Evaluating low cost chemical sensors for air pollution measurement

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

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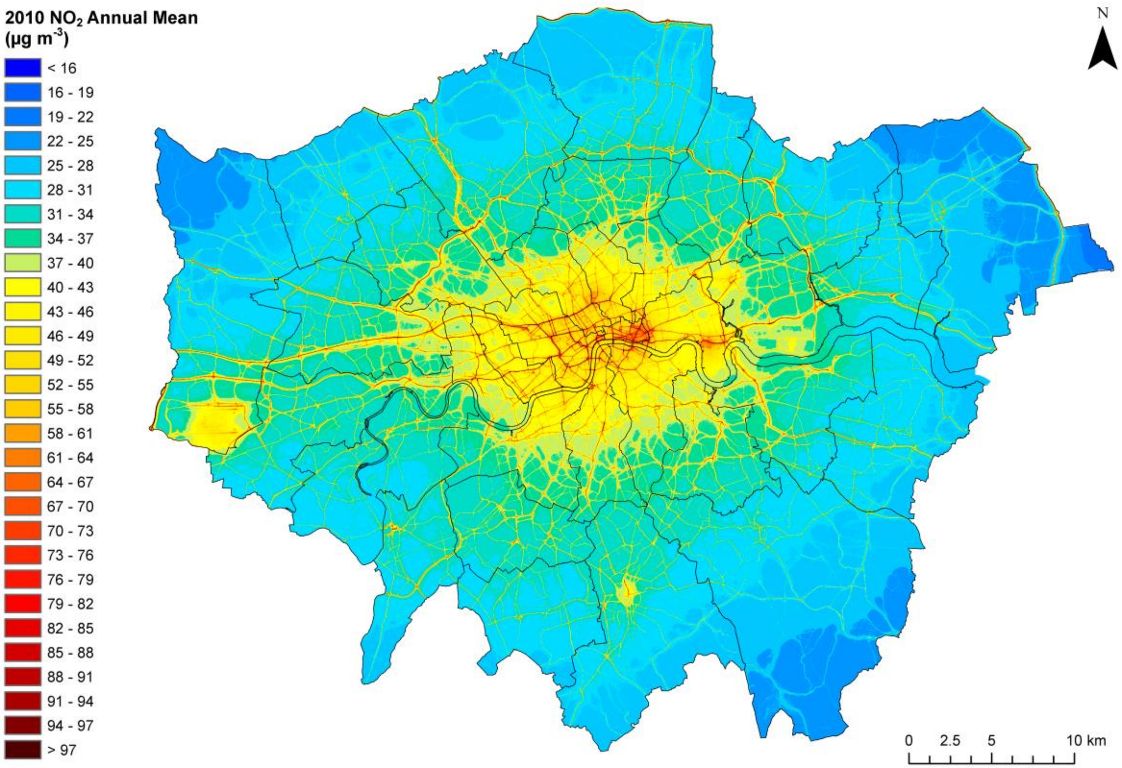
Sensors – a revolution in air pollution measurement?



- **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-Presse — 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
Issue Date: October 5, 2015 | Web Date: October 1, 2015

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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

Share

A project to mount air quality sensors on Transport for London's (TFL) hire bikes has been ... ta will be used to provide ... The event was organised

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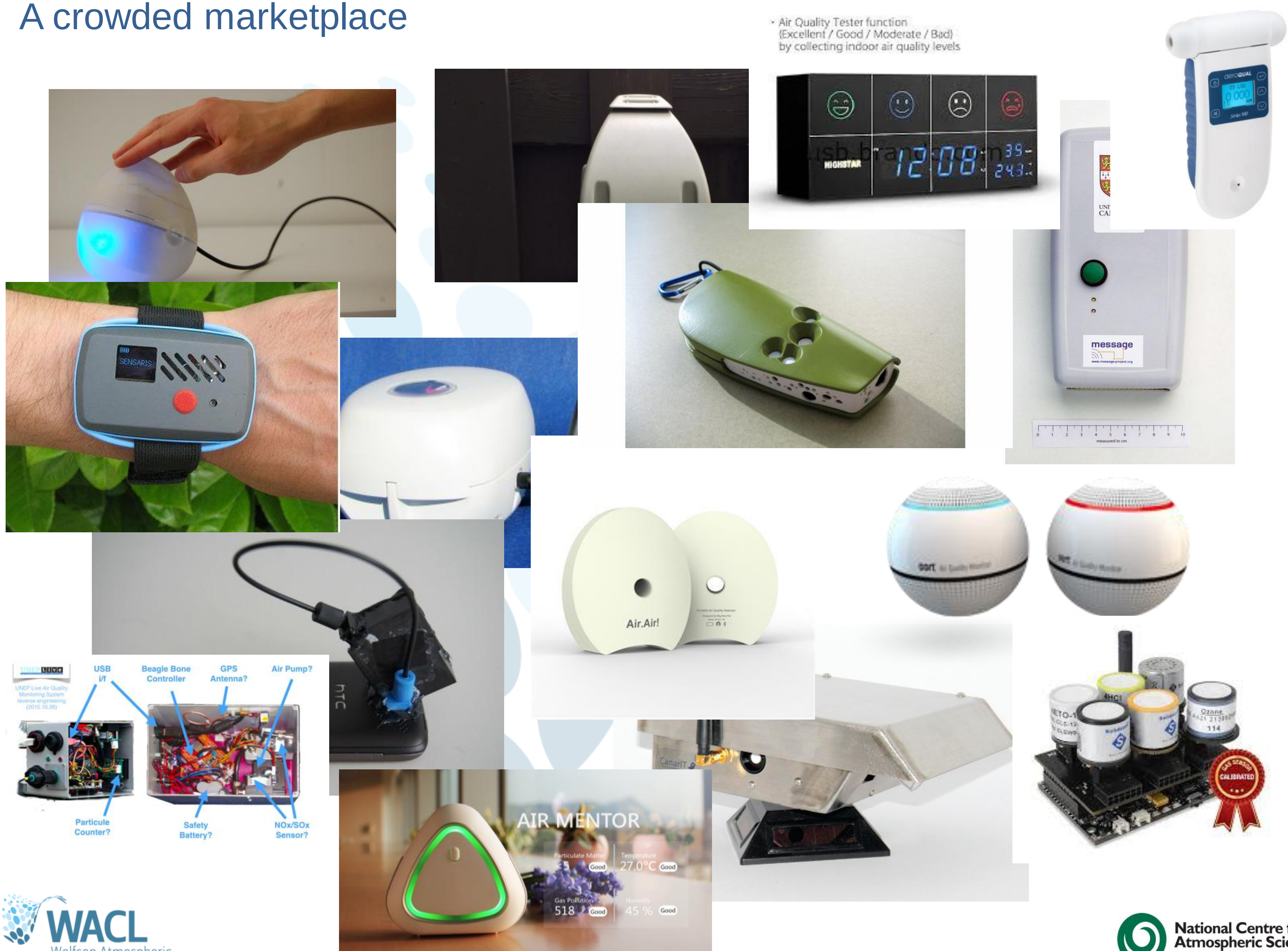
...he Heathrow: Democratising air data to meet local needs

