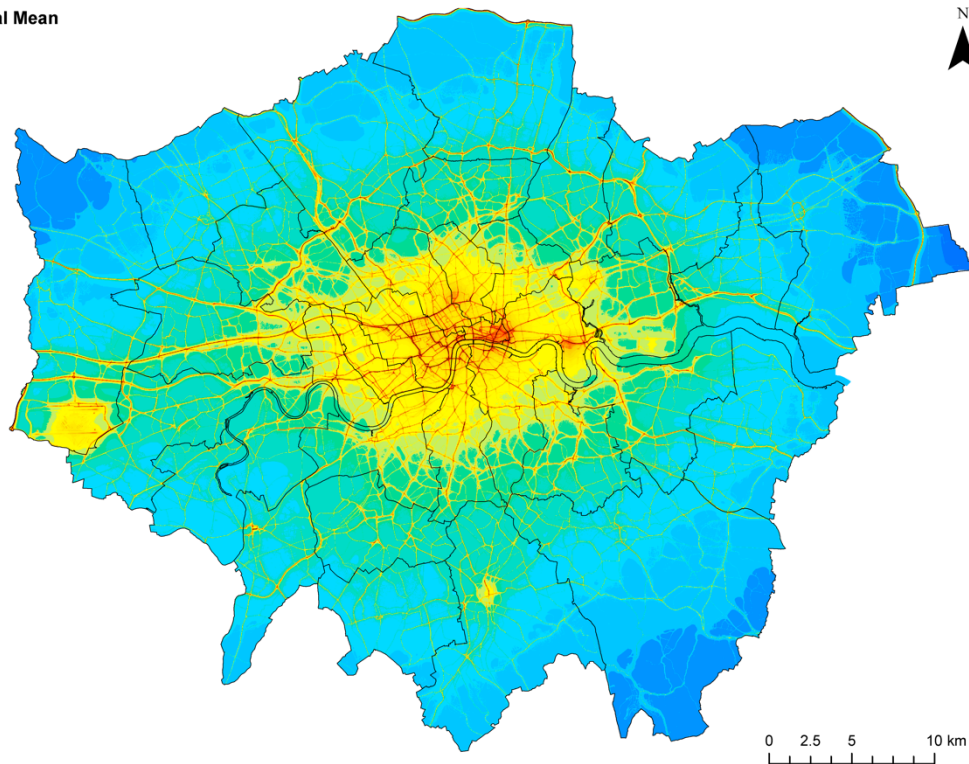
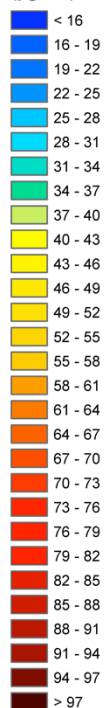
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Based on Lewis *et al.*, *Faraday Discuss.* **2015**, DOI: 10.1039/C5FD00201J

Sensors – a revolution in air pollution measurement?



2010 NO₂ Annual Mean
($\mu\text{g m}^{-3}$)



- Current approach offers high quality measurements but poor spatial coverage.
- Distributed sensors could greatly improve coverage – personal exposure.
- Relies on assumption that the sensor data is fit for purpose.

Some of the hype.....

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Welcome to your preview of The Times

Air pollution monitors fitted to schools



Ben Webster
Published at 9:38PM, September 26 2014

The sensors are being installed by Change London, a non-profit

The New York Times

Experimenting at Home With Air Quality Monitors

APRIL 15, 2015



In Hong Kong, the dense population is exposed to high levels of vehicle exhaust.
Philippe Lopez/Agence France-Press — Getty Images

Green Column
By KATE GALBRAITH

Two years ago, when Thomas Talhelm was a Fulbright scholar in Beijing, he built his own air purifier after growing concerned about the city's notorious pollution. To test his handiwork, he spent about \$260 for a portable device that counts tiny particles in the air.

theguardian

Lord Drayson takes on UK air pollution crisis with new smart sensor

CleanSpace service uses shared data from personal air quality sensors to create network of pollution hotspots



In September, Drayson will launch a personal air quality sensor that he hopes will help people avoid the most polluted routes and add to pressure on local and central government to act on the problem. Photograph: REX shutterstock

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Volume 93 Issue 39 | p. 8 | News of The Week
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Googling Air Pollution

Sensors: Tech companies and researchers team up to map air quality

By Matt Davenport

Department: Science & Technology
News Channels: Analytical SCENE, Environmental SCENE
Keywords: Google, Aclima, sensors, air pollution, air quality

[*]Enlarge



Mapping air quality with hire bike sensors

AirPublic proposes to put sensors on London's rental bikes so as to fill in the gaps in air quality sensor networks.

By Jeremy Green | Jul 07, 2015 | MachinaTion

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A project to mount air quality sensors on Transport for London's (TfL) hire bikes has been announced. The sensors will be used to provide real-time data on air quality. The event was organised by AirPublic.



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the Heathrow: Democratising air data to meet local needs

London's air pollution levels recently breach EU limits

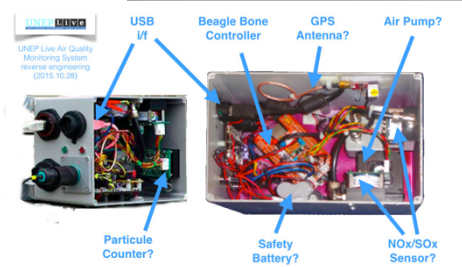


- About
- Background
- About the data
- Methodology

Breathe Heathrow uses air quality sensors to help residents understand how the airport affects their area, bringing more data into the hands of communities to address local needs

A crowded marketplace

• Air Quality Tester function
 (Excellent / Good / Moderate / Bad)
 by collecting indoor air quality levels



What is in the box?

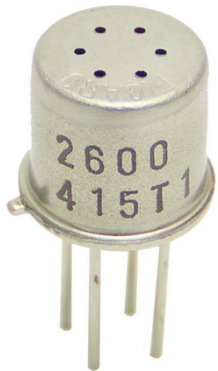
sensor

/ˈsɛnsə/ 

noun

noun: **sensor**; plural noun: **sensors**

a device which detects or measures a physical property and records, indicates, or otherwise responds to it.



