University of Leicester

EOS

New mission ideas for Air Quality and Greenhouse Gas Measurements from space.

Professor John Remedios

Dr. Roland Leigh

Dr. Hartmut Boesch

Professor Paul Monks

Earth Observation Science

University of Leicester

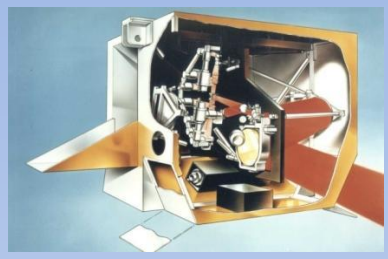
CompAQS

ENVISAT

G-STEP Innovating / Training / Collaborating

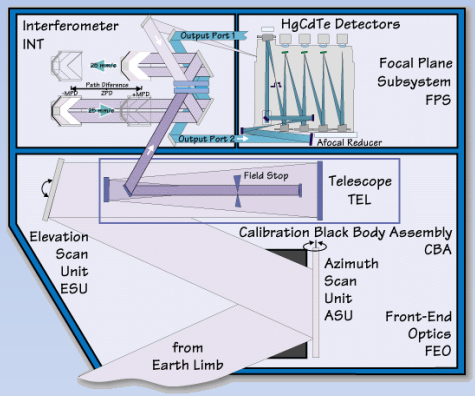
The Earth's atmosphere from space

- **UK has a long tradition in atmosphere science**
  - Understanding of the stratosphere/ozone depletion, and monitoring of the health of the ozone layer.
  - Strong role in satellite data for weather forecasting.
  - Focus of atmosphere research is now in the lower atmosphere



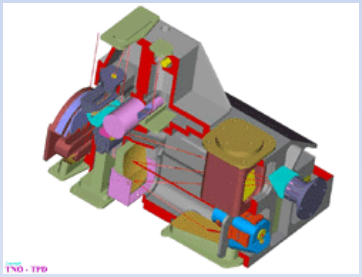
The ISAMS on UARS

- **UK has a strong heritage in the development and build of satellite instruments for sounding the Earth's atmosphere.**
  - Technology has been strongly led by the deployment of infra-red radiometers in the 1970s.
  - Strong infra-red and microwave technology for science, and commercial visible camera technology



The MIPAS/ENVISAT(detectors)

- **Current science demands tropospheric information, including sensitivity to the lowermost atmosphere:**
  - Want spectrometers with relatively high spectral resolution and good signal-to-noise.
  - Operate in nadir but also limb sounding to lower altitudes (PREMIER)
  - Access different wavelength ranges so visible and shortwave infrared (SWIR).
  - Look at compact spectrometers



OMI on AURA (detectors)

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Earth's troposphere from space

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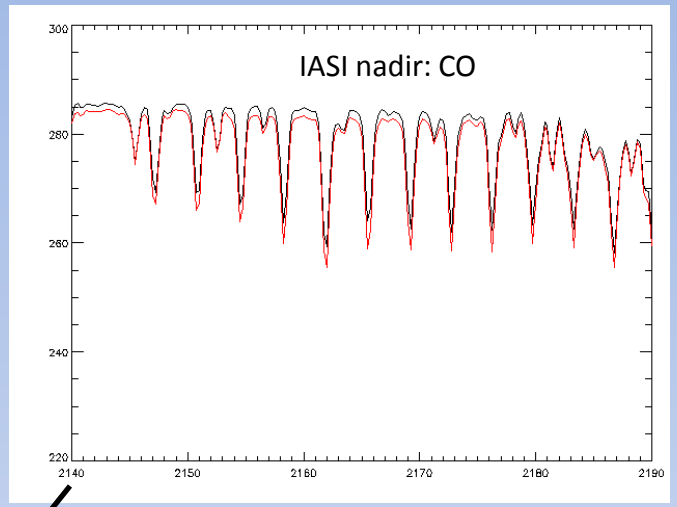
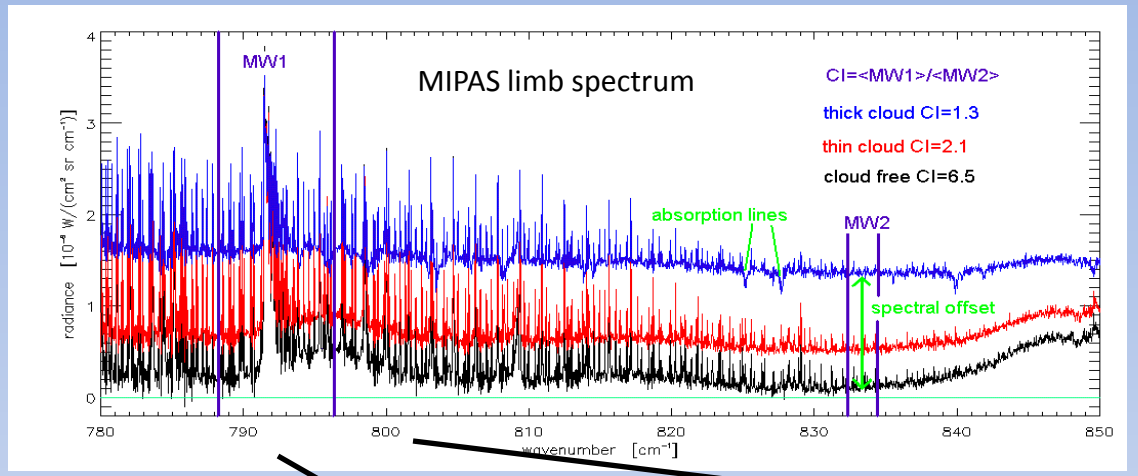
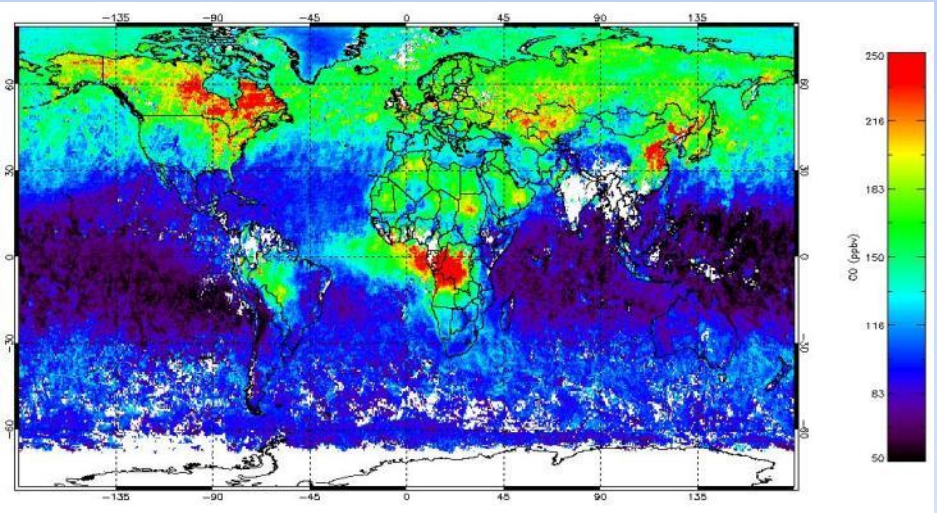
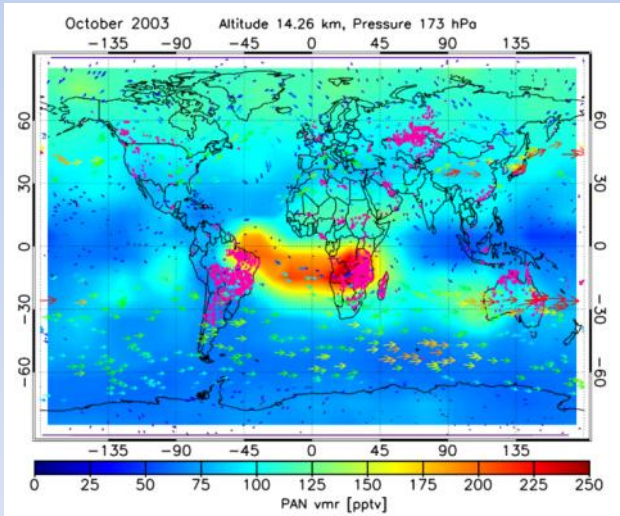






