CO2MVS RESEARCH ON SUPPLEMENTARY OBSERVATIONS

Database of existing O_2 measurements

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1 Executive Summary

Atmospheric oxygen (O_2) measurements, combined with CO_2, allow to disentangle processes in the carbon cycle. Oxygen informs about ocean carbon uptake, fossil fuel emissions and biosphere exchange. Within CORSO, additional combined measurements of O_2 and CO_2 were taken at Cabauw, the Netherlands, see deliverable D3.3. The work in this task was to create a database of existing O_2 observations. Besides the new CORSO measurements at Cabauw, also ICOS flask samples that are measured for O_2 are included, together with continuous measurements in the UK by University of East Anglia, and flask samples from Scripps and University of Groningen. This has resulted in the first global ObsPack product for combined O_2 and CO_2 measurements, which is available from the ICOS Carbon Portal:

https://meta.icos-cp.eu/objects/kQYF65EDcj-k2Gf9zUq8rtvS

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2 Introduction

2.1 Background

To enable the European Union (EU) to move towards a low-carbon economy and implement its commitments under the Paris Agreement, a binding target was set to cut emissions in the EU by at least 40% below 1990 levels by 2030. European Commission (EC) President von der Leyen committed to deepen this target to at least 55% reduction by 2030. This was further consolidated with the release of the Commission's European Green Deal on the 11th of December 2019, setting the targets for the European environment, economy, and society to reach zero net emissions of greenhouse gases in 2050, outlining all needed technological and societal transformations that are aiming at combining prosperity and sustainability. To support EU countries in achieving the targets, the EU and European Commission (EC) recognised the need for an objective way to monitor anthropogenic CO_2 emissions and their evolution over time.

Such a monitoring capacity will deliver consistent and reliable information to support informed policy- and decision-making processes, both at national and European level. To maintain independence in this domain, it is seen as critical that the EU establishes an observation-based operational anthropogenic CO_2 emissions Monitoring and Verification Support (MVS) (CO2MVS) capacity as part of its Copernicus Earth Observation programme.

The CORSO research and innovation project will build on and complement the work of previous projects such as CHE (the CO2 Human Emissions), and CoCO2 (Copernicus CO2 service) projects, both led by ECMWF. These projects have already started the ramping-up of the CO2MVS prototype systems, and can be implemented within the Copernicus Atmosphere Monitoring Service (CAMS) with the aim to be operational by 2026. The CORSO project will further support establishing the new CO2MVS addressing specific research & development questions.

The main objectives of CORSO are to deliver further research activities and outcomes with a focus on the use of supplementary observations, i.e., of co-emitted species as well as the use of auxiliary observations to better separate fossil fuel emissions from the other sources of atmospheric CO_2. CORSO will deliver improved estimates of emission factors/ratios and their uncertainties as well as the capabilities at global and local scale to optimally use observations of co-emitted species to better estimate anthropogenic CO_2 emissions. CORSO will also provide clear recommendations to CAMS, ICOS, and WMO about the potential added-value of high-temporal resolution $^{14}CO_2$ and APO observations as tracers for anthropogenic emissions in both global and regional scale inversions and develop coupled land-atmosphere data assimilation in the global CO2MVS system constraining carbon cycle variables with satellite observations of soil moisture, leaf-area index (LAI), sun induced fluorescence (SIF), and biomass. Finally, CORSO will provide specific recommendations for the topics above for the operational implementation of the CO2MVS within the Copernicus programme.

2.2 Scope of this deliverable

WP3 is dedicated to the assessment of the potential added value of in-situ measurements of $^{14}CO_2$ and O_2. Combined atmospheric O_2 and CO_2 measurements provide additional information on the contribution of natural and fossil fuel components to CO_2 mole fractions, with the added advantage that they can be measured continuously (e.g., Pickers et al., 2022; Stephens et al., 1998). Fossil fuel combustion consumes atmospheric O_2, and the O_2/CO_2 signal allows different fossil fuels to be distinguished by their oxidative (or exchange) ratio (Steinbach et al., 2011), helping to disentangle the fossil fuel CO_2 ($ffCO_2$) component from the net atmospheric CO_2 signal (Pickers et al., 2022). Atmospheric O_2 and CO_2 can also be combined into the tracer Atmospheric Potential Oxygen (APO), defined as APO $\approx O_2 + 1.1 \times CO_2$, which excludes the biosphere signal by assuming a fixed exchange ratio of 1.1, following the definition by Stephens et al. (1998). APO is primarily sensitive to ocean–atmosphere exchange on large spatial and temporal scales. However, on shorter timescales, the initial study by Pickers et al. (2022) shows that atmospheric O_2 has the potential to provide information on the fossil fuel CO_2 signal, through the deviation from the biospheric exchange ratio of 1.1. The exchange ratio of fossil fuels ranges between 1.2 and 1.9, with the global average fossil fuel mix corresponding to approximately 1.4 (Keeling and Manning, 2014). The use of APO to derive $ffCO_2$ was confirmed by a modelling OSSE study by Rödenbeck et al. (2023). Further research is needed to establish the use of O_2 as a fossil fuel tracer, considering the influence of short-term ocean signals (Chawner et al., 2024) and biosphere ER variability (Faassen et al., 2025).

