Emerging technologies for atmospheric monitoring

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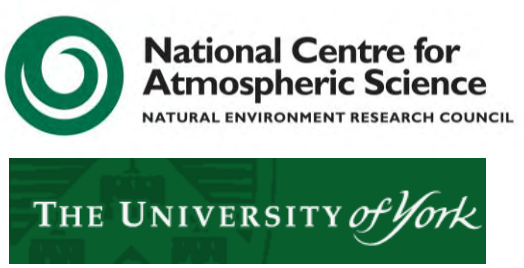


Input from: James Lee, Roland Leigh, Paul Monks, Rod Jones, Jacqui Hamilton James Allen, Lucy Carpenter, Stephen Belcher.

Emerging technologies for atmospheric monitoring

- Bigger and better..
- Faster, smaller, cheaper…

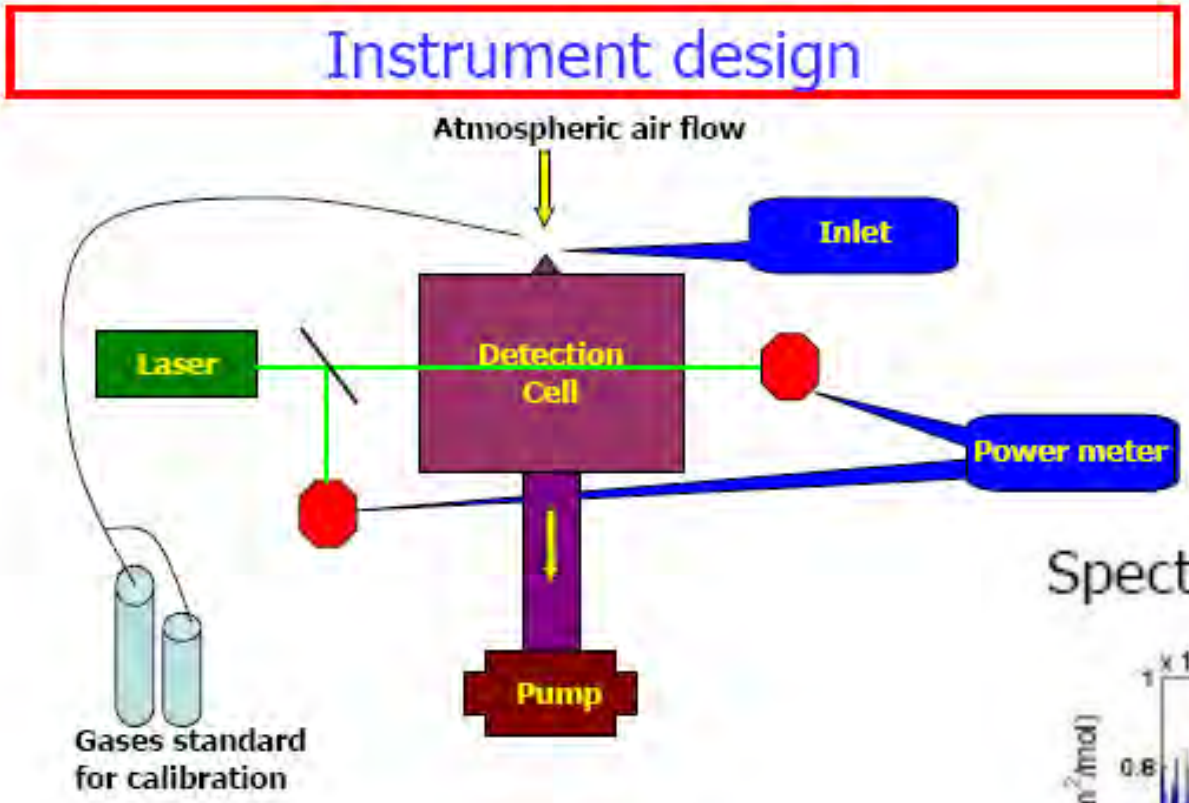
- Focus on NOxy, PM, VOCs
- Many other new research instruments for other elements of composition

Emerging technologies for atmospheric monitoring

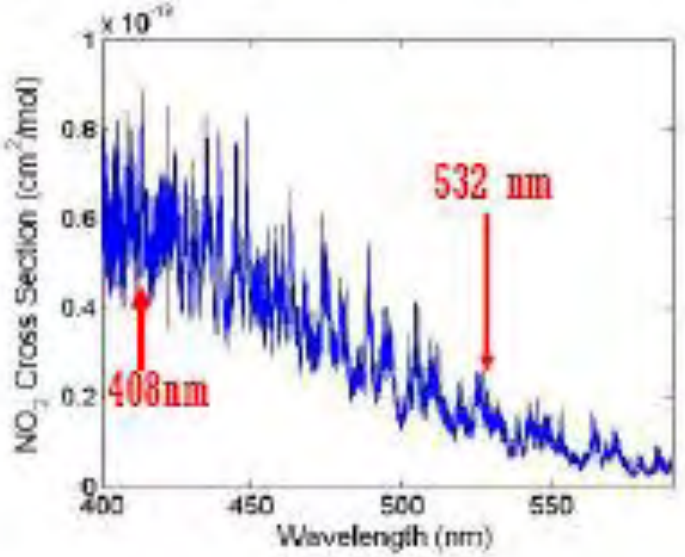
NO, NO_2, NOy components

- NO – generally good
- NO_2 – do we really measure it?
- NO_y or NO_z components – no routine observations

Laser Induced Fluorescence to measure NO_2



Spectral signature of the NO_2



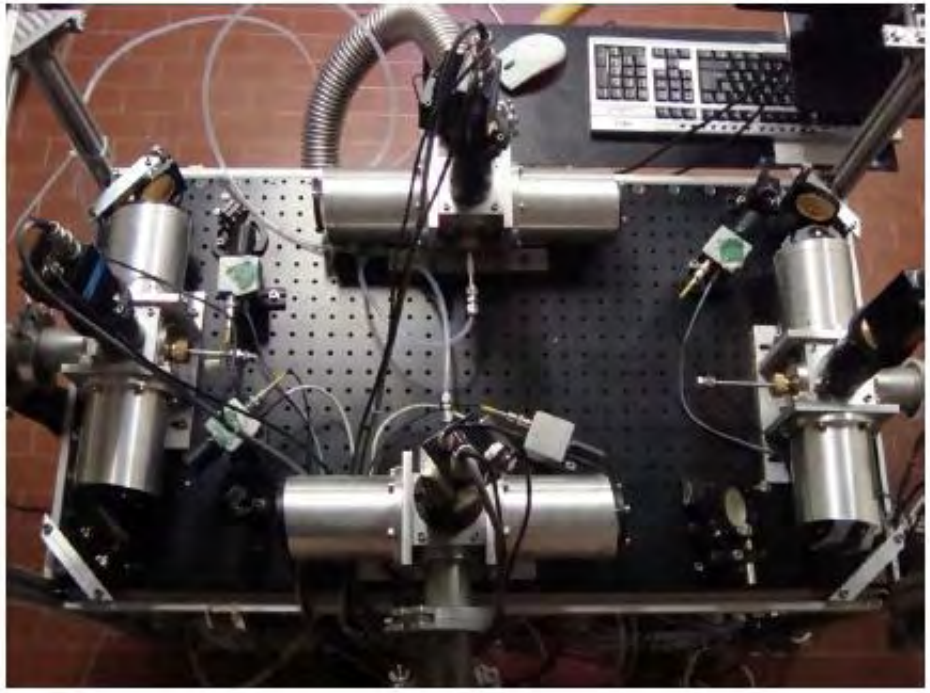
Lower cost – higher reliability lasers suggest we should move to the direct measurement of NO_2

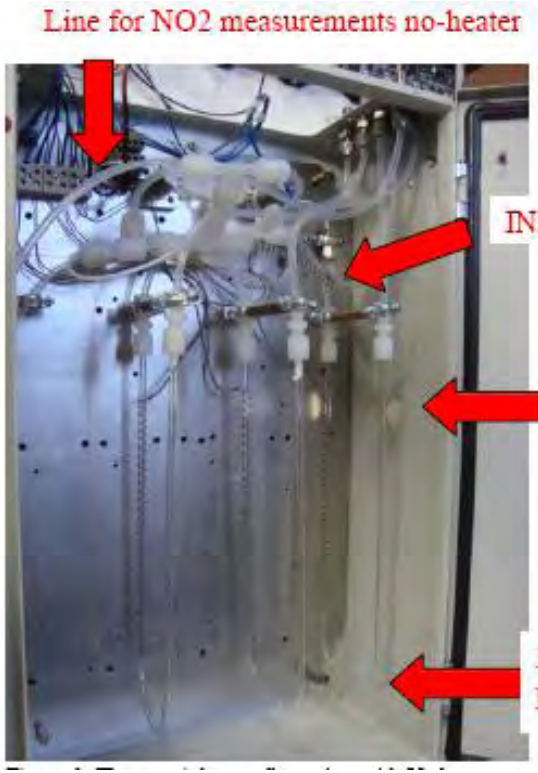
Strategies for NO_z

Heated quartz inlet to convert NOz species to NO_2

4 x Detection cells for: NO_2, PANs, Alkyl Nitrates, HNO_3

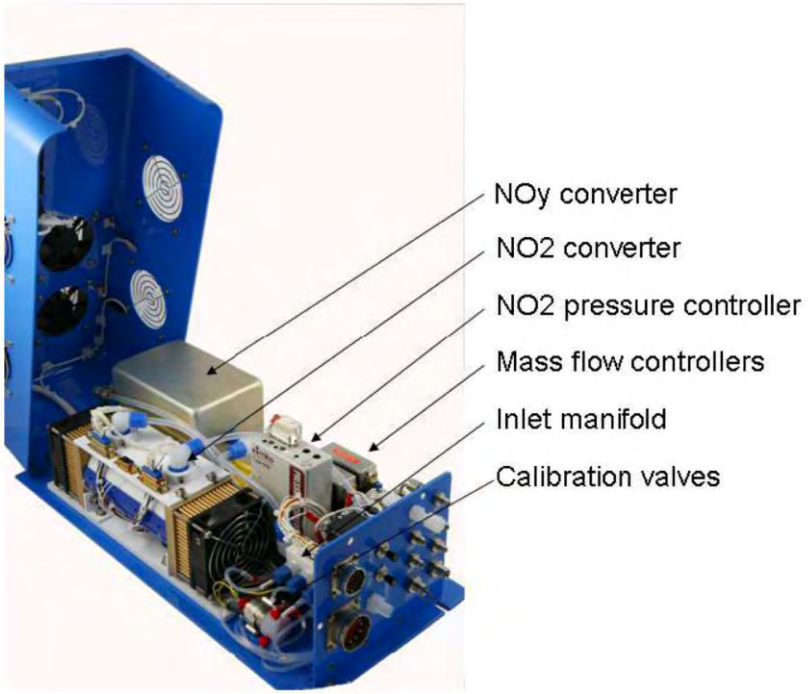
< 5 pptv NO_2 dl for 1 s data



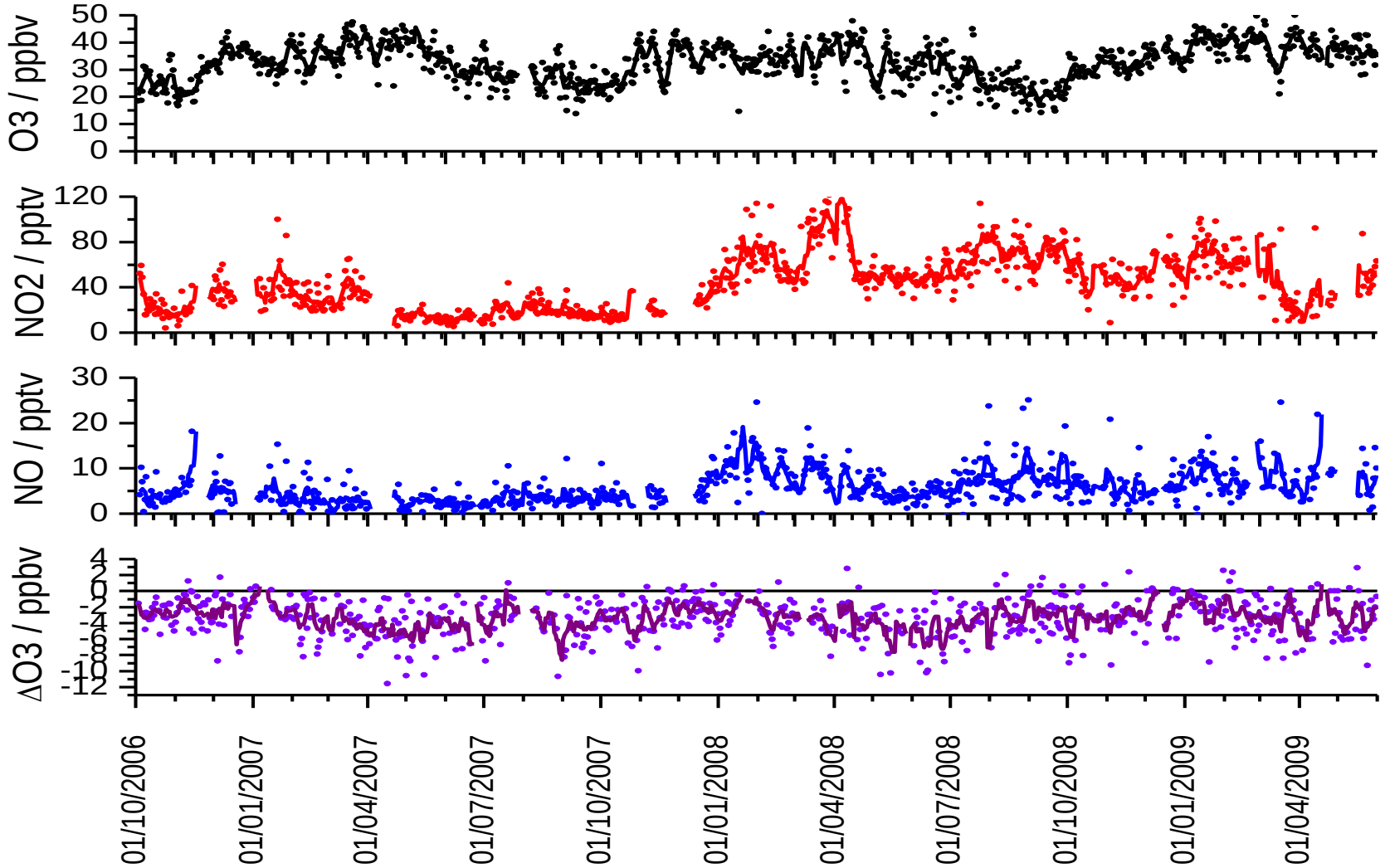


Scale of ambition:

Urban NOx instrumentation lags way behind what is used in remote GAW stations. If it can be done in clean remote air, we can do this in cities.