MOPITT CO: summer 2004, "surface" level



MIPAS PAN: 14 km; October 2003

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Air Quality from Space

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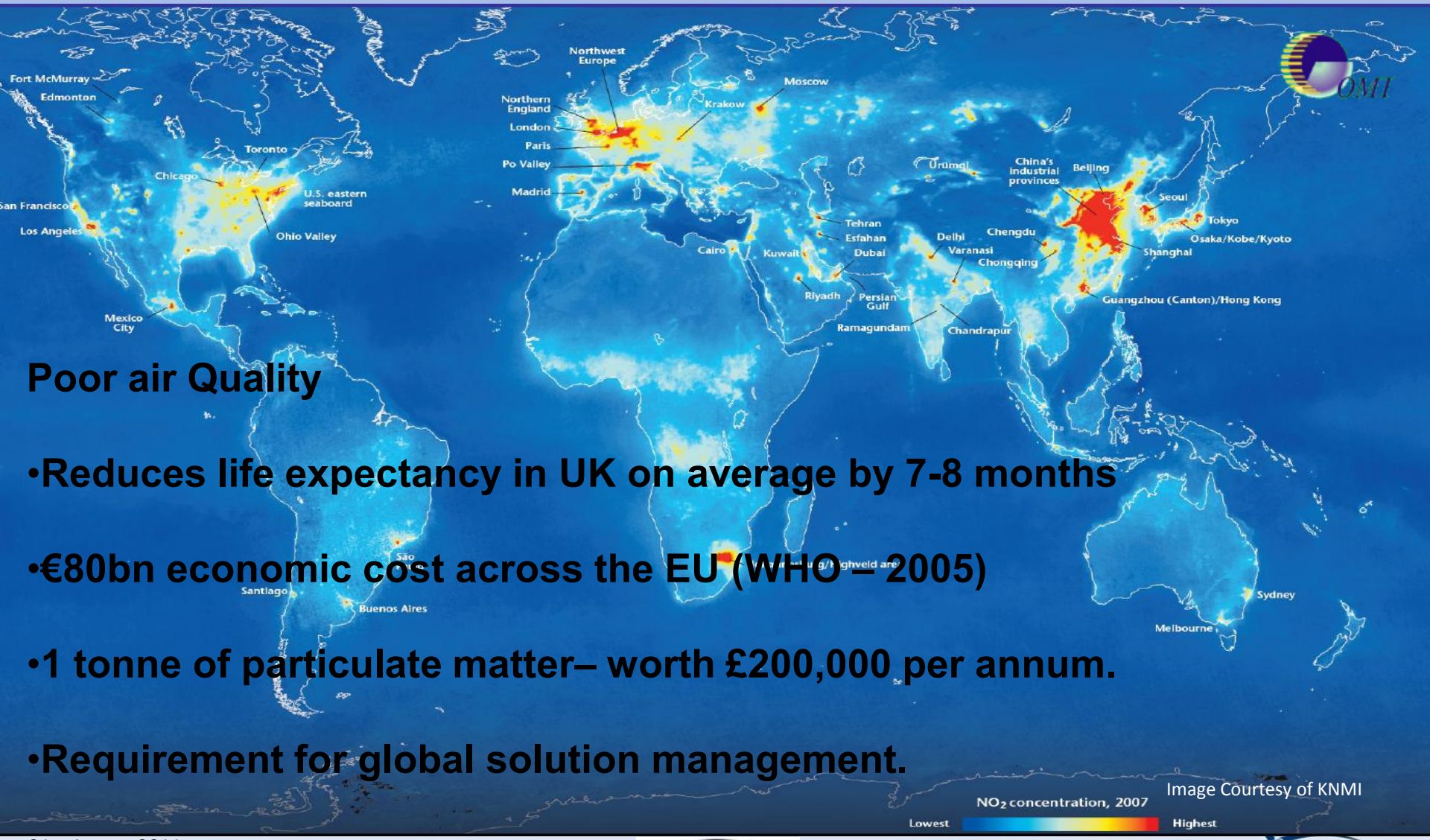
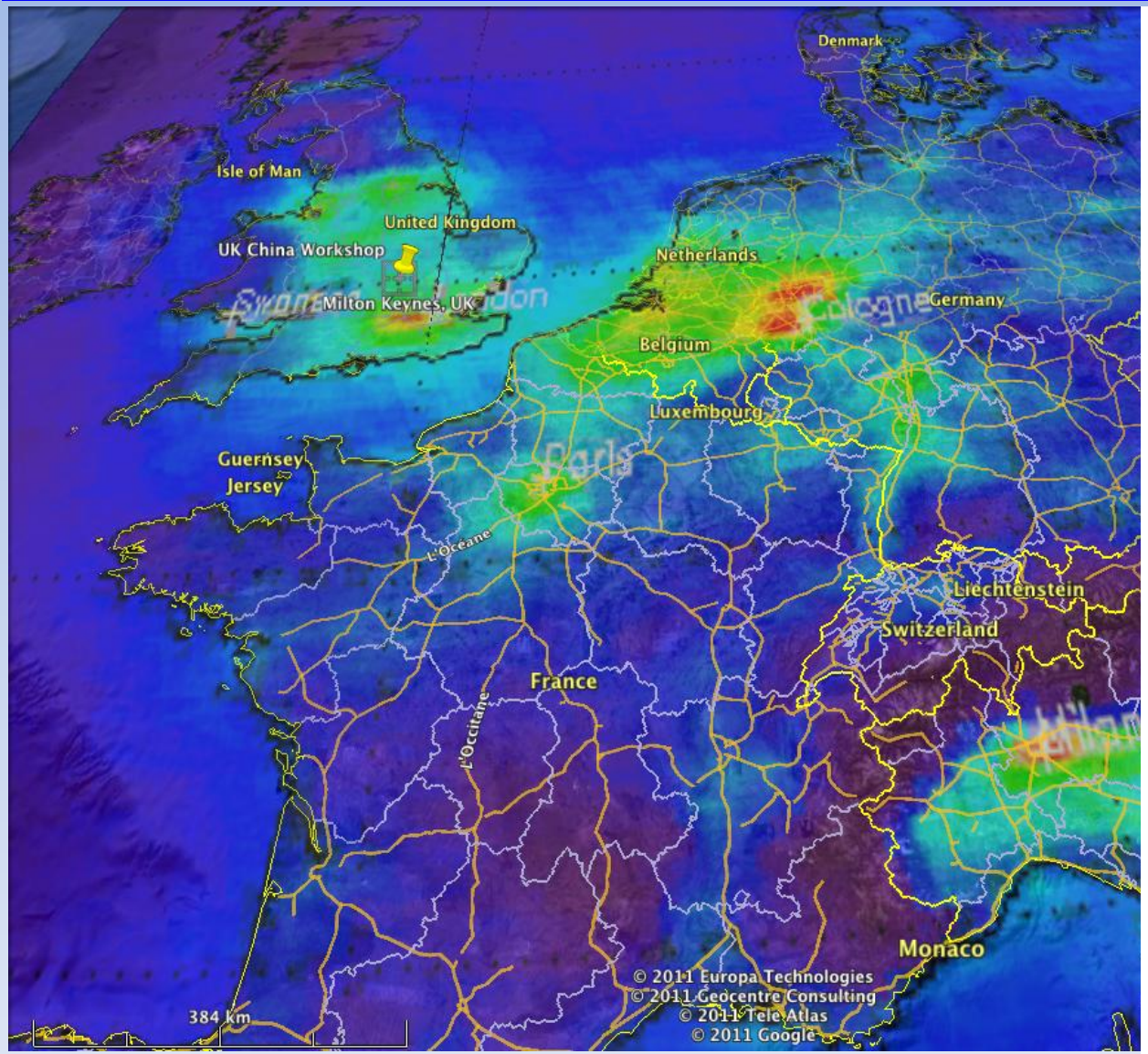