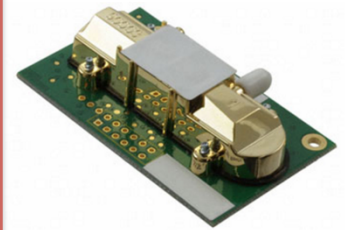
Metal oxide
~ £5
~ 1960



Electrochemical
/ voltammetric
~ £50
~ 1980



Photochemical
~ £100
~ 1990



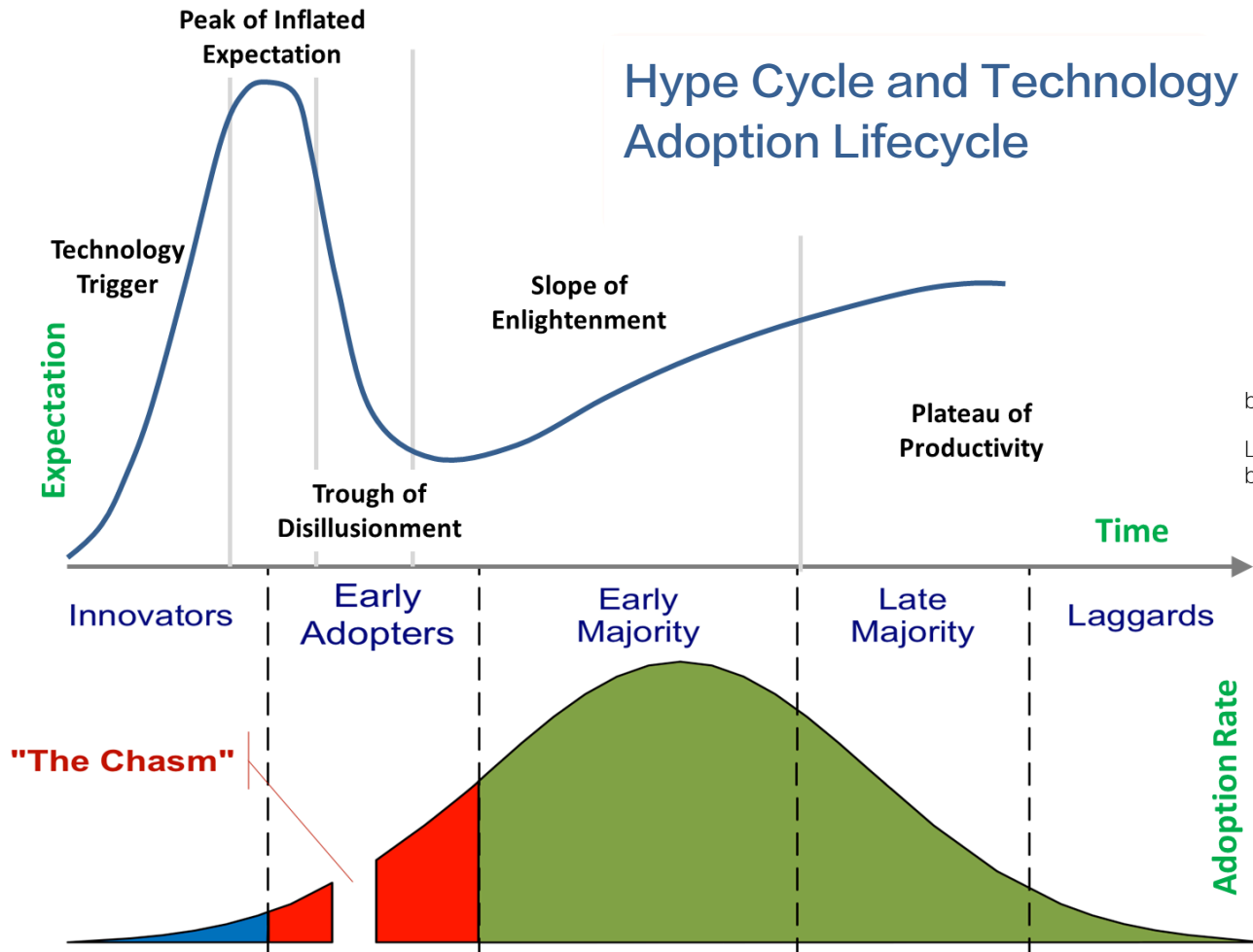
Micro-optical
> £100
~ 2000

Sensor



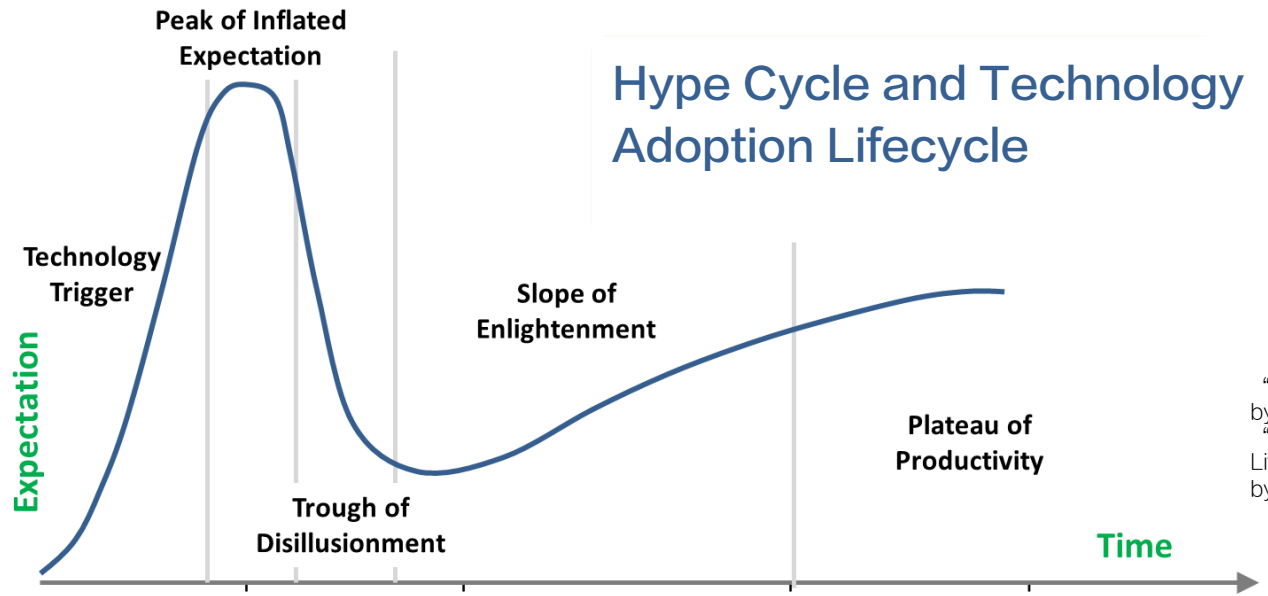
Micro-electro-mechanical
(MEMS) device

Hype Cycle and Technology Adoption Lifecycle

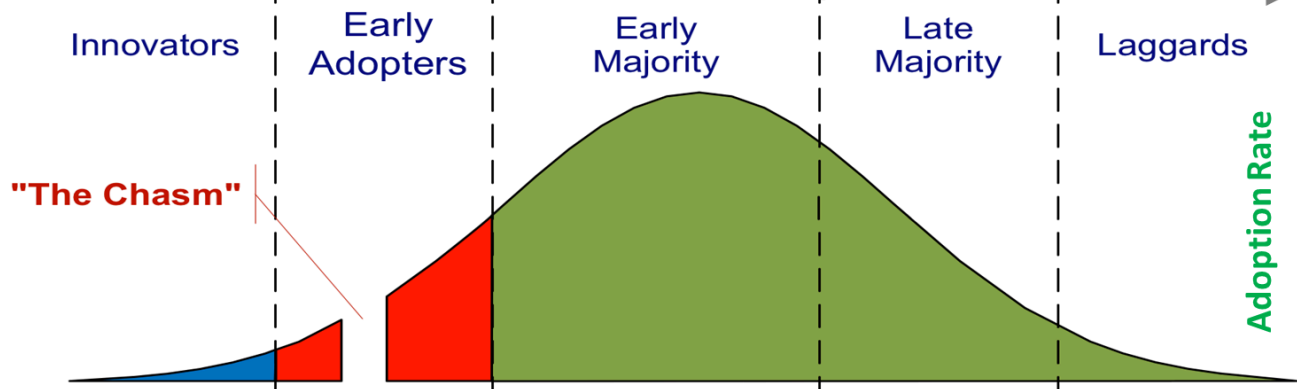


"Hype Cycle" model used by Gartner since 1995 and the "Technology Adoption Lifecycle" model popularized by Rogers and Moore