Tropical Atlantic NO and NO_2

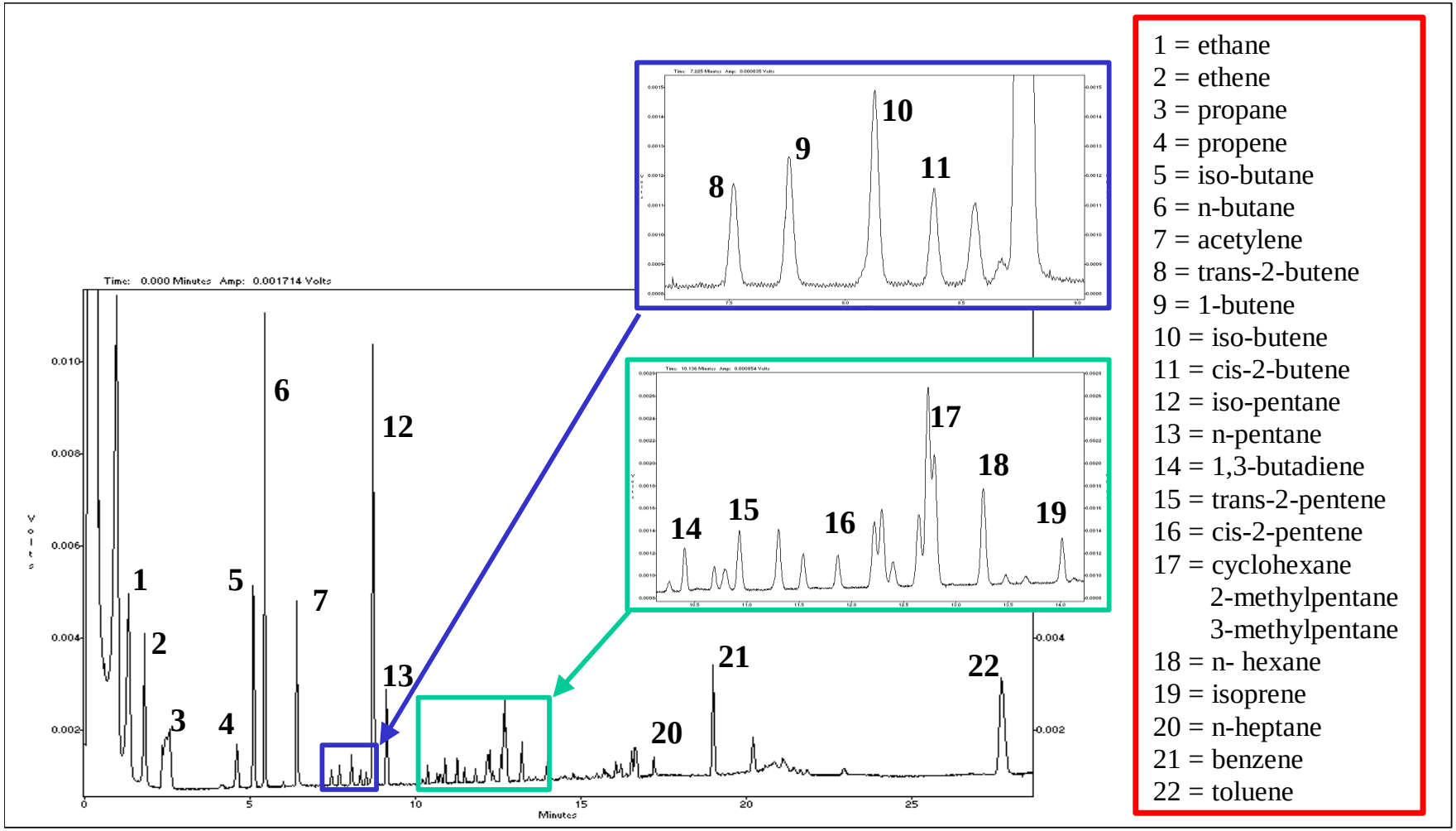


Emerging technologies for atmospheric monitoring

Volatile organic compounds

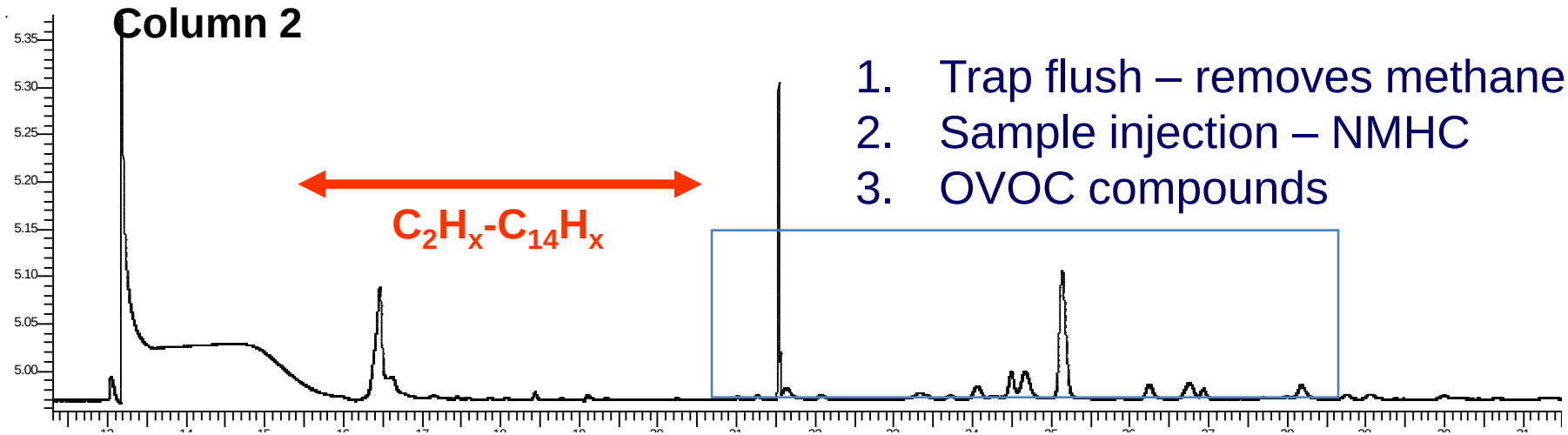
- Very few on-line observations
- Several near term and longer term technologies
- Robust GC-FID, PTR-MS
- Microfabricated GC-on-a-chip

On-line GC-FID technology is now much more robust than a decade ago.
No cryogens, more species, oxygenated compounds, better standards

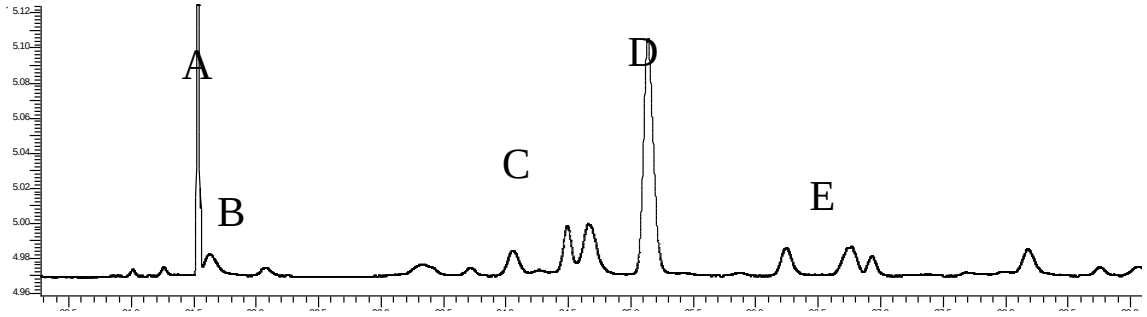


NMHC and oxygenates measured together

1. **2.** **3.**



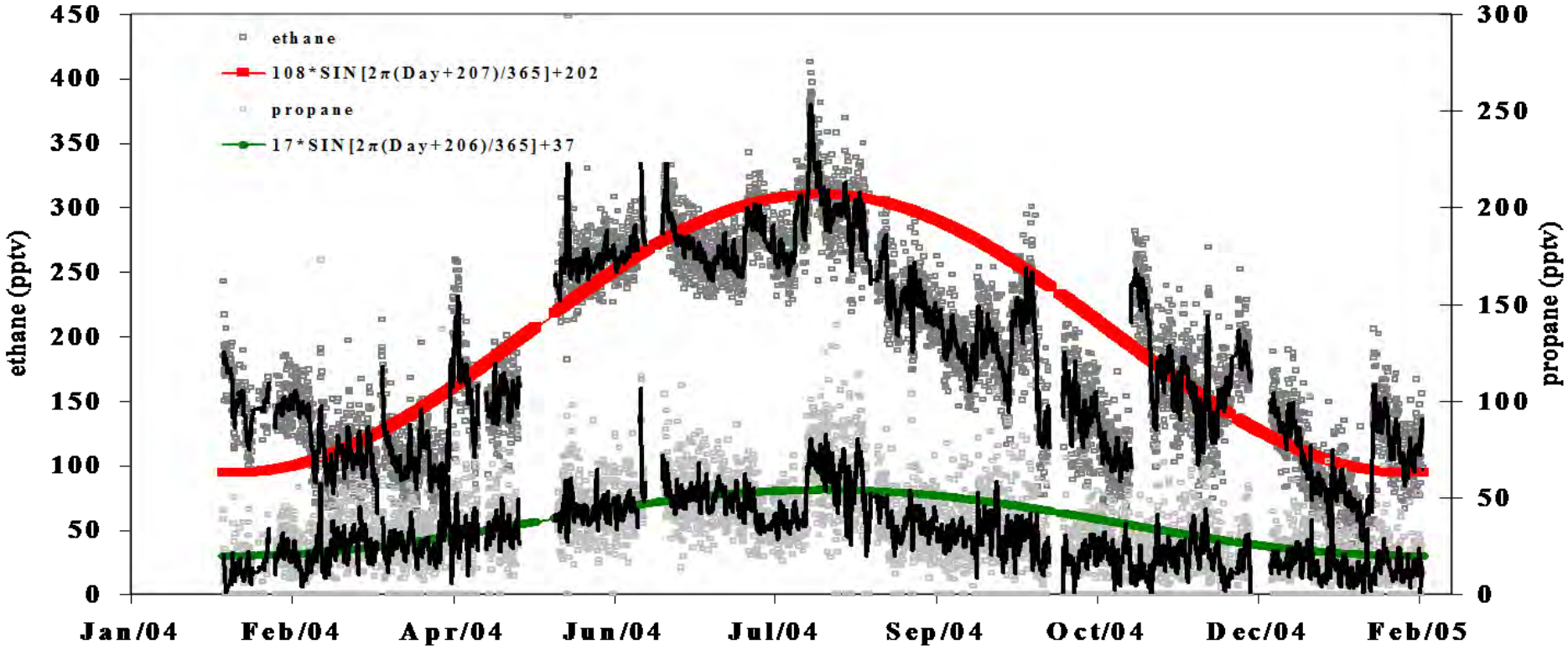
1. Trap flush – removes methane
2. Sample injection – NMHC
3. OVOC compounds



A. - acetaldehyde
B. - methacrolein
C. - methanol
D. - acetone
E. - ethanol + MVK + MEK

Scale of ambition:

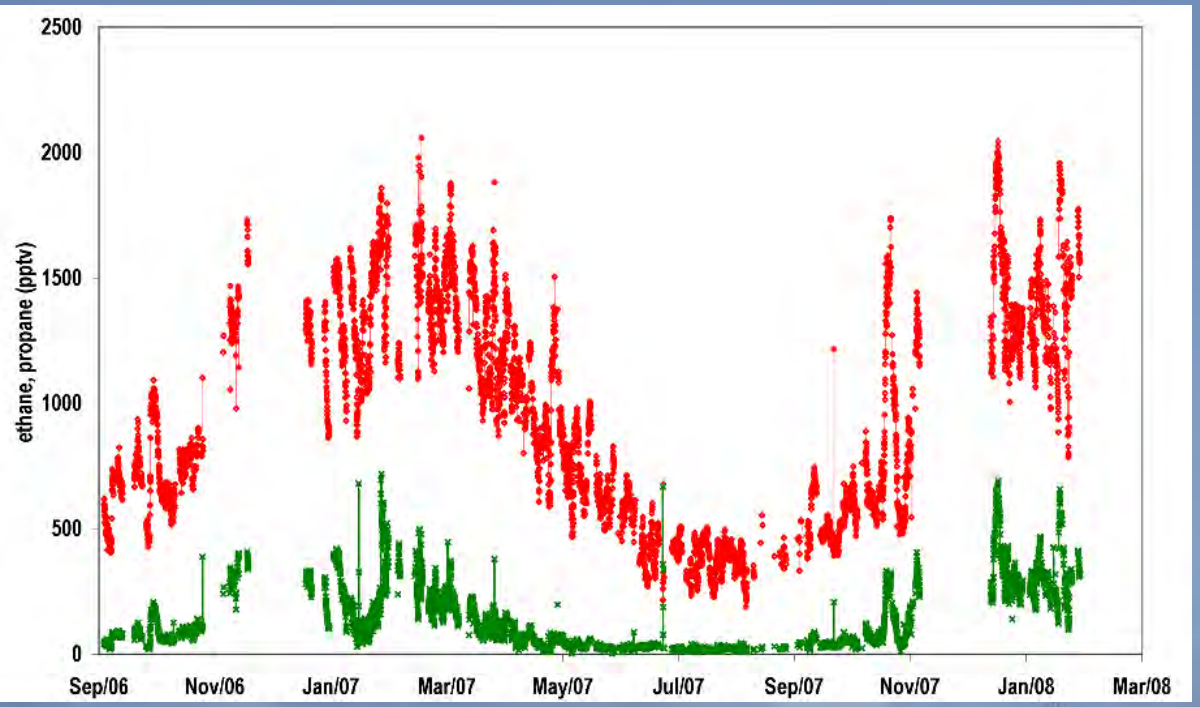
VOCs measured on-line at remote GAW stations. If it can be done in clean remote air, again we can do this in cities.