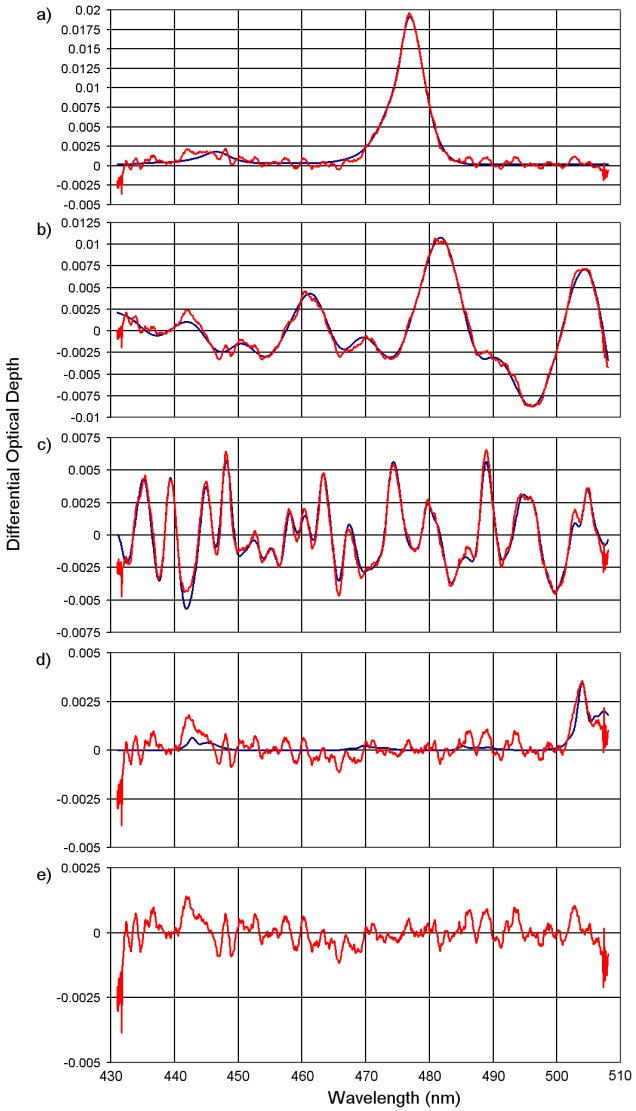
Poor air Quality

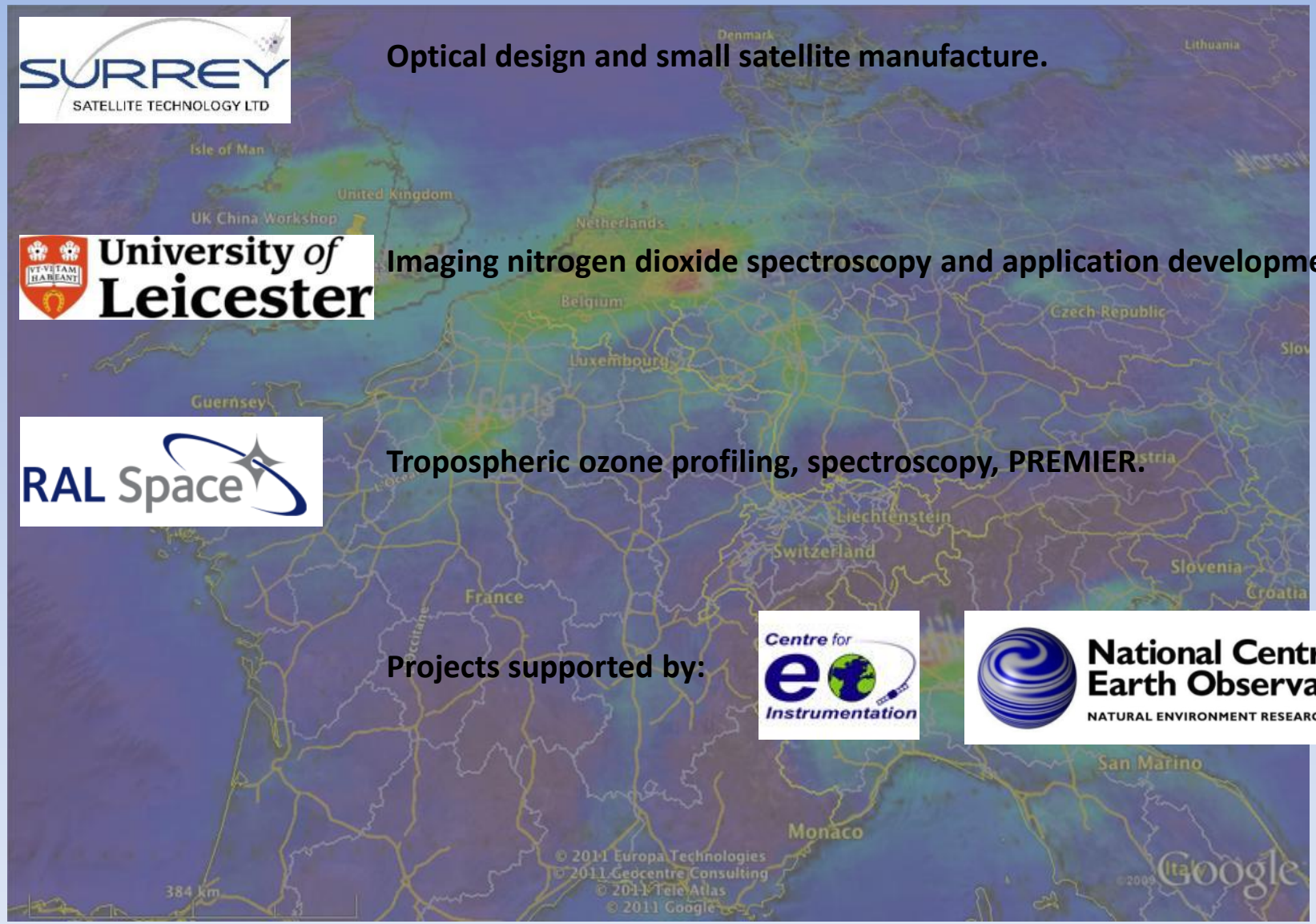
- Reduces life expectancy in UK on average by 7-8 months
- €80bn economic cost across the EU (WHO – 2005)
- 1 tonne of particulate matter– worth £200,000 per annum.
- Requirement for global solution management.

