Funded by the European Union

Co-ordinated by ECMWF

CORSO
CO2MVS Research on Supplementary Observations

WP3: IMPROVED USE OF IN SITU 14CO2 AND APO OBSERVATIONS TO SEPARATE THE IMPACT OF FOSSIL FUEL EMISSIONS FROM OBSERVED CO2 VARIABILITY

Kick-off Meeting

Ingrid Luijkx (WU) , Gregoire Broquet (LSCE) and the WP3 team (ECMWF, AGH, LSCE, TNO, UNIVBRIS, RUG, UHEI, ULUND, UT3, WU, ETHZ)

23/01/2023

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CONTEXT and RATIONALE

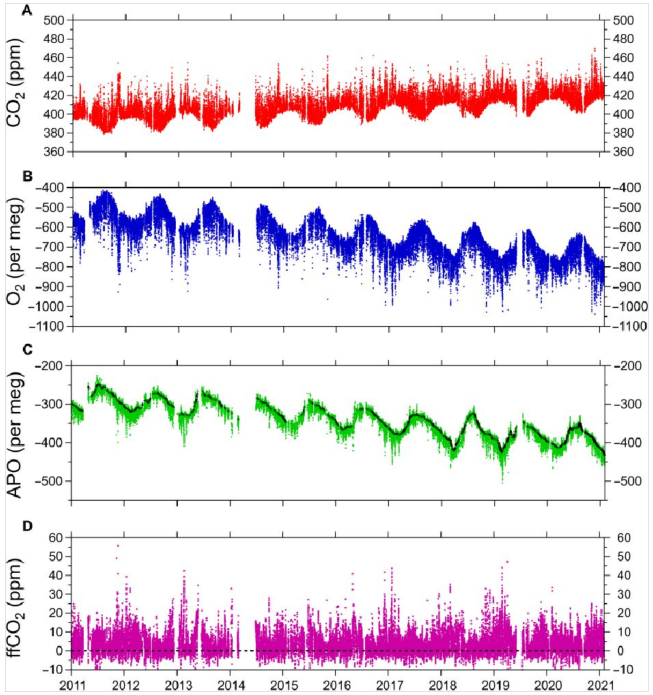
- CO_2 surface sites: to complement satellite data or benchmark the inversions based on satellite data for the CO2MVS service
- Radiocarbon ($ffCO_2$ is free from ^{14}C) and Atmospheric Potential Oxygen (APO short scale variations mainly from ff combustion) to better separate anthropogenic and natural CO_2 signals

→ specific sample and measurement frameworks, additional components in the modelling & inversion systems

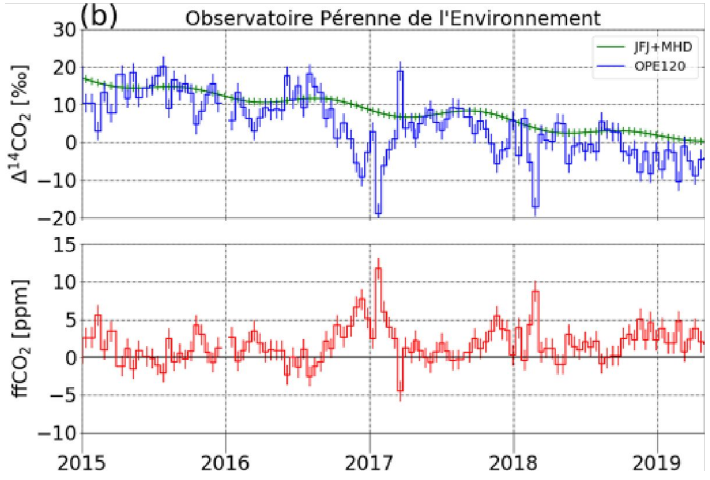
→ need to assess the use of such data for CO2MVS

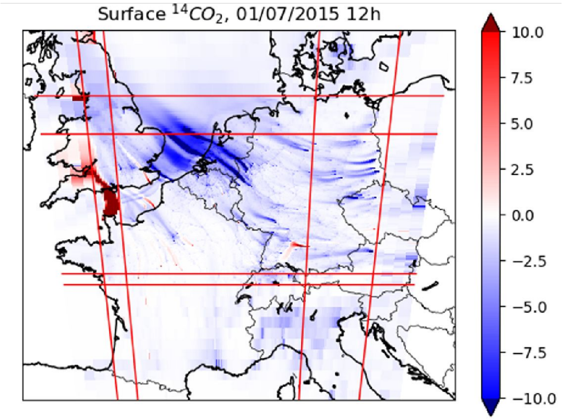
- Challenges: sparse and heterogeneous coverage over past decades, costs, network compatibility