Read KA and Lewis AC, Tellus B, 2007

Tropical Atlantic – Cape Verde

See live field GC data from www.york.ac.uk/capeverde

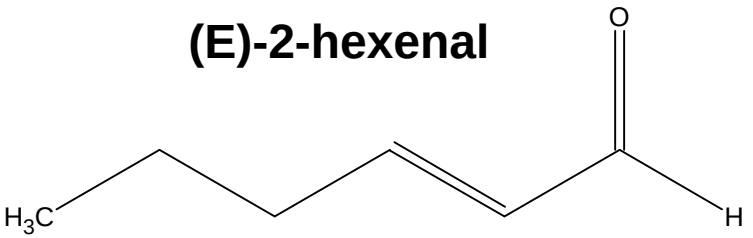


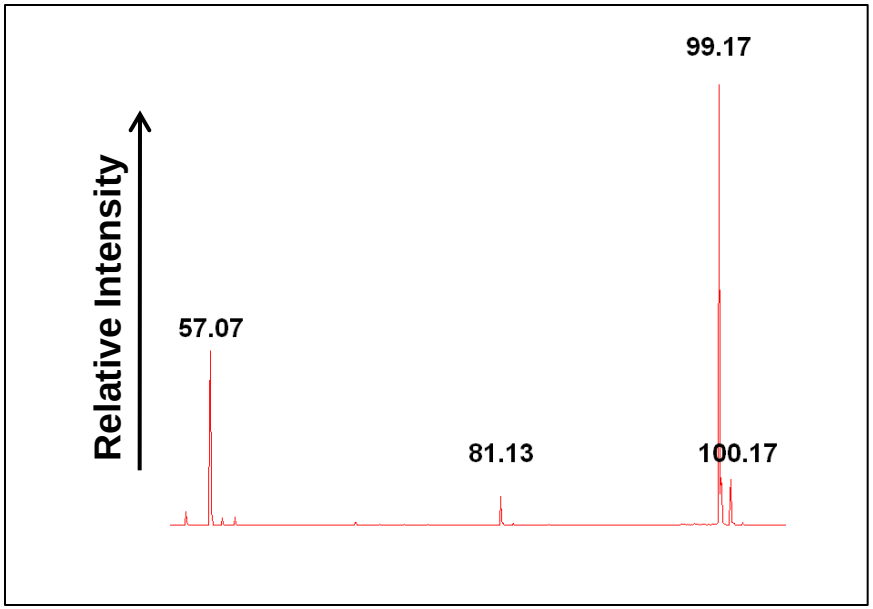
Read KA et al. Nature, 453, 2008

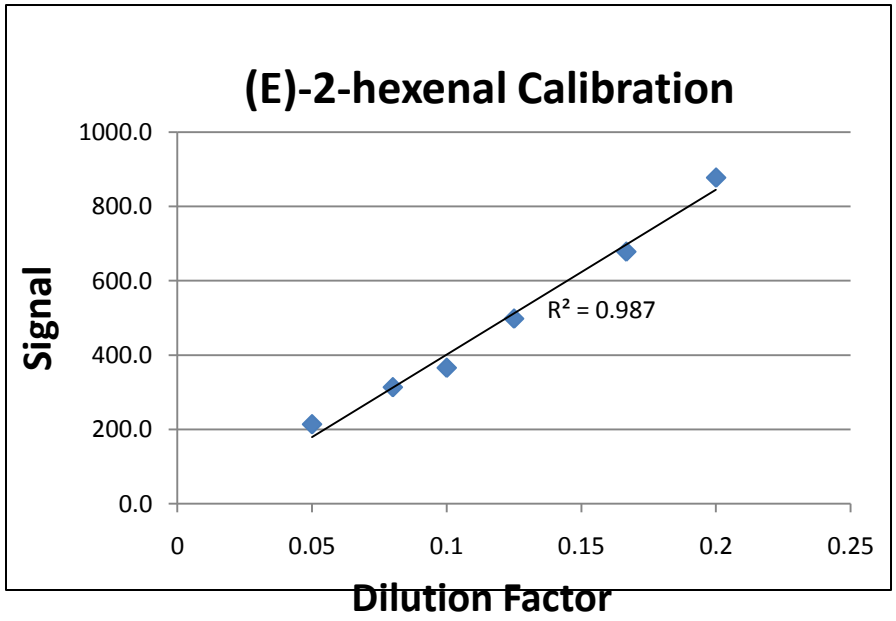
PTR-ToF-MS

$$[RH^+] = [H_3O^+]_o\left(1 - e^{-k[R]t}\right) \approx [H_3O^+]_o[R]kt$$

Chemical ionisation by hydronium ions produces fewer fragment ions than other ionisation methods.

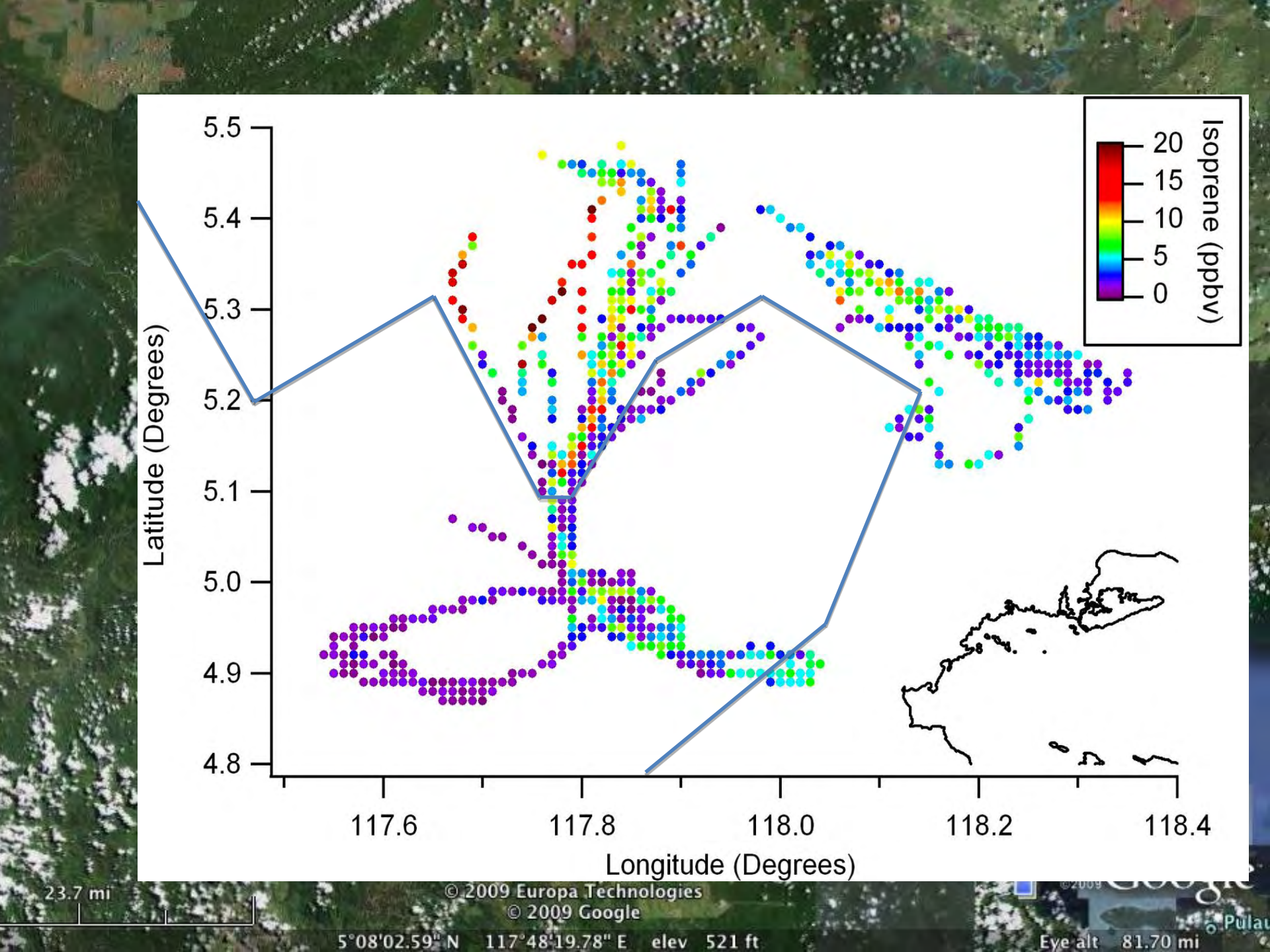




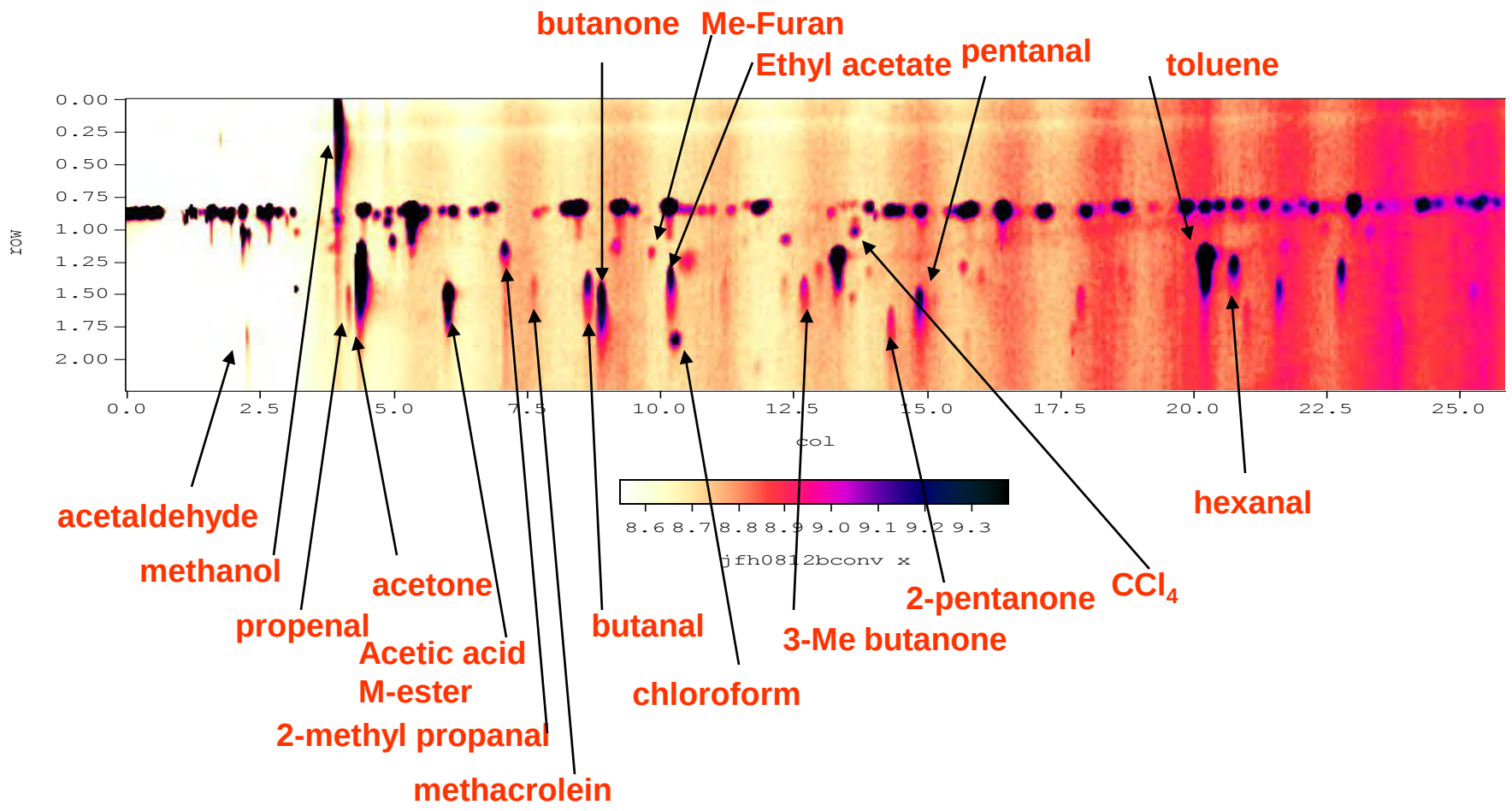


PTR-qMS - fast on-line measurements of selected VOCs

Atmosphere – Land Surface Interactions


Isoprene (ppbv)
20
15
10
5
0
Latitude (Degrees)
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
117.6
117.8
118.0
118.2
118.4
Longitude (Degrees)
23.7 mi
© 2009 Europa Technologies
© 2009 Google
5°08'02.59" N 117°48'19.78" E elev 521 ft
Eye alt 81.70 mi