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

About
Background
About the data
Methodology

A crowded marketplace



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What is in the box?

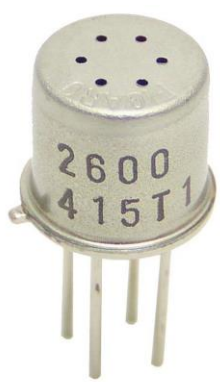
sensor

/ˈsɛnsə/

noun

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

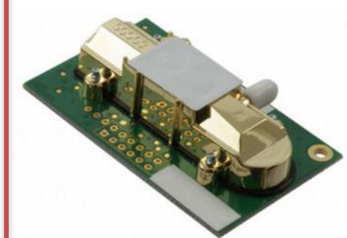
a device which detects or measures a physical property and records, indicates, or otherwise responds to it.



Metal oxide
~ £5
~ 1960

Electrochemical / voltammetric
~ £50
~ 1980

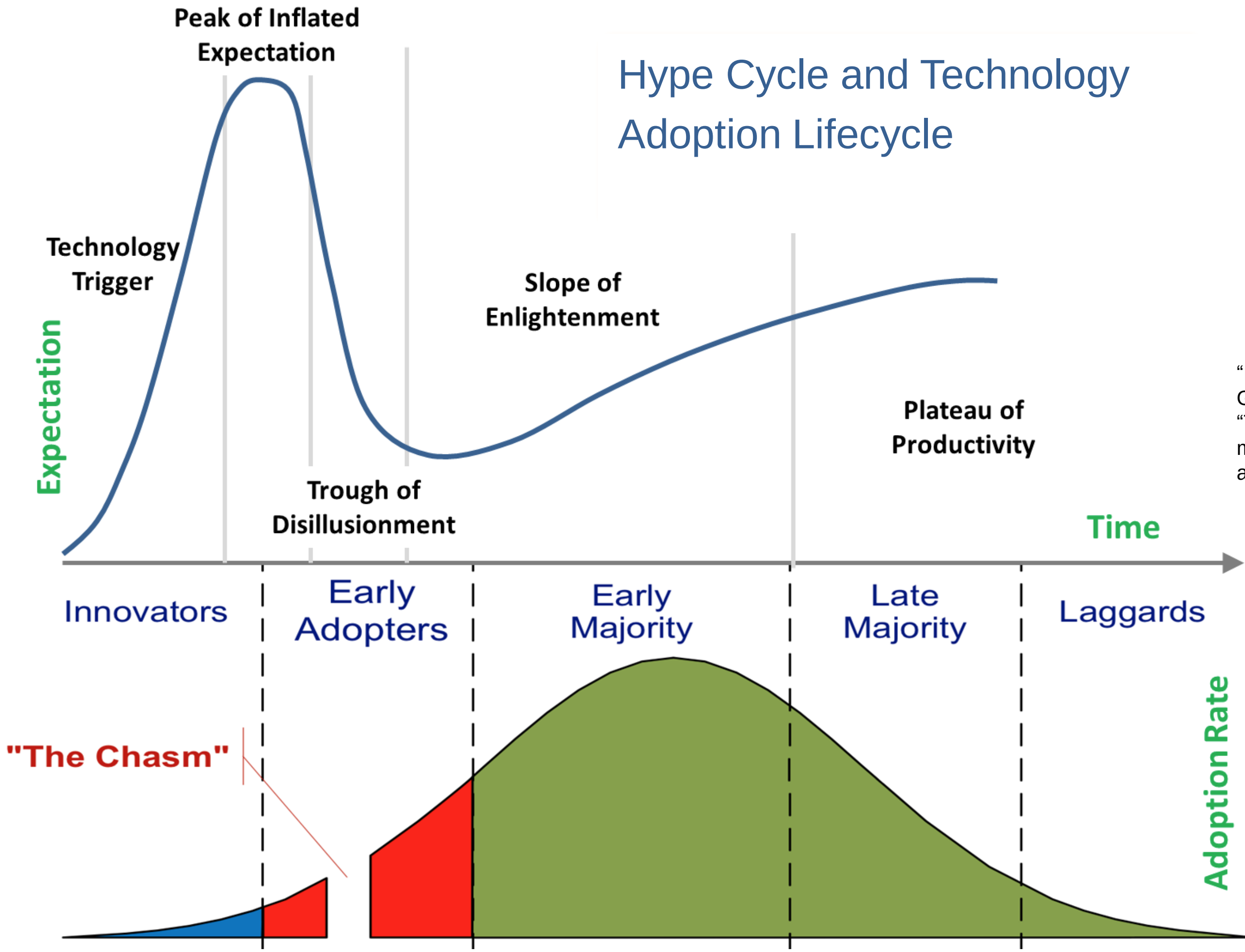
Photochemical
~ £100
~ 1990



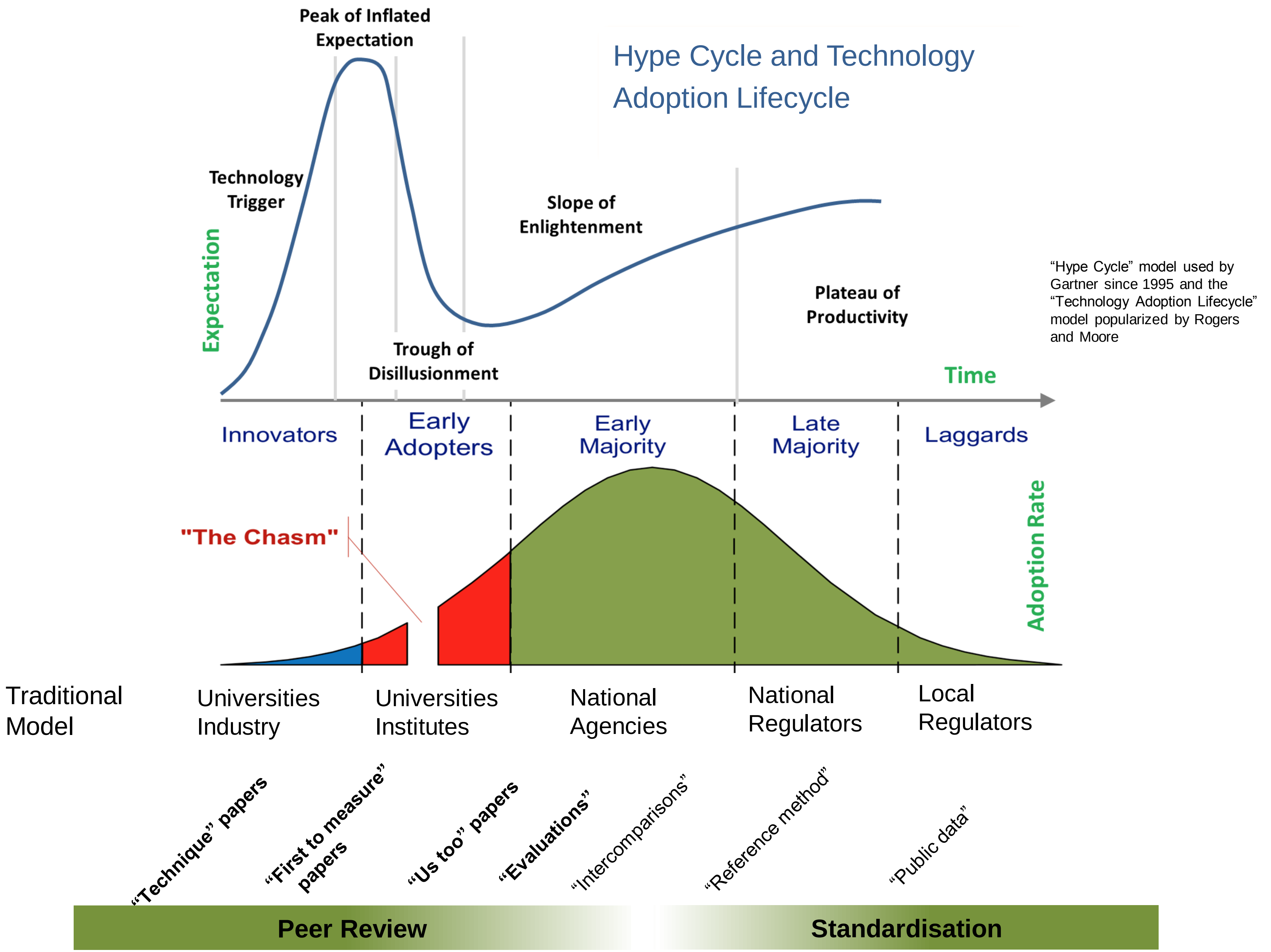
