Remote sensing of NO_2: Integrating slant column measurements into operational air quality management systems.

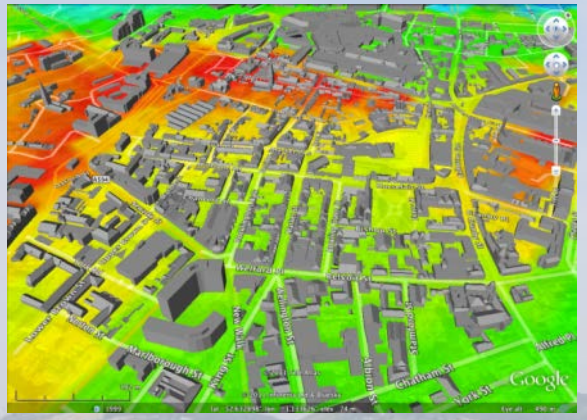
Roland Leigh

University of Leicester

What's coming up

- Stretching the envelope of ground-based remote sensing
- A role for airborne NO_2 mappers?
- Reducing "spectral complexity" and instrumental payload constraints.
- Assimilation of spaceborne, ground-based and airborne remotely-sensed NO_2 into models and applications

Urban-scale air quality from orbit



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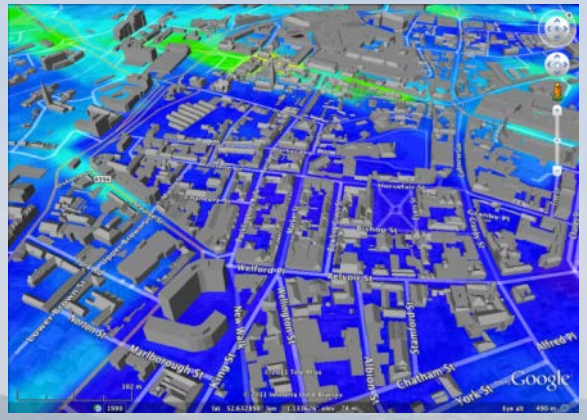

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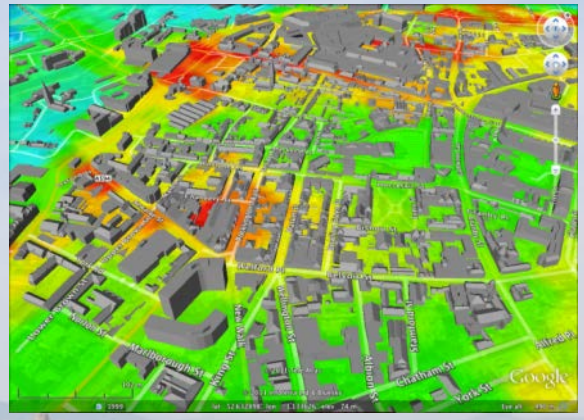

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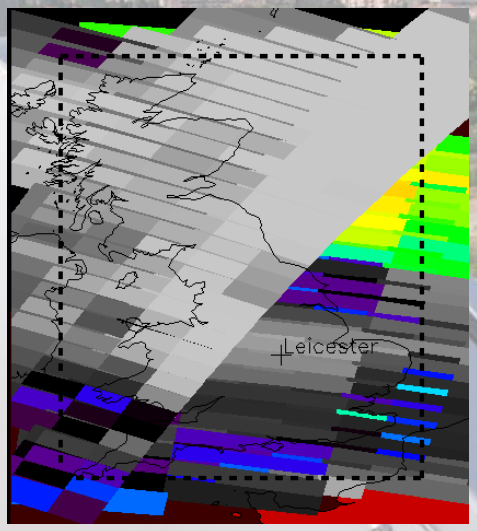
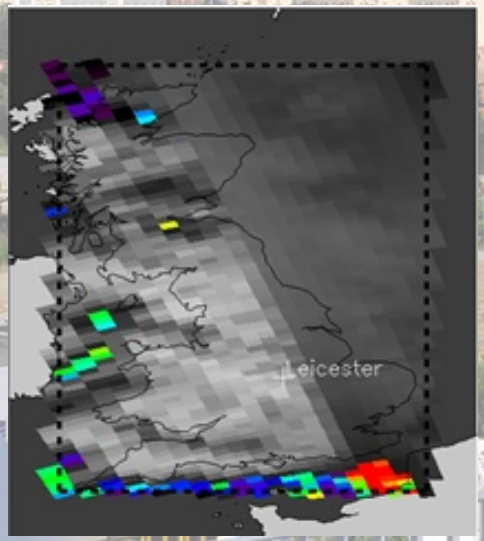


GOME 2



OMI

?

Design of the CompAQS imaging Spectrometer

Whyte et al. 2009, AMT

	Wavelength (nm)	Target Species	Signal-to-Noise
CAPACITY	290	Stratospheric O3 Col	100
	300		300
	305		500
	312	Total & Trop O3, SO2, HCHO, O4, AAI, SSA, AOT	1000
	320		1500
	350		1800
	450	NO2, O3, CTH	2500
	550		2500

	Wavelength (nm)	Target Species	Signal-to-Noise
MTG	295-302	O3 profile	150
	302-310		150
	310-325	SO2	850
	325-335	Tropospheric O3	1060
	335-360	O3	2000
	420-450	HCHO	2500

	Wavelength (nm)	Target Species	Signal-to-Noise
OMI	Global View		
	270-310	O3 profile	60
	310-335	O3 column	265
	335-365	HCHO	1450
	365-420	OClO	700
	420-450	NO2	2600
	450-500	O4	1400
	Spatial Zoom		
	270-310	O3 profile	45
	310-335	O3 column	190
	335-365	HCHO	1050
	365-420	OClO	470
	420-450	NO2	1850
	450-500	O4	1000

Atmos. Meas. Tech., 2, 789–800, 2009
www.atmos-meas-tech.net/2/789/2009/

Atmospheric Measurement Techniques

Assessment of the performance of a compact concentric spectrometer system for Atmospheric Differential Optical Absorption Spectroscopy

C. Whyte[1], R. J. Leigh[1], D. Lobb[2], T. Williams[2], J. J. Remedios[1], M. Cutter[2], and P. S. Monks[3]

University of Leicester

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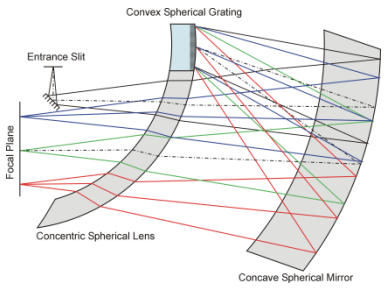
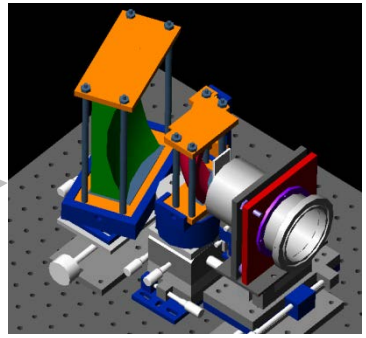
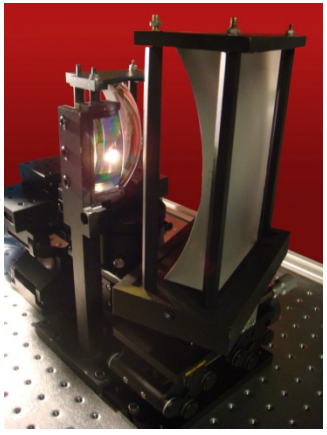
Centre for eo Instrumentation