Field GC in more complex or polluted environments

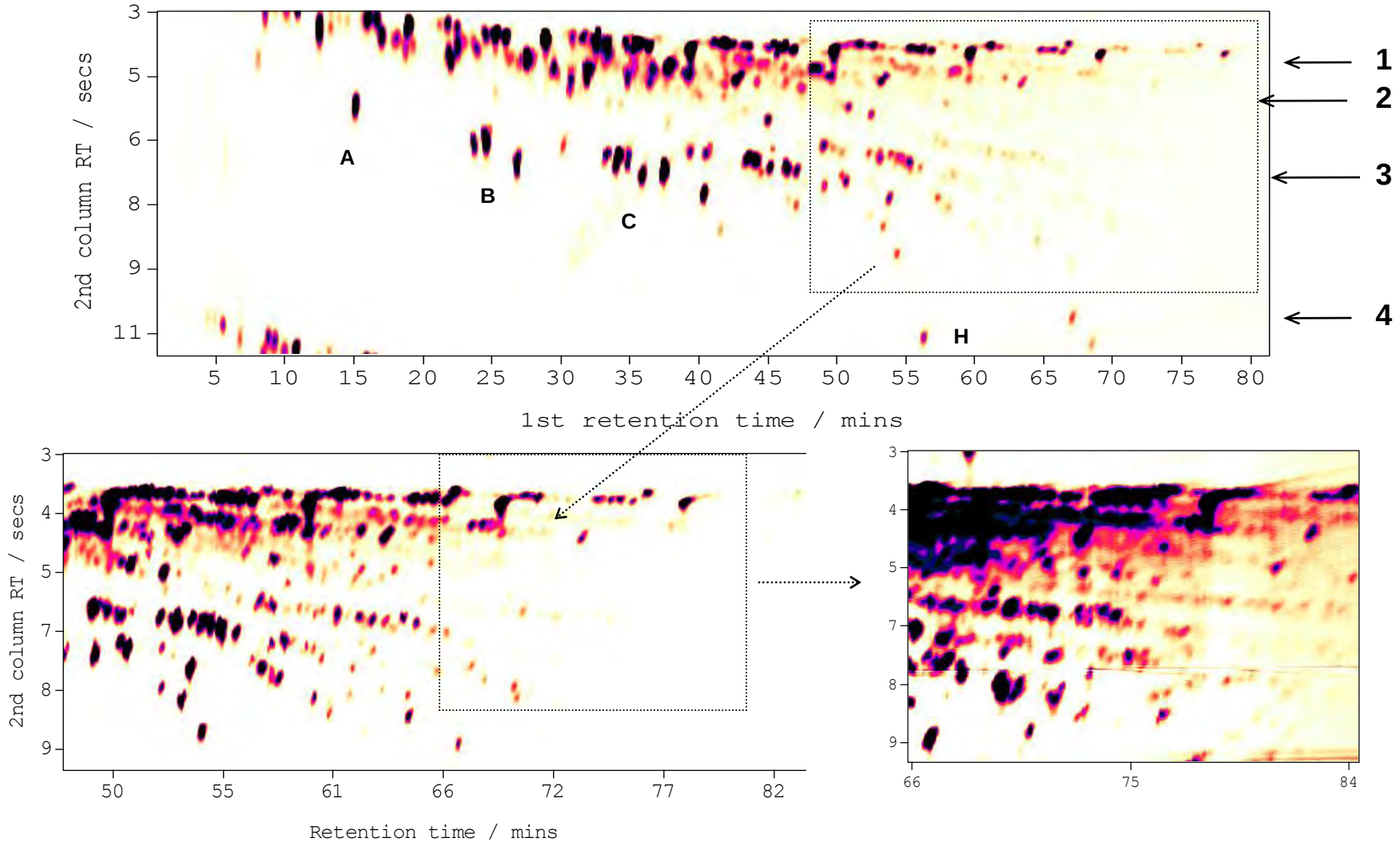


GCxGC 50m BP1, 0.32mm i.d. 3µm film

2.5m CP-WAX / PEG, 0.18mm i.d. 1µm flim

100Hz FID / 4s mod / 10uL valve loop

High complexity VOC C_6-C_{12} fraction



Comprehensive GC resolves the VOC content in the key volatility regions associated with higher gasoline and diesel evaporation.

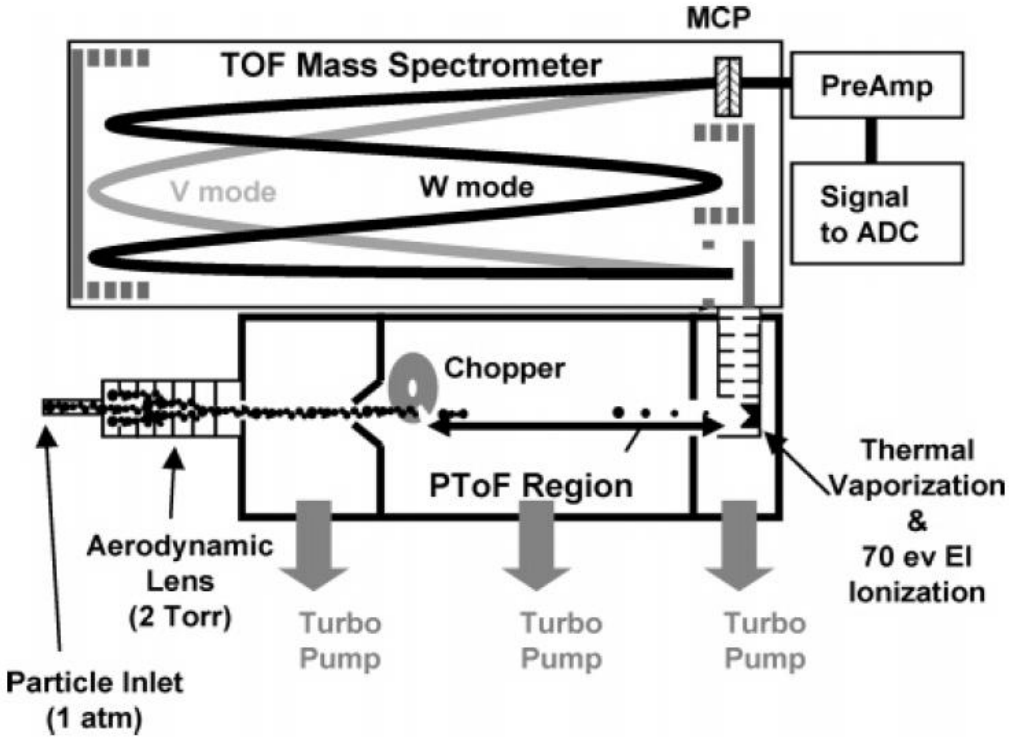
Emerging technologies for atmospheric monitoring

Particulate Mater

- Extensive on-line PM mass network
- Air quality challenges lie in deconvolving different sources to understand trends and impact of composition on health
- Major advances in on and offline instrumental capability
- Routinely used in a research setting

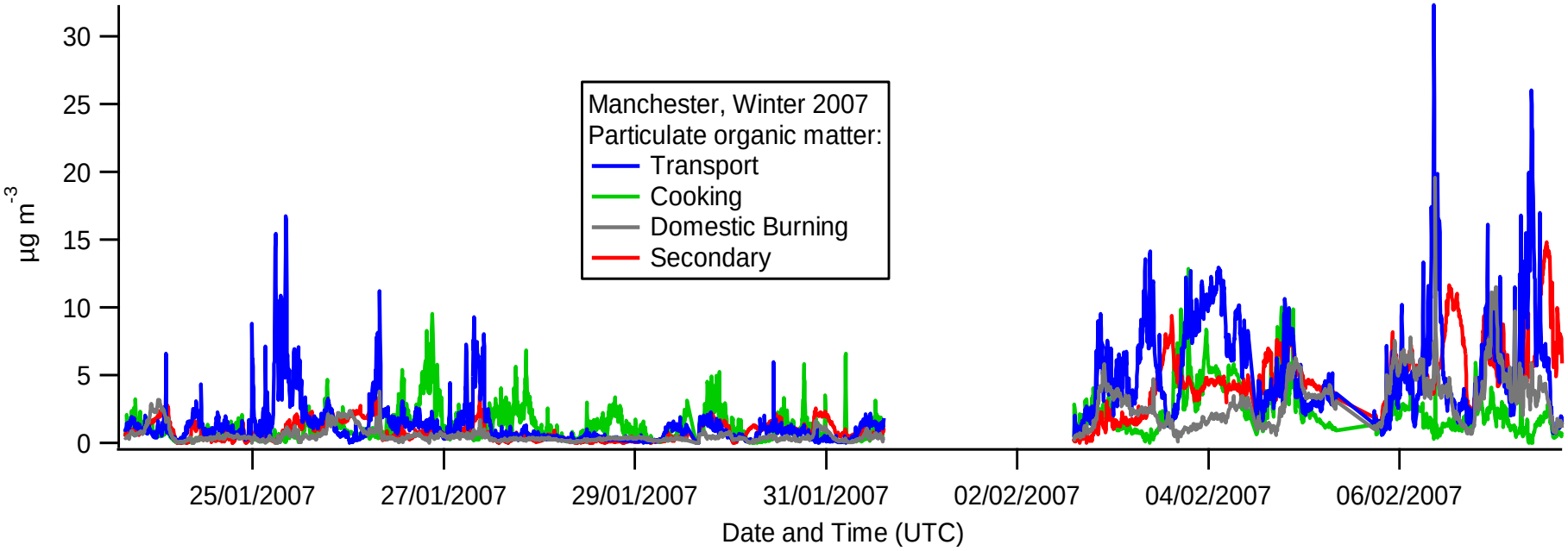
High Resolution Time-of-flight AMS

- Delivers composition data on nonrefractory submicron particulate matter
  - Sulphate, nitrate, ammonium, organic matter
- Performs aerodynamic sizing
- Provides additional data on organic functionality
  - Can be used to identify types of organic aerosols
  - Can provide estimates of elemental ratios, e.g. C/O, C/H, C/N

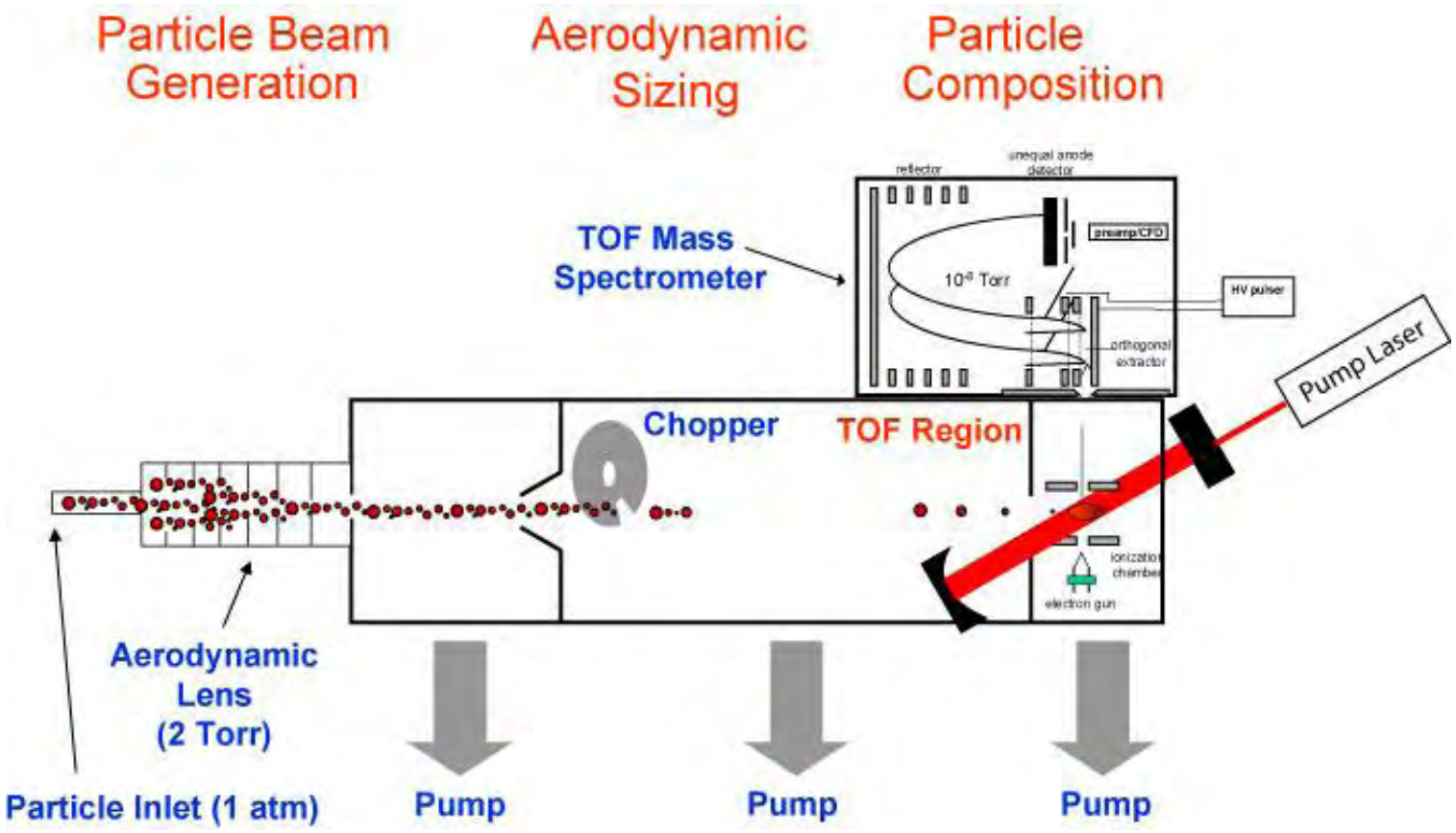


Positive Matrix Factorisation

- A factorisation technique previously applied to other aerosol data for source apportionment work
- Can be applied to AMS organic data



