

# Long-term measurements of atmospheric trace gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, SF<sub>6</sub>, CO, H<sub>2</sub>), O<sub>2</sub>, and $\delta^{13}\text{C}_4$ isotopes at Weybourne Atmospheric Observatory, UK: past, present and future.

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## Introduction

The Weybourne Atmospheric Observatory (WAO) is a WMO GAW regional station and a component of the National Centre for Atmospheric Science (NCAS) Atmospheric Measurement Facility (AMF). WAO is located on the north Norfolk Coast (52.95°N, 1.13°E) in the UK and is run by the University of East Anglia with support from NCAS. Since 2008 we have been collecting high-precision long-term measurements of atmospheric carbon monoxide (CO), molecular hydrogen (H<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), oxygen (O<sub>2</sub>) and  $\delta^{13}\text{C}_4$  isotopes. In March 2013, the measurement of atmospheric methane (CH<sub>4</sub>) commenced, and nitrous oxide (N<sub>2</sub>O) and sulphur hexafluoride (SF<sub>6</sub>) began in October 2014. In 2016, WAO will become a part of the EU ICOS network.



## Long-term measurements

Species	Instrument	Scale	Calibration Range	Data coverage period
CO <sub>2</sub>	Siemens NDIR	WMO CO2 X2007	388.5 to 426.4 ppm	2008 - present
O <sub>2</sub>	Oxzilla II	Scripps	-811 to -426 per meg	2008 - present
CH <sub>4</sub>	GC-FID	WMO CH4 X2004	1753 to 2495 ppb	03/2013 - present
CO	RGA3	WMO CO X2004	61 to 503 ppb	03/2008 - present
H <sub>2</sub>	RGA3	WMO H2 X2009	375 to 1182 ppb	03/2008 - present
N <sub>2</sub> O	GC-ECD	WMO N2O X2006A	314.1 to 345.3 ppb	11/2014 - present
SF <sub>6</sub>	GC-ECD	WMO SF6 X2006	7.5 to 15.9 ppt	11/2014 - present
$\delta^{13}\text{C}_4$	GC-IRMS	NIWA/INSTAAR	-57 to -47 ‰	12/2008 - present

Table 1. Summary of long-term measurements made at Weybourne Atmospheric Observatory

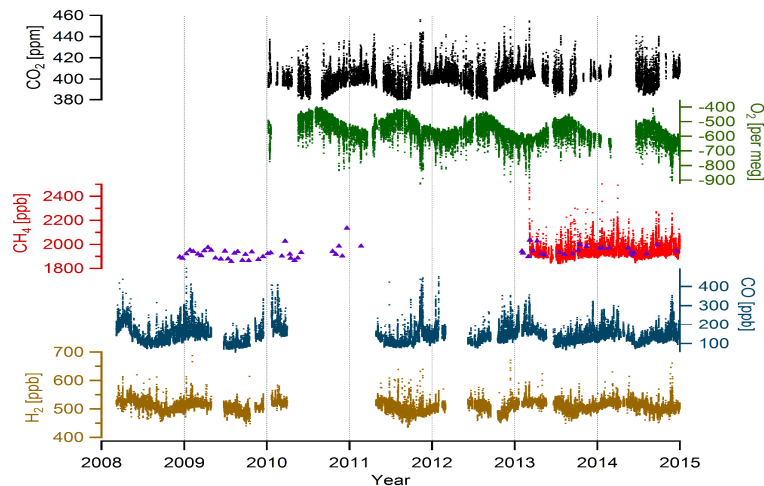


Figure 1. Time-series of CO<sub>2</sub>, O<sub>2</sub>, CH<sub>4</sub>, CO and H<sub>2</sub> for WAO. Purple rectangles represent CH<sub>4</sub> mole fraction measurements from samples collected for  $\delta^{13}\text{C}_4$  analysis.

## Annual variations - CO, H<sub>2</sub>, CH<sub>4</sub>, CO<sub>2</sub> and O<sub>2</sub>

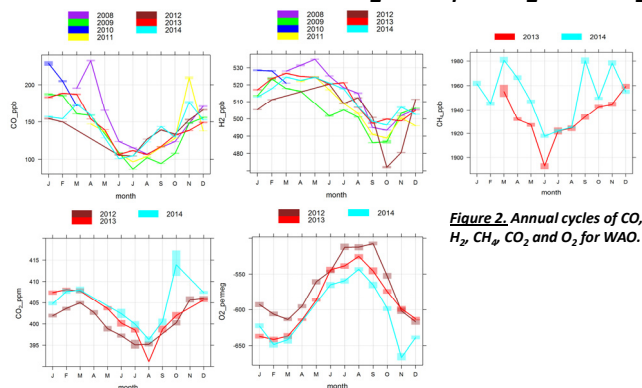


Figure 2. Annual cycles of CO, H<sub>2</sub>, CH<sub>4</sub>, CO<sub>2</sub> and O<sub>2</sub> for WAO.

## Data availability and submission

- Data are available from BADC and are updated on a biannual basis.
- All data will shortly be submitted to both WMO/GAW WDCGG and EU ICOS repositories.
- Near Real Time H<sub>2</sub>, CO and CH<sub>4</sub> mole fractions are displayed at <http://ingos-atm.lsc.eipsi.fr/WAO-NRT>
- ...and CO<sub>2</sub> and O<sub>2</sub> at <http://www.cramlab.uea.ac.uk/data/WAO/AmbientWAOHR.html>.

