Data
Models
Inventories

PARIS

Process Attribution of Regional Emissions

GA 101081430, RIA

Atmospheric oxygen and carbon dioxide observations from Weybourne Atmospheric Observatory, Norfolk, UK uploaded to public archives

Deliverable D6.1	
Delivery due date Annex I	PM 14 | February 2024
Actual date of submission	PM 17
Lead beneficiary: UNIVBRIS	Work package: WP6 Nature: DATA Dissemination level: PU
Responsible scientist	Penelope Pickers
Contributors	Penelope Pickers, Karina Adcock, Andrew Manning
Internal reviewers	-
Version: 1	

Table of content

1. Changes with respect to the DoA (Description of the Action)

N/A

2. Dissemination and uptake

The dissemination of D6.1 involves uploading the validated atmospheric oxygen (O_2) and carbon dioxide (CO_2) dataset from Weybourne Atmospheric Observatory, Norfolk, UK, in 2023 in the ICOS Carbon Portal database, where it is fully accessible to the public (https://meta.icos-cp.eu/objects/j4LzdHQiq3fPgfNeXHruC0Bb).

This ensures broad dissemination of the O_2 and CO_2 data, allowing stakeholders and the broader scientific community to access and utilize the dataset for various research purposes.

3. Short summary of results

Continuous, high-frequency (every 2-minutes) measurements of atmospheric CO_2 and O_2 were made from Weybourne Atmospheric Observatory throughout 2023 using a Siemens Ultramat 6E analyser for CO_2 and an Oxzilla analyser for O_2.

The analysers were calibrated approximately every 47 hours following the established protocols of the high-precision atmospheric CO_2 and O_2 measurement communities. Data were quality controlled using a standardised procedure, with code written in R, followed by manual quality assurance, as well as by assessing associated QC information such as target cylinder results. Data are then averaged to hourly values before being uploaded to the ICOS Carbon Portal.

Historical measurements since May 2010 have also been uploaded. In 2023, there are O_2 measurements for 66% of the year, and CO_2 measurements for 77% of the year. The historical record with full description of the instrumental setup, methodology and description of the key features of the dataset Is published In Adcock et al., 2023.

4. Evidence of accomplishment

4.1 Introduction | Background of the deliverable | milestone

It has recently been shown that high-precision atmospheric measurements of O_2 and CO_2, when combined into the tracer Atmospheric Potential Oxygen (APO), can be used to differentiate between biospheric and fossil fuel CO_2 ($ffCO_2$) in the atmosphere (Pickers et al., 2022), where APO = O_2 + 1.1 x CO_2. The value 1.1 denotes the mean O_2:CO_2 molar ratio of terrestrial biosphere-atmosphere exchange. APO is therefore, by design, invariant to terrestrial biosphere exchange processes, making it a tracer for $ffCO_2$. APO has previously been used as a tracer for ocean carbon cycle processes, which operate mostly on seasonal and long-term timescales (Keeling and Manning, 2014).

Regional $ffCO_2$ signals can be isolated in APO by subtracting a 'clean-air' baseline that incorporates oceanic APO variations (Pickers, 2016):

$$ffCO2[APO]=(APO-APO\_BL)/R\_APO \quad (1)$$

where APOBL is the 'baseline' APO and RAPO is the molar ratio (R) of APO:CO_2 for fossil fuel emissions. PARIS will advance the ability to partition top-down estimates of CO_2 emissions into fossil fuel and biosphere components by delivering new atmospheric APO measurement and modelling capabilities.

4.2 Scope of the deliverable | milestone

1. **Data collection:** Measure in-situ atmospheric O_2 and CO_2 continuously with high-frequency (2-min sampling). Ensure the instrument is well-maintained and calibrated regularly.

2. **Data processing and quality control**: The bespoke instrument software collects raw data and automatically calculates calibrated values. Some technical issues are automatically recorded in a 'flags' column in the raw data files, while others are manually recorded in the user log alongside other unautomated metadata. All files produced are .csv format.

3. **Data documentation**: data is documented on the ICOS Carbon Portal website. Details Include site location and time period, uncertainty of the hourly averages and contact information for the data providers.

4. **Data formatting and standardization**: data is provided as .csv files using ICOS format for missing values, uncertainties, and QC flags. Metadata is included in the file header.

5. **Data submission to ICOS Carbon Portal database**: Observation data files are submitted to the ICOS Carbon Portal database following submission procedures and requirements.

6. **Accessibility and data sharing:** The submitted O_2 and CO_2 observation data is fully accessible to the public, including stakeholders and the broader scientific community, through the ICOS Carbon Portal.

4.3 Content of the deliverable | milestone

Data description: Time series of continuous atmospheric measurements of O_2 and CO_2 at the Weybourne Atmospheric Observatory in the United Kingdom between May 2010 and December 2023. The measurements are ongoing. The CO_2 is reported in ppm units and was measured using a non-dispersive infrared (NDIR) CO_2 analyser from Siemens Corp., model Ultramat 6E. The O_2 is reported as O_2/N_2 in per meg units and was measured using a dual lead fuel cell O_2 analyser, Oxzilla from Sable Systems International Inc. We report hourly averages of 2-minute measurements. An hour must have at least 9 measurements or the hourly average is not included. The standard deviations are the hourly standard deviations of the 2-minute measurements. "NA" is used when there is no data. Gaps in the data are due to routine running of calibration cylinders, maintenance and removal of data with known technical issues. CO_2 data were transferred onto the WMO NOAA X2019 calibration scale using Equation 6 in Hall et al., 2021, doi.org/10.5194/amt-14-3015-2021. O_2 data are on the Scripps Institution of Oceanography (SIO) 'S2' scale that was used by SIO from April 1995 to August 2017. Full details are provided in Adcock et al., 2023.