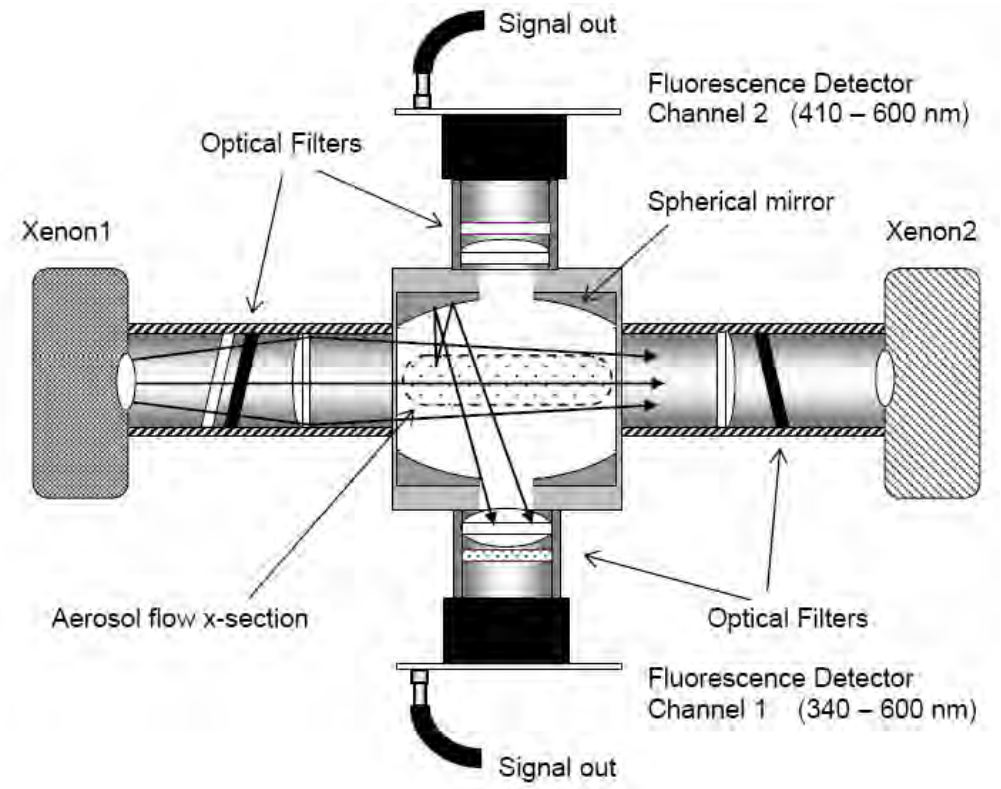
Soot Particle AMS



- Like the standard AMS, except particles are vaporised by a near infra red laser instead of a heated surface
- Selectively analyses black carbon particles and their coatings
- Currently at the testing stage

Wide Issue Bio-aerosol Sensor (WIBS)

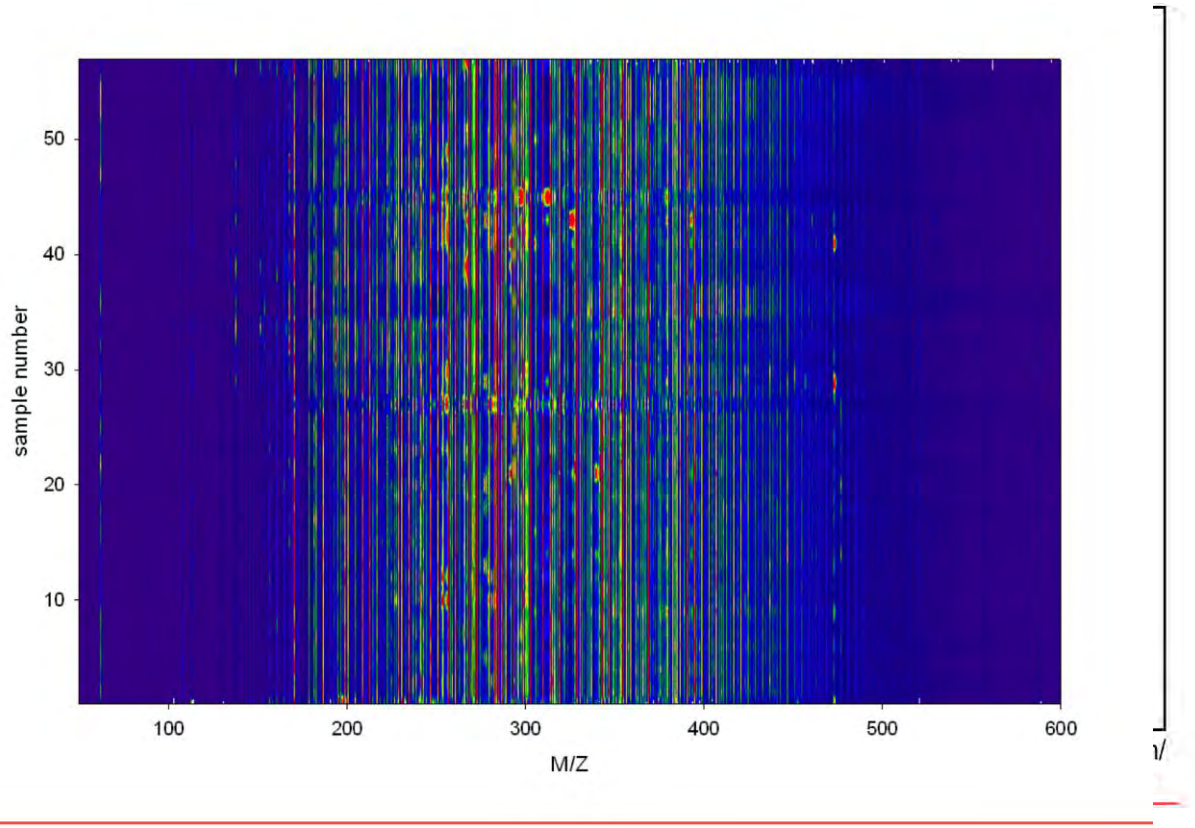
- Detects bioaerosols through fluorescence
- Uses multiple wavelengths to detect specific fluorophores
- Can be used to detect pollen, spores, etc.

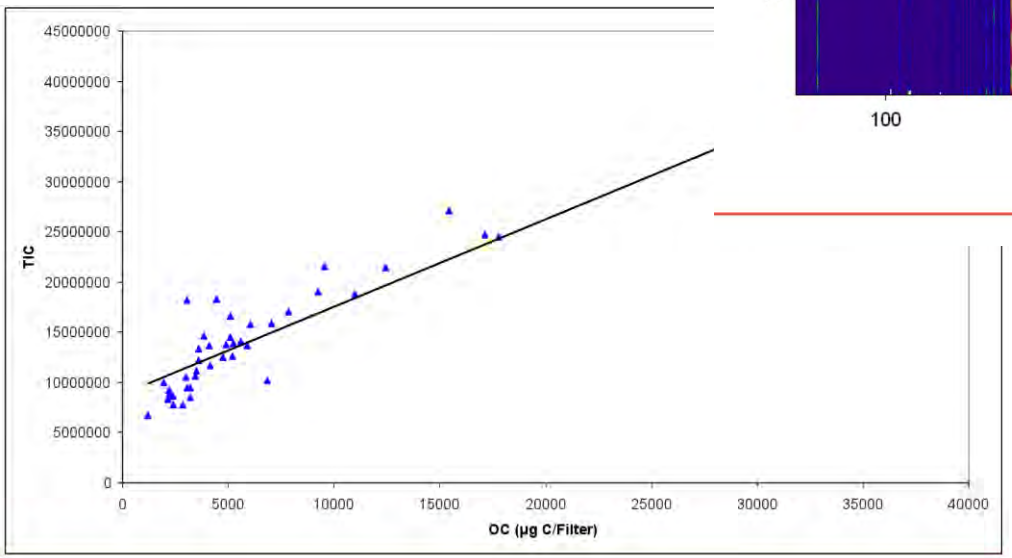


Water soluble aerosol - MS

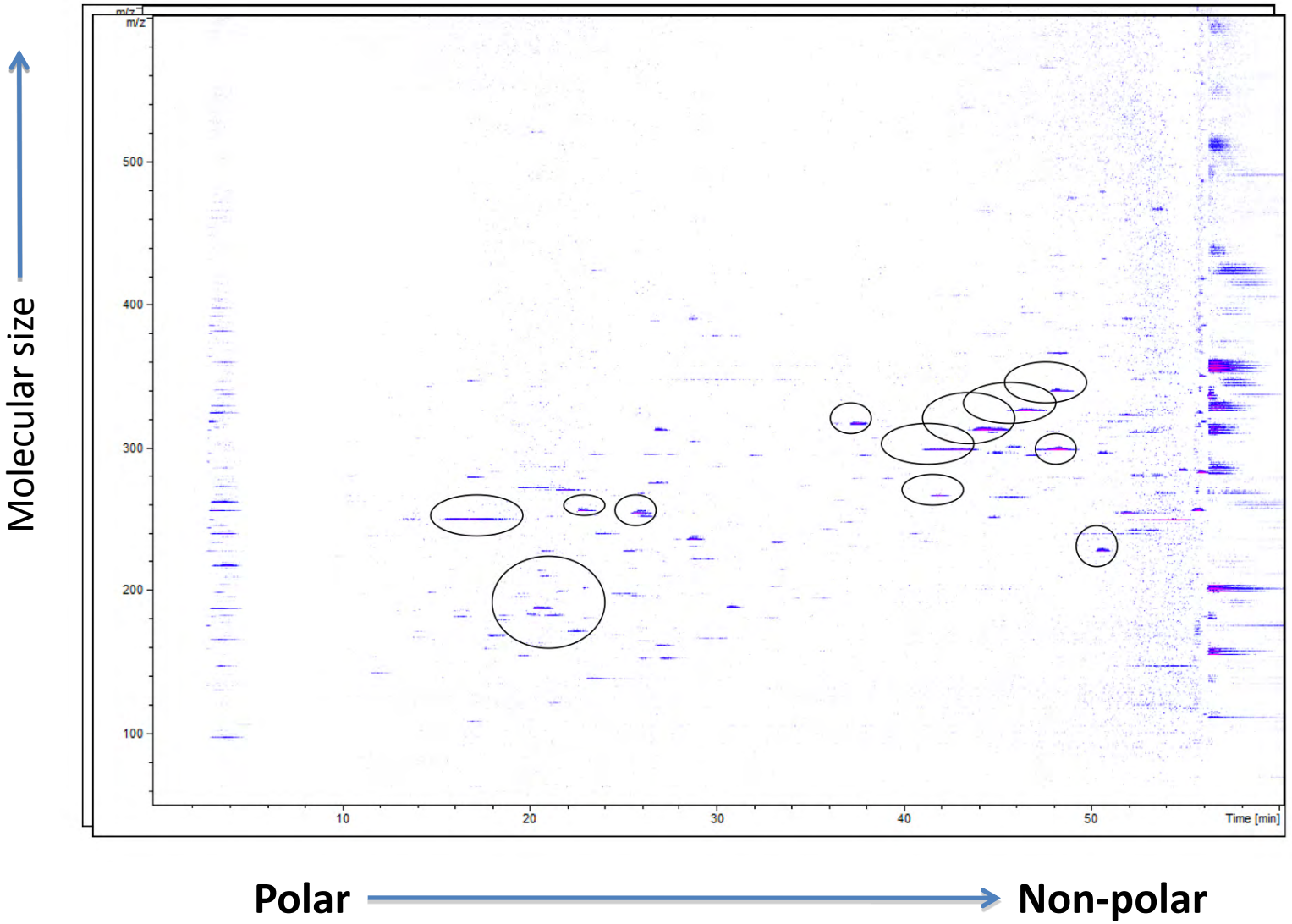
Infused WSOC extract into ion trap MS gives mass distribution of organic composition.