Image Courtesy of KNMI

Mapped air quality – how safe are we today?







SURREY SATELLITE TECHNOLOGY LTD

Optical design and small satellite manufacture.

University of Leicester

Imaging nitrogen dioxide spectroscopy and application development.

RAL Space

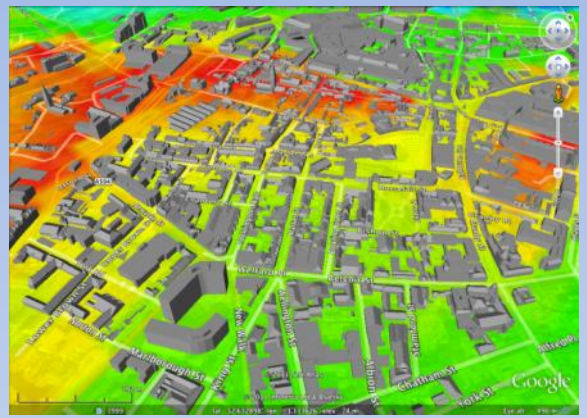
Tropospheric ozone profiling, spectroscopy, PREMIER.

Projects supported by:

Centre for Earth Observation Instrumentation

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Urban-scale air quality from orbit



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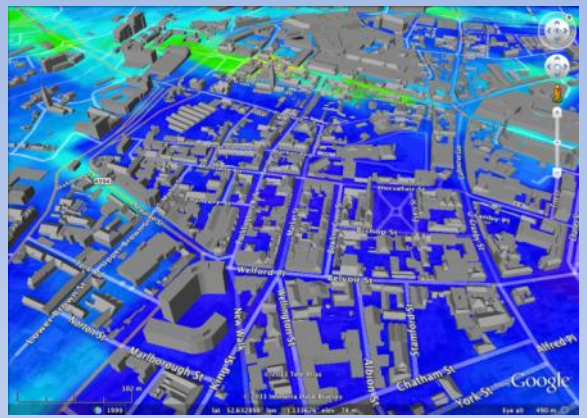

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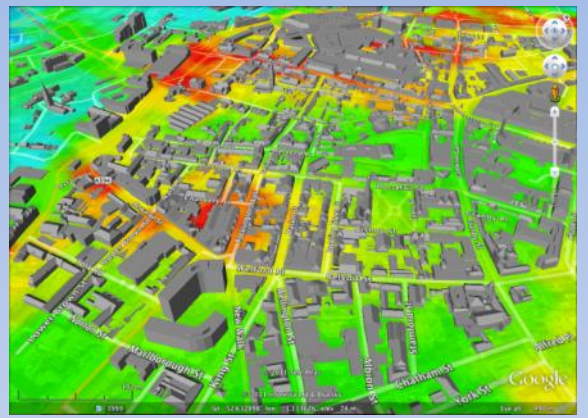

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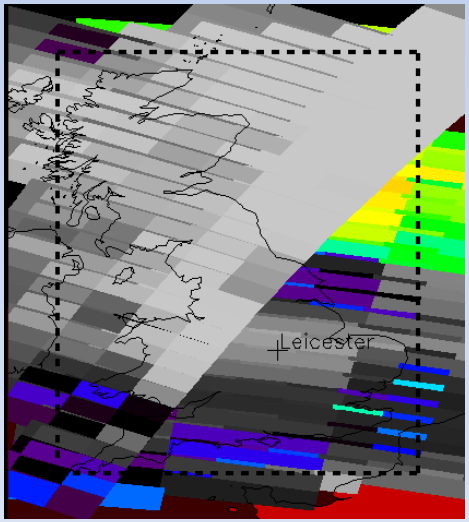
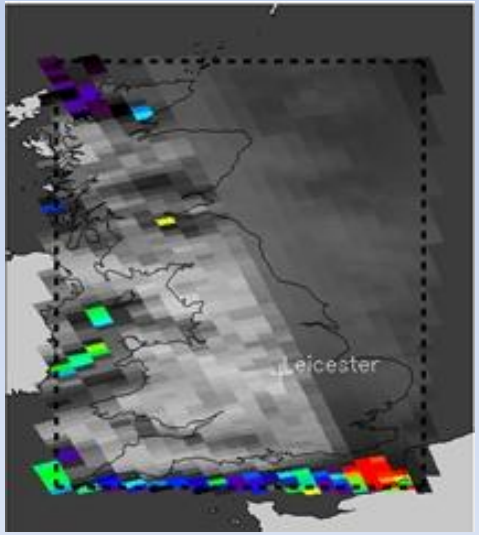


GOME 2



OMI

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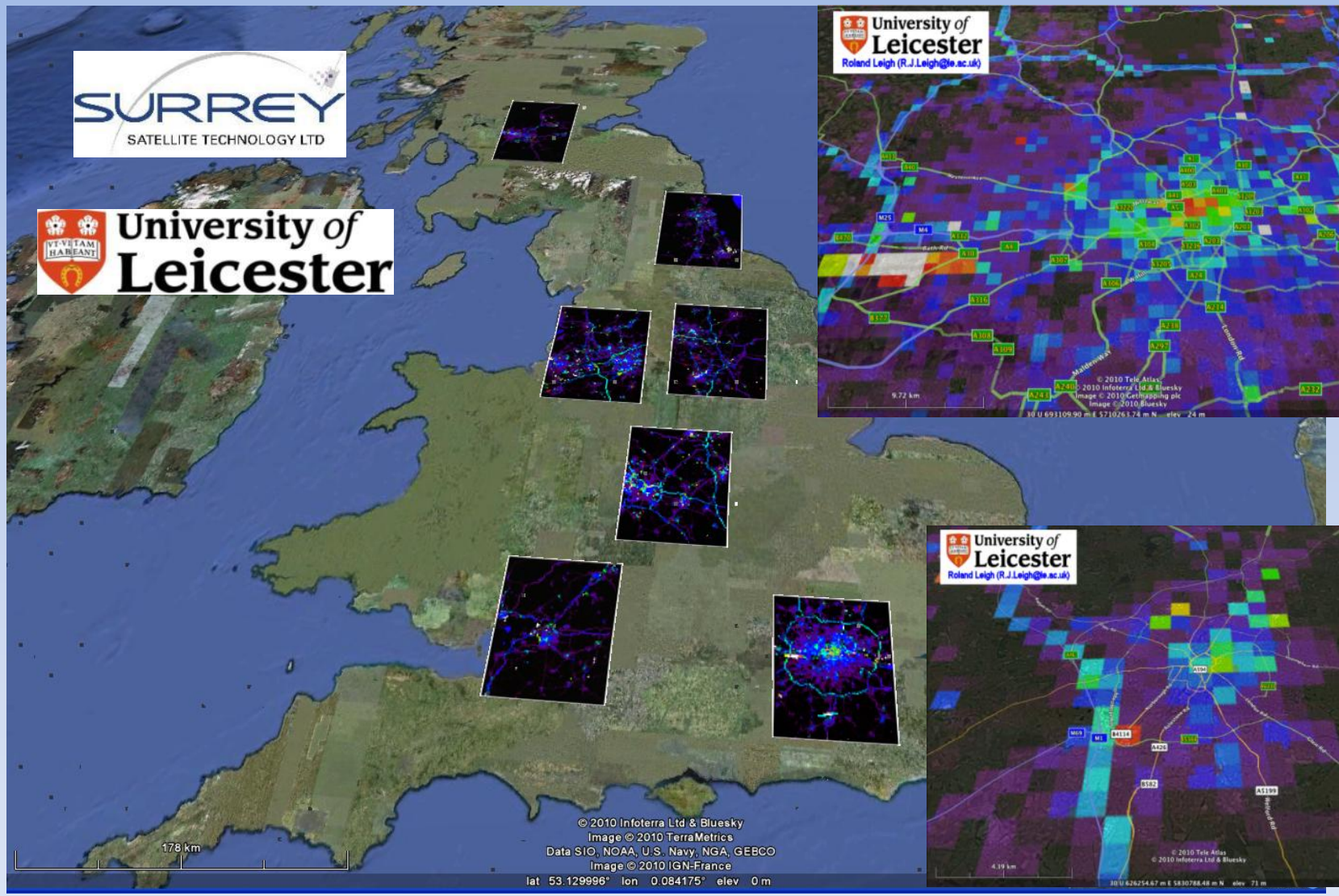
SURREY
SATELLITE TECHNOLOGY LTD
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178 km
© 2010 Infoterra Ltd & Bluesky
Image © 2010 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 IGN-France
lat 53.129996° lon 0.084175° elev 0 m