Hype Cycle and Technology Adoption Lifecycle



“Hype Cycle” model used by Gartner since 1995 and the “Technology Adoption Lifecycle” model popularized by Rogers and Moore



Traditional Model

Universities Industry

Universities Institutes

National Agencies

National Regulators

Local Regulators

“Technique” papers

“First to measure” papers

“Us too” papers

“Evaluations”

“Intercomparisons”

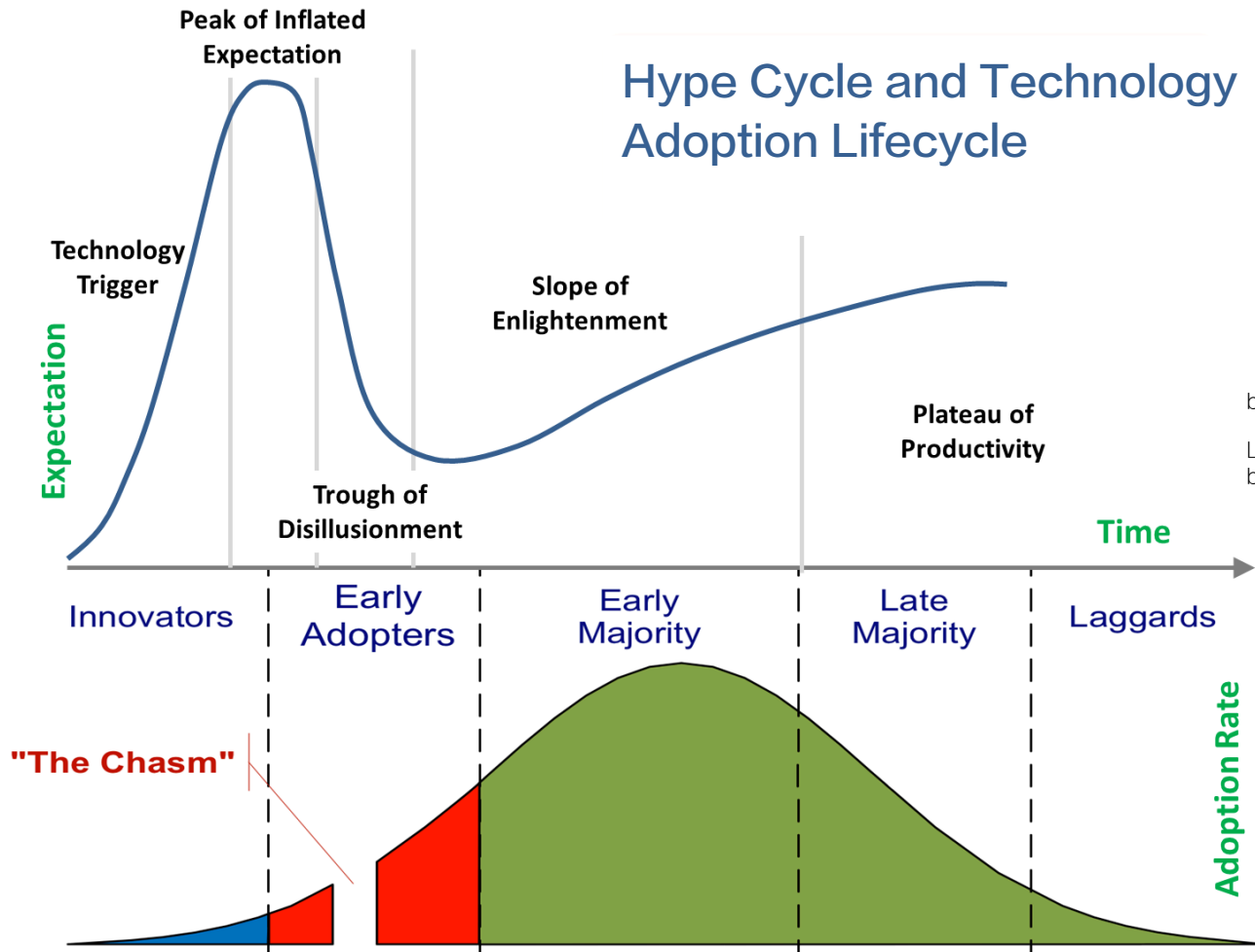
“Reference method”