Direct derivation of $ffCO_2$ from APO at WAO Pickers et al., 2020, Science. Advances

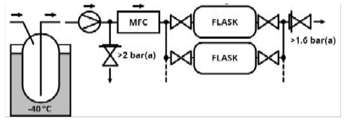


Direct derivation of $ffCO_2$ from ^{14}C-CO_2 measurements at OPE
Levin et al., 2020, ACP





Simulation of CO_2,$\delta^{14}CO_2$ (ppm ‰)
Potier et al., 2020, AMT (CHE / CoCO2)

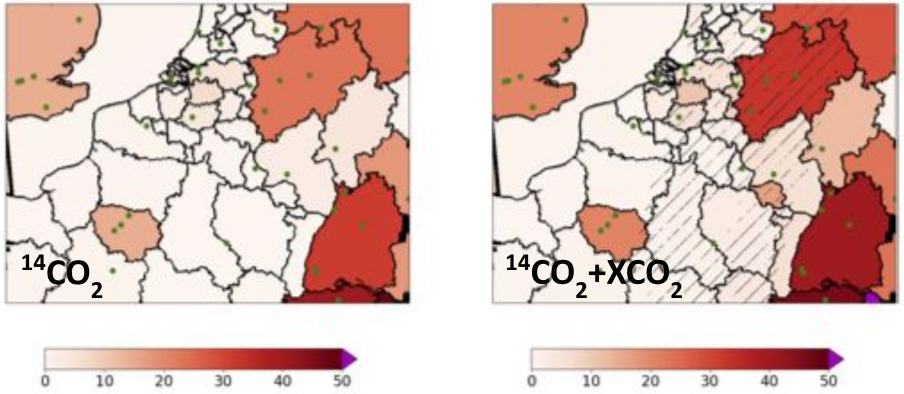


ICOS flask sampler
Levin et al., 2020, ACP

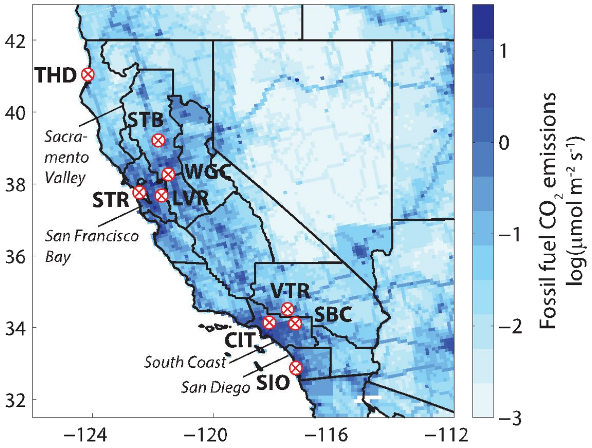
CONTEXT and RATIONALE

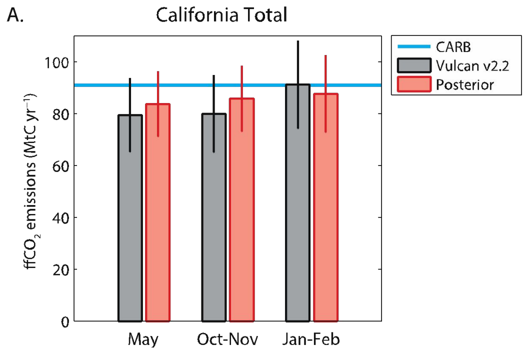
Assessment of the potential of $^{14}CO_2$ and APO networks

- positive insights from experiments with pseudo data (incl. CHE WP4) and from regional analysis

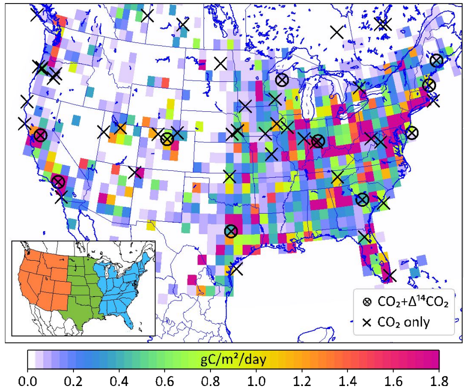


Studying the complementarity between XCO_2 and $^{14}CO_2$ data in CHE: uncertainty reduction (from ~20% prior uncert.) for the regional budgets of FF CO_2 emissions on a day of overpass by CO2M when assimilating $^{14}CO_2$ and XCO_2 data; Potier et al., 2022, AMT, with results from CHE / CoCO2