University of Leicester
Roland Leigh (R.J.Leigh@le.ac.uk)
Google

University of Leicester
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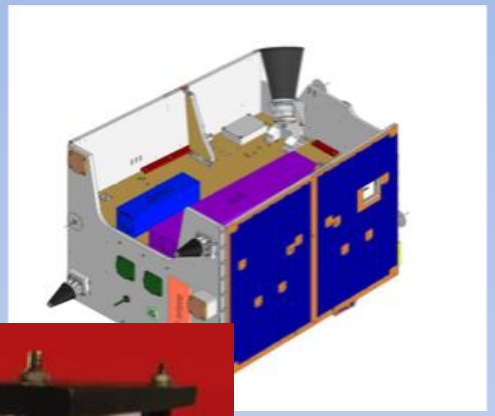
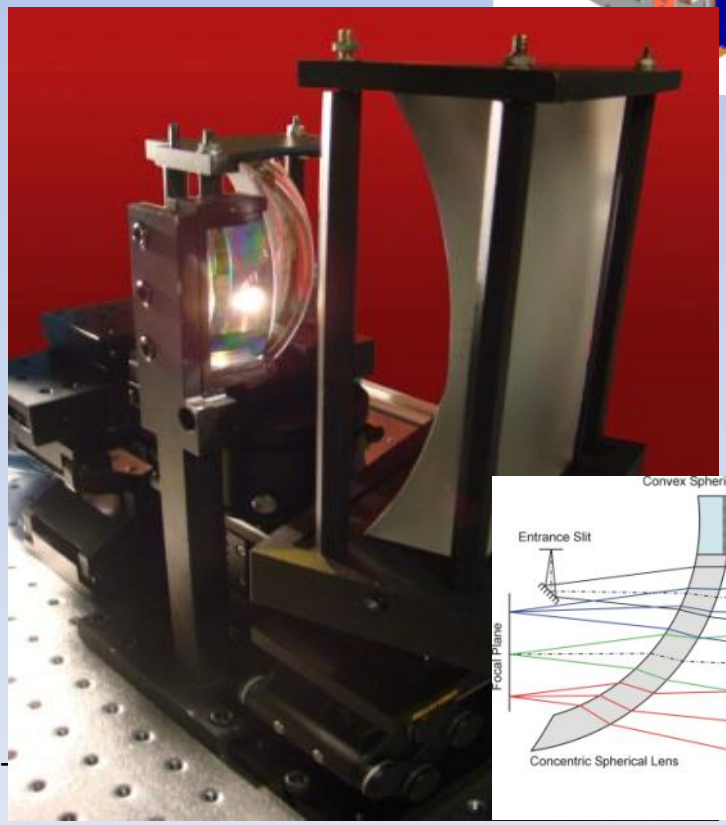
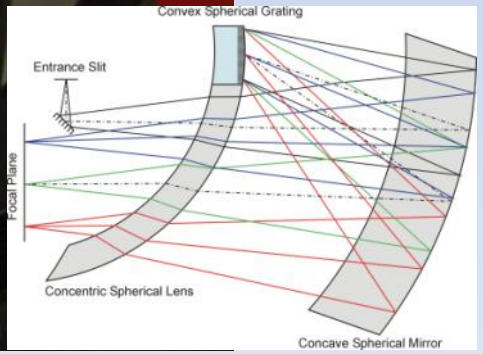
Google

The Compact Air Quality Spectrometer (CompAQS)

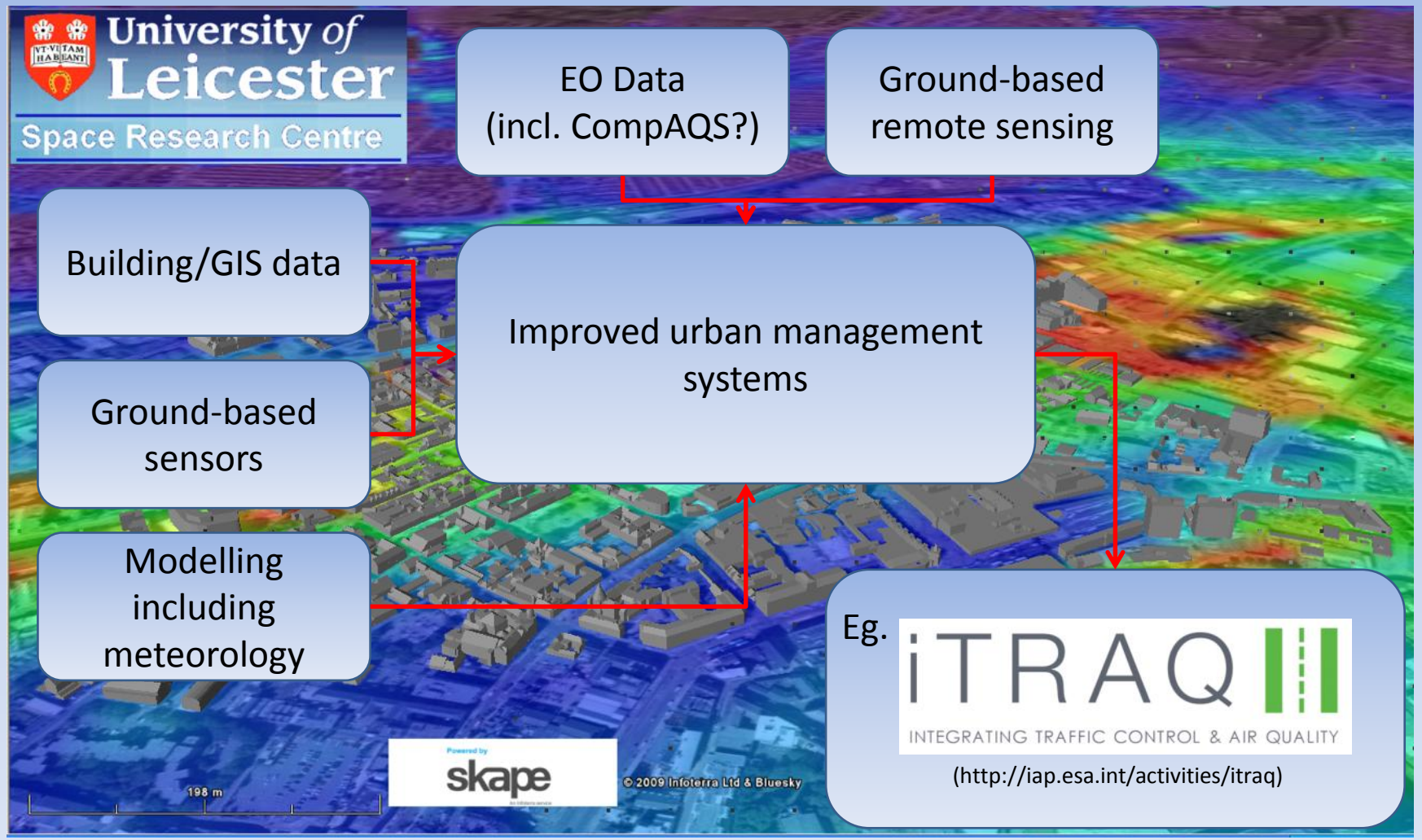
- Small payload for nitrogen dioxide and aerosol mapping
- Low mass, power
- Studies ongoing to reduce data volume
- Environmental data service at urban scale
- Target: 1 x 1 km data product
- Specific urban targets (1000 cities? + 100 other targets?)
- Intelligent/agile pointing
- Highly suitable for constellation deployment.
- Well-suited to piggy-back opportunities as small additional payload.
- Two spectrometers built and undergoing ground-based testing at the University of Leicester.