Proposed to S5P by SSTL

University of Leicester

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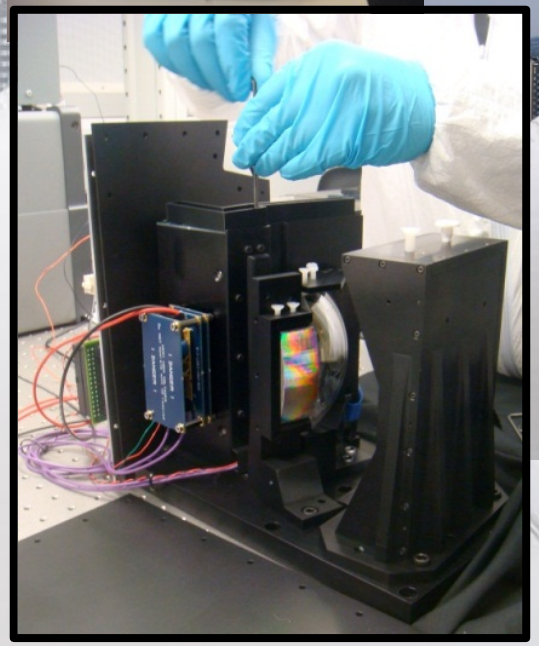
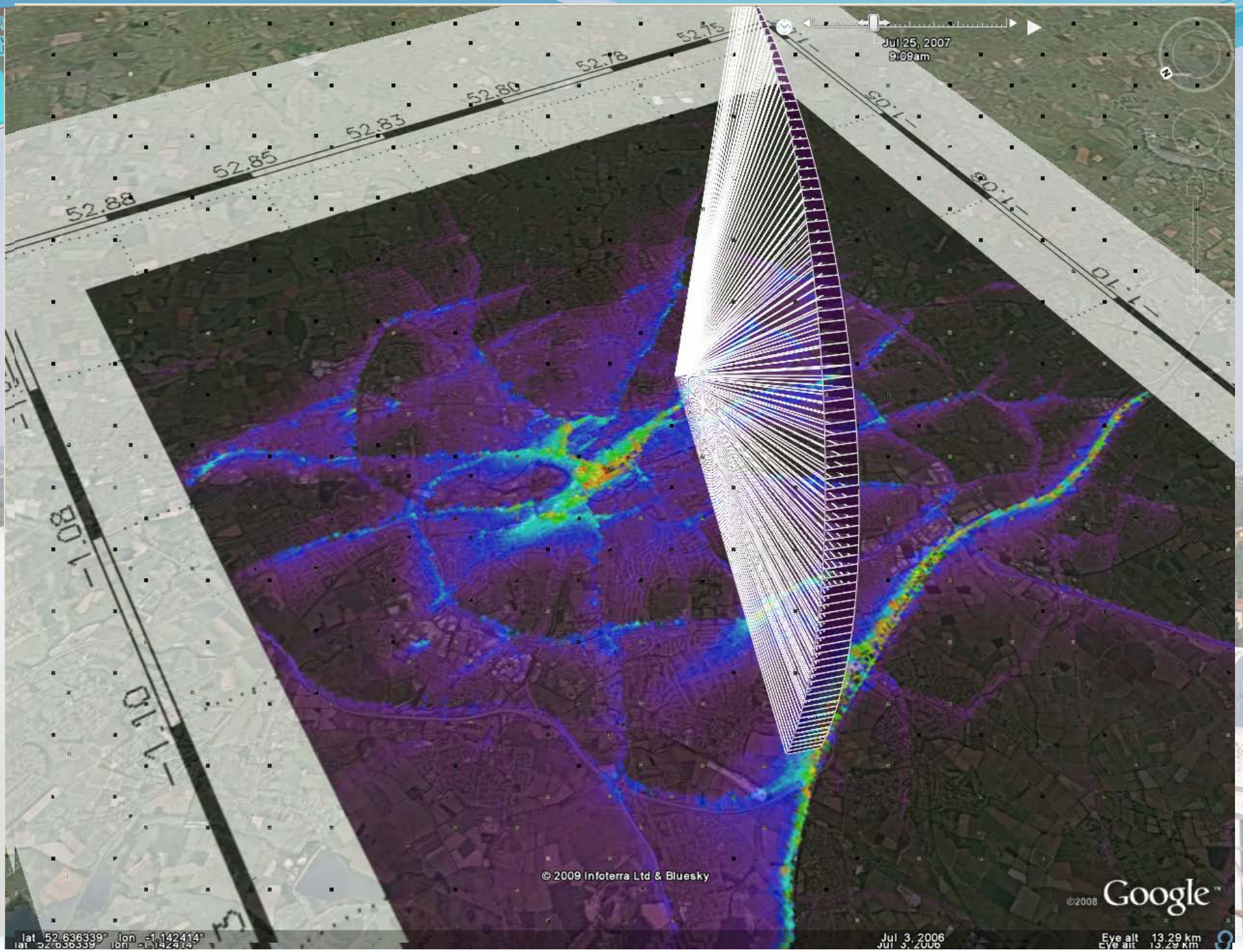
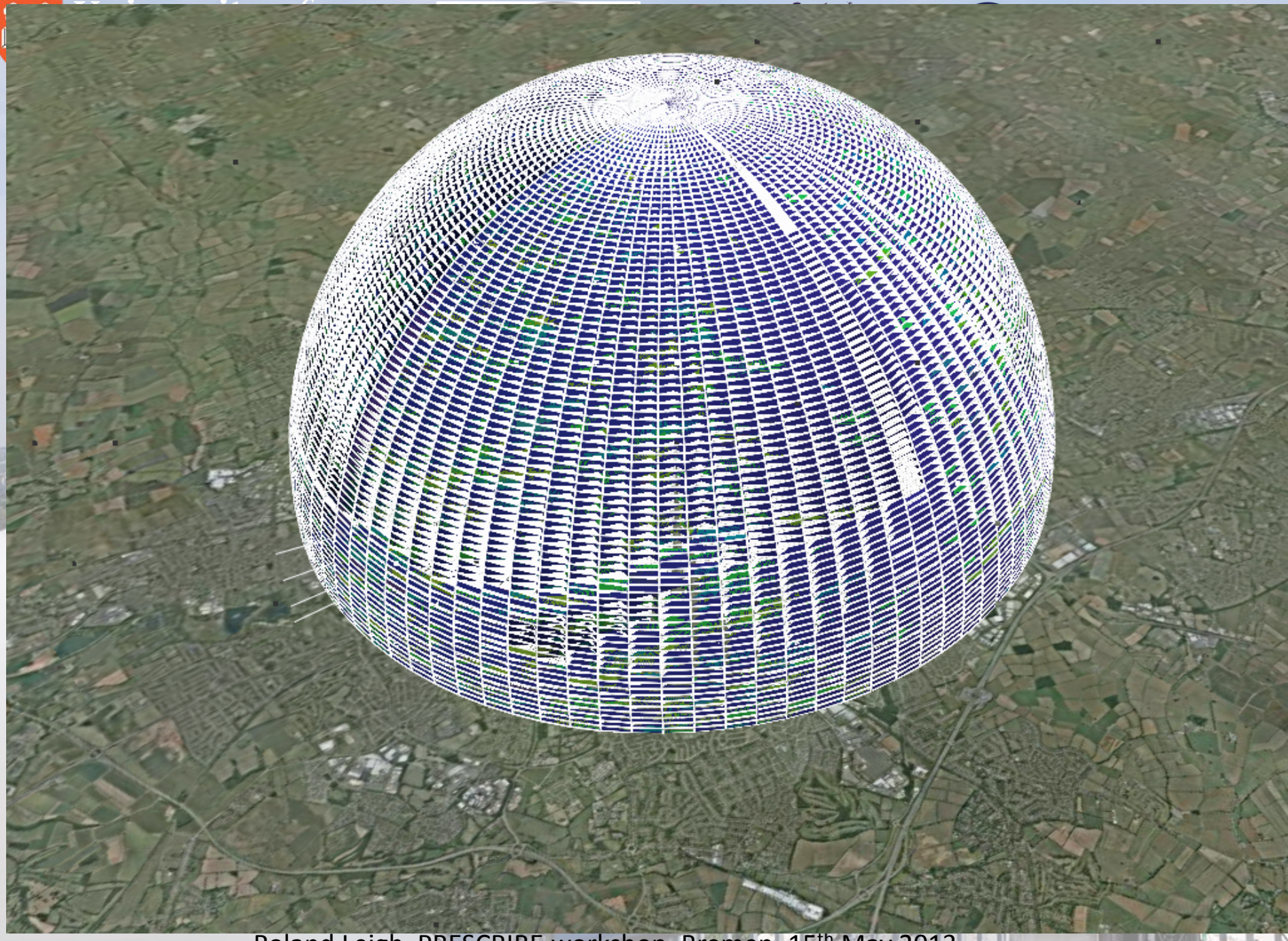
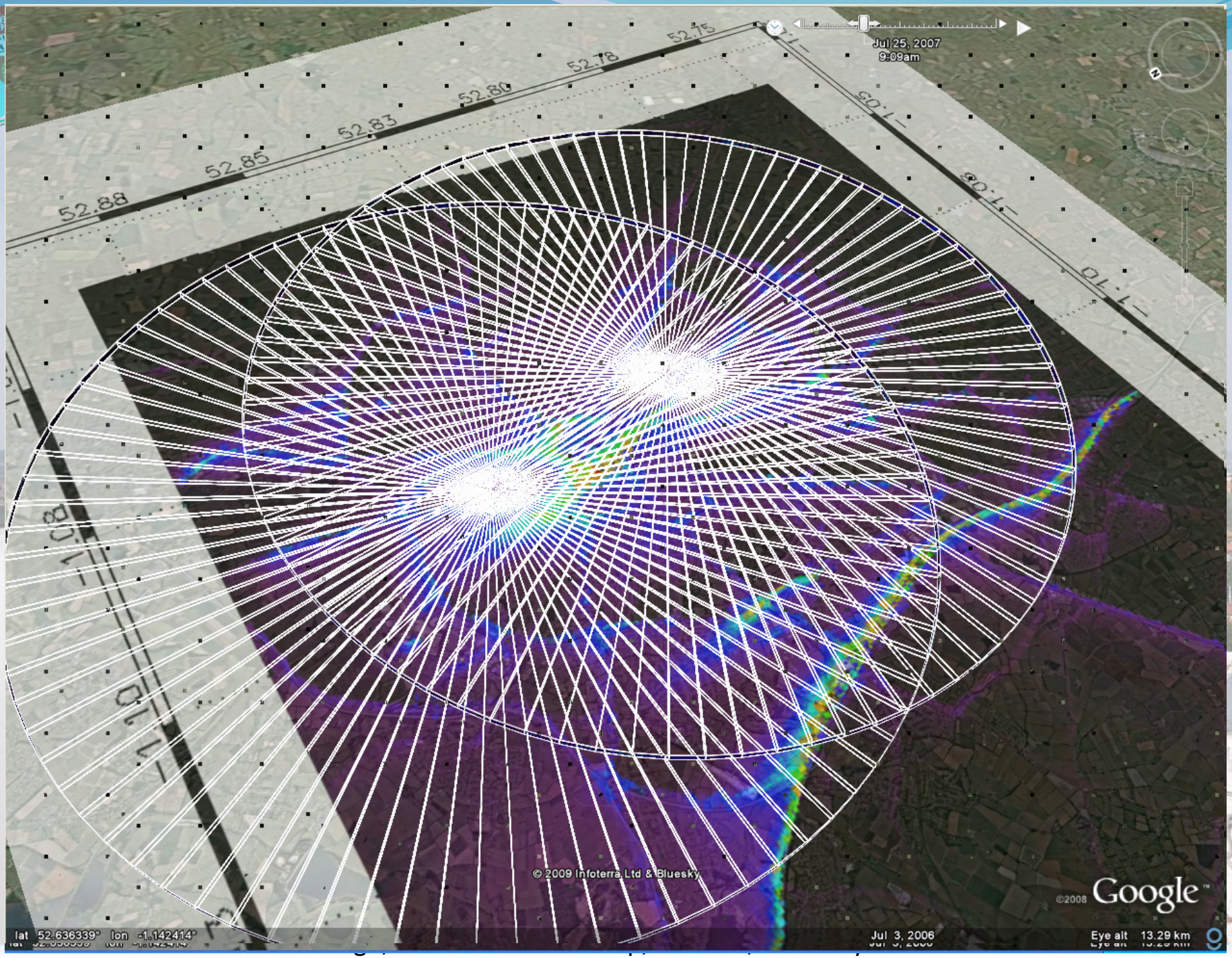
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL




52.75
52.78
52.80
52.83
52.85
52.88
-1.05
-1.08
-1.10
Jul 25, 2007
9:09am
© 2009 Infoterra Ltd & Bluesky
©2008 Google
lat 52.636339° lon -1.142414°
Jul 3, 2006
Eye alt 13.29 km