Inversion of California's $ffCO_2$ emissions in 2014-2015 using nine ^{14}C-CO_2 sites with samples every 2-3 days in May 2014, Oct-Nov 2014 and Jan-Feb 2015; Graven et al., 2018, ERL



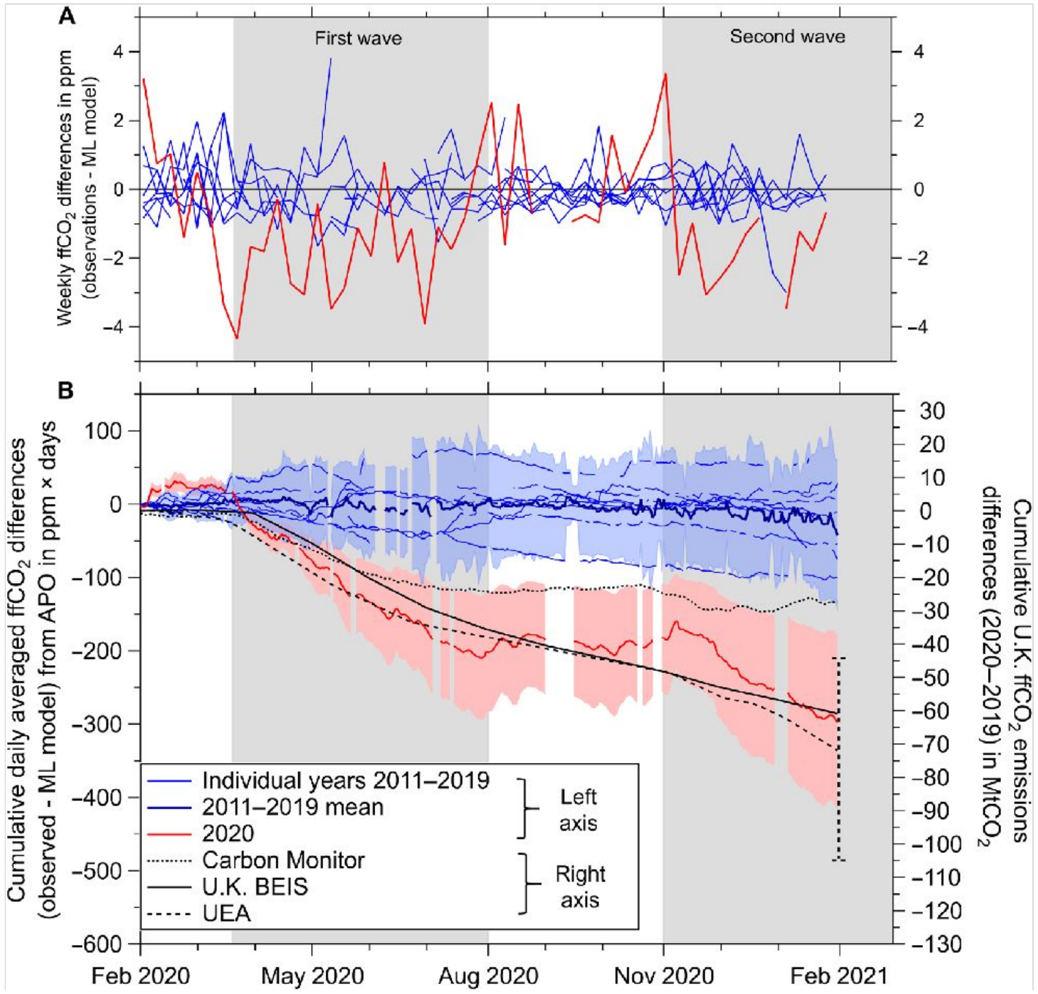
	FF CO_2, TgC yr^{-1}			
Source	Reported	Adjusted	Prior	Posterior
CDIAC	1,471	1,513		
EDGAR 4.2 FT2010	1,497	1,522		
EDGAR 4.3	1,505	1,545		
US EPA	$1{,}555^{+62}_{-31}$	$1{,}581^{+62}_{-31}$		
Vulcan 3.0	1,638	1,676		
Inverse estimate (mean)			1,528	1,653 ± 30
Inverse estimate (Miller/CT prior)			1,543	1,627 ± 30
Inverse estimate (seasonal FFDAS prior)			1,485	1,656 ± 30
Inverse estimate (ODIAC prior)			1,555	1,675 ± 30

US $ffCO_2$ emission estimates for 2010 including inversions using ~1000 ^{14}C-CO_2 samples from 16 sites and CO_2 continuous measurents; Basu et al., 2020, PNAS