Integrated applications.



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Greenhouse gases (GHG) from Space

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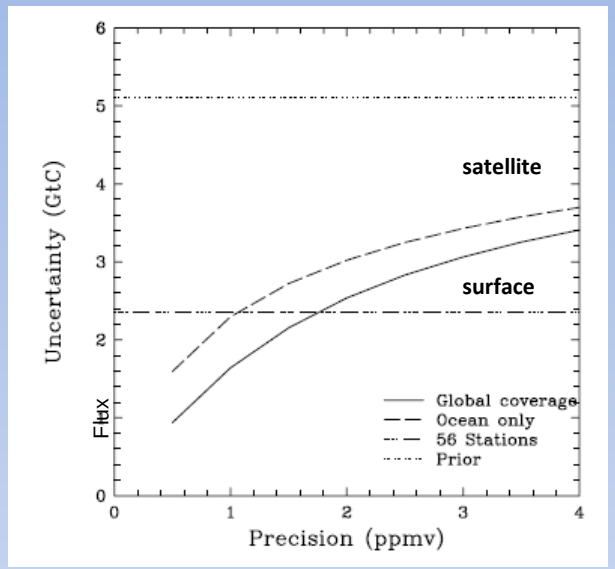
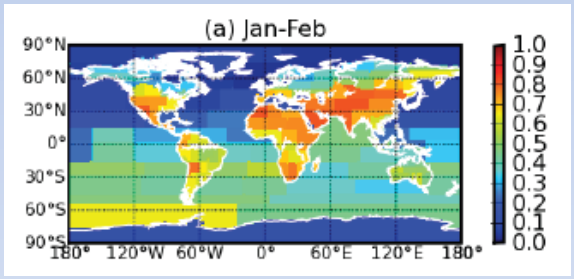
Satellites for GHG fluxes

- CO_2 and CH_4 are most important anthropogenic greenhouse gases (Essential Climate Variables)
- Satellite observations can dramatically improve surface flux estimates of GHG due to
  - Global coverage
  - Quantity of data
  - Columns better capture transport
- But gradients in column CO_2 and CH_4 are small
  - Very high precision and accuracy required

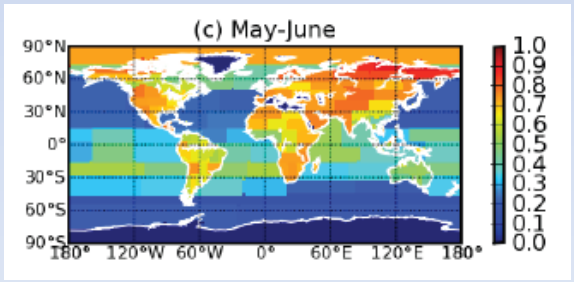


Column measurements vs. surface

(Rayner and O'Brien, GRL, 2001)

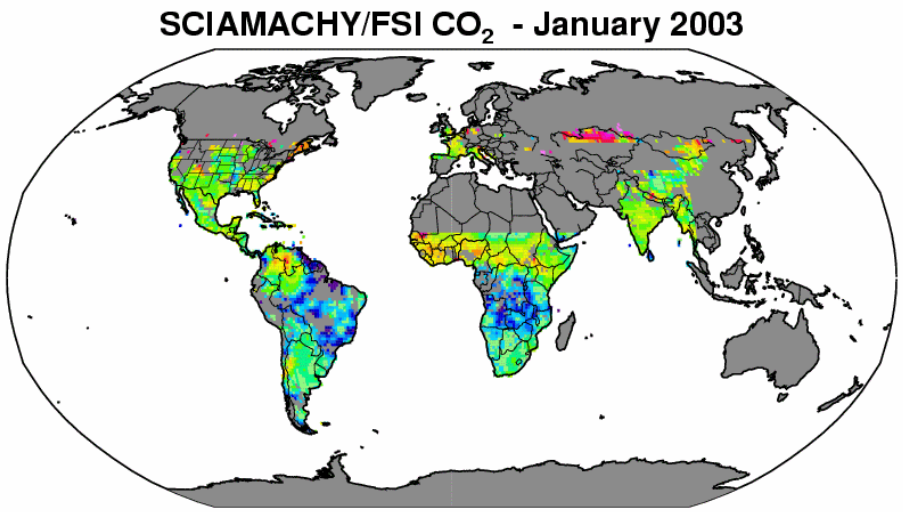


Expected CO_2 Flux Error Reduction (for OCO)



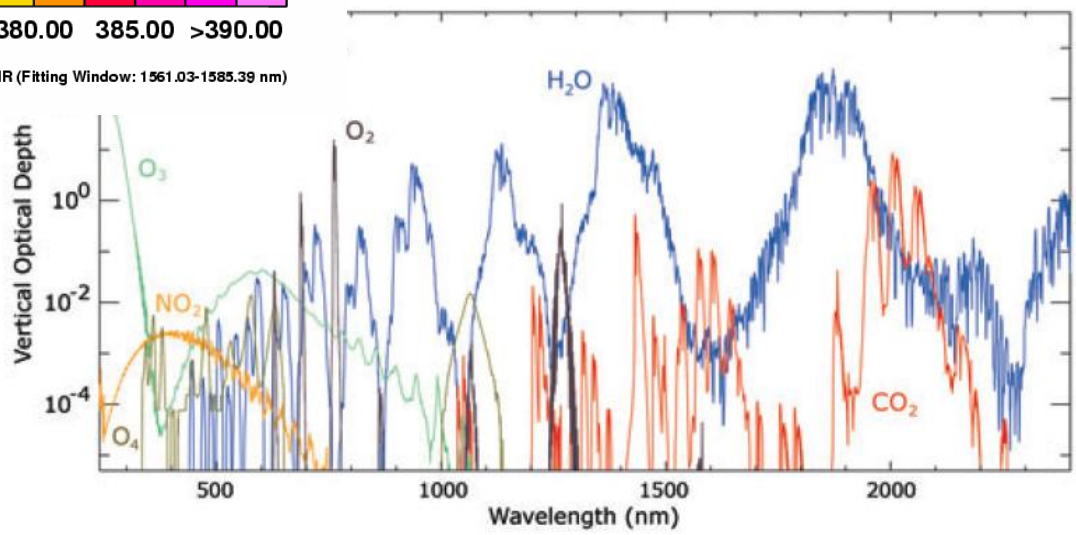
(Feng, Palmer, Boesch, Dance, ACP, 2009)