Jul 25, 2007
9:09am
52.75
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-1.08
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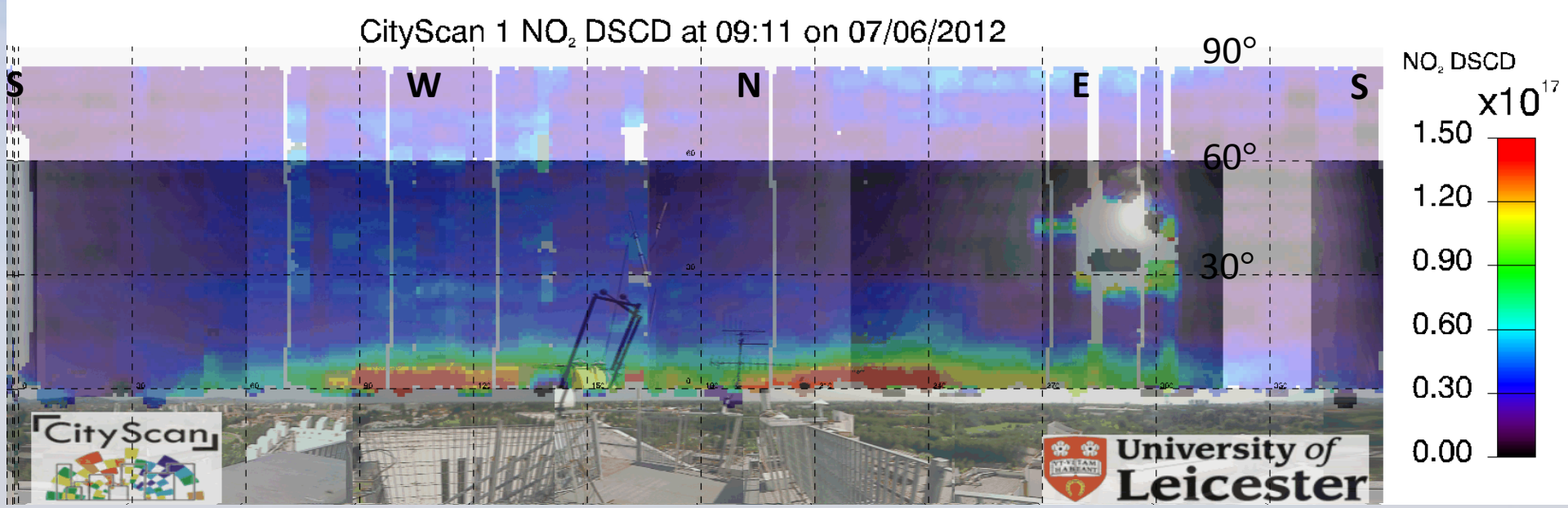
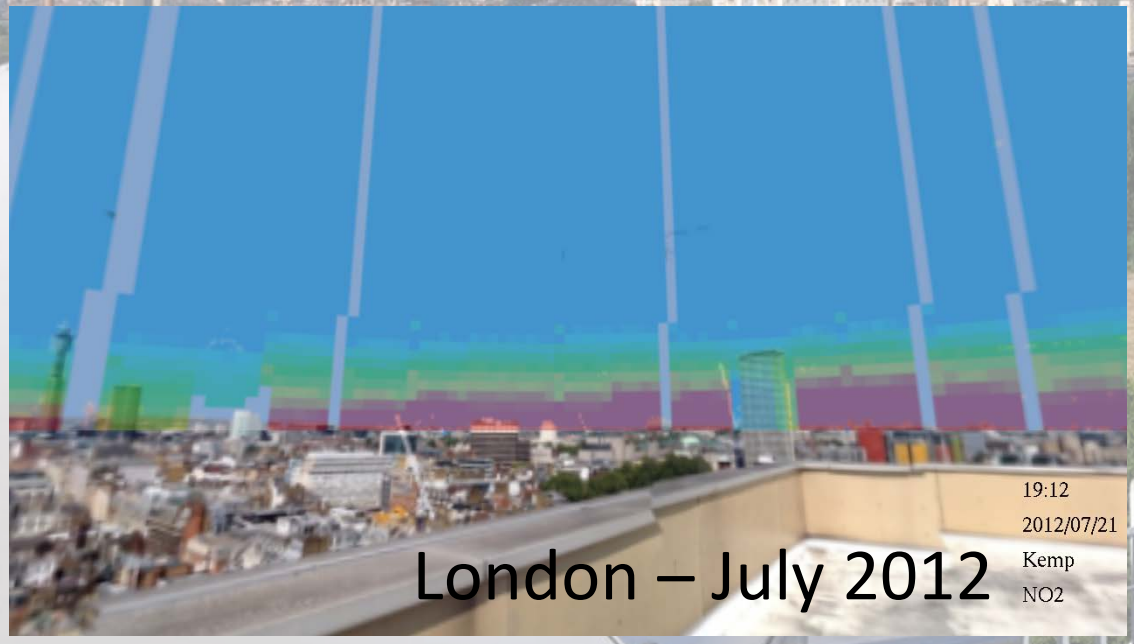
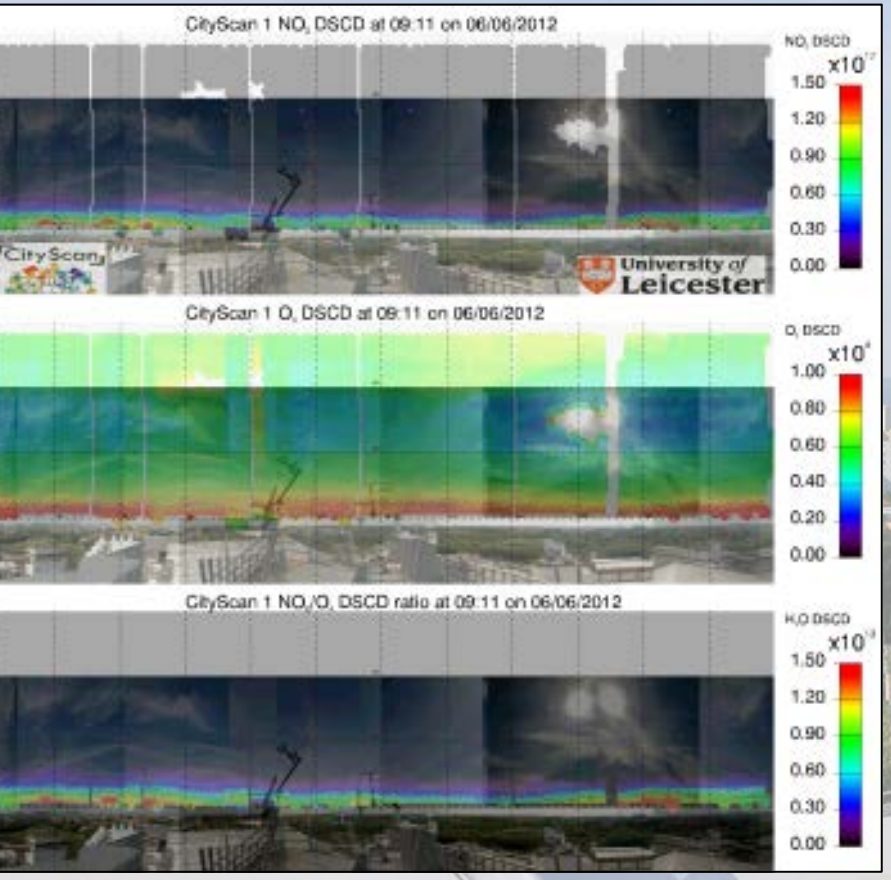
© 2009 Infoterra Ltd & Bluesky
©2008 Google
lat 52.636339° lon -1.142414°
Jul 3, 2006
Eye alt 13.29 km

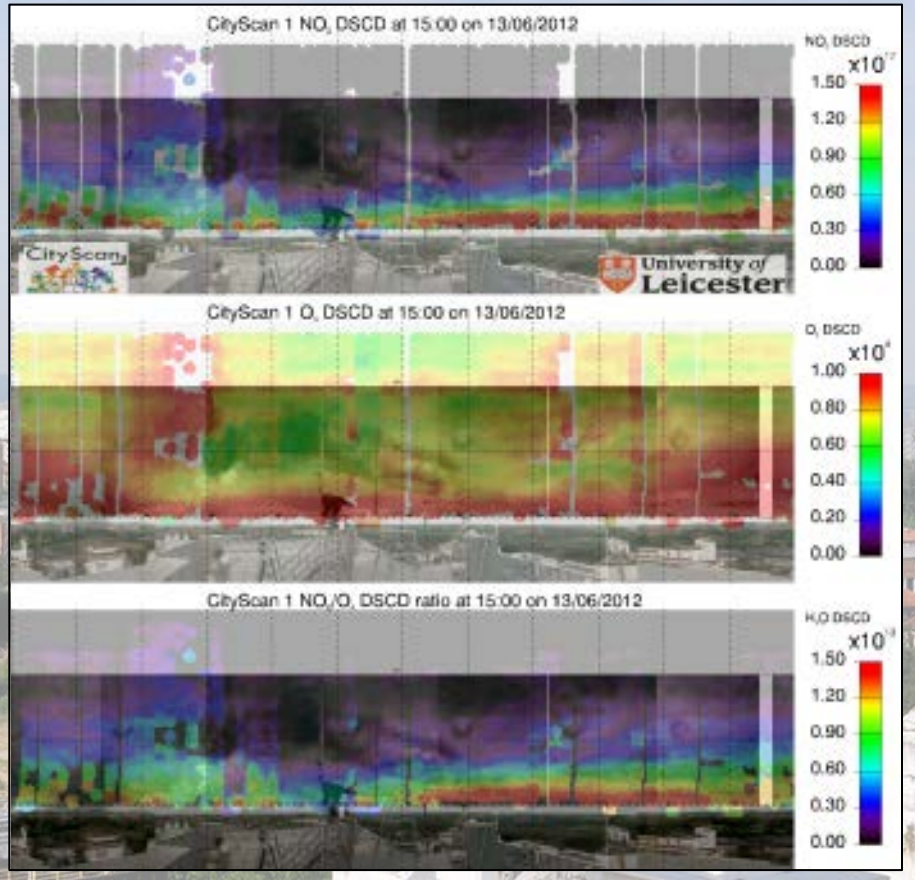


Bologna – June 2012



London – July 2012


CityScan 1 NO2 DSCD at 09:11 on 06/06/2012
NO2 DSCD
x10^17
1.50
1.20
0.90
0.60
0.30
0.00
CityScan
University of Leicester
CityScan 1 O4 DSCD at 09:11 on 06/06/2012
O4 DSCD
x10^43
1.00
0.80
0.60
0.40
0.20
0.00
CityScan 1 NO2/O4 DSCD ratio at 09:11 on 06/06/2012
H2O DSCD
x10^-3
1.50
1.20
0.90
0.60
0.30
0.00


CityScan 1 NO2 DSCD at 15:00 on 13/06/2012
NO2 DSCD
x10^17
1.50
1.20
0.90
0.60
0.30
0.00
CityScan
University of Leicester
CityScan 1 O4 DSCD at 15:00 on 13/06/2012
O4 DSCD
x10^43
1.00
0.80
0.60
0.40
0.20
0.00
CityScan 1 NO2/O4 DSCD ratio at 15:00 on 13/06/2012
H2O DSCD
x10^-3
1.50
1.20
0.90
0.60
0.30
0.00