Task 3.1 is dedicated to intensifying $^{14}CO_2$ and APO observations in Western Europe throughout the calendar year 2024 and to collect databases of background observations of both species.

2.2.1 Objectives of this deliverable

The objective of this deliverable was to gather existing combined O_2 and CO_2 measurements into a combined database.

2.2.2 Work performed in this deliverable

Within this deliverable, we have collected a database of existing combined O_2 and CO_2 measurements.

2.2.3 Deviations and counter measures

This task and deliverable have been delayed to the end of the project, but earlier internal versions of the datasets were available to the modelling groups of the project to not delay the modelling tasks in WP3.

2.3 Project partners

This deliverable was conducted by University of Groningen and Wageningen University in collaboration with the ICOS Carbon Portal:

CORSO Partners / Collaborators /Laboratories	
University of Groningen, the Netherlands	RUG
Wageningen University, the Netherlands	WU

3 Results

The result of this deliverable was the creation of a global ObsPack product for combined O_2 and CO_2 measurements. We have included observations from the following laboratories:

- ICOS flask network
- University of East Anglia
- University of Groningen
- Scripps Institute for Oceanography.

The database includes observations from the sites shown in the figures below:

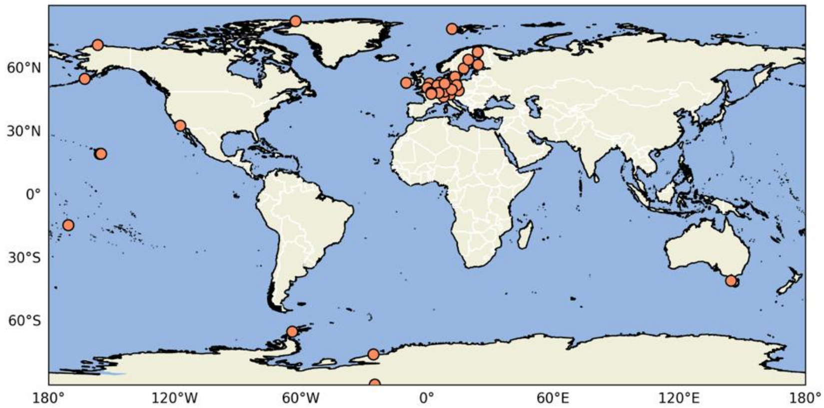

Figure 1: map showing the locations of measurements sites where combined O_2 and CO_2 measurements are taken, which are included in the global database.

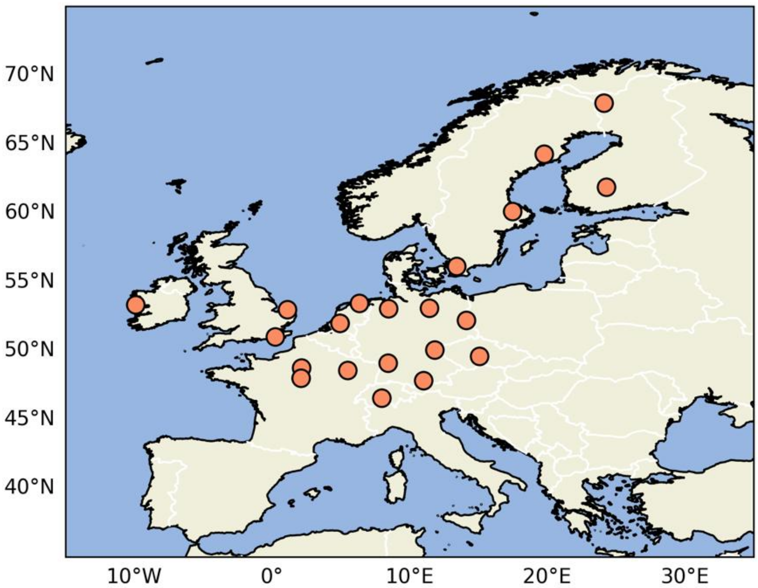

Figure 2: A zoom of the map for Europe, showing the locations of measurements sites where combined O_2 and CO_2 measurements are taken, which are included in the global database.