CO_2 from SCIAMACHY



SCIAMACHY on board ENVISAT

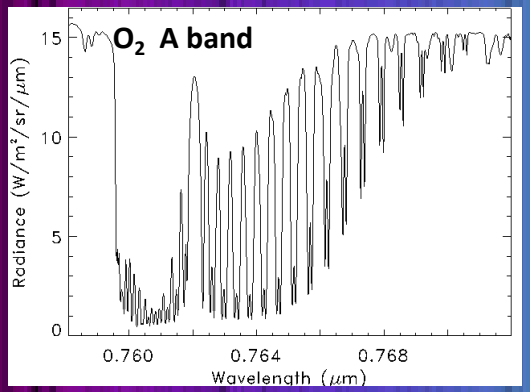
SCIAMACHY: first global satellite observations of total atmospheric CO_2 using 1.6 μm CO_2 band, and O_2 A band, with relatively low spectral resolution



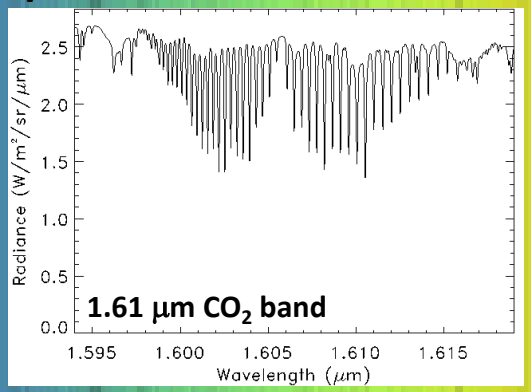
Accurate CO_2

- Measurement of SWIR CO_2 and O_2 bands to retrieve aerosol/cloud parameters together with CO_2:
  - 1.61 μm CO_2 band: Column CO_2
  - 2.06 μm CO_2 band: Column CO_2, clouds/aerosols
  - 0.76 μm O_2 A-band: Surface pressure, clouds/aerosols
- GOSAT and OCO have been specifically designed for CO_2 column observations and measure with high spectral resolution:
  - Large number of key parameters can be retrieved independently
  - Enhanced sensitivity and minimized biases due to interferences