CONTEXT and RATIONALE

Assessment of the potential of $^{14}CO_2$ and APO networks

- positive insights from experiments with pseudo data (incl. CHE WP4) and from regional analysis



Quantifying of $ffCO_2$ reduction in UK during COVID-19 lockdowns using continuous APO measurements at WAO; Pickers et al., 2022, Science Advances with results reported in CHE

CONTEXT and RATIONALE

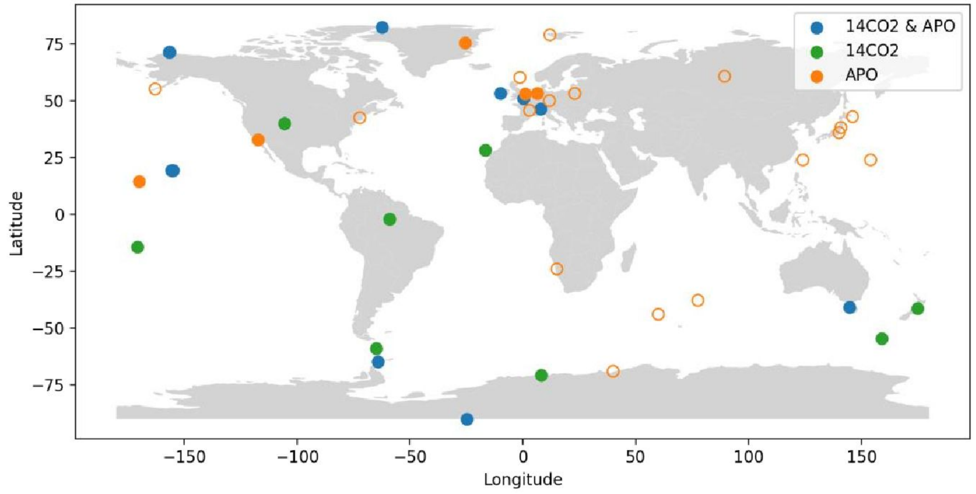
Assessment of the potential of $^{14}CO_2$ and APO networks

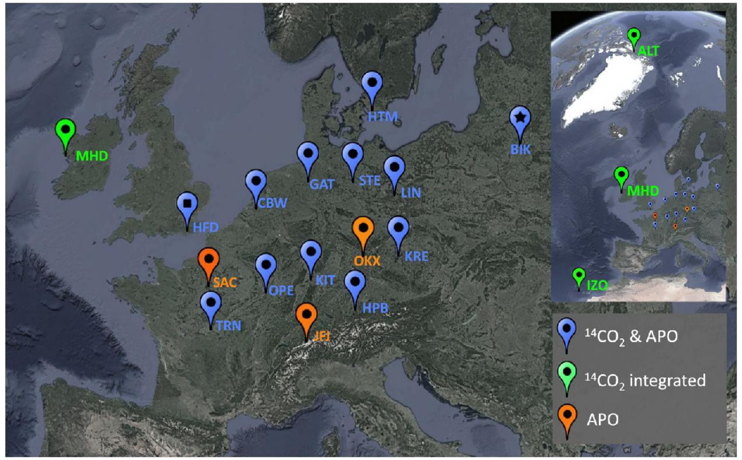
- positive insights from experiments with pseudo data (incl. CHE WP4) and from regional analysis
- but need for a new detailed assessment using real data to weight the contribution to the MVS with respect to the requirements in terms of global to regional observation and modelling

→ background stations with coarse sample and global scale atmospheric inversion approaches to constrain emissions at large-scales and the background fields

→ dense continental networks with $^{14}CO_2$ / APO high frequency sampling and continuous APO sites and mesoscale atmospheric inversion approaches to constrain national to local emissions

Stations for which obs should be available for use in CORSO from ICOS and collaborating laboratories





GOALS

- **Assess the relevance of including $^{14}CO_2$ and APO data assimilation in the CO2MVS system to monitor ff emissions (attribution, verification)** → to benchmark or feed the main analysis
- **Quantify the regional and large-scale constraints on the ff emission estimates**
- **Evaluate the added value of high-temporal resolution $^{14}CO_2$ and APO observations**, and of the extension of current networks