University of Leicester

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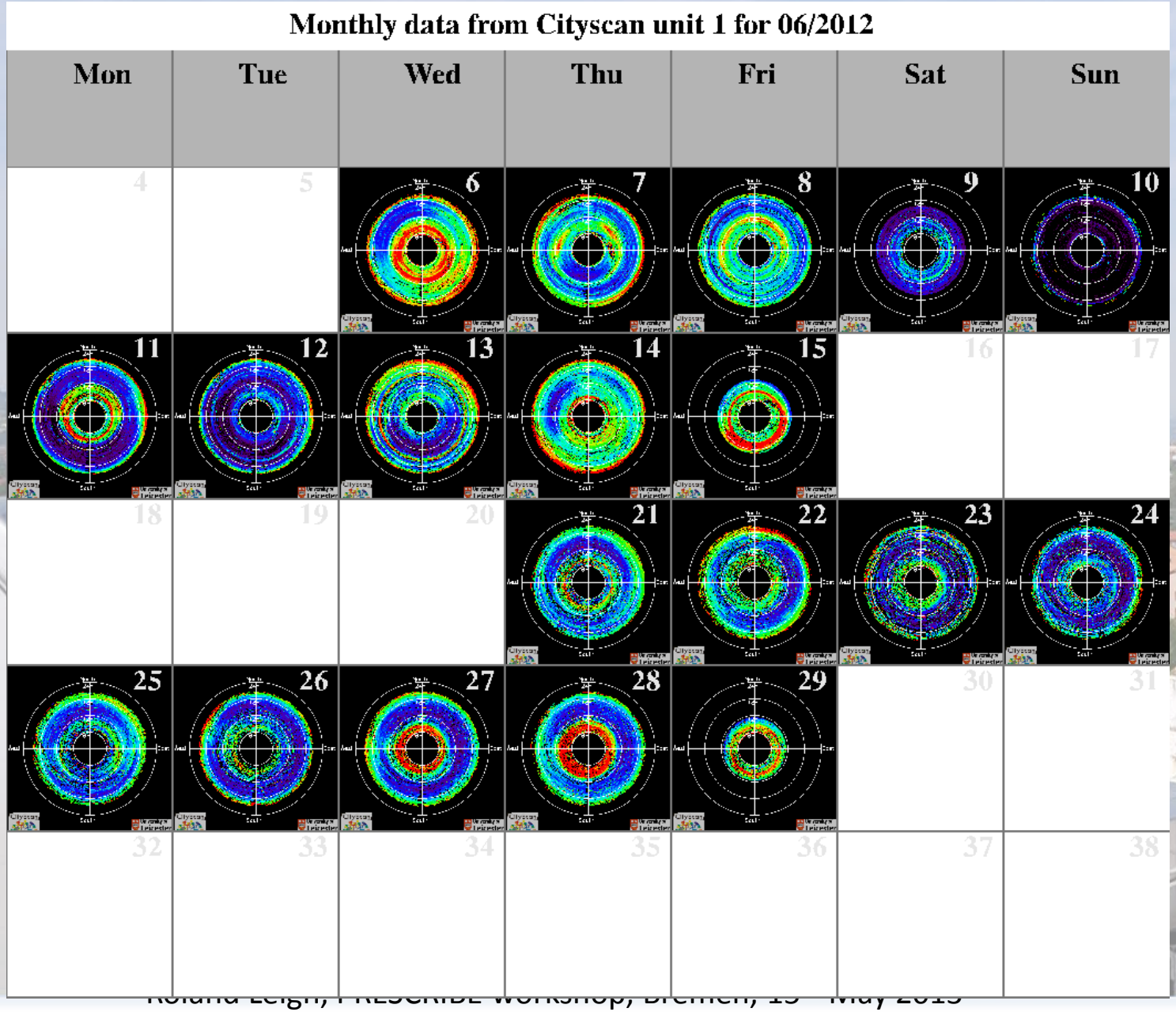
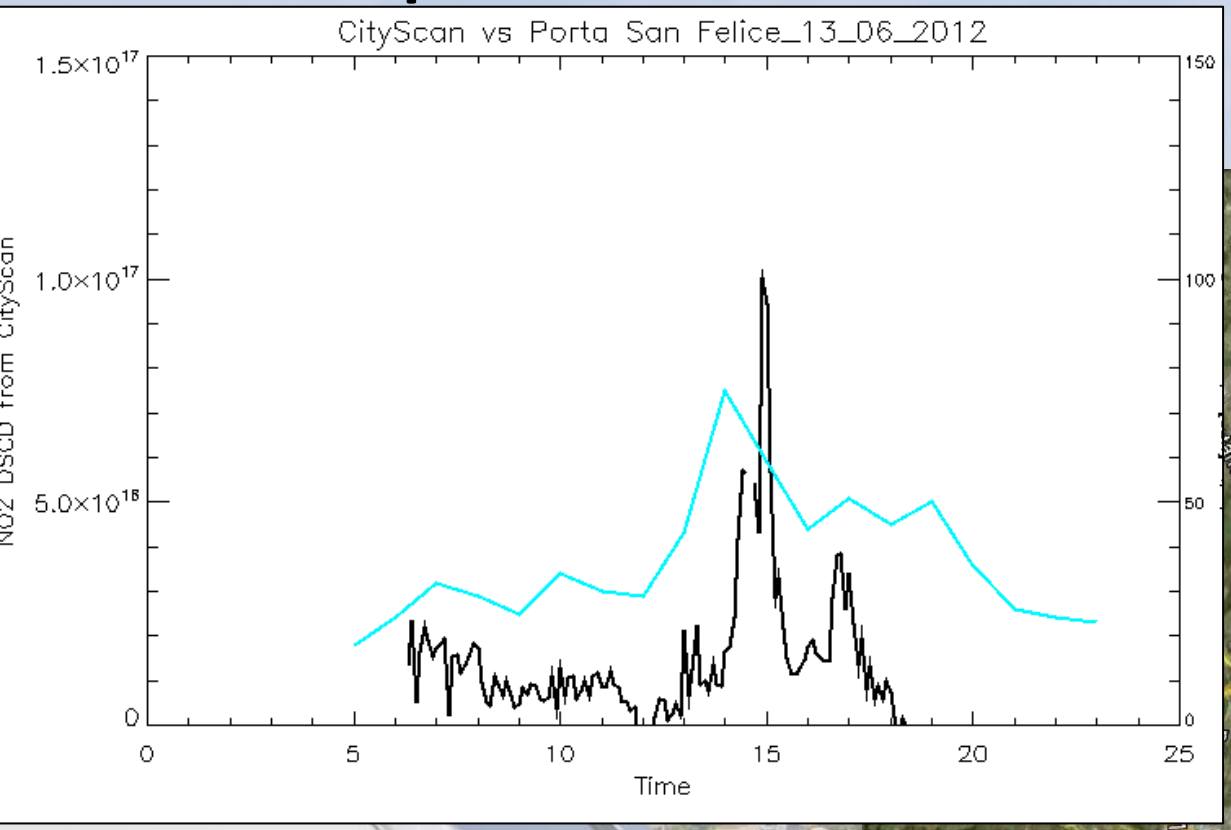
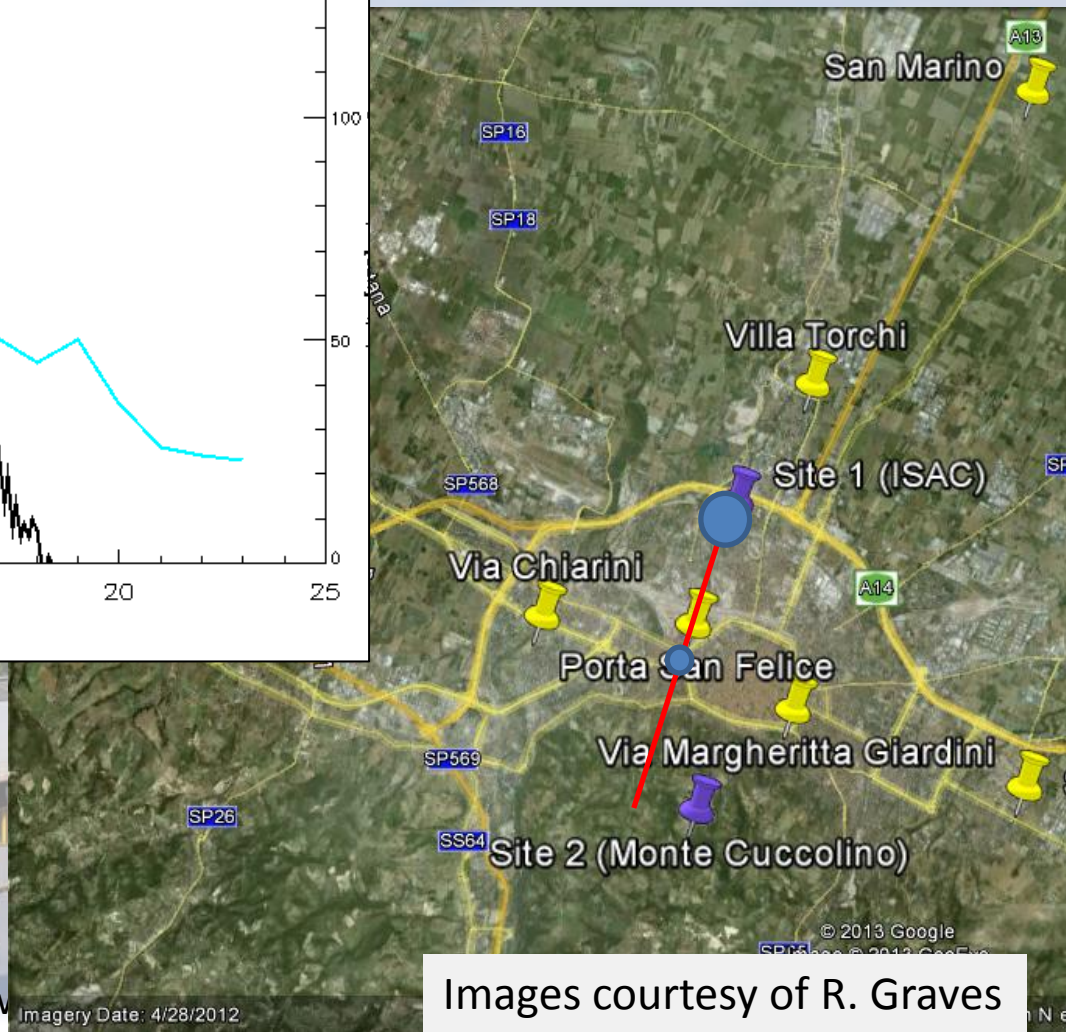


Comparisons with in situ sensors





Roland Leigh, PRESCRIBE w

Images courtesy of R. Graves

University of Leicester

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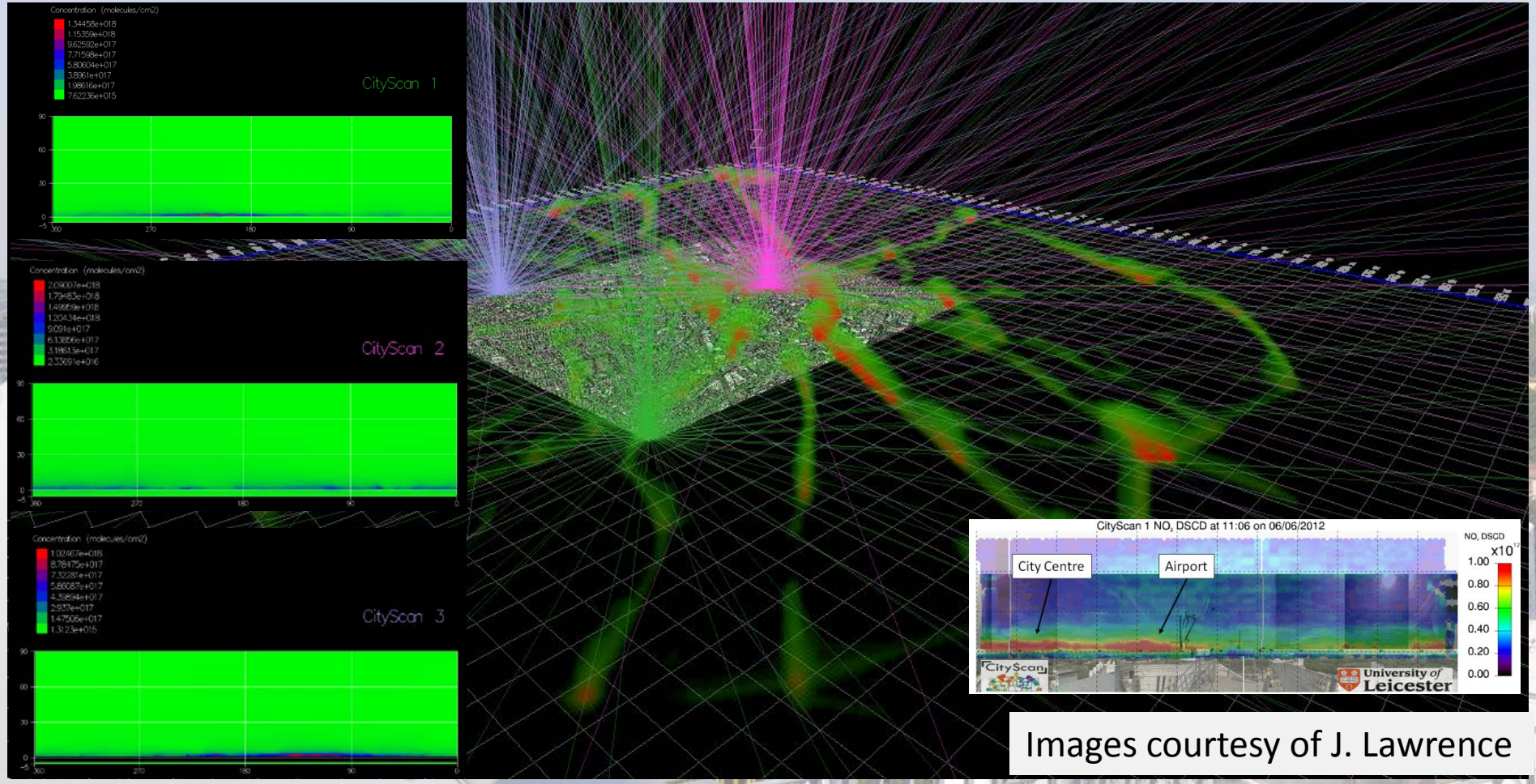
3D Environment for NO_2 data assimilation



Images courtesy of J. Lawrence

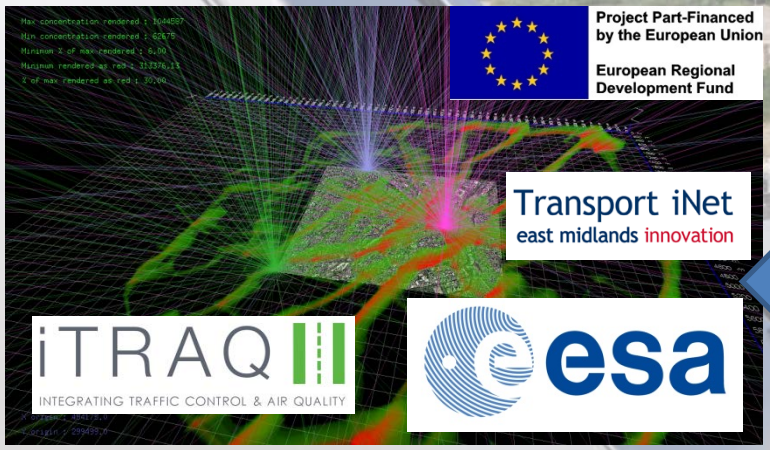
CompAQS – The NO_2 Imager

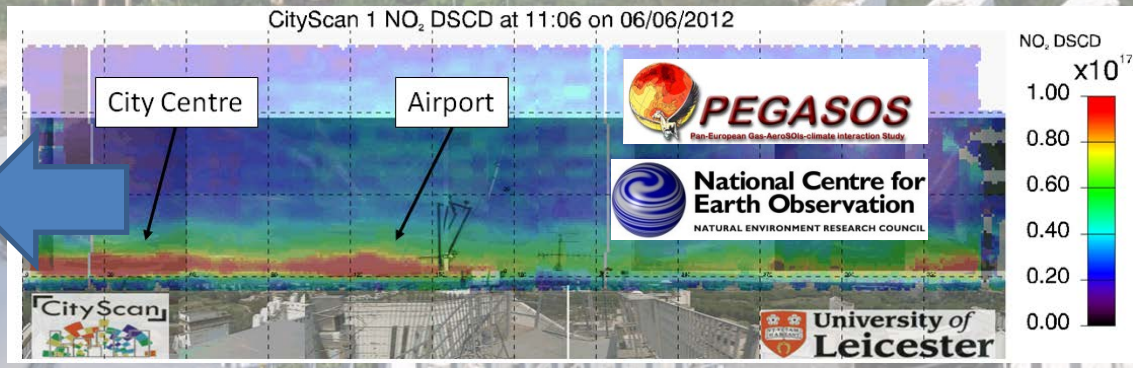
A novel imaging spectrometer
Using scattered sunlight