Micro-optical
> £100
~ 2000

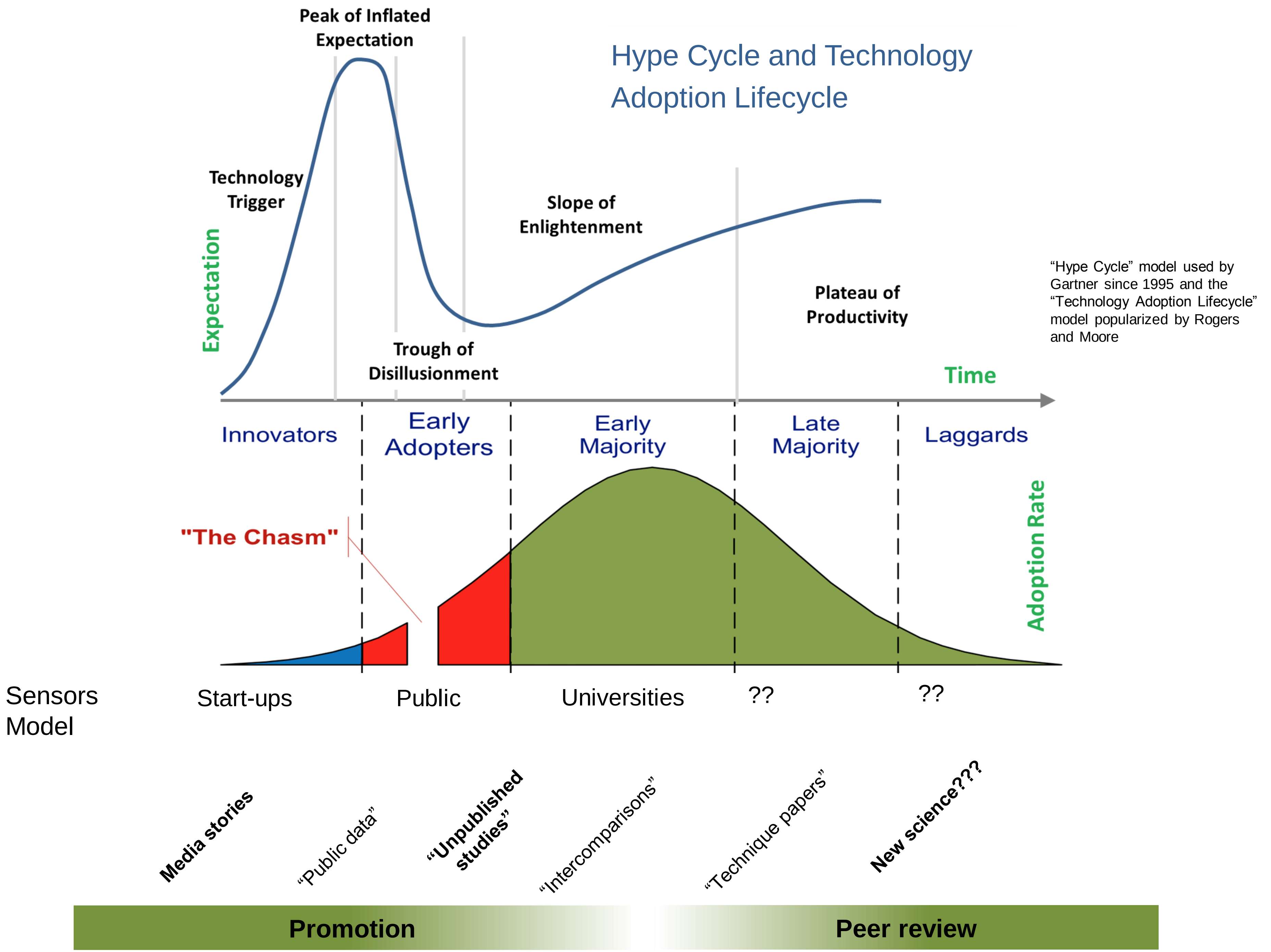
Sensor → Micro-electro-mechanical (MEMS) device

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
Peak of Inflated Expectation
Technology Trigger
Slope of Enlightenment
Trough of Disillusionment
Plateau of Productivity
Expectation
Time
"Hype Cycle" model used by Gartner since 1995 and the "Technology Adoption Lifecycle" model popularized by Rogers and Moore
Innovators
Early Adopters
Early Majority
Late Majority
Laggards
"The Chasm"
Adoption Rate
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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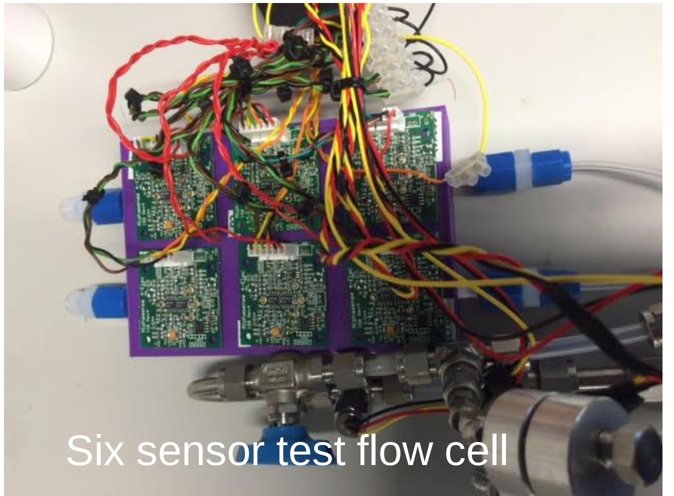
Adoption Rate
Sensors Model
Start-ups
Public
Universities
??
??
Media stories
"Public data"
"Unpublished studies"
"Intercomparisons"
"Technique papers"
New science???
Promotion
Peer review

Sensor interferences from co-pollutants

Sensor	Compound					Co-pollutants		
	CO	SO_2	NO	O_3	NO_2	CO_2	H_2	%RH [a]
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	9.5×10^{-5}		0.560
SO_2-B4	0.013	0.210	0.023	-0.014	-0.32	9.8×10^{-6}		0.000
NO-B4	0	0.007	0.558	-0.011	-0.590	1.8×10^{-5}		-0.303
NO_2-B4	0	0.004	-0.008	0	0.148	2.3×10^{-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