Good agreement with older bulk OC measurement methods





PM composition by LC-MS

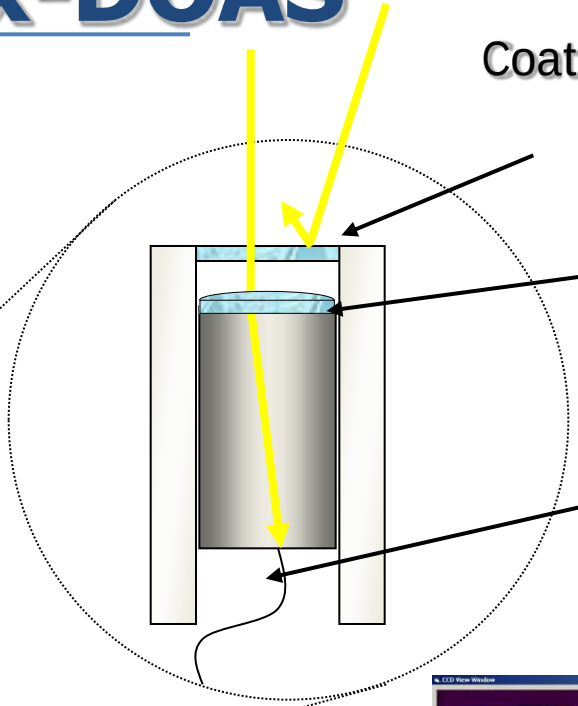


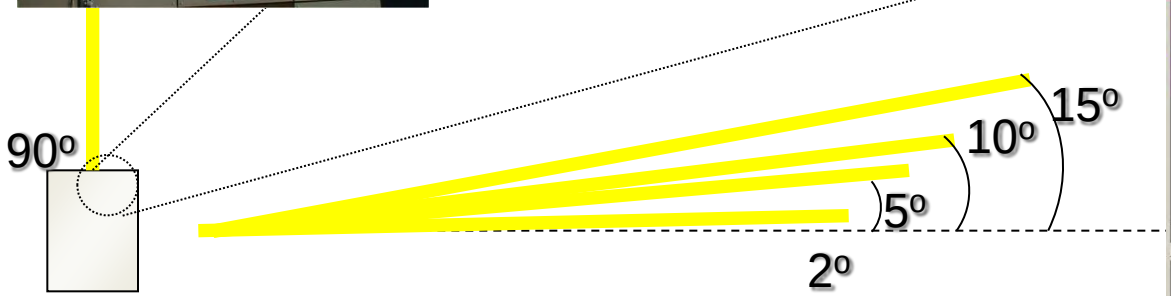
Emerging technologies for atmospheric monitoring

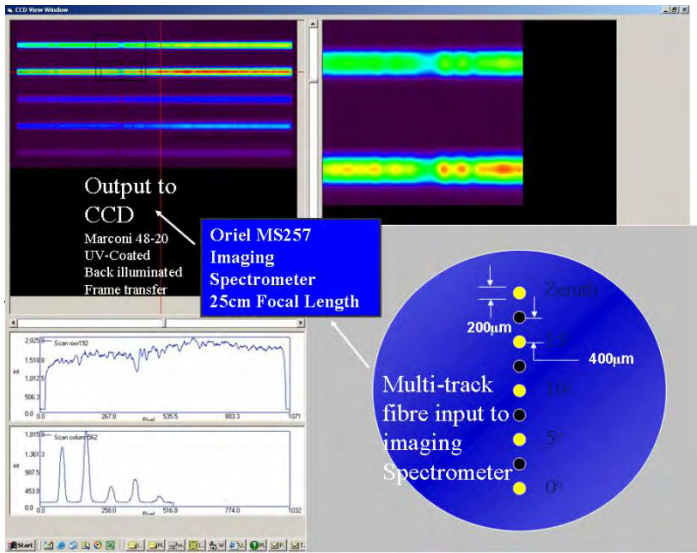
Smaller and Cheaper

- Simple parameters measured more widely
- Mobile observations
- Towards personalised monitoring
- Opportunities and risks