Multiple rotating instruments for tomography

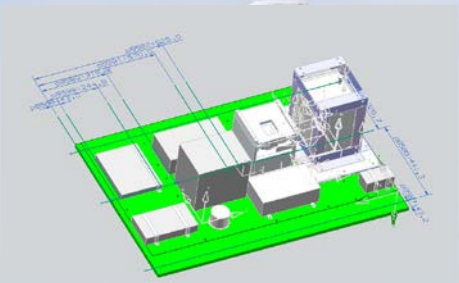
Placed in a housing looking over a city for NO_2 retrievals

Produces Panoramas of NO_2

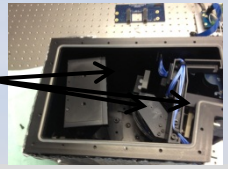




The Airborne AQ Mapper

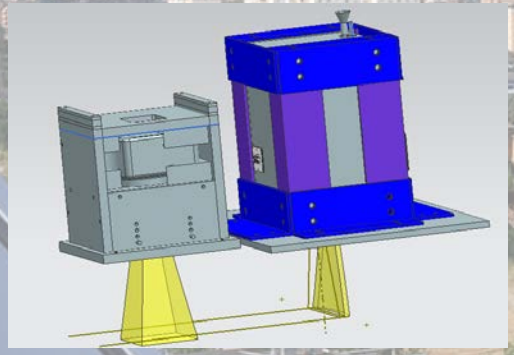


Optical Mount modifications



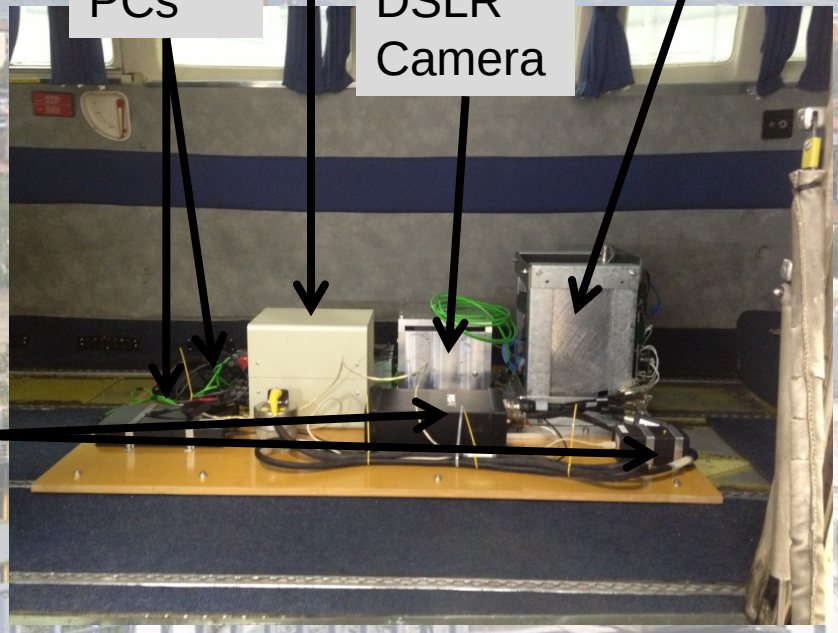
Power Supply

CompAQS Spectrometer



PCs

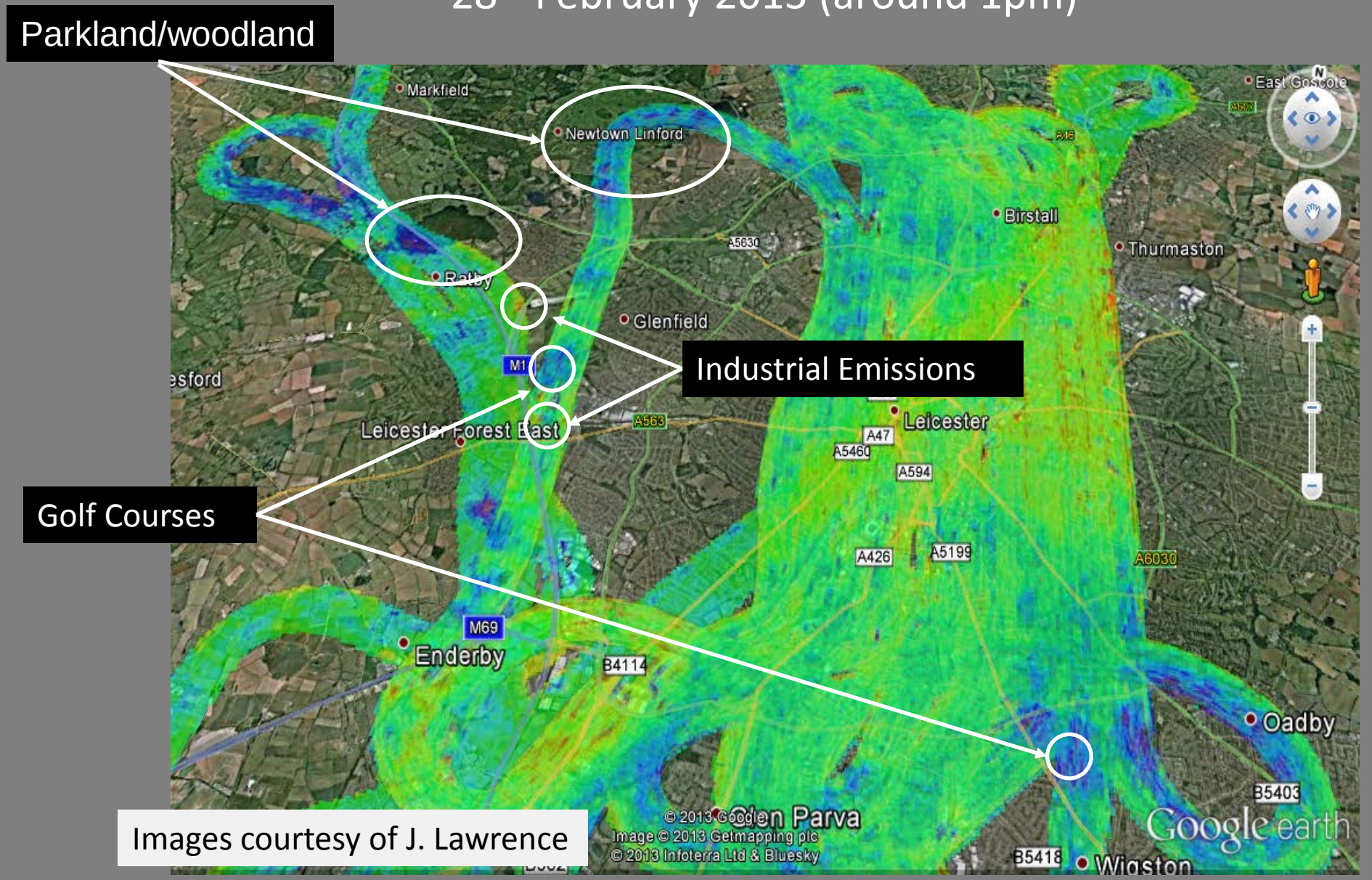
DSLR Camera



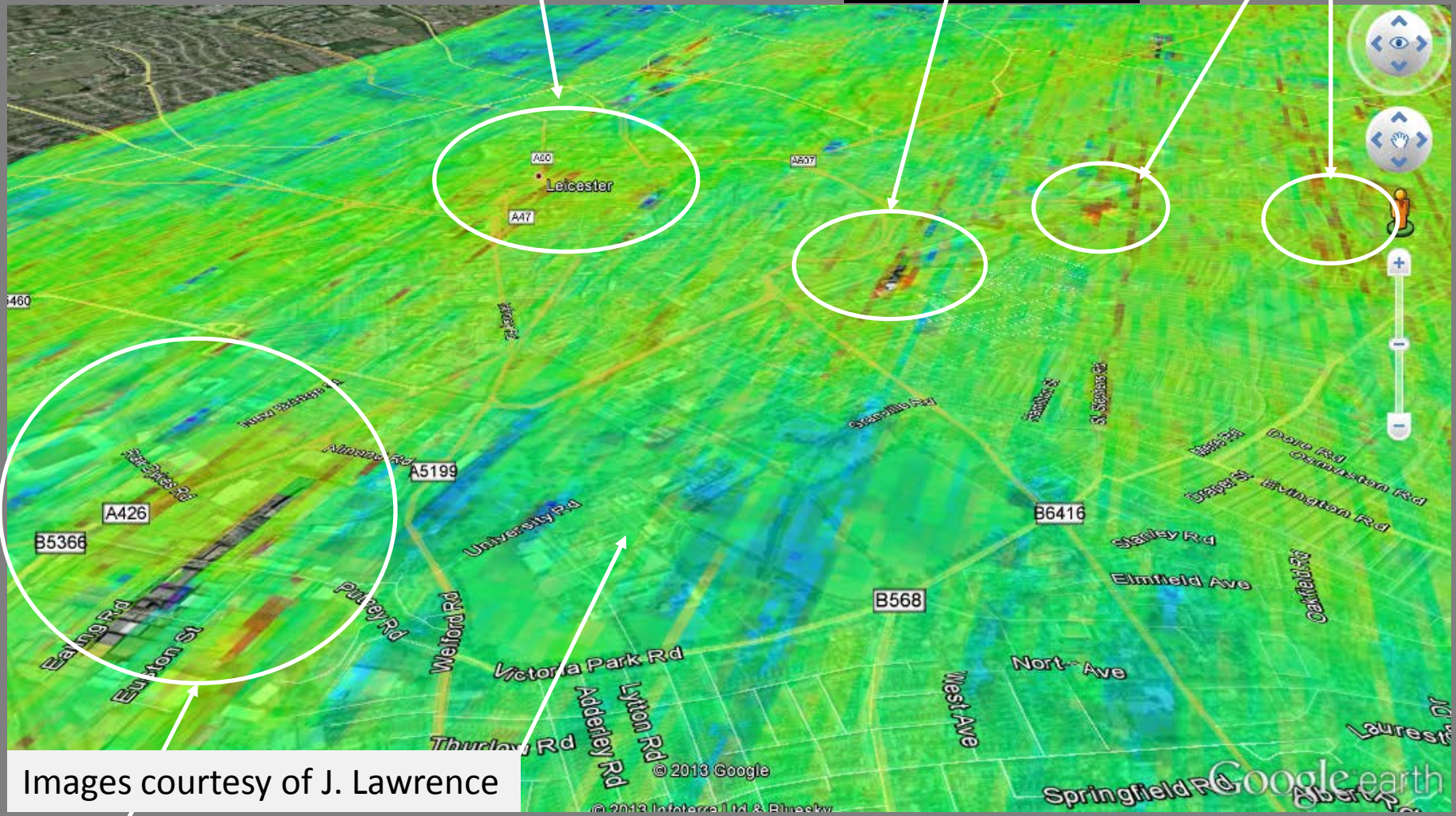
IMU/GPS

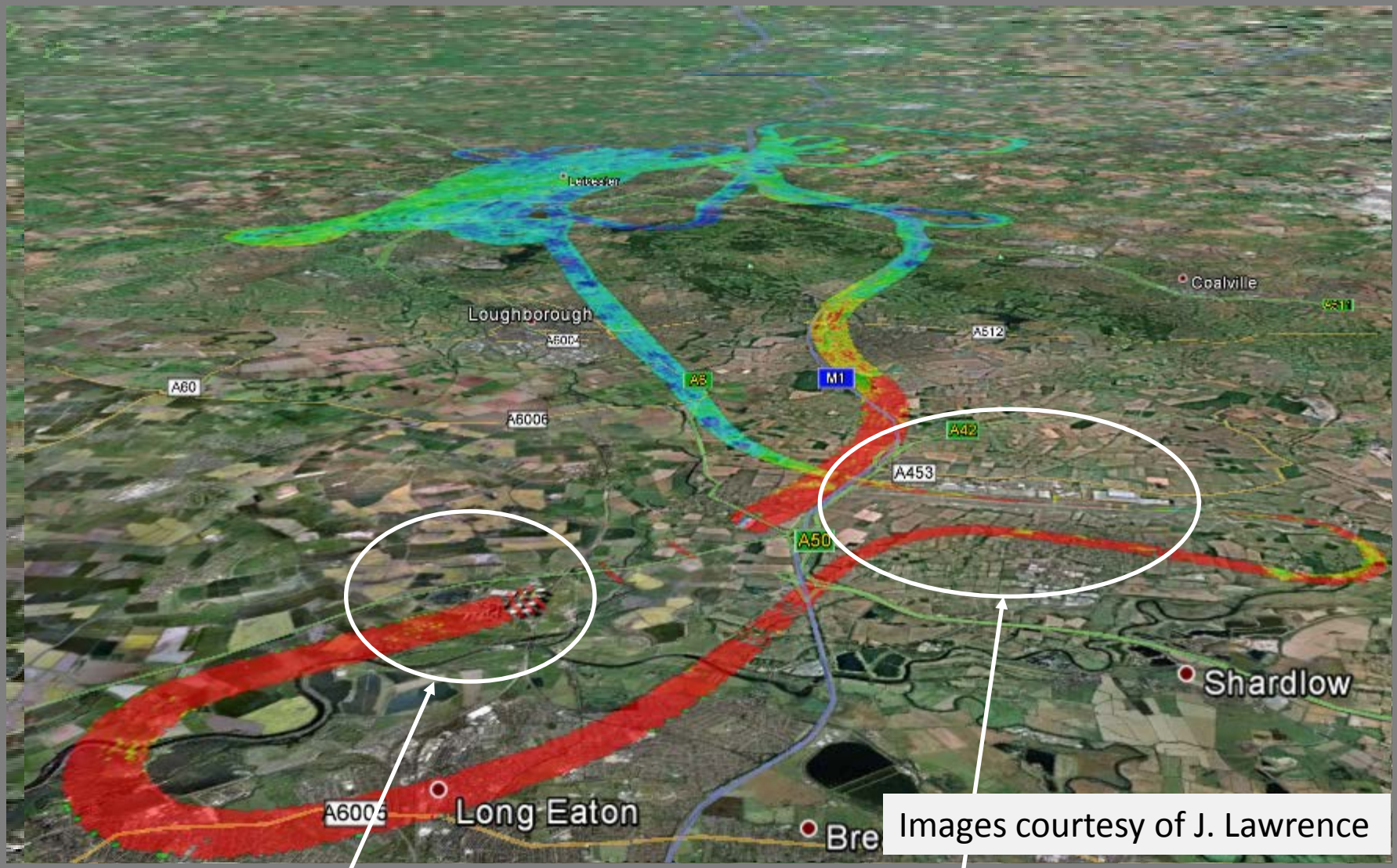
Test Flight: 28th Feb 2013 – 12:30

Nitrogen Dioxide Concentrations as imaged on 28th February 2013 (around 1pm)



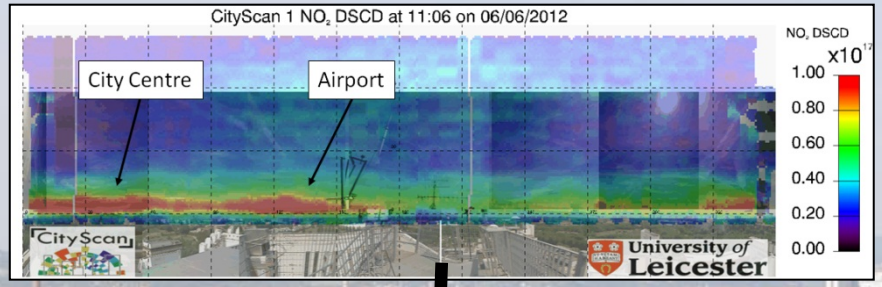
Images courtesy of J. Lawrence

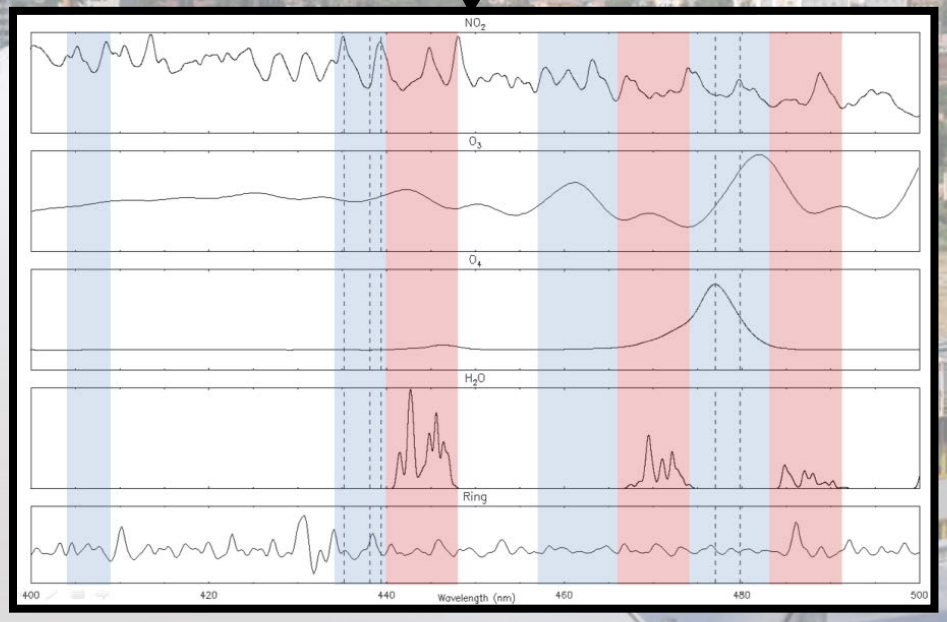

Traffic emissions?
Railway Station
Industrial Estates
Leicester
A50
A607
A47
A5199