Metadata: The dataset is accompanied by comprehensive metadata, detailing information such as the measurement units, station name, and contact information of the data providers.

Findability: The dataset can be accessed via the ICOS Carbon Portal database. Users can locate the dataset by specifying the station (WAO or Weybourne Atmospheric Observatory), and component (O_2 and/or CO_2)

Accessibility: The dataset is publicly accessible through the ICOS Carbon Portal database, ensuring that stakeholders and the broader scientific community can easily access and utilize the data for their research and applications.

Interoperability: The dataset is formatted into standardized .csv files using the ICOS data format, facilitating interoperability with other datasets and platforms.

Reusability: The dataset includes hourly averages with uncertainty, providing a comprehensive view of the observed atmospheric O_2 and CO_2. Atmospheric Potential Oxygen (APO) is not provided but can easily be calculated by the data user, ensuring that the data are reusable for various research purposes and analyses.

The validated atmospheric O_2 and CO_2 data from Weybourne Atmospheric Observatory in 2023 have been submitted to the ICOS Carbon portal database, where the public is fully accessible to by specifying the station and species, or by following the link here: https://meta.icos-cp.eu/objects/j4LzdHQiq3fPgfNeXHruC0Bb (Fig. 1).

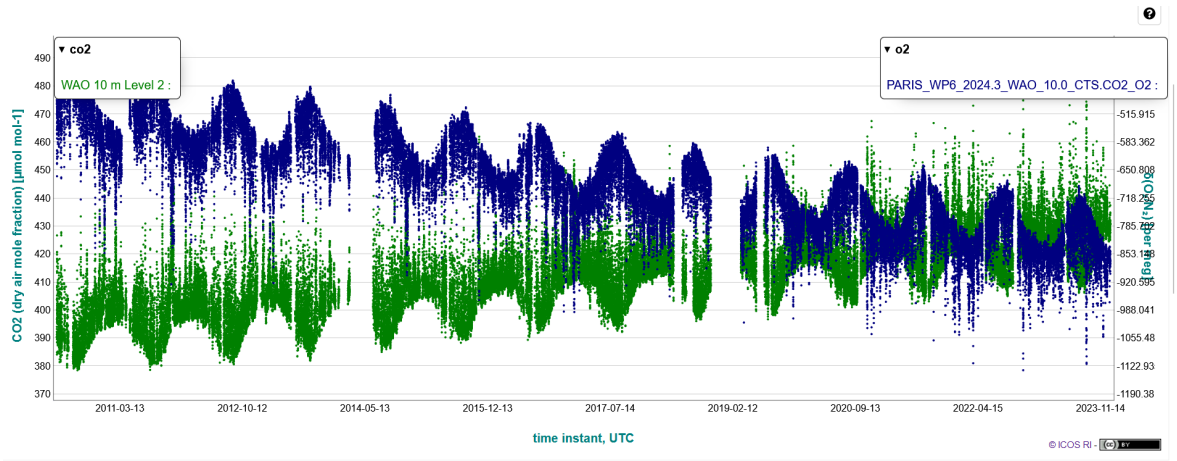

Fig. 1: Screenshot showing uploaded O2 and CO2 data on ICOS Carbon Portal website.

4.4 Conclusion and possible impact

The online ambient observations of atmospheric O_2 and CO_2 from Weybourne provide detailed and valuable insights into carbon cycle processes including variability of regional fossil fuel CO_2 in the atmosphere in the UK and Europe. The dataset provides valuable information for assessing agreement with similar datasets from other locations and will help contribute to modelling outputs.

The availability of the atmospheric O_2 and CO_2 dataset enhances collaboration and knowledge exchange among consortium members, fostering interdisciplinary research and innovation and serving as a valuable resource for the project. The dataset complements the greenhouse gas (GHGs) emissions data analysed in other work packages, contributing to efforts on accurately assessing climate change.

By sharing the dataset openly, the dataset facilitates broader scientific inquiry and exploration within the research community, researchers can leverage the data for diverse research applications. The dataset also aligns with the EU's objectives and priorities related to climate.

4.5 References

Adcock et al., 12 years of continuous atmospheric O_2, CO_2 and APO data from Weybourne Atmospheric Observatory in the United Kingdom, *Earth System Science Data*, 2023

Hall et al., Revision of the World Meteorological Organization Global Atmosphere Watch (WMO/GAW) CO_2 calibration scale, *Atmospheric Measurement Techniques*, 2021

Keeling and Manning, Studies of Recent Changes in Atmospheric O_2 Content. In: *Treatise on Geochemistry (Second Edition), Holland, H. D. and Turekian, K. K. (Eds.), Elsevier, Oxford*, 2014

Pickers et al., Novel quantification of regional fossil fuel CO_2 reductions during COVID-19 lockdowns using atmospheric oxygen measurements, *Science Advances*, 2022

Pickers, New applications of continuous atmospheric O_2 measurements: meridional transects across the Atlantic Ocean, and improved quantification of fossil fuel-derived CO_2, *PhD thesis, University of East Anglia*, 2016

5. History of the document

Version	Author(s)	Date	Changes
V 1.0	Penelope Pickers	17/06/2024	New document
	S. Walter	21/06/2024	Final check, formatting