THE LONDON CARBON EMISSIONS EXPERIMENT

NEIL HUMPAGE – UNIVERSITY OF LEICESTER

HARTMUT BOESCH – NCEO, UNIVERSITY OF LEICESTER

ROBBIE RAMSAY, ANDREW GRAY, JACK GILLESPIE, MATHEW WILLIAMS – FIELD SPECTROSCOPY FACILITY, UNIVERSITY OF EDINBURGH

JEROME WOODWARK – UNIVERSITY OF EDINBURGH
THE LONDON CARBON EMISSIONS EXPERIMENT CONCEPT

- Part of UK Natural Environment Research Council (NERC) DARE-UK project – see dareuk.blogs.bristol.ac.uk
- Establish ground-based remote sensing network (CO₂, CH₄, CO, NO₂, aerosol)
- Combine with city-focused satellites (OCO-3, MicroCarb)
- City-scale modelling to link to emission inventories
- London as testbed for studies on CO₂ emissions
In 2019, the Field Spectroscopy Facility (FSF) acquired transformational capital to build a greenhouse gas (GHG) monitoring network.

Working with the University of Leicester, FSF will build three nodes that will be deployed to monitor London emissions.

Each node will include an automatic weather station, a Multi-Axis Differential Optical Absorption Spectrometer (MAX-DOAS), and an EM27/SUN Fourier transform spectrometer.

This network will monitor CO$_2$, CH$_4$, CO, NO$_2$ and other trace gases above London, and provide a crucial resource for validating satellite-derived measurements of GHG products.
PROPOSED LOCATIONS

- Three “nodes” along a SW-NE transect, following the prevailing wind direction:
  - SW Node – National Physical Laboratory, Teddington
  - Central Node – University College London, Torrington Place
  - NE Node – Highfield Residential Tower
BRUKER EM27/SUN SPECTROMETER FOR GREENHOUSE GAS MONITORING

- Measures atmospheric absorption spectrum using direct sunlight as the light source: automatic solar tracker uses camera-based feedback system
- Fourier Transform spectrometer: in standard operation, 10 interferograms are co-added per observation → temporal frequency approximately 1 minute
- Two detectors at 0.5 cm$^{-1}$ spectral resolution:
  - 5000 to 14500 cm$^{-1}$ (0.69 to 2.0 µm): InGaAs detector
  - 4000 to 5500 cm$^{-1}$ (1.8 to 2.5 µm): for carbon monoxide, extended range InGaAs detector with Ge filter
- Internal calibration source
- Portable and robust instrument
- Performance vs. TCCON (Gisi et al. 2012 AMT): difference in retrieved XCO$_2$ of (0.12 ± 0.08) % over 26 measurement days
- COCCON (Collaborative Carbon Column Observing Network, Frey et al. 2019 AMT):
  - Over 100 instruments in network, operated by universities and research institutes around the world
  - Calibrated against Karlsruhe Institute of Technology (KIT) reference instrument → traceability
  - Retrieval software (PROFFAST) developed by KIT and used by all EM27/SUN operators → consistency of data processing approach
NEW ENCLOSURE DESIGN FOR THE EM27/SUN

• EM27/SUNs are not weatherproof → operate from within an enclosure, which also allows remote and autonomous operation

• Original concept by Heinle and Chen, AMT 2018 (TU Munich)

• Design by Jerome Woodwark (University of Edinburgh)

• Key to CAD rendering:
  • EM27/SUN
  • Power system components: includes UPS in case of sudden interruption of power supply, allowing safe shutdown
  • Control systems: mini-PC controlling spectrometer, other sub-systems, remote access via Internet
  • Thermal control: fan-assisted heating and cooling to prevent extremes of temperature
  • Optical dome mount: protects interior whilst allowing high optical transmittance across the observed wavelength range
  • Movable dome protective cover: for protection from dust, dirt when not observing
  • System support frame
TESTING OF SAMPLE MATERIAL FOR THE PROTECTIVE DOME

- Performed observations in Edinburgh both with and without a sample of dome material (5mm thick optical glass) in the line of sight of the solar tracker.

- Check optical transmittance of material at wavelengths used by XGAS retrievals – transmittance estimated from EM27/SUN spectra has same wavelength dependence as transmittance from lab measurement.

- Confirmed that slight refraction of incoming light does not impair solar tracker performance.

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$O</td>
<td>O$_2$</td>
</tr>
</tbody>
</table>
MAX-DOAS INSTRUMENTATION FOR AIR QUALITY MONITORING

- Each node contains one Multi-AXis differential optical absorption spectroscopy unit
- Provided by Enviro Technology Services (ETS), manufactured by AirYX
- Telescope unit mounted on roof; collects stray light. Connected to spectrometer unit.
- Two spectrometers, measuring in UV-Vis (290—450 nm) and Vis (430 – 565 nm) ranges, resolution of 0.6 nm.
- Provides column densities and surface concentrations of NO_2, O_3, SO_2, O_2 dimer, HONO and other trace gases.
THE LONDON CARBON EMISSIONS EXPERIMENT - SUMMARY

• Currently in the planning stage of setting up **three observation nodes for ground-based remote sensing of the atmosphere** along a SW-NE transect of London

• Each node will host:
  • Bruker EM27/SUN spectrometer for greenhouse gas monitoring
  • MAX-DOAS instrumentation for monitoring air quality and other trace gases
  • Weather station for local meteorology

• Developing new enclosure design to allow automation of the EM27/SUNs

• Once ground-based remote sensing network is established, incorporate data from city-scale focused satellites, in-situ sampling networks and modelling based on emissions inventories to study London’s carbon emissions footprint

• For further info, please contact:
  • Dr Neil Humpage: nh58@le.ac.uk / @DrNeilHumpage
  • Field Spectroscopy Facility: fsf@nerc.ac.uk / @NERC_FSF