## Diel cycles – CO, H<sub>2</sub>, CH<sub>4</sub>, CO<sub>2</sub> and O<sub>2</sub>

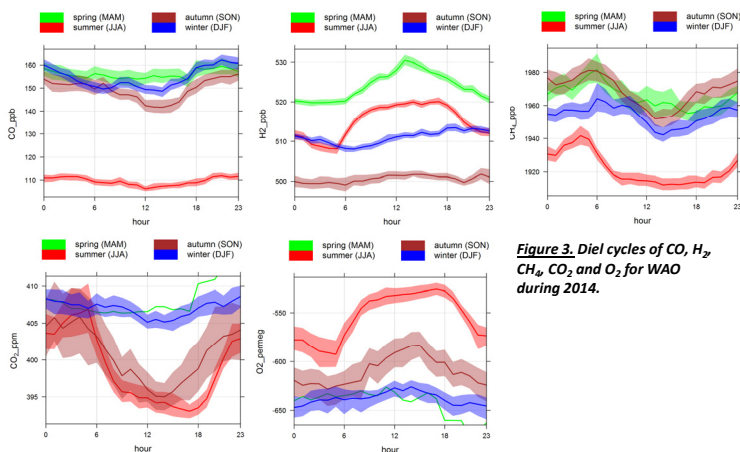
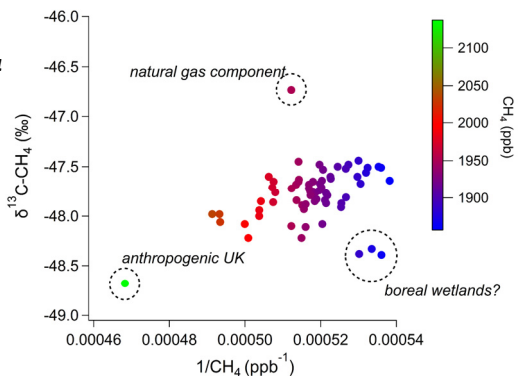


Figure 3. Diel cycles of CO, H<sub>2</sub>, CH<sub>4</sub>, CO<sub>2</sub> and O<sub>2</sub> for WAO during 2014.

## $\delta^{13}\text{C}$ in CH<sub>4</sub>

Figure 4. Keeling plot for all samples collected for  $\delta^{13}\text{C}_4$ . The temporal distribution of the samples can be seen in Figure 1 (purple triangles).



## NAME atmospheric transport model as a tool to identify trace gas origins

The NAME model uses UK Met Office Unified Model meteorological data (25 km resolution) to simulate the backward movement of tracer particles according to atmospheric conditions and turbulence. For this study 10,000 theoretical air particles are released at WAO (here 25 m above ground level). These particles are followed as they spread backwards in time over a 10-day period. The residence of these particles within the 0-100 m surface layer reflects the probable pathways the air passed over at surface level which would influence the emissions (i.e. footprint).



Figure 5. NAME 'footprint' for 07Mar2013 03:00.

To examine the impact of the different regions on trace gas mole fractions at WAO we employed NAME to identify regions (figure 6) with >10% of the particles residing below 100 m for any 3-hour period. These were further flagged as UK, Europe, UK and Europe, Arctic, Arctic and Greenland and Mixture using the following criteria:

- UK - if > 10% of the footprint resides over the UK.
- Europe - if > 10% of the particles reside over the Europe.
- UK and Europe - if > 10% of the particles reside over each of the UK and Europe.
- Arctic - if > 10% of the particles reside over either the Arctic or over Greenland & Iceland, with < 5% of the particles residing over UK and Europe.
- Mixture - Any footprint that does not fit into any of the categories above.

Figure 6. Regional domains used to constrain air-mass origin for WAO.

- Highest mole fractions of CO in air flagged as "Europe" and "UK and Europe".
- "UK" flag accounts for approximately 50% of total.
- Footprints flagged as "Mixture" has the lowest values.

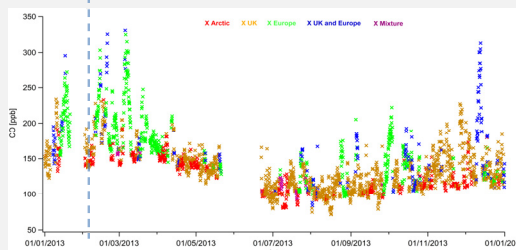


Figure 7. CO mole fractions for 2013 coloured by flag. CO data are 3-hour averages to coincide with the 3-hourly NAME footprints. Grey dashed line indicates the period shown in the NAME footprint in Figure 5.

## Measurement support: past, present and future

- EUROHYDROS – a EUROpean network for HYdrogen Observations and Studies (EU project).
- InGOS – Integrated non-CO<sub>2</sub> Greenhouse gas Observing System (EU project).
- MAMM – Methane and other Greenhouse Gases in the Arctic: Measurements, Process Studies and Modelling (NERC project).
- NERC's National Centre for Atmospheric Sciences (NCAS) through the Atmospheric Measurement Facility (AMF).