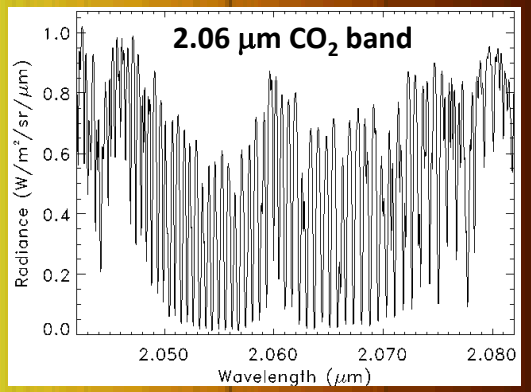
Spectral Bands of OCO



Clouds/Aerosols, Surface Pressure



Column CO_2



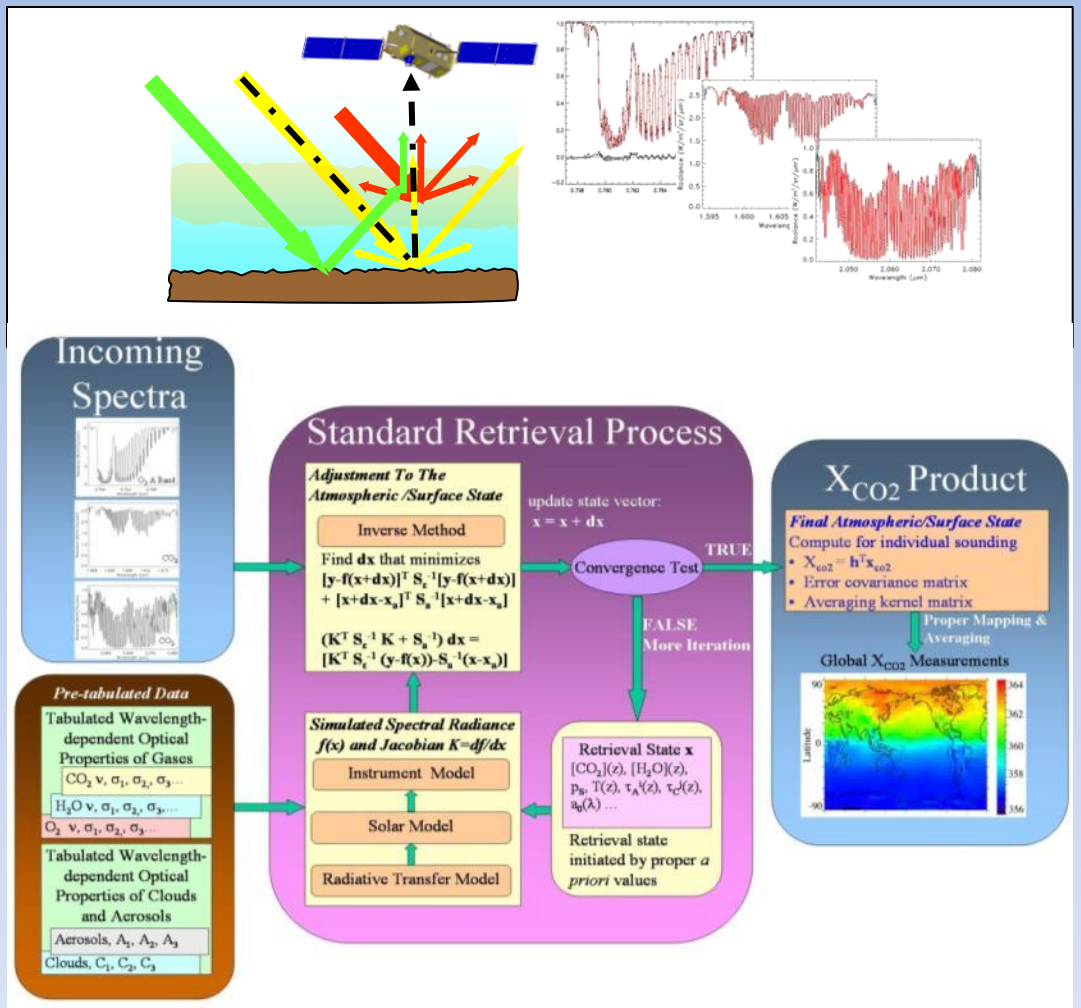
Clouds/Aerosols, H_2O, Temperature

‘Full-Physics’ Retrieval Algorithms

- Measured radiance spectra are non-linear functions of atmospheric parameters

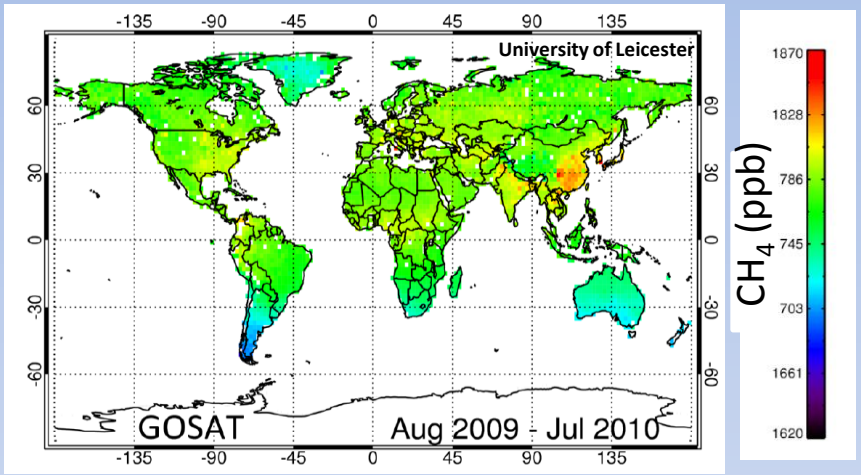
  -> retrieval is performed iteratively by alternating calls to:

- Forward Model needs to describe accurately physics of measurement:
  - Multiple-scattering RT (by aerosol, clouds)
  - Polarization Correction
  - Instrument Model
  - Solar Model
  - Up-to-date Spectroscopy (incl. line-mixing)
  - Etc.
- Inverse Method estimates state:
  - Rodger’s optimal estimation technique



GOSAT

- GOSAT extends the spectral range of measurements in the SWIR region (see OCO) and increases the spectral resolution from SCIAMACHY



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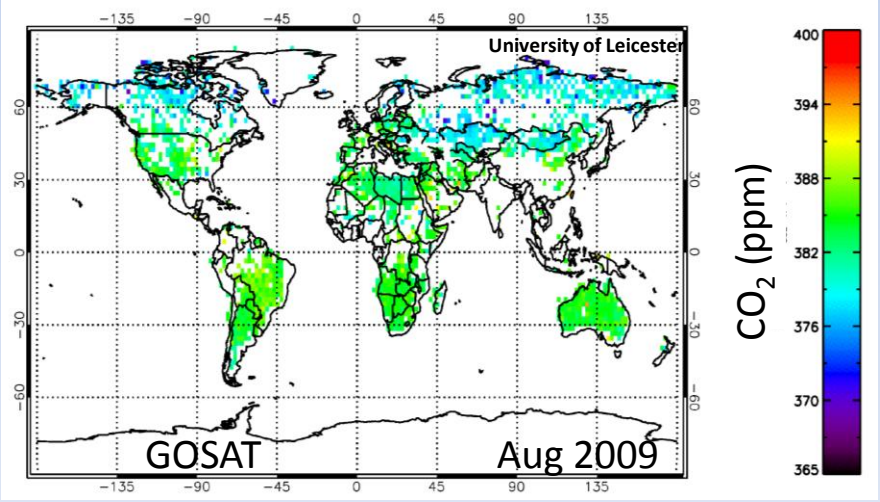


UK Expertise

UK has key expertise in critical areas for Greenhouse Gas Missions

- **Retrieval + Validation + Data Assimilation of Level 2 Products**
  - **UK groups have leading role in GOSAT data analysis (NCEO, ESA Climate Change Initiative)**
  - **Analysis of IASI, ACE, MIPAS, SCIAMACHY data**
- **Mission Preparation**
  - **Mission concept design (ISIC concurrent design facility)**
  - **Definition of Mission and Instrument Requirements**
- **Technology – Compact Shortwave-infrared spectrometers**
  - **Surrey Satellite Technology Ltd (SSTL): immersed grating technology (ESA Sentinel 5 precursor)**
  - **Astronomy Technology Centre (ATC): image slicer – transfer technology developed for astronomy to EO applications (CEOI)**

Future Missions

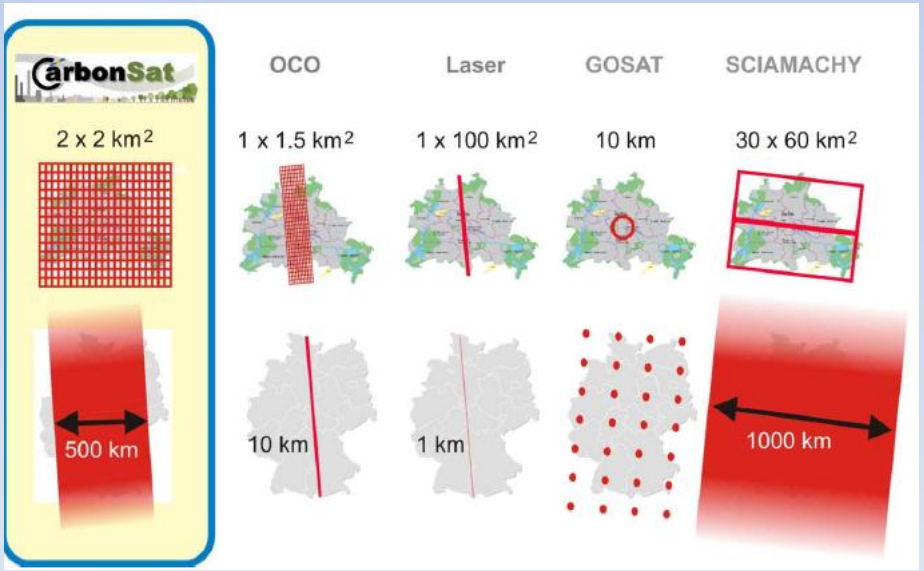
- Several Greenhouse Gas Missions will be launched in next few years to continue and improve the GOSAT and SCIAMACHY data records

- OCO-2 (NASA, launch, 2014): UK is directly involved in areas such as
  - Retrieval algorithm development
  - Data analysis and data assimilation

- Sentinel 5 Precursor and Sentinel 5 (ESA, launch 2014 and 2020)
  - Hardware (SSTL, SWIR channel)
  - Mission Advisory Group (RAL)

Proposed Missions

- Next generation passive GHG missions will aim at denser and more frequent coverage to allow establishing regional carbon budget and to move towards emissions verification/monitoring
  - ESA Earth Explorer 8 Candidate Mission **Carbonsat** (Mission Advisory Group)
  - Proposed UK/NASA mission **Tropical Carbon Mission**
- **Active lidar missions** will provide increased accuracy in the presence of thin clouds and day/night sampling
  - CNES/DLR MERLIN
  - NASA Ascends
- Future carbon Observing system might be based on constellation of small satellites or geostationary satellites



Summary

Air quality and GHG

- **UK has strongly developing capabilities in air quality and greenhouse gases**
  - Data inversion (retrieval) and data assimilation
  - Validation
  - Ground-based instrument concept demonstrations
  - Innovative new (small) missions

- **We would be very interested in:**
  - New collaborative mission opportunities
  - Collaborations for deployment of ground-based instruments
  - Science collaborations in data and models.
  - Student training.