“Public data”

Peer Review

Standardisation

Hype Cycle and Technology Adoption Lifecycle



"Hype Cycle" model used by Gartner since 1995 and the "Technology Adoption Lifecycle" model popularized by Rogers and Moore

Sensors Model

Media stories
 "Public data"
 "Unpublished studies"
 "Intercomparisons"
 "Technique papers"
 New science???

Promotion

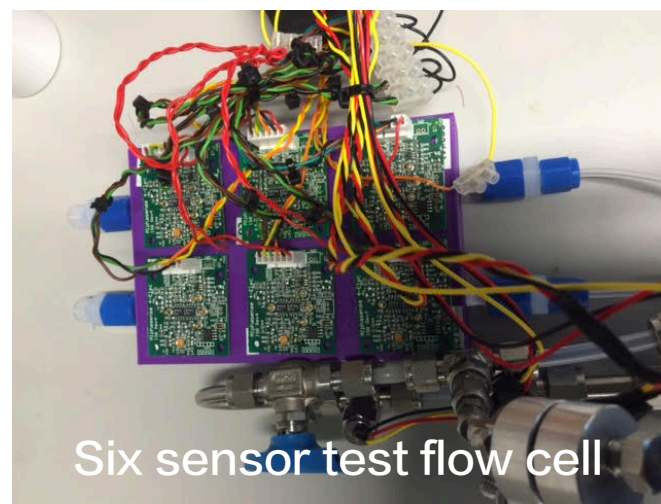
Peer review

Sensor interferences from co-pollutants

Sensor	Compound							Co-pollutants
	CO	SO ₂	NO	O ₃	NO ₂	CO ₂	H ₂	
CO - B4	0.378	-0.013	0.000	0.0200	0.032	0.000	-0.032	0.201
OX-B421	0.000	-0.016	-0.110	0.439	0.44	9.5 x 10 ⁻⁵		0.560
SO ₂ -B4	0.013	0.210	0.023	-0.014	-0.32	9.8 x 10 ⁻⁶		0.000
NO-B4	0	0.007	0.558	-0.011	-0.590	1.8 x 10 ⁻⁵		-0.303
NO ₂ -B4	0	0.004	-0.008	0	0.148	2.3 x 10 ⁻⁵		0.000

Working electrode responses (in mV ppb⁻¹ of co-pollutant) induced by the presentation of co-pollutants in zero air across five electrochemical sensors