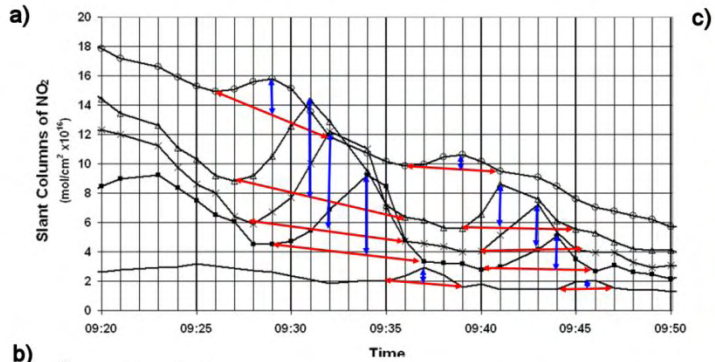
Compact Max-DOAS

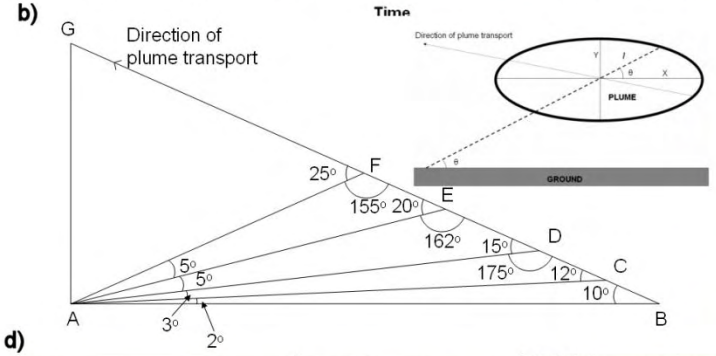


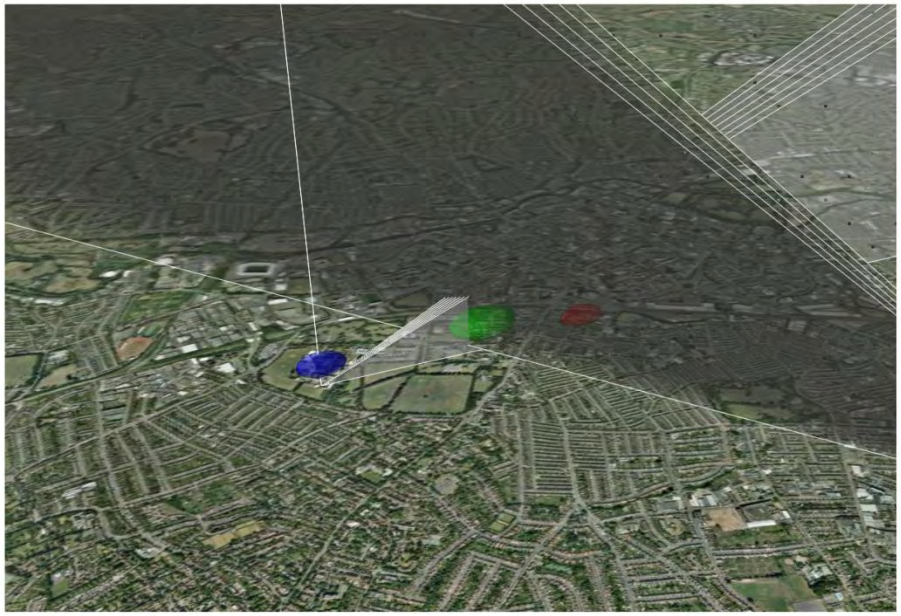


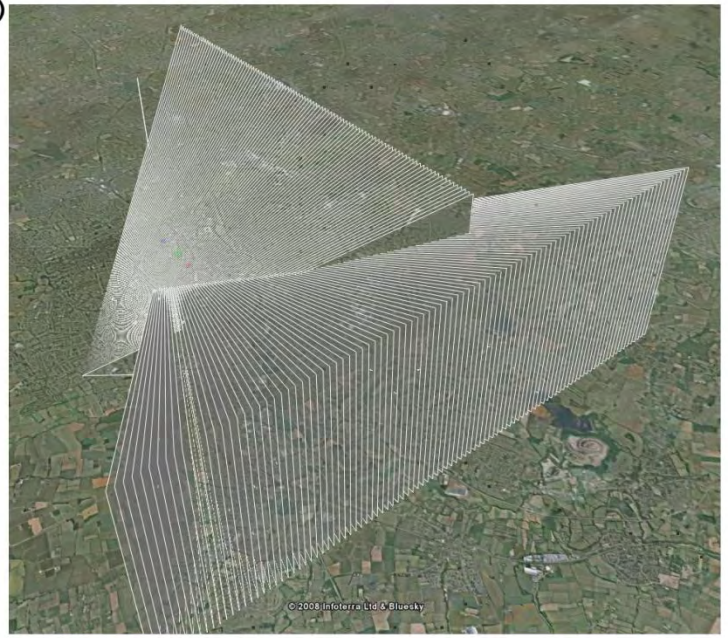


Leigh *et al*, 2006

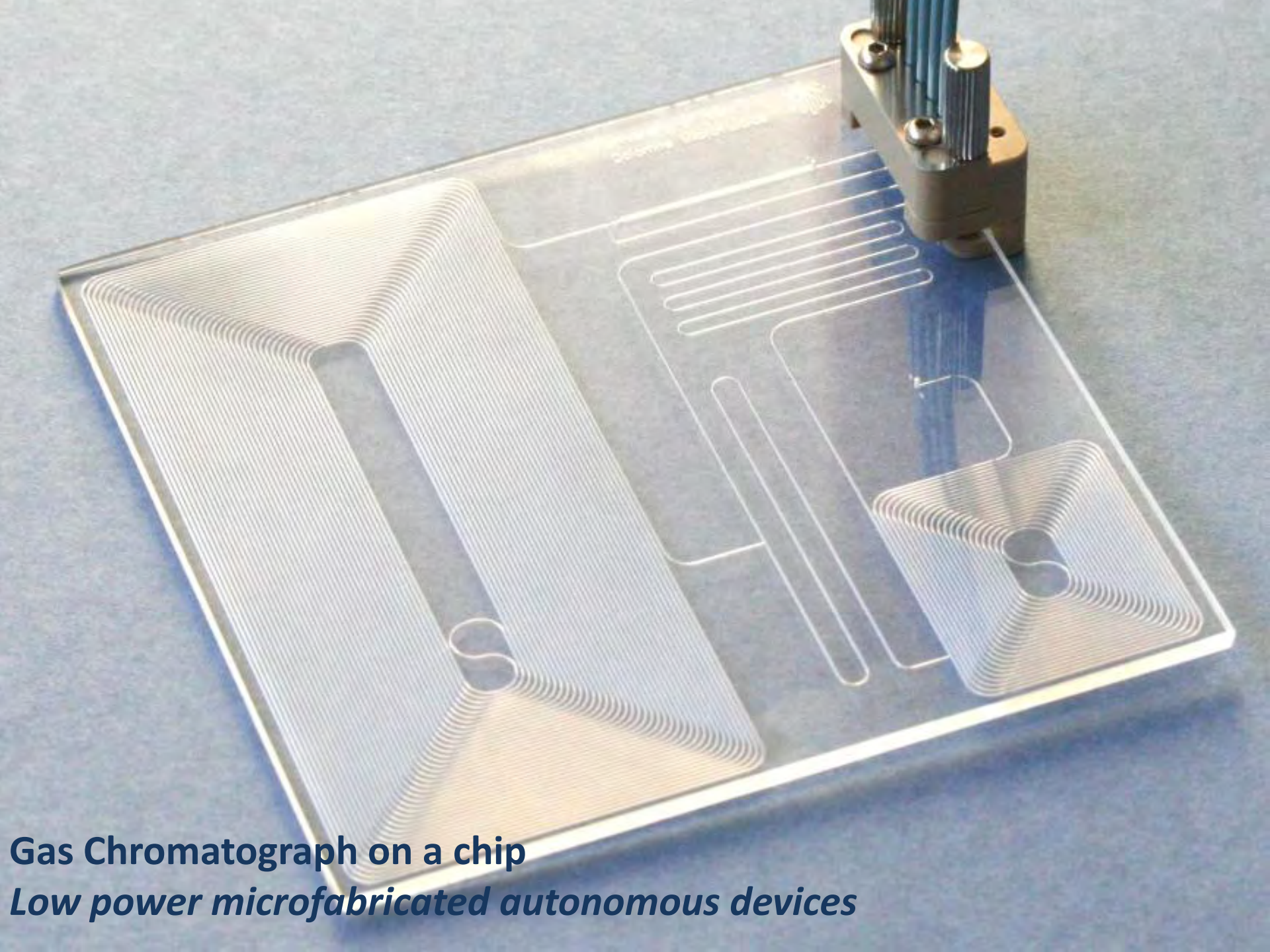








Towards a city wide view and scale up to earth observation

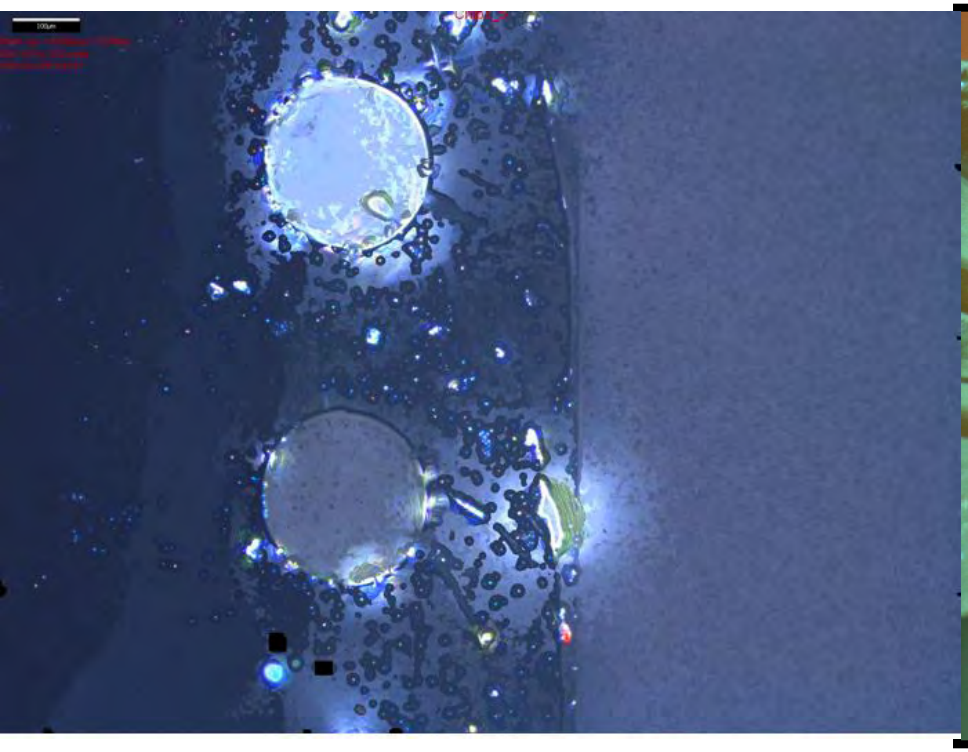


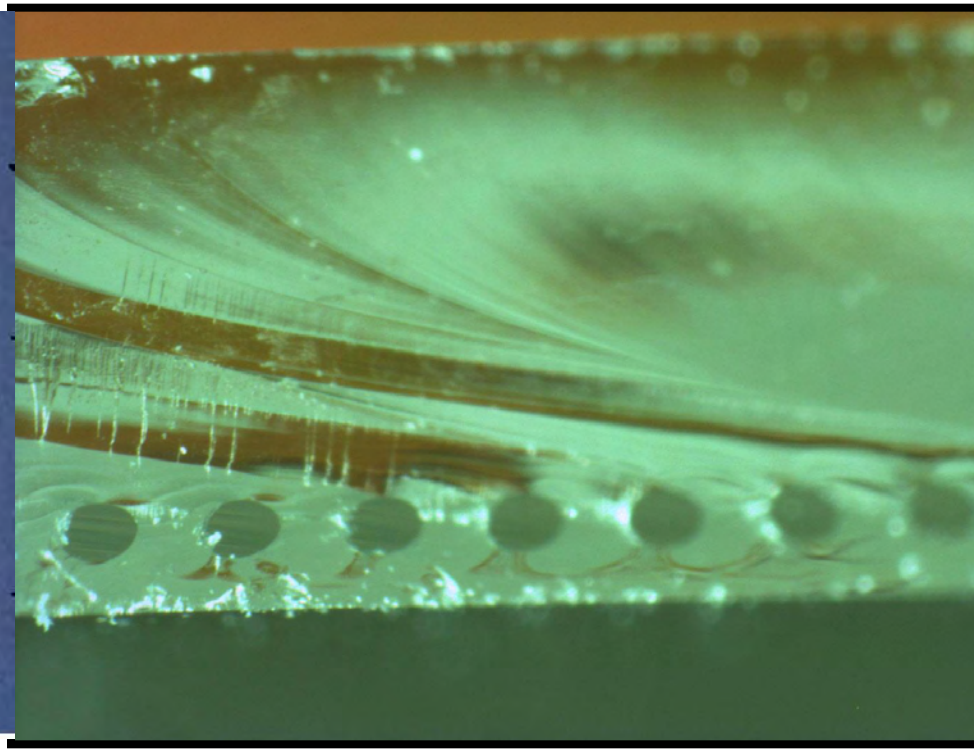
Gas Chromatograph on a chip

Low power microfabricated autonomous devices

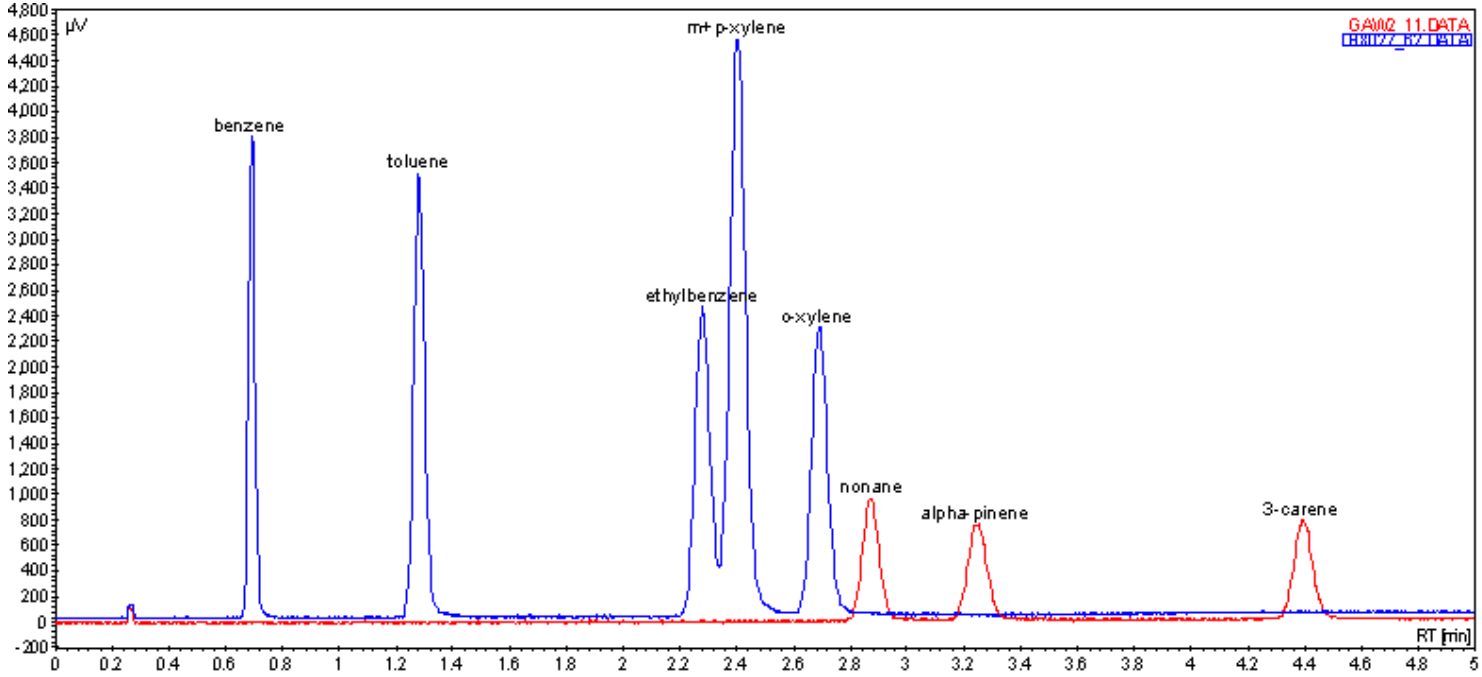
Future VOC technology

- Uses the tested and straightforward GC approach
- All components fabricated in a single step to improve robustness
- Planar structure for direct heating / cooling
- Acid etched glass structure to make circular column channels





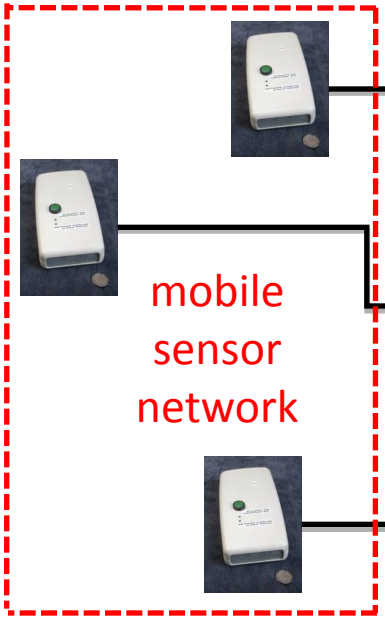
GC-on-a-chip



Simple gas mixture of VOCs, sub ng detection limit

Power consumption around 25W

Compact *low cost* sensor networks:
EPSRC MESSAGE project
http://bioinf.ncl.ac.uk/message/



Other data
(met, traffic….)

archive

[Hayes]

Real time data processing/ data assimilation

PRODUCTS

Environment…..
Regulation……
Exposure…..
Transport…..
……

GPS
(location)

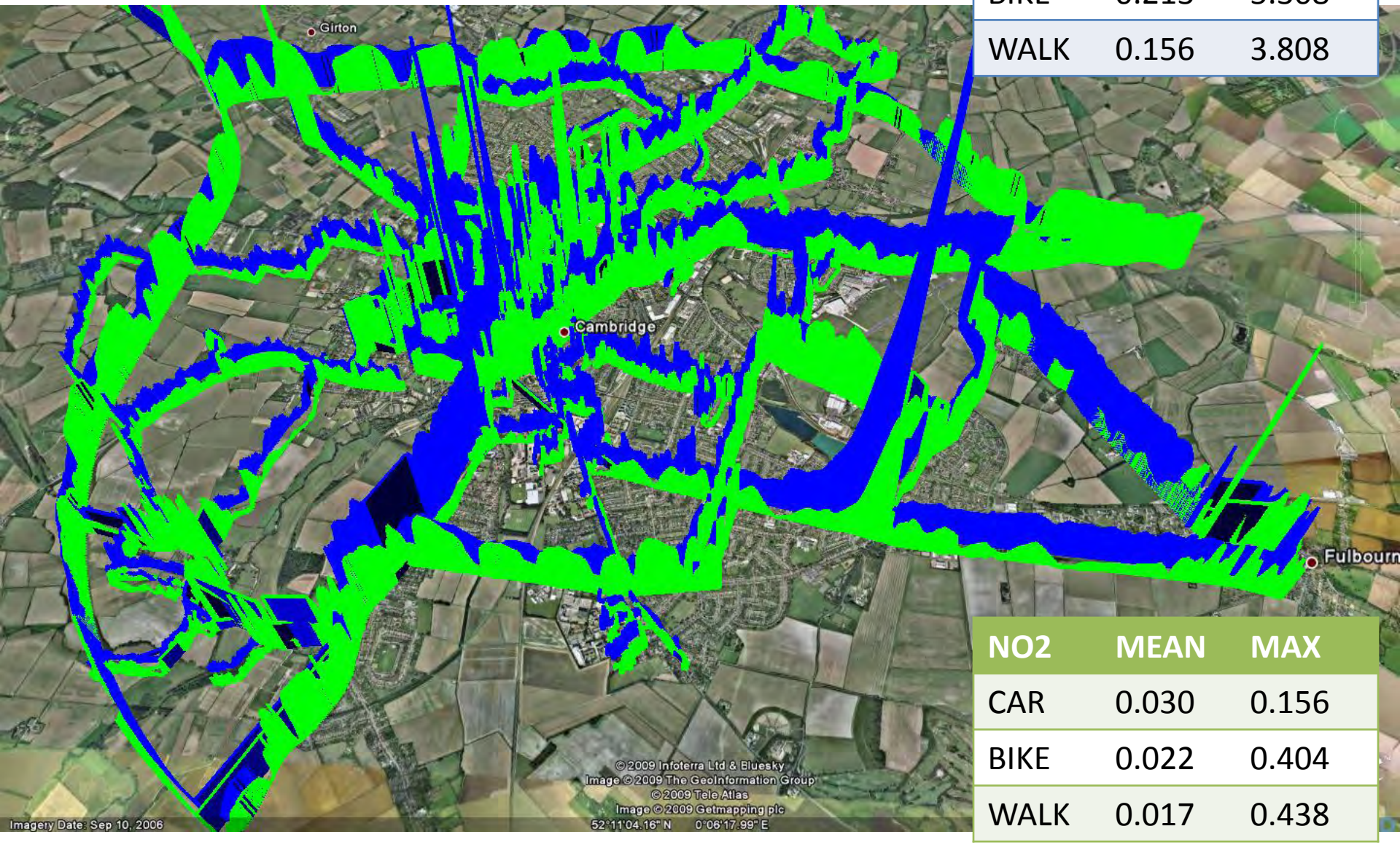
GPRS
(data
transmission)

SENSORS

[Kanjo, Louden, Mead]

NOX

NO	MEAN	MAX
CAR	0.211	0.973
BIKE	0.213	5.308
WALK	0.156	3.808



NO2	MEAN	MAX
CAR	0.030	0.156
BIKE	0.022	0.404
WALK	0.017	0.438

CO

CO	MEAN	MAX
CAR	O.674	6.745
BIKE	0.630	5.013
WALK	0.481	7.860

Emerging technologies for atmospheric monitoring

Bigger – Better vs Smaller - Cheaper

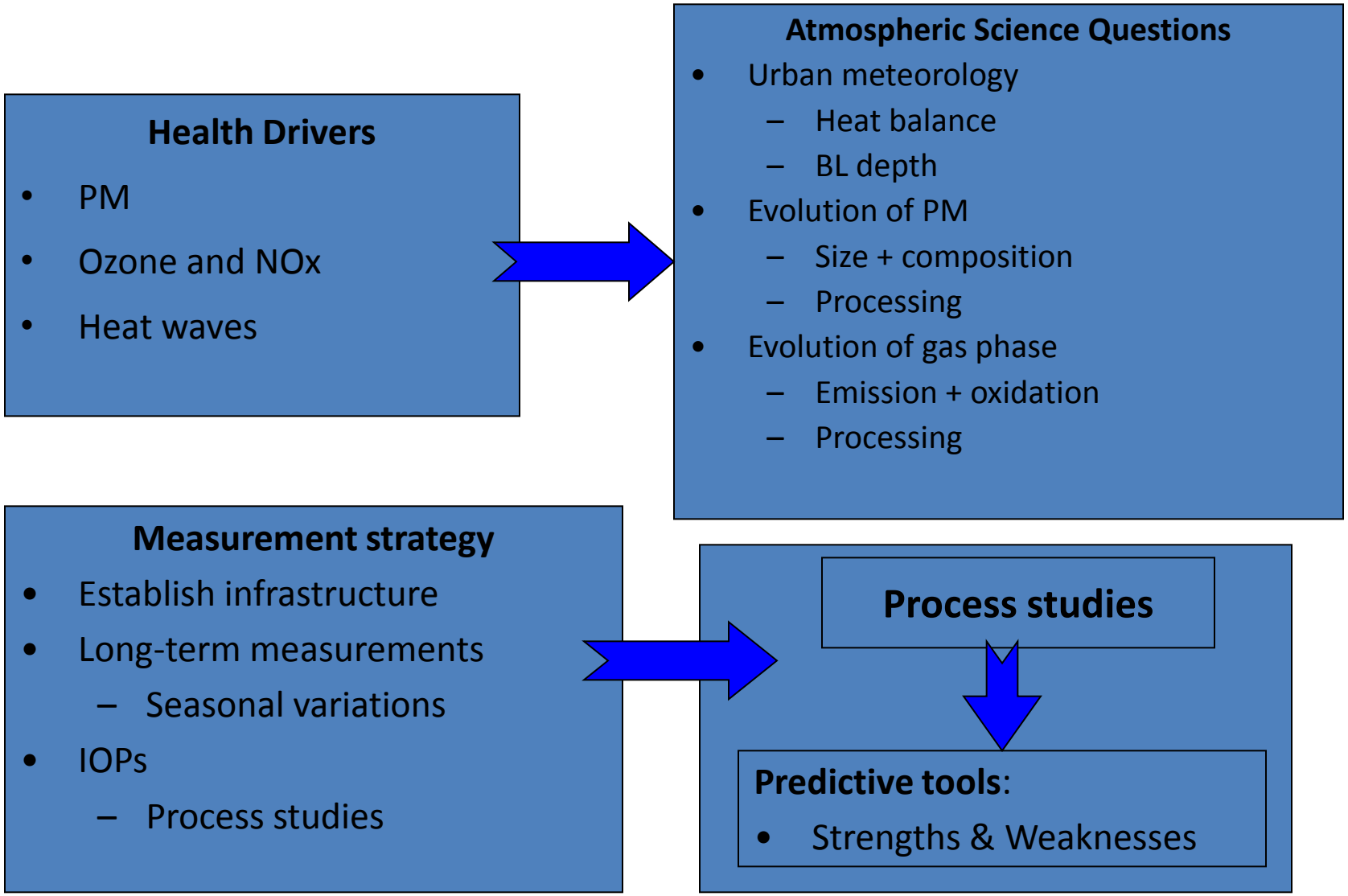
- Need to understand trade off between accuracy and spatial distribution - subtle trends in AQ remain important
- Speciation in all areas is rapidly expanding and this may add extra dimensions to our study of sources and processes
- A ‘generalised’ AQ sensor will probably be on a domestic mobile phone within 5 years – *issues*?