A426
B5366
B6416
B568
University Rd
Victoria Park Rd
Welford Rd
Aylestone Rd
Elmfield Ave
Springfield Rd
Addersley Rd
Lytton Rd
West Ave
© 2013 Google
Google earth
Images courtesy of J. Lawrence
Industrial Emissions
University of Leicester


Loughborough
Coalville
A60
A6006
A6
M1
A512
A42
A453
A50
Shardlow
A6005
Long Eaton
Images courtesy of J. Lawrence
Ratcliffe Power Station
East Midlands Airport

The Ultra-Compact Air quality Mapper (UCAM)

A CEOI seedcorn study between the University of Leicester and SSTL



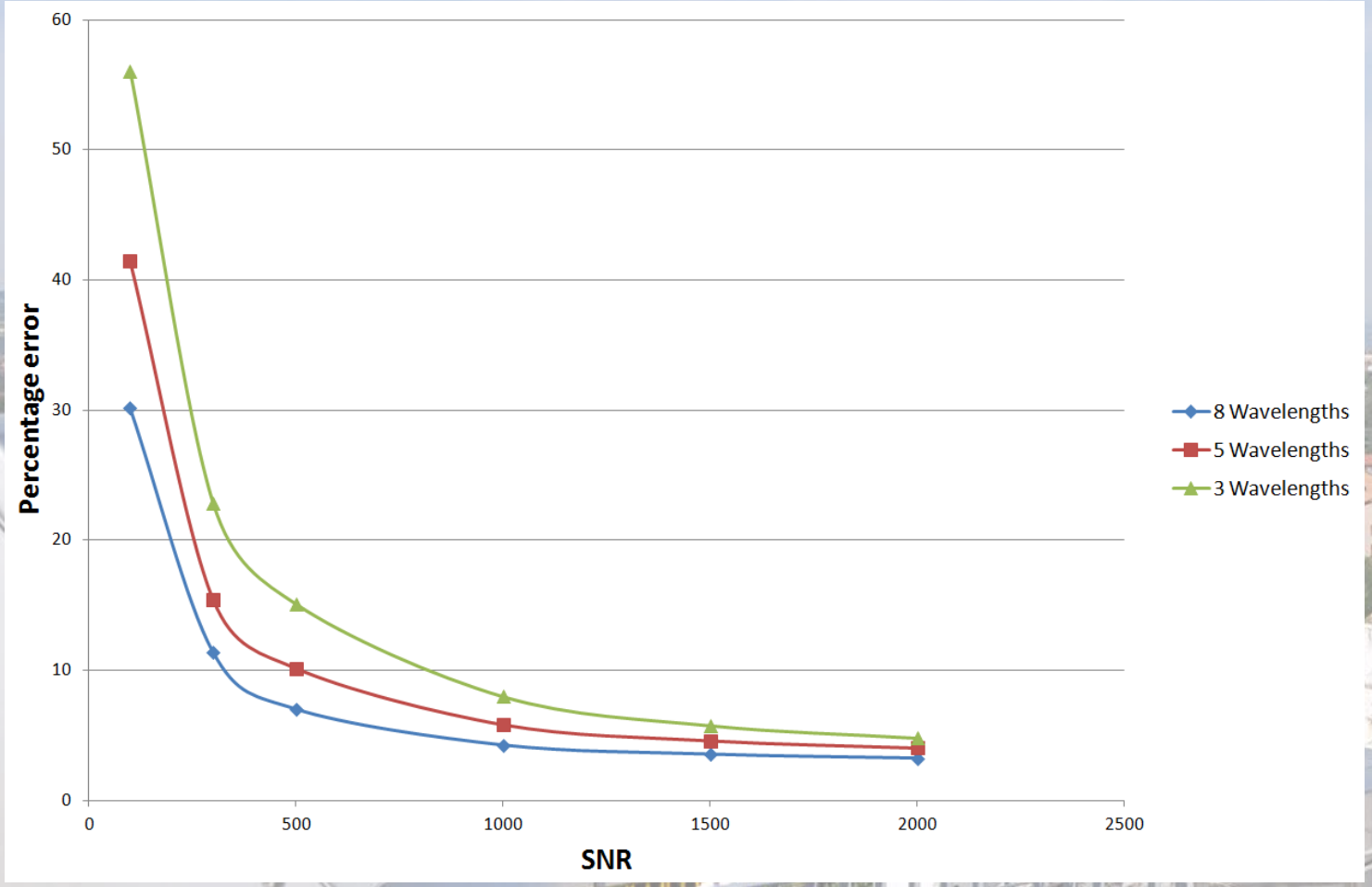


Shoe-boxed size CompAQS imaging spectrometer

UCAM pushbroom or full imaging NO_2 mapper

- Filter (discrete wavelength) retrieval using a neural network
- Real-time retrieval
- 10% of the volume
- 10% of the mass
- <10% of the data volume

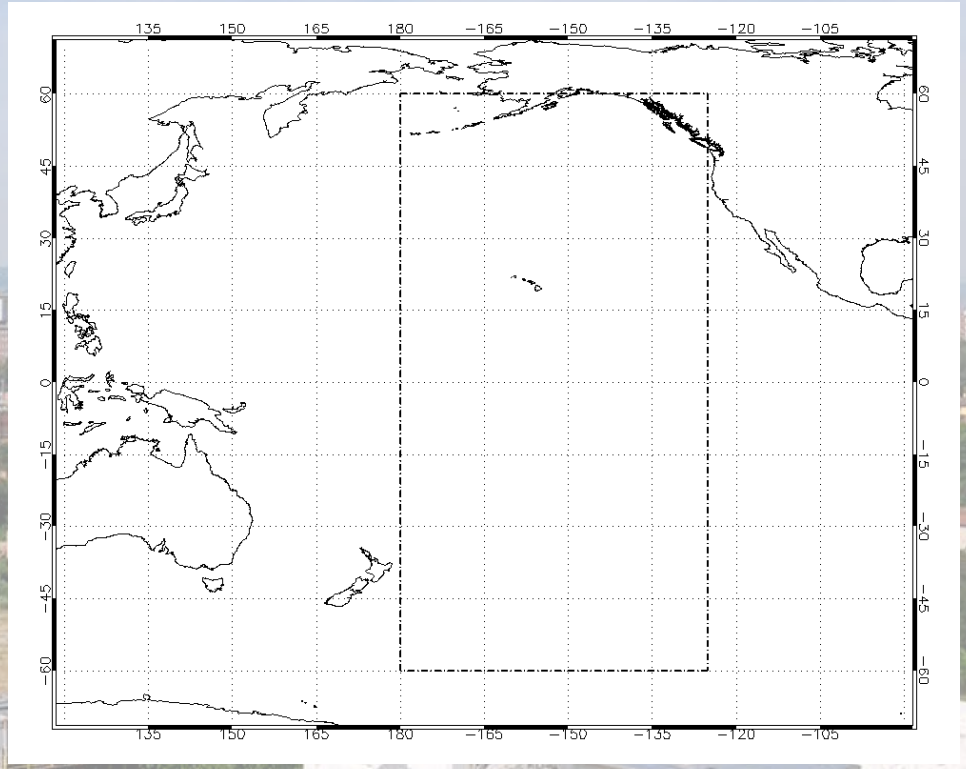
Preliminary findings..