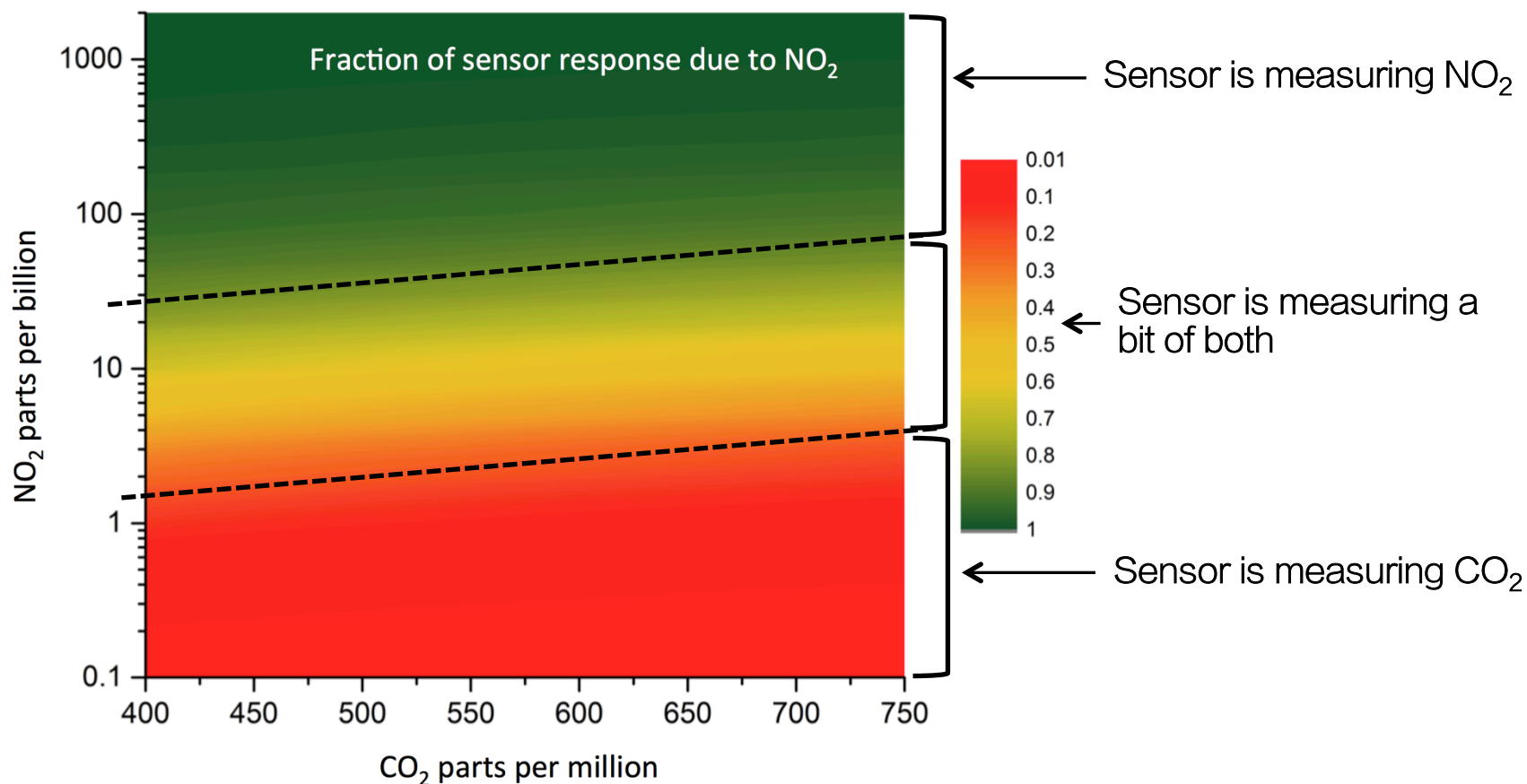
Potentially significant interference



Six sensor test flow cell

NO₂ sensor interference example

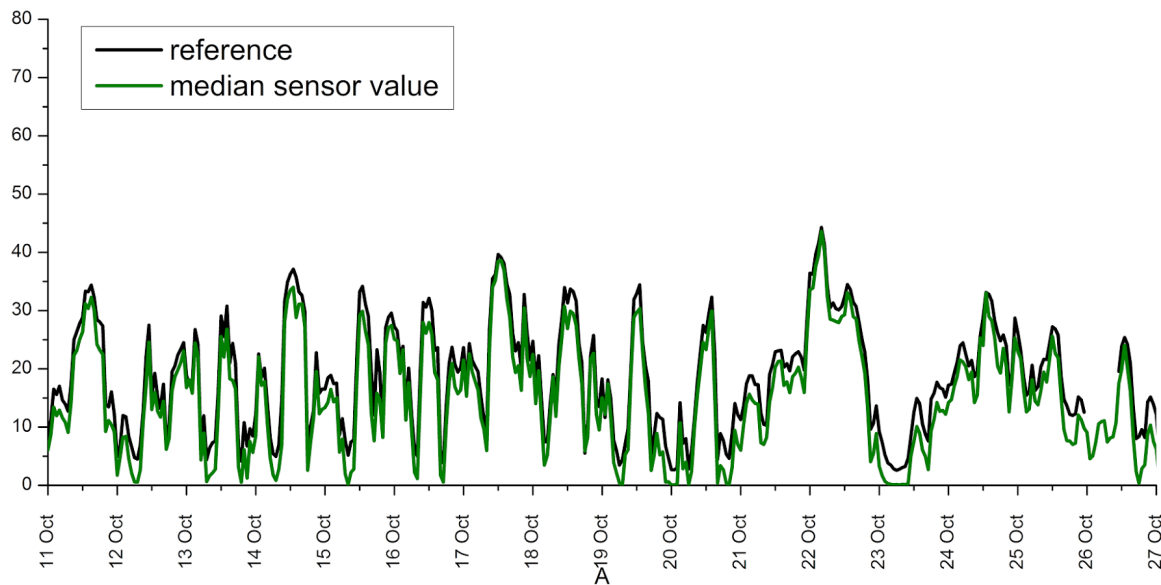
- NO₂ electrochemical sensor has a small cross sensitivity to CO₂
- But CO₂ is generally in huge excess to NO₂.
- At low [NO₂] the sensor is primarily sensing CO₂