A challenge in atmospheric O_2 measurements is that there is currently not yet a WMO scale for these relative measurements. Most laboratories use the scale from the Scripps Institute for Oceanography, but also other scales are in use. Intercomparison efforts are ongoing to assess if measurements from different laboratories can be compared directly, or whether there are offsets. We therefore recommend users to be cautious when using observations from different laboratories and have added this in the disclaimer of the product. The O_2 community will work on this in the future.

Table 1: measurement sites included in the O_2 ObsPack product, with coordinates and scales.

Site	Location (lat, lon)	Lab	Scale CO_2	Scale O_2	Type
SPO	-89.98, -24.8	Scripps	SIOX12	SIO2023	flask
SAM	-14.2474, -170.5644	Scripps	SIOX12	SIO2023	flask
PSA	-64.7742, -64.0527	Scripps	SIOX12	SIO2023	flask
MLO	19.5362, -155.5763	Scripps	SIOX12	SIO2023	flask
LJO	32.8669, -117.2572	Scripps	SIOX12	SIO2023	flask
KUM	19.5608, -154.8883	Scripps	SIOX12	SIO2023	flask
CGO	-40.683, 144.69	Scripps	SIOX12	SIO2023	flask
CBA	55.21, -162.72	Scripps	SIOX12	SIO2023	flask
BRW	71.323, -156.6114	Scripps	SIOX12	SIO2023	flask
ALT	82.4508, -62.5072	Scripps	SIOX12	SIO2023	flask
HBA	-75.571509, -25.50386	University of Groningen	NOAAX2019	SIO2017	flask
LUT	53.4036, 6.3528	University of Groningen	NOAAX2019	SIO2017	flask
MHD	53.3261, -9.9036	University of Groningen	NOAAX2019	SIO2017	flask
WAO	52.95, 1.121	University of East Anglia	NOAAX2019	SIO2023	insitu
HFD	50.9767, 0.2306	University of East Anglia	NOAAX2019	SIO2023	insitu
CBW_cnt	51.9703, 4.9264	University of Groningen	NOAAX2019	SIO2023	insitu
CBW_flask	51.9703, 4.9264	ICOS FCL	NOAAX2019	SIO2023	flask
GAT	53.0657, 11.4429	ICOS FCL	NOAAX2019	SIO2023	flask
HPB	47.8011, 11.0246	ICOS FCL	NOAAX2019	SIO2023	flask
HTM	56.0976, 13.4189	ICOS FCL	NOAAX2019	SIO2023	flask
JFJ	46.5475, 7.9851	ICOS FCL	NOAAX2019	SIO2023	flask
KIT	49.0915, 8.4249	ICOS FCL	NOAAX2019	SIO2023	flask
KRE	49.572, 15.08	ICOS FCL	NOAAX2019	SIO2023	flask
LIN	52.1663, 14.1226	ICOS FCL	NOAAX2019	SIO2023	flask
NOR	60.0864, 17.4794	ICOS FCL	NOAAX2019	SIO2023	flask
OPE	48.5619, 5.5036	ICOS FCL	NOAAX2019	SIO2023	flask
OXK	50.03, 11.8083	ICOS FCL	NOAAX2019	SIO2023	flask
PAL	67.9733, 24.1157	ICOS FCL	NOAAX2019	SIO2023	flask
SAC	48.7227, 2.142	ICOS FCL	NOAAX2019	SIO2023	flask
SMR	61.8474, 24.2947	ICOS FCL	NOAAX2019	SIO2023	flask
STE	53.0431, 8.4588	ICOS FCL	NOAAX2019	SIO2023	flask
SVB	64.256, 19.775	ICOS FCL	NOAAX2019	SIO2023	flask
TRN	47.9647, 2.1125	ICOS FCL	NOAAX2019	SIO2023	flask
ZEP	78.9072, 11.8867	ICOS FCL	NOAAX2019	SIO2023	flask

4 Conclusion

In this task, we have provided a database of global combined O_2 and CO_2 measurements, available at the ICOS Carbon Portal. This product serves as a first step, and in the future, the O_2 community will work on expanding this product, and also provide further information on the uncertainties of the measurements related to the measurement scales used in the different laboratories.

5 References

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Document History

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