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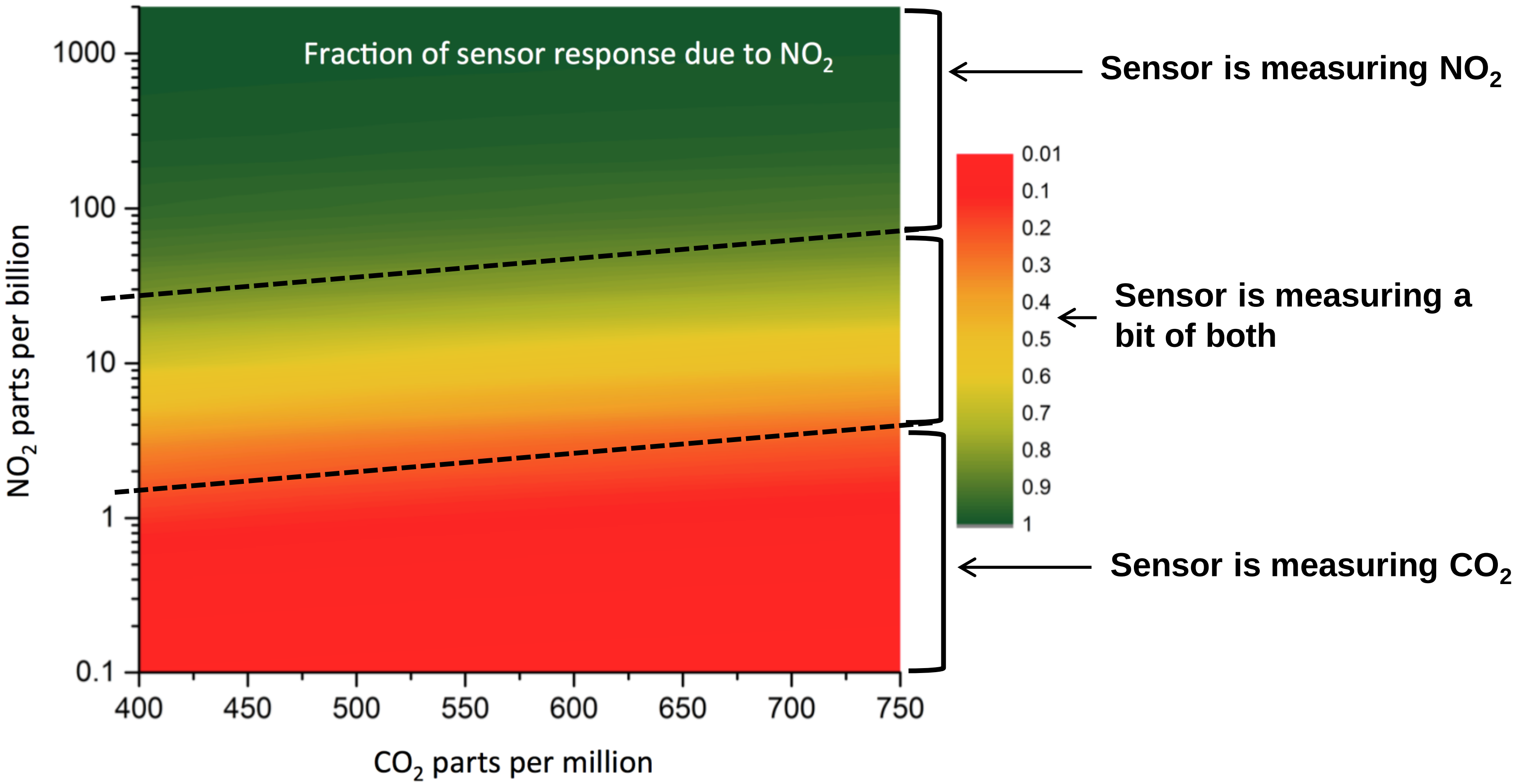
NO_2 sensor interference example

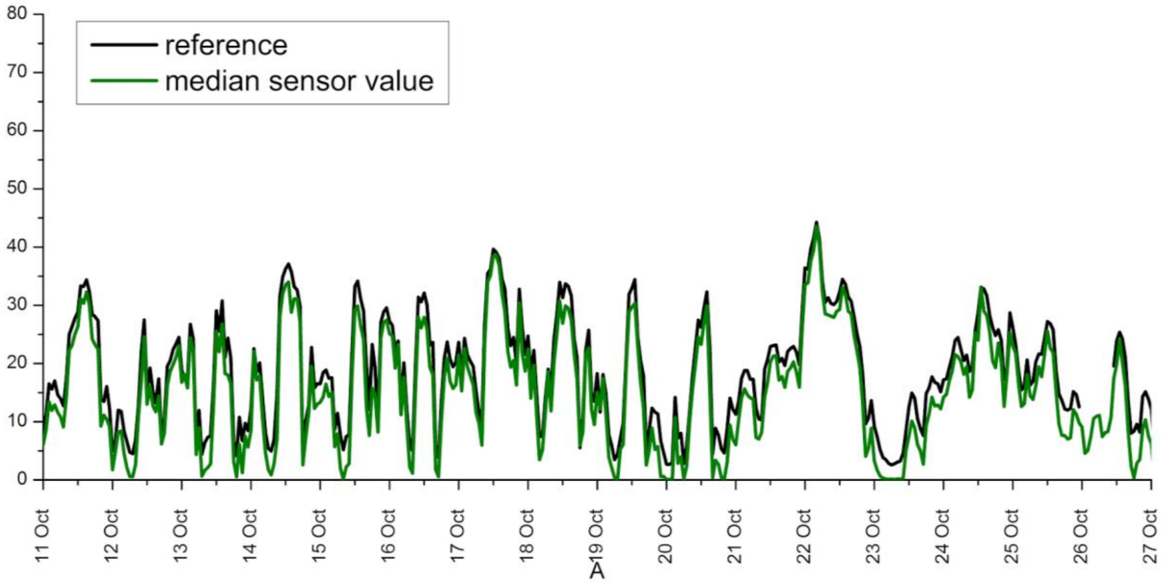
- NO_2 electrochemical sensor has a small cross sensitivity to CO_2
- But CO_2 is generally in huge excess to NO_2.
- At low [NO_2] the sensor is primarily sensing CO_2