Emerging technologies for atmospheric monitoring

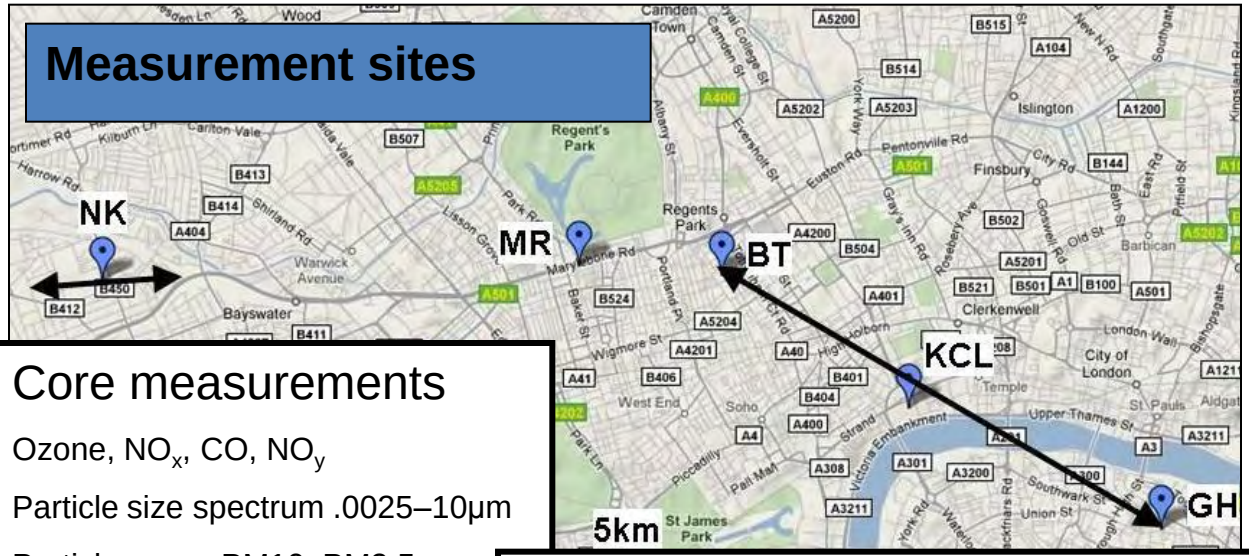
Relationships with NERC

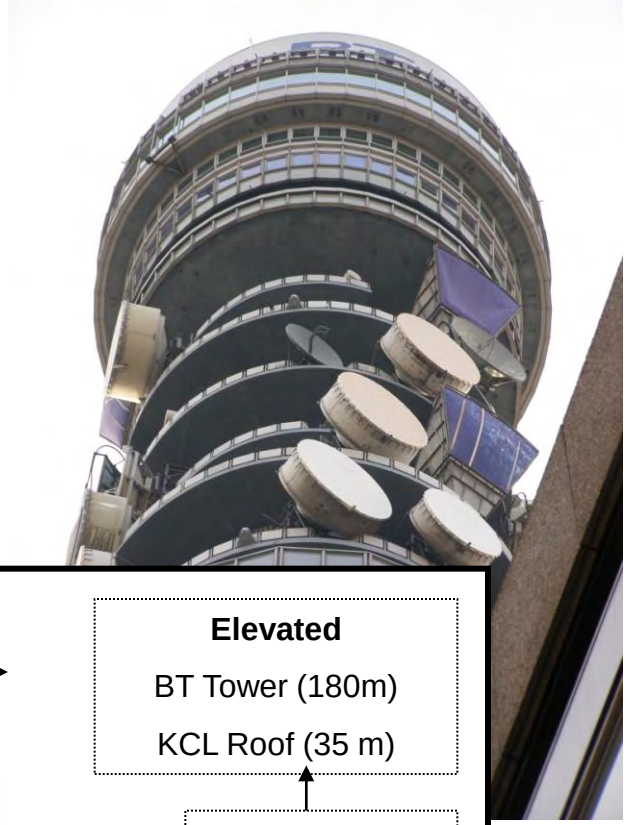
- NERC remains the largest funder of environmental research
- Historic relationship with AQ and instrument research was less than perfect
- Much improved visibility of AQ science challenges and potential sources of support.

£2.9M project in Atmospheric Science for Health Impacts of Urban Air Quality, - ClearFlo – PI Stephen Belcher + 6 other Universities



Measurement sites





Core measurements

Ozone, NO_x, CO, NO_y

Particle size spectrum .0025–10μm

Particle mass, PM10, PM2.5

Particle composition samples

Boundary-layer structure and ener
fluxes

Urban increment

Elevated

BT Tower (180m)

KCL Roof (35 m)

Rural

Chilbolton

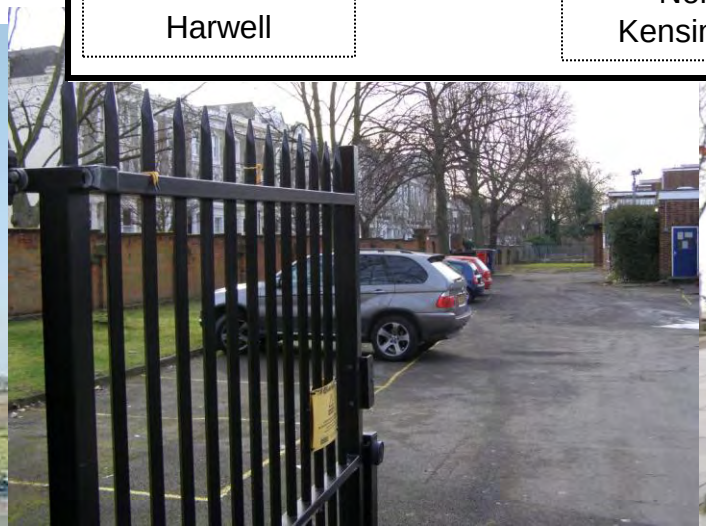
Harwell

Urban background

North Kensington

Kerbside

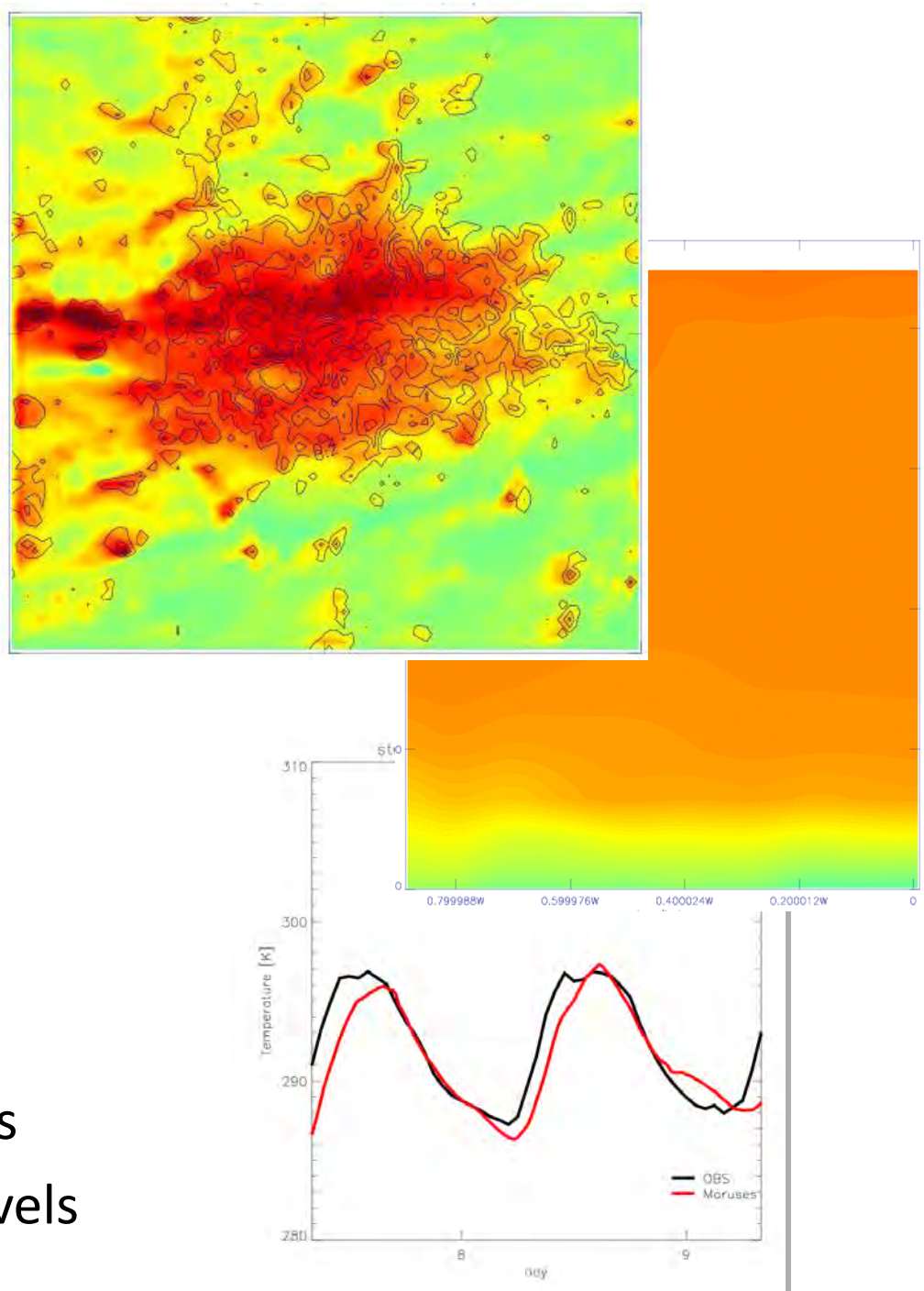
Marylebone Road



Modelling & integration

Informing next generation models

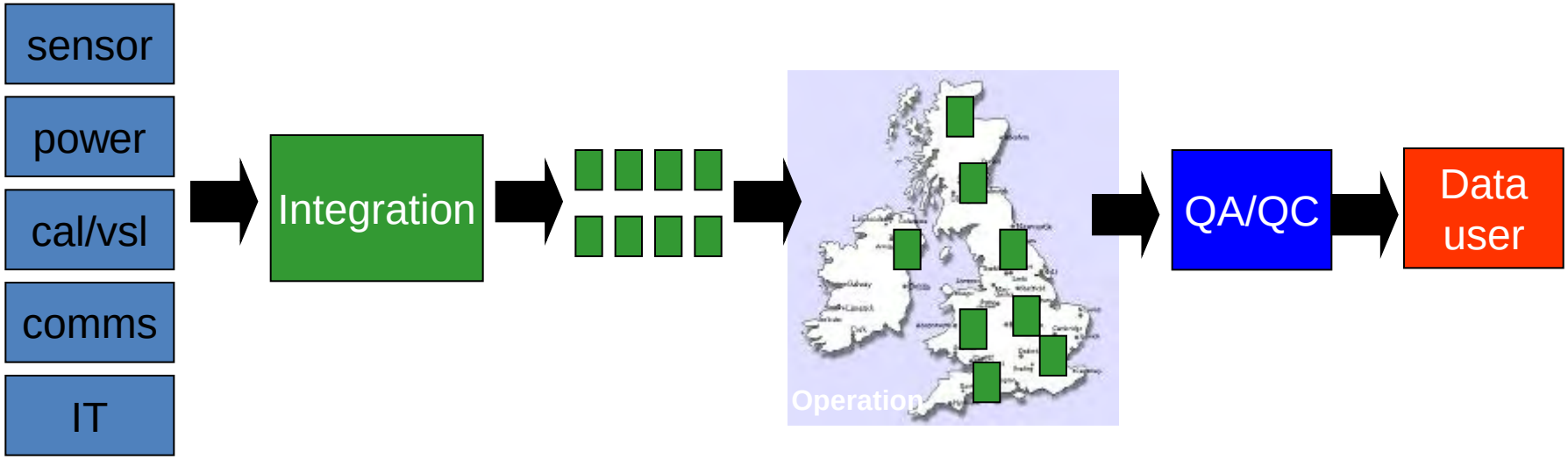
- Met modelling
  - LondUM + WRF
- AQ modelling
  - CMAQ
- Integration
  - Data archive
  - Model vs observations
  - Elevated vs ground levels



Networks of sensors – demonstration projects

NERC recently recommended a new research programme for the development of demonstration networks of sensors

- Recent two page Expressions of Interest call – 30 responses
- Highly diverse technological approaches and applied science areas
  e.g Mammal tracking, lightening, rainfall to sustainable cities – strong AQ interest.
- Delivered as consortium projects to enable end to end integration
- £5M from NERC, plus potentially additional support from TSB and EPSRC.



Who?	Different HEI/RCC	HEI/RCC or Private	Manufacturer	Govt. Agency or service sector	NMS	HEI/RCC