Images courtesy of J. Lawrence

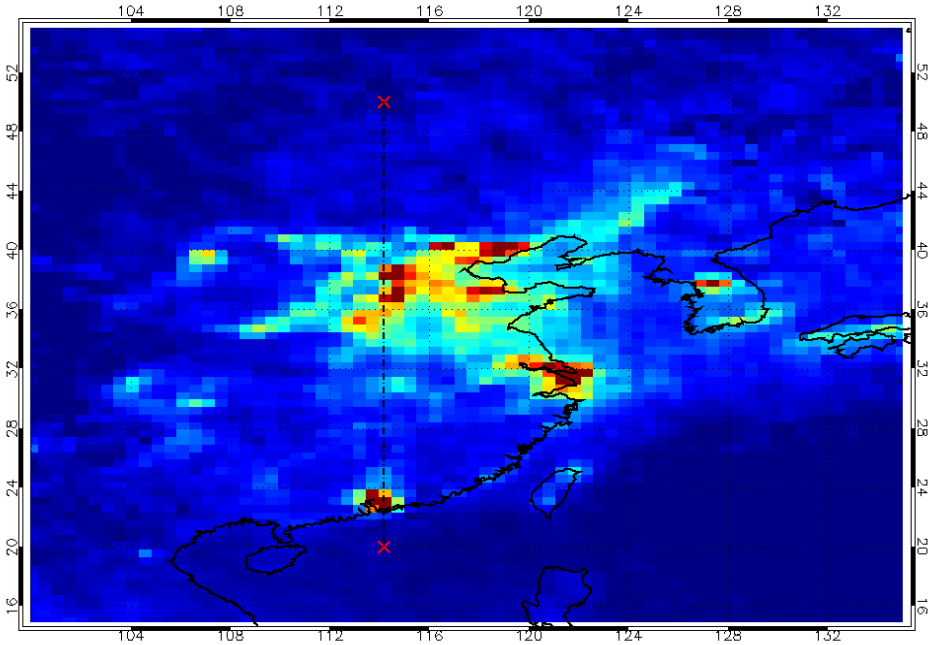
Earthshine DOAS – Principles and application

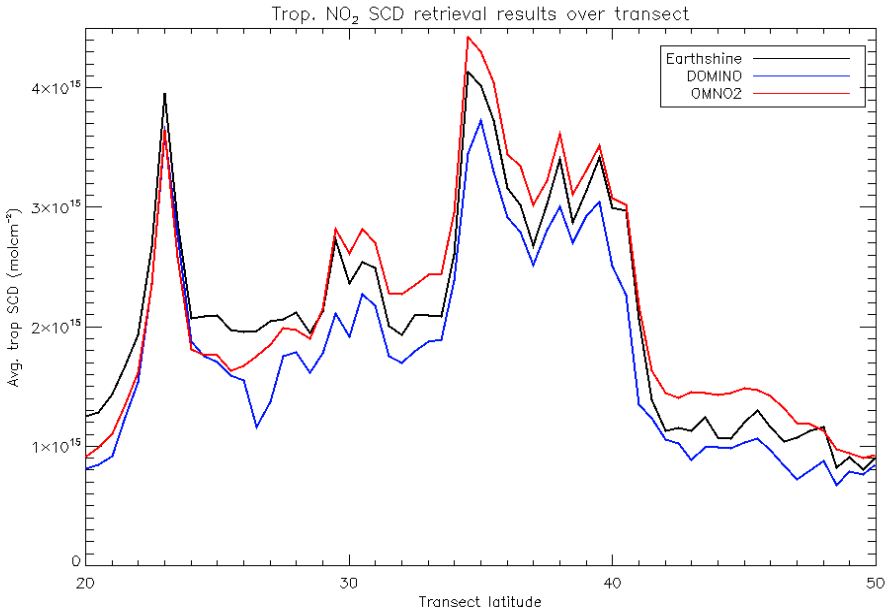
- Earthshine reference spectra have previously been used to determine IO concentrations over Antarctica (Schönhardt et al, 2008).
  - Ring effect present in reference spectrum - reduced impact in final retrieval
  - Instrument noise accounted for in reference spectrum
  - Less interference when retrieving trace absorbers
- Could this be applied to directly retrieve tropospheric NO_2?
  - Primarily stratospheric NO_2 exists over the Pacific compared with urban areas
  - VCDs retrieved over the Pacific have previously been used as an estimate of stratospheric NO_2 in order to determine tropospheric contribution.
- Stratospheric NO_2 shows strong latitudinal dependence. Latitudinal path length enhancement due to changing SZA also an issue.
  - Solution: bin daily spectra measured over reference region to 1° latitude bands
  - Only use cloud-free scenes to prevent signal enhancement & wavelength shifts due to clouds.



Images courtesy of J. Anand

Results





- Test case: Tropospheric NO2 retrieved by OMI during June 2006
- Average tropospheric NO_2 SCDs retrieved over transect using Pacific reference spectra comparable with OMNO2 & DOMINO results
- Method assumes longitudinally invariant stratospheric NO_2, as in reference region – retrieved VCDs may need to be spatially filtered to remove residual features caused by local stratospheric NO_2 features.

Images courtesy of J. Anand

University of Leicester

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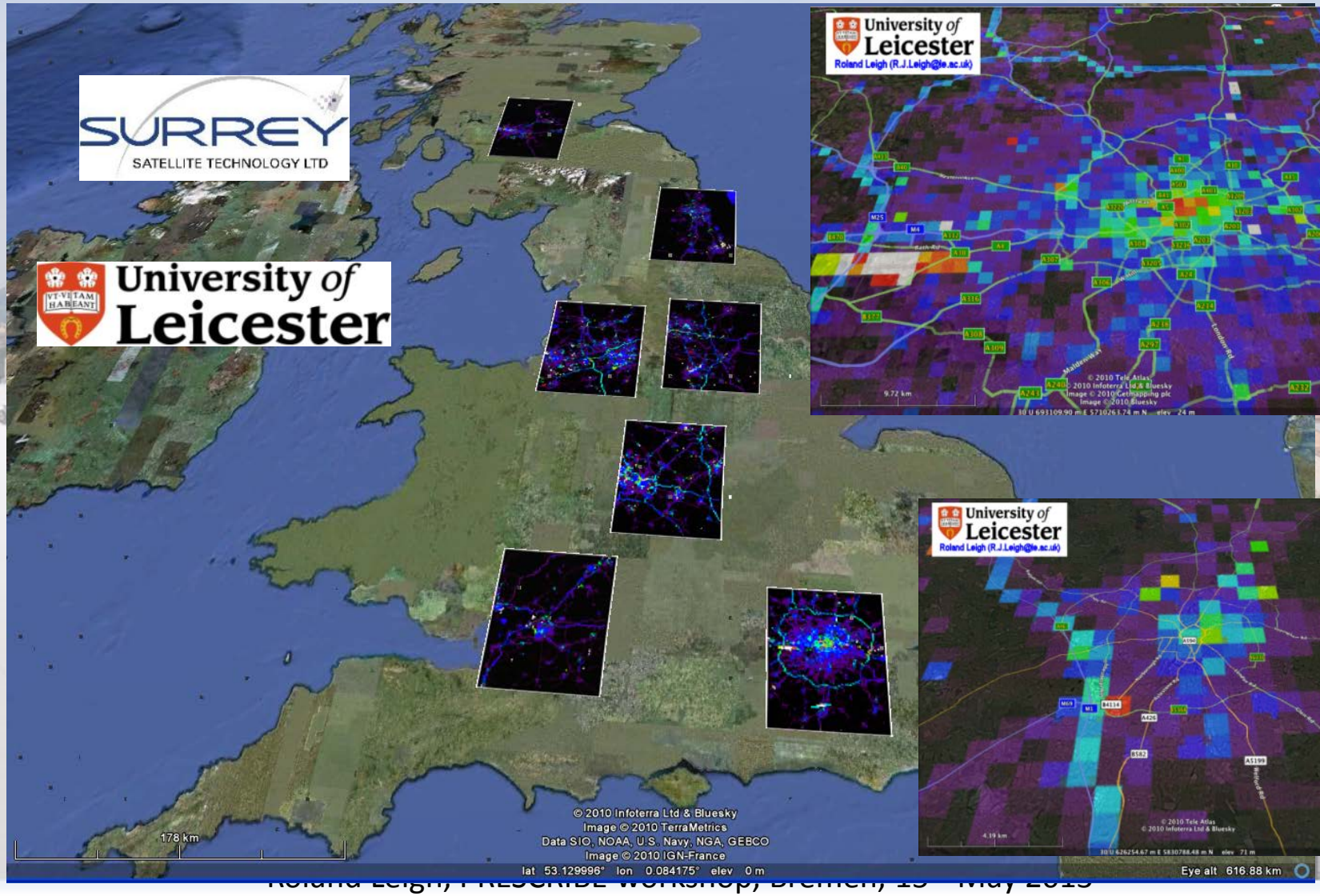
The CompAQS mission concept

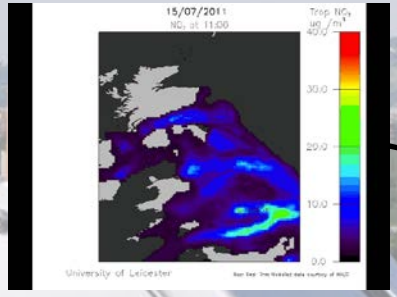


Applications

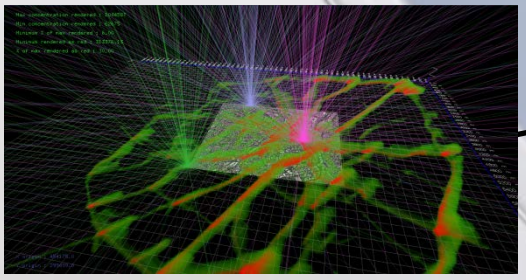
iTRAQ – An integrated traffic and air quality management tool.