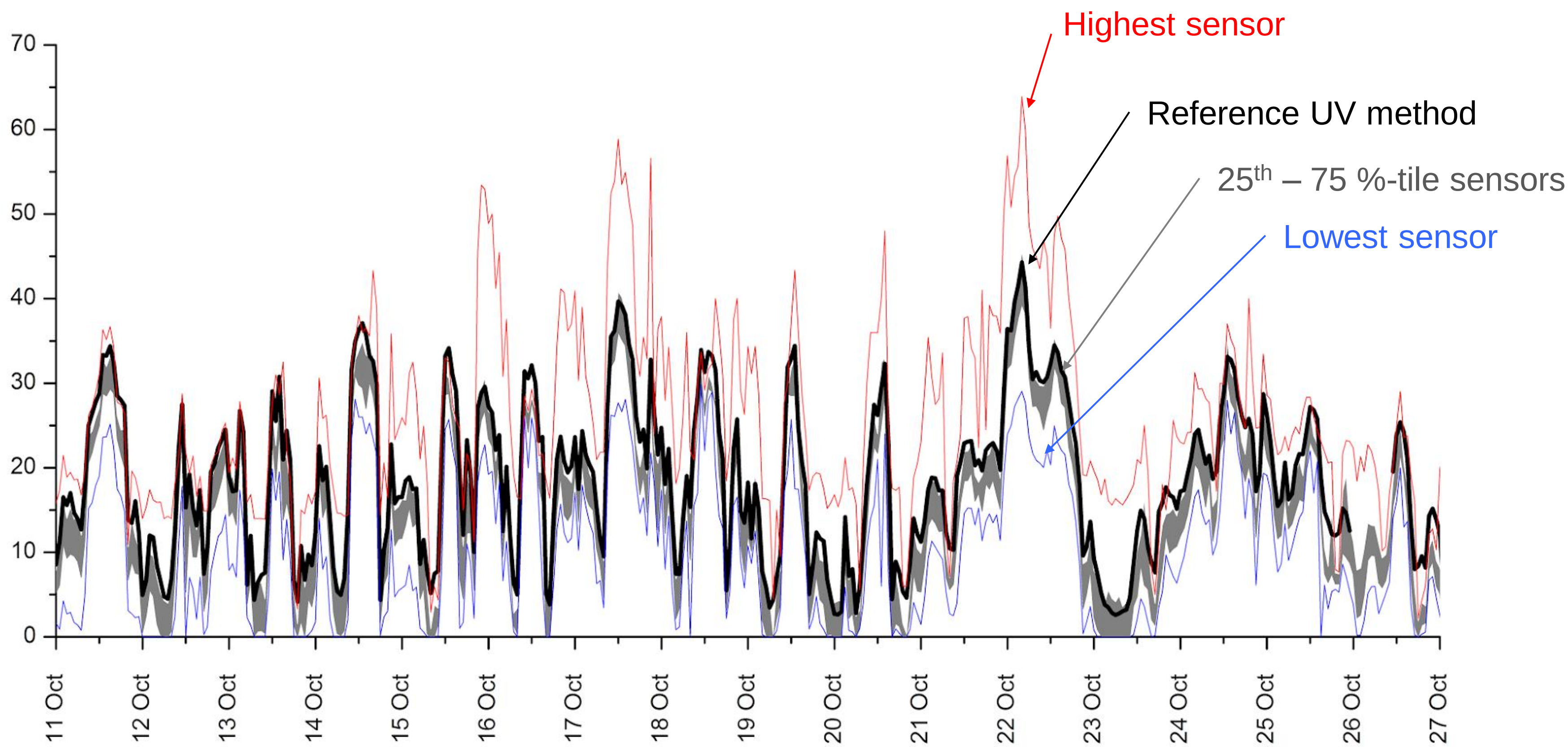
Twenty sensor intercomparison

- 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



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

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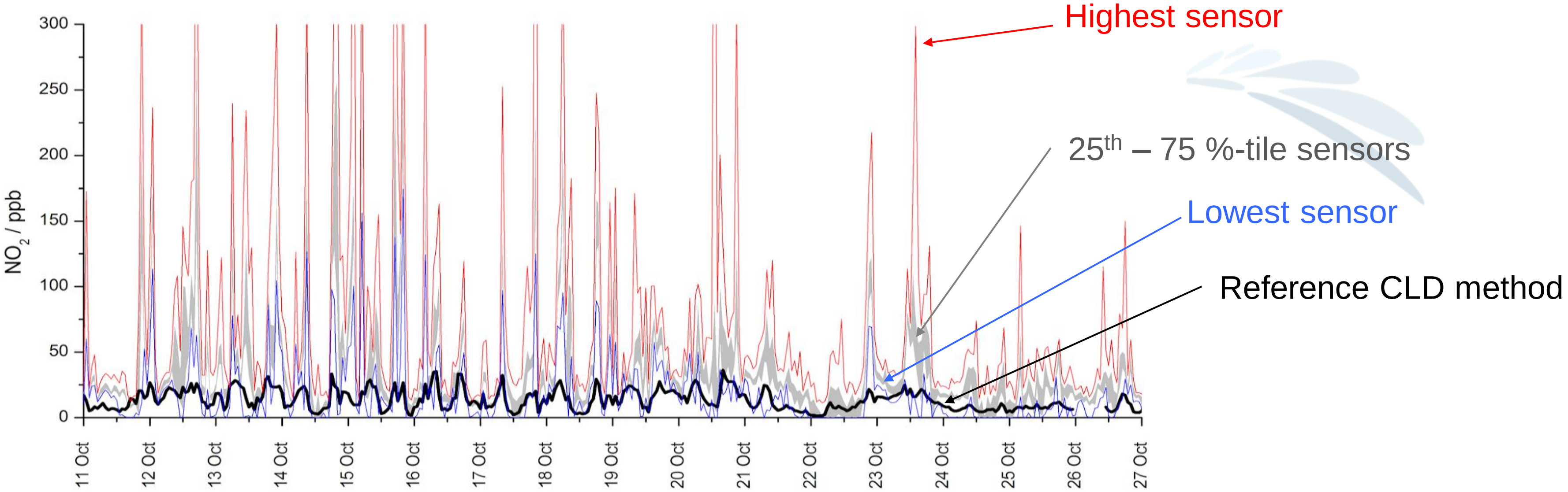
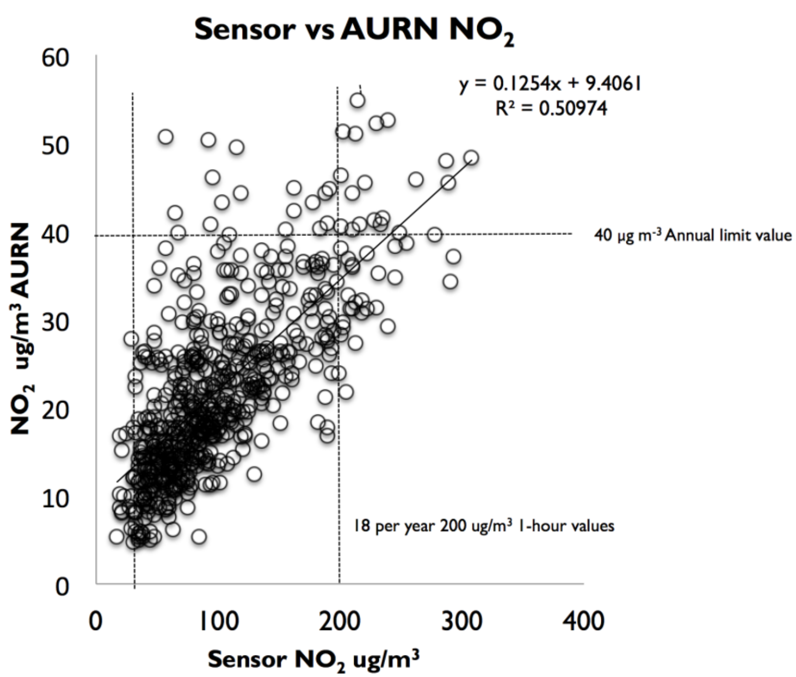
NO_2– sensor to sensor variability