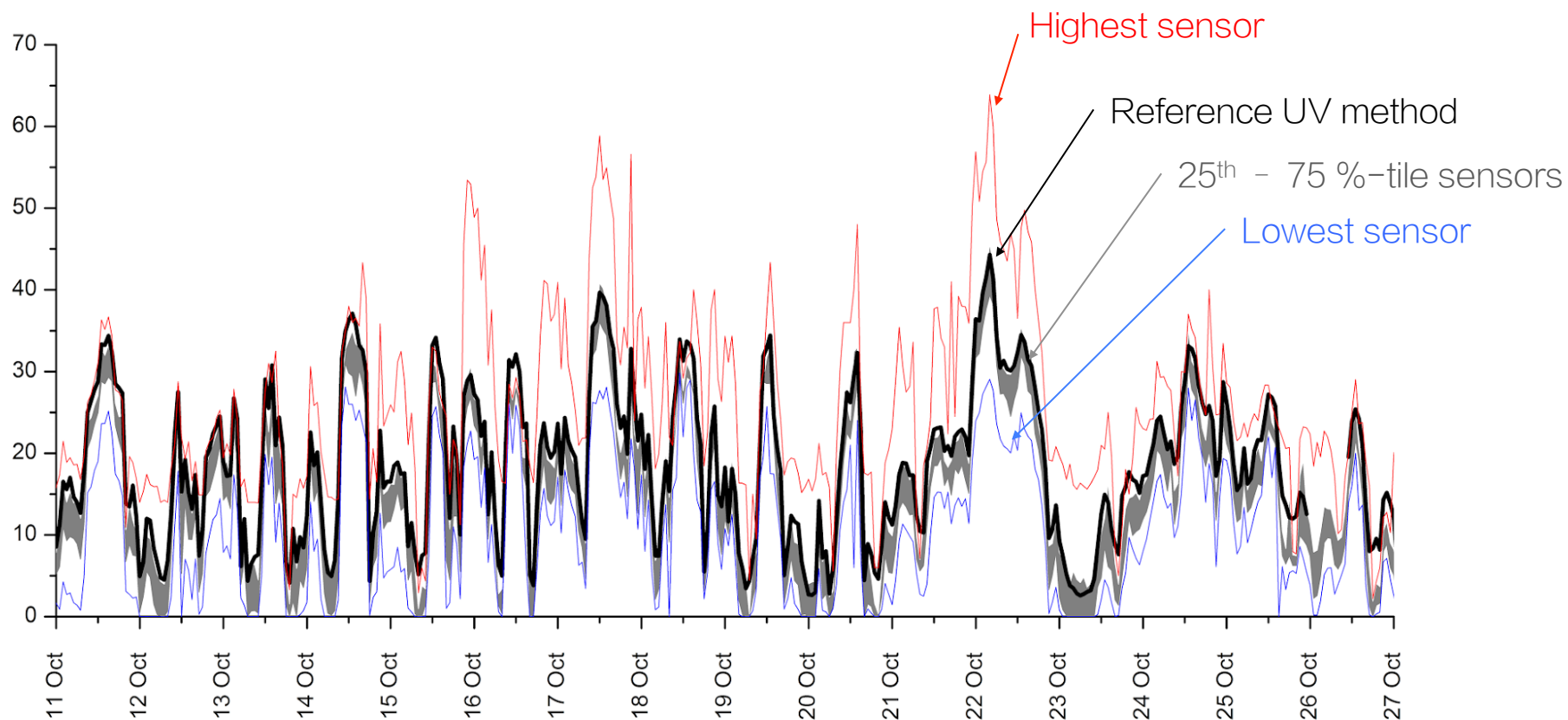
Twenty sensor intercomparison

- Reference methods used UV, Chemiluminescence, GC, TEOM-FDMS
- Devices initially calibrated to the reference value (e.g. slope applied on 11 Oct)

Ozone intercomparison - a success story?

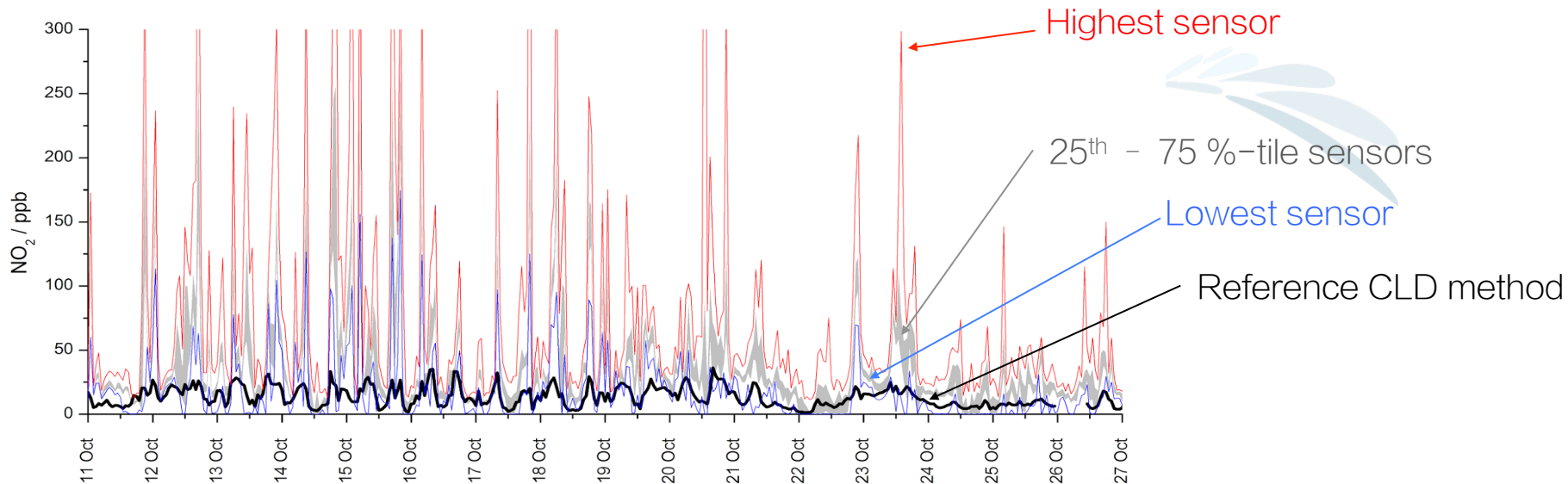


Ozone sensors in more detail

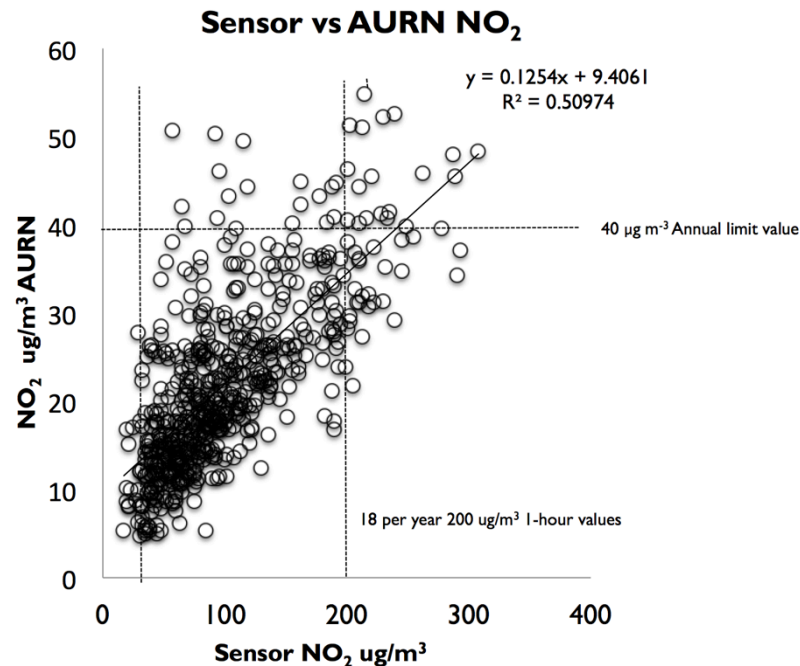


- Collective accuracy is good, but individual accuracy is poor.
- Useable for research?? Probably.
- For the public?? They are not overtly misleading, since no collective bias