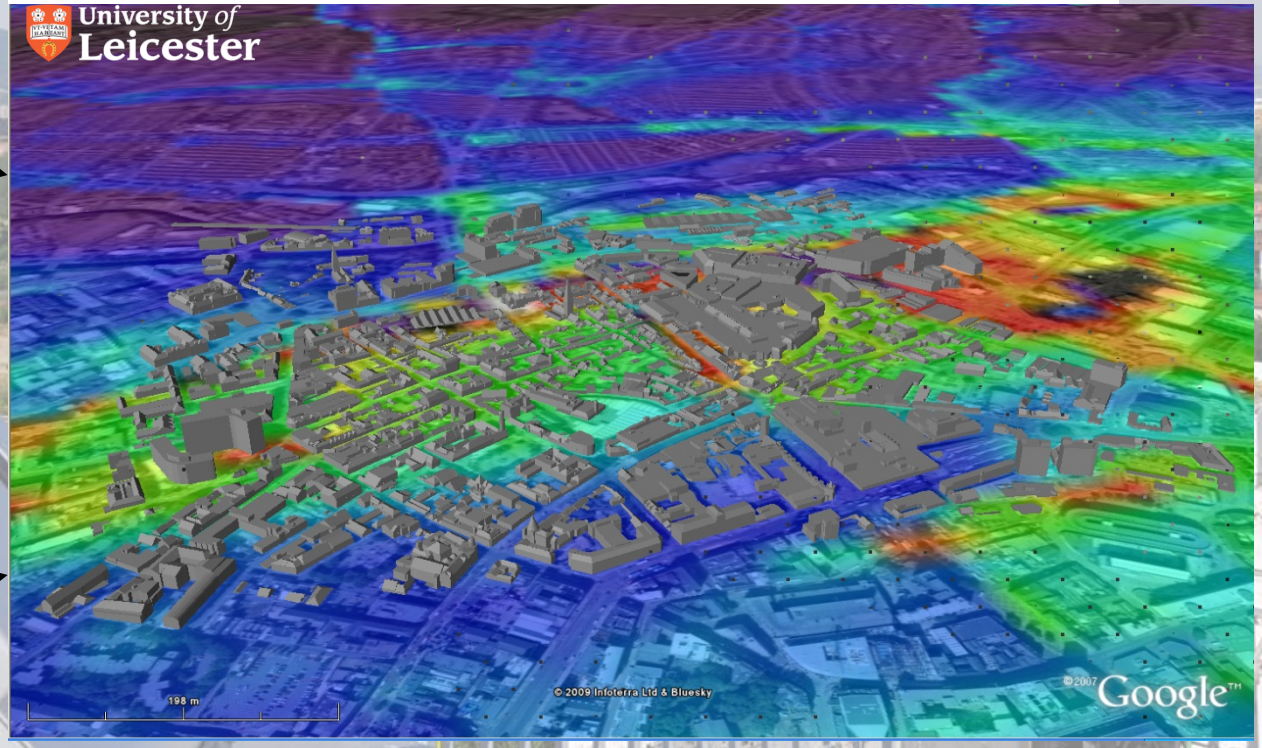
http://iap.esa.int/projects/transport/itraq

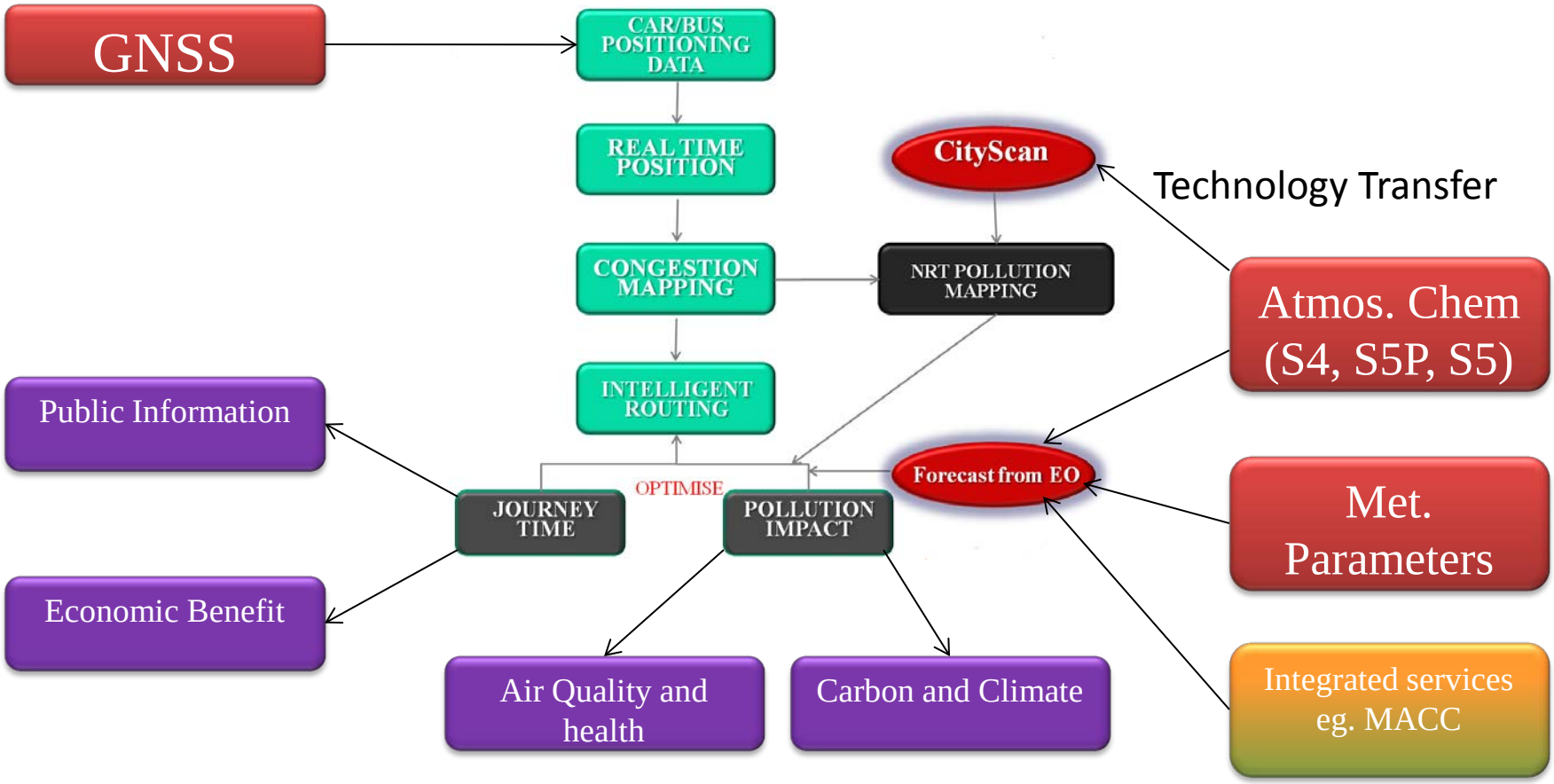
Earth Observation Data



AQ measurement and modelling

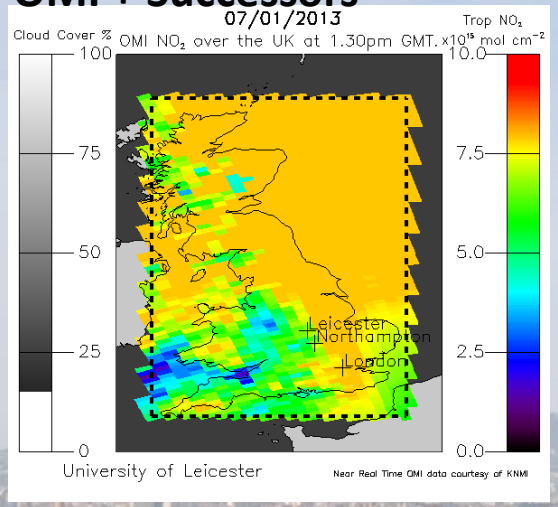




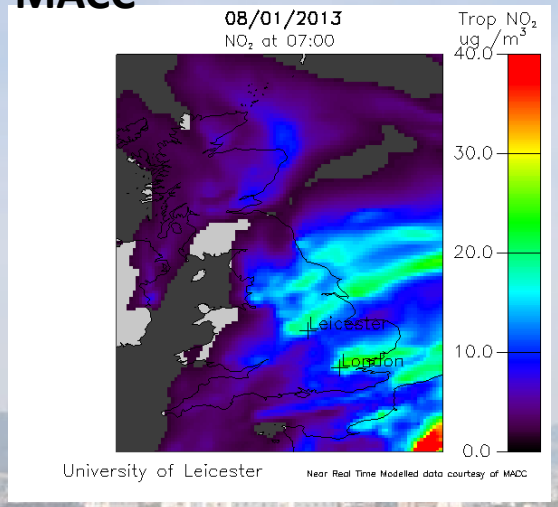

GNSS
CAR/BUS POSITIONING DATA
REAL TIME POSITION
CONGESTION MAPPING
INTELLIGENT ROUTING
CityScan
NRT POLLUTION MAPPING
Technology Transfer
Atmos. Chem (S4, S5P, S5)
Public Information
Economic Benefit
JOURNEY TIME
OPTIMISE
POLLUTION IMPACT
Forecast from EO
Met. Parameters
Air Quality and health
Carbon and Climate
Integrated services eg. MACC

iTRAQ: The remote-sensing of NO_2 perspective

OMI + Successors



MACC



Improved air quality. Reduced human exposure.

Background Field

Static Emission Sources

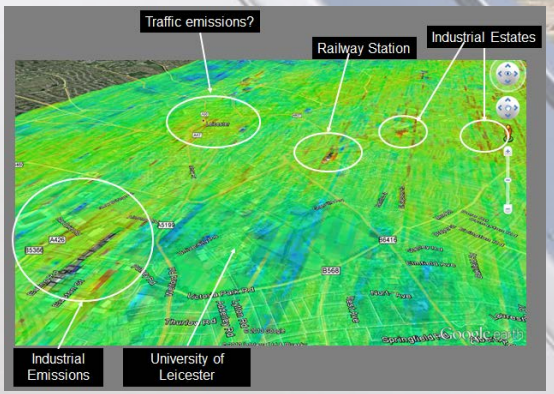
Vehicle Emission validation

Air Quality model

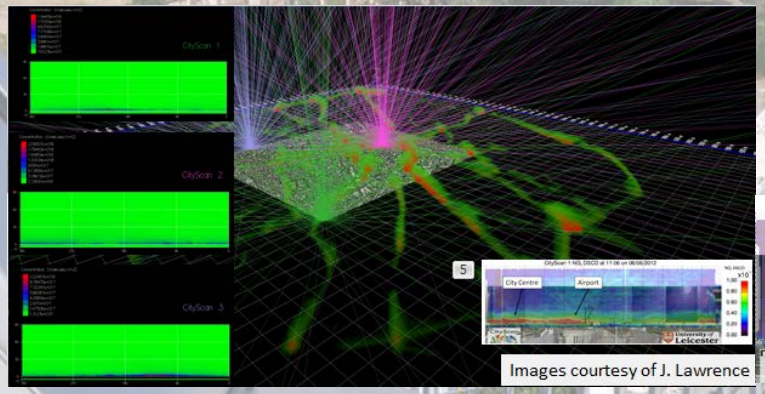
Guidance to urban management systems

Emissions, Dynamics

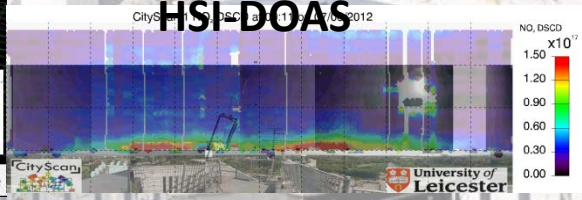
Airborne DOAS mapping



Modelling with photon path calcs



HSI-DOAS



Concluding remarks

- There are advances to be made by taking satellite technology for NO_2 mapping into the urban environment.
- Clear capability to explore emissions and urban dynamics.
- Role for airborne mapping?
- There is a need to explore techniques for minimising complexity in NO_2 systems.
- MACC is a key enabler for assimilation of space-borne NO_2 measurements into operational AQ management systems.
- 2015 – iTRAQ, HSI-DOAS + AAQM + MACC?

- Acknowledgements
  - Co-authors: P. Monks, R. Graves, J. Lawrence, J. Anand.
  - Collaborators: SSTL, Dan Lobb, Mike Cutter, Bluesky International Ltd, RVL.
  - Funding: CEOI, NERC, NCEO
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