- **Bias of** 3.2 ± 1.7 – sensors over-measure vs. reference
- Poorer agreement on trends –some other parameter e.g. CO_2?
- Misleading public data – widespread exceedances indicated



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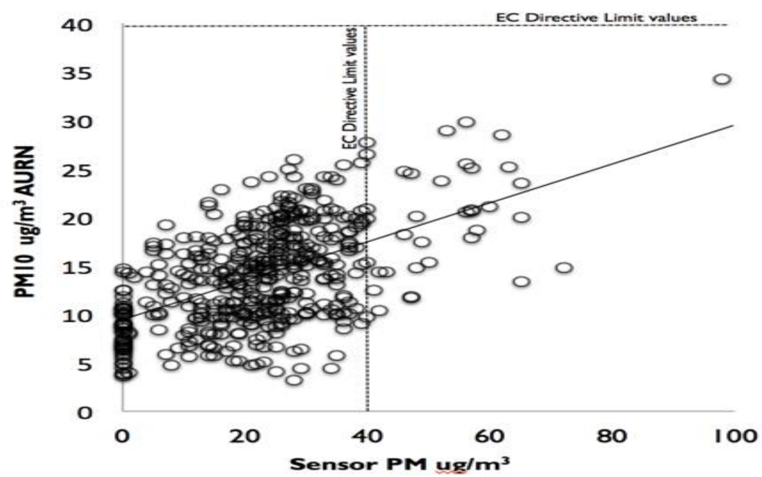
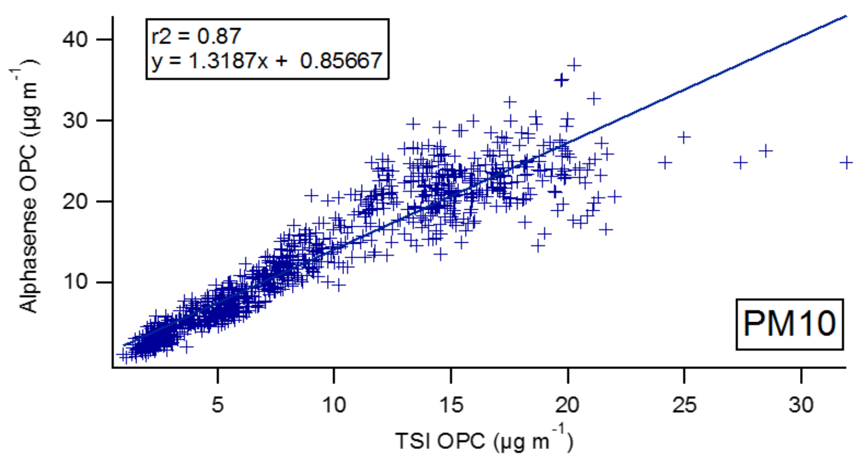
Not all sensors components are equal – e.g. PM