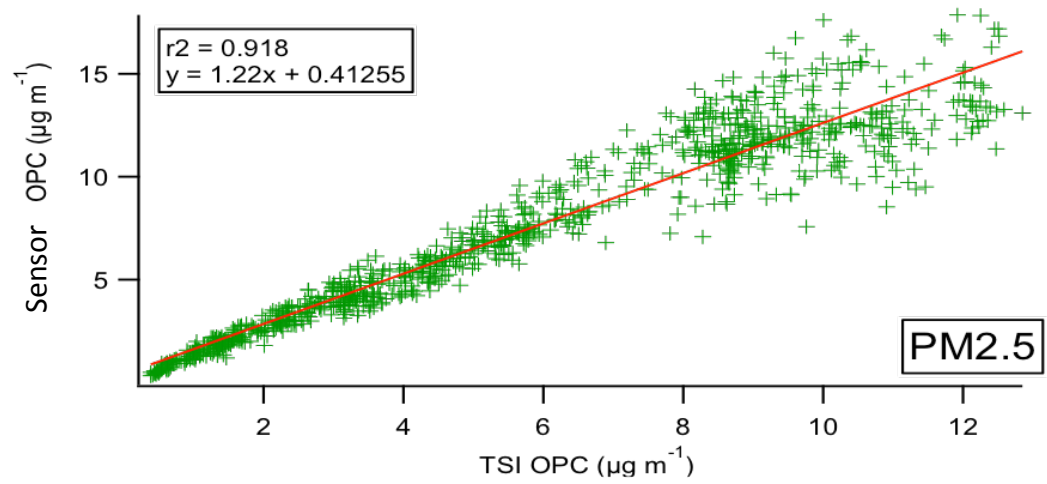
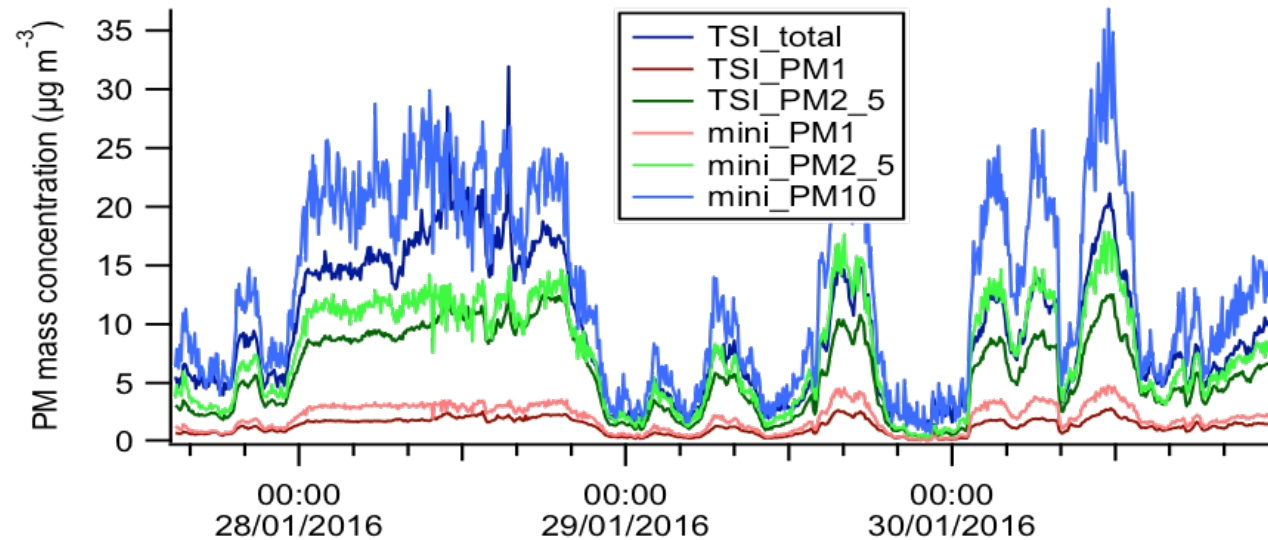
NO₂ – sensor to sensor variability



- Bias of 3.2 ± 1.7 – sensors over-measure vs. reference
- Poorer agreement on trends – some other parameter e.g. CO₂?
- Misleading public data – widespread exceedances indicated