- **Large observed variability in sensor performance.**

PM10 sensor 1



PM10 sensor 2



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

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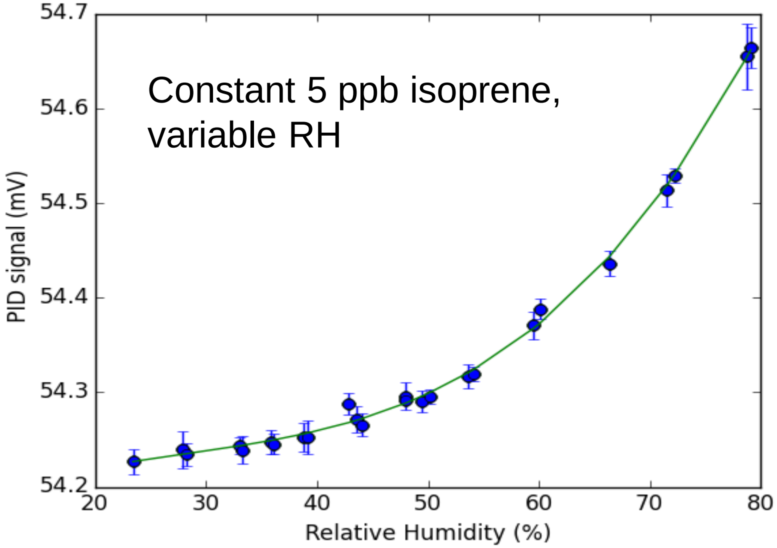
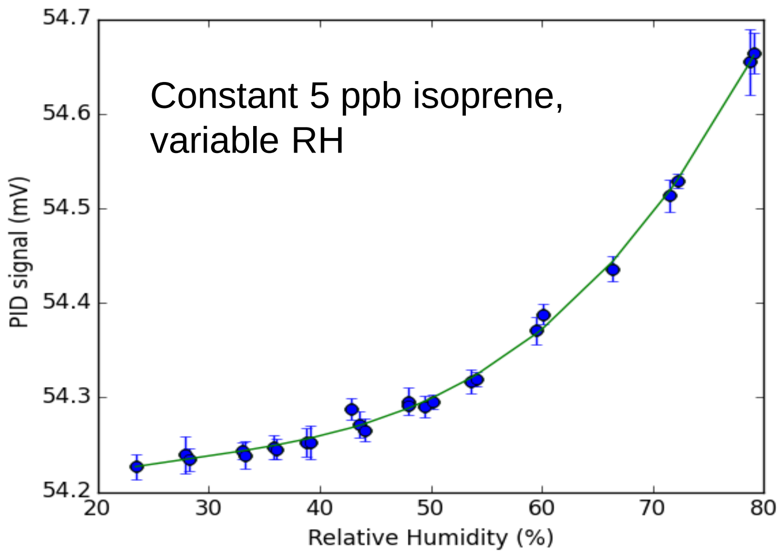
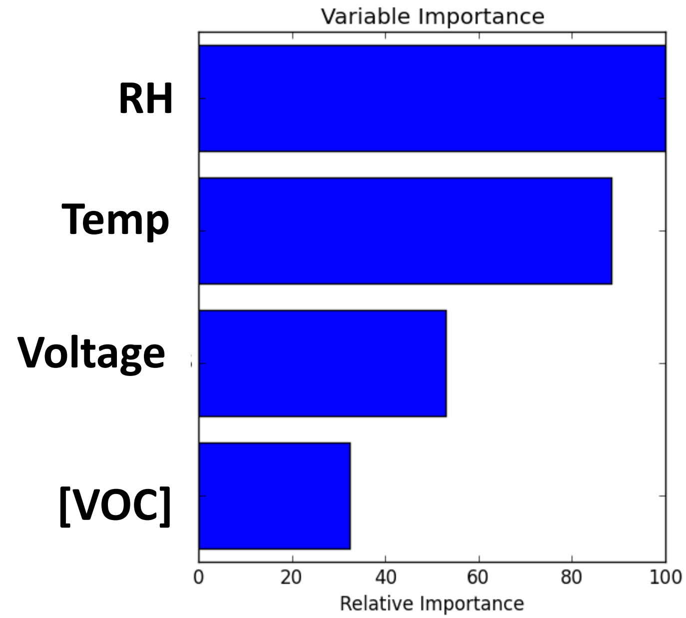
Can we separate the signals?



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

Can we separate the signals?





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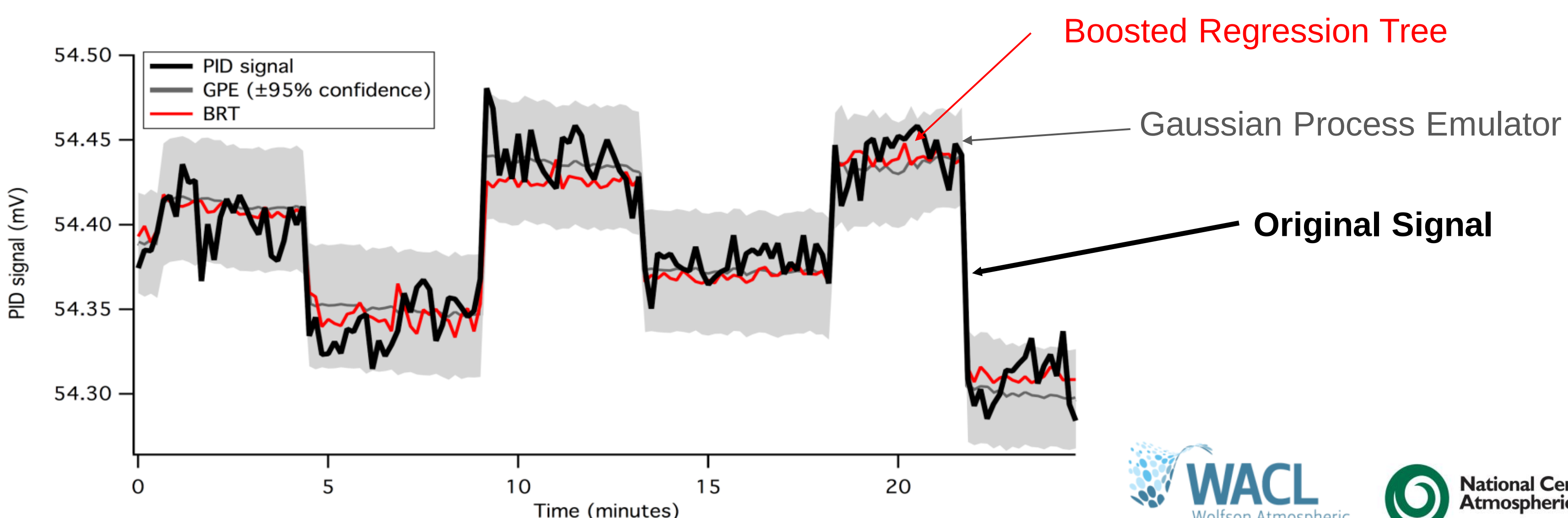

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Conclusions

- 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!**

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