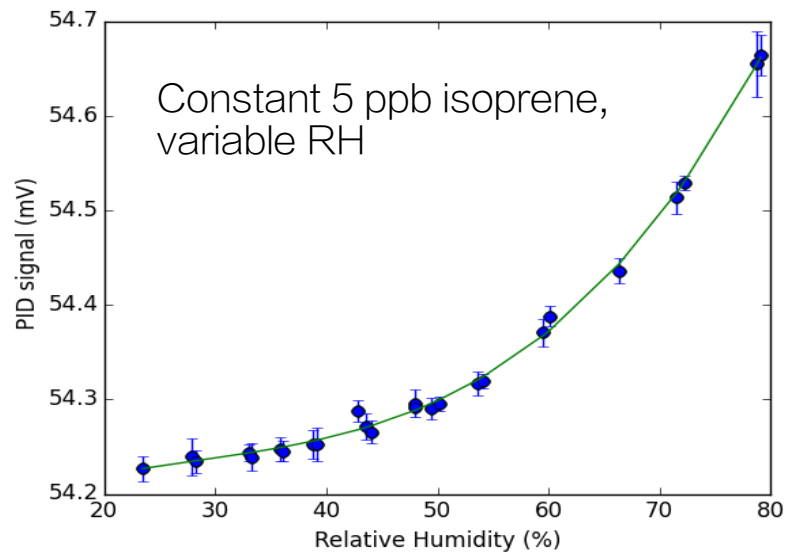


Not all sensors components are equal – e.g. PM



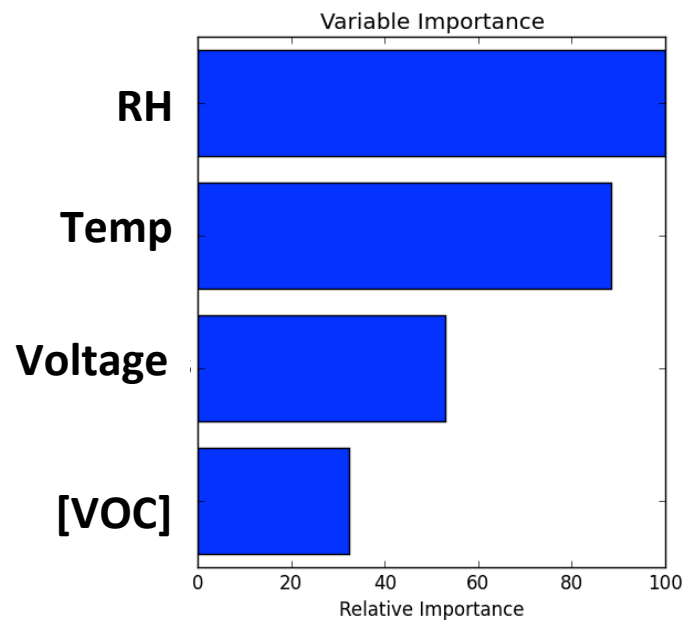
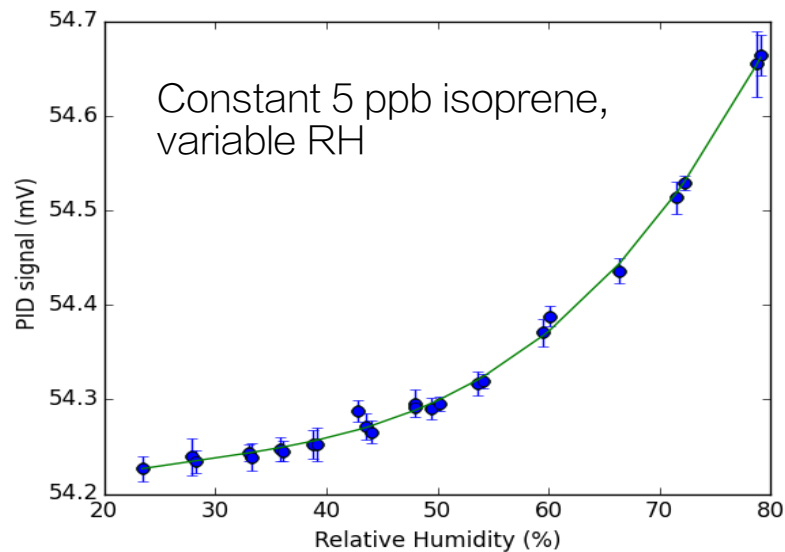
- Not obvious which sensors / technologies used in commercial units.

Can we separate the signals?

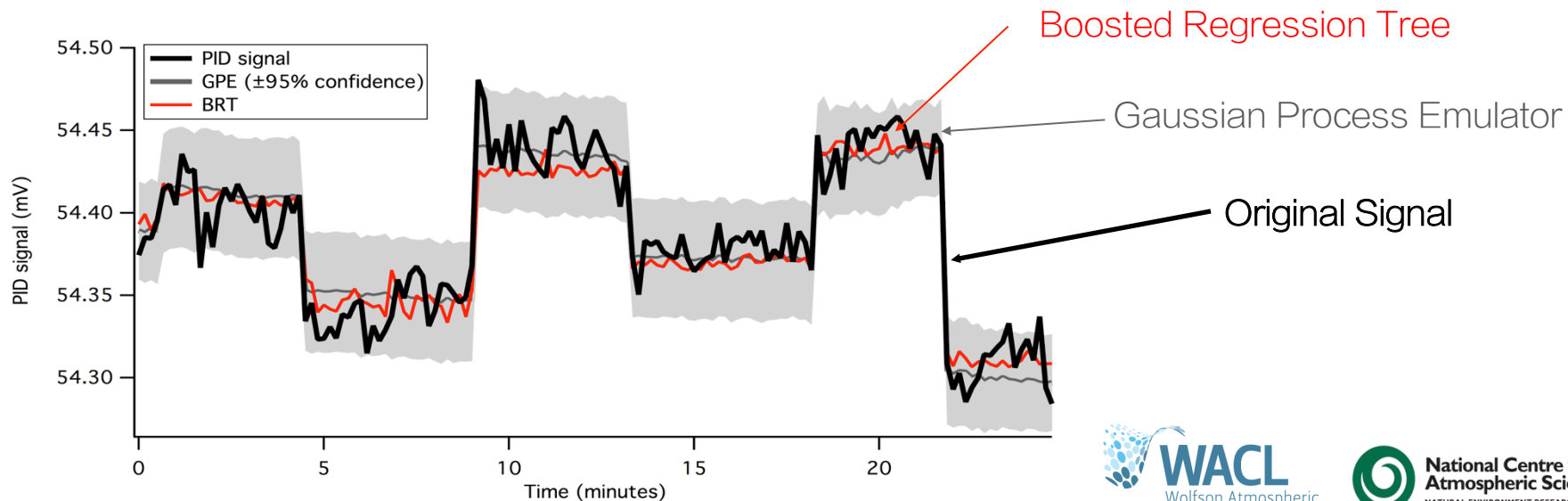


- Interferences from other variables are the key sensor weakness
- These can interact with one another in non-linear ways

Can we separate the signals?



- Interferences from other variables are the key sensor weakness
- These can interact with one another in non-linear ways



Conclusions

- Low cost sensors are an **exciting opportunity**.
- Wide range of sub-components of variable quality.
- **Publication bias**, few independent tests reported, limited academic publication.
- **Cross-interferences** from other pollutants.
- Unit – to – unit **reproducibility** can be very poor.
- Can generate misleading information - **over-reporting** is commonplace.
- ‘Miniaturized’ instruments using known methodologies look more promising, e.g. OPCs.
- Long-term stability is untested.
- Statistical methods offer considerable promise, if backed up by lab work.
- **Buyer beware!**