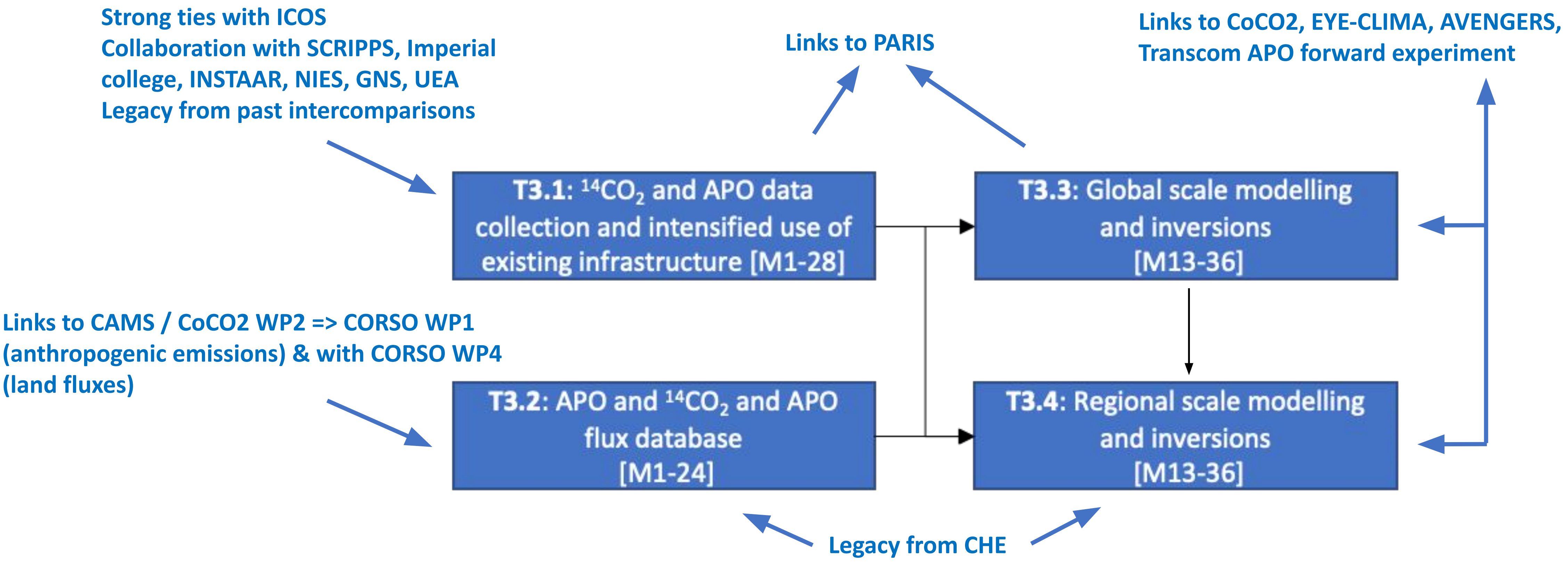
→ developing global and European scale $^{14}CO_2$ and APO inverse modelling frameworks, with dedicated flux products and new/improved inversion techniques (incl. legacy from CHE)

→ demonstrations with 20-year analysis and projections for the coming decade at global scale and with intensive measurements and inversion experiments during a focus year in Europe

- **Prepare the transfer of capacity to the CO2MVS**
- Provide recommendations to CAMS, ICOS and WMO regarding the measurement infrastructure

STRUCTURE AND CONNECTION TO OTHER WPs

- Relatively independent from other WPs within CORSO
- Legacy from past projects including CHE, complementarity with new projects
- 4 tasks covering three aspects, observations, bottom-up modelling of fluxes and inverse modeling



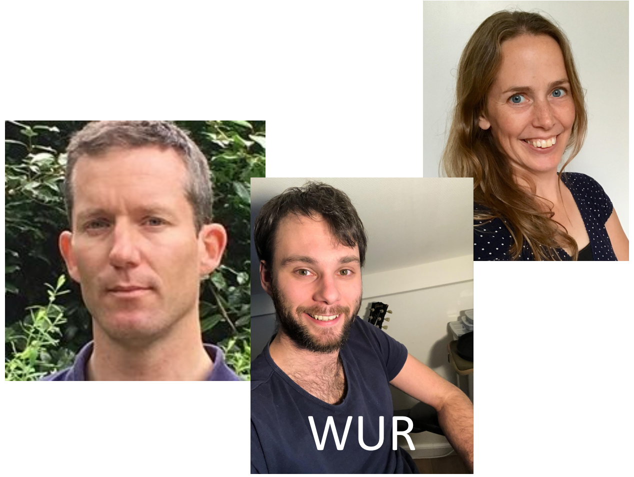
TEAM Work Package 3

- ECMWF: Nicolas Bousserez + postdoc
- AGH: Jaroslaw Necki
- LSCE: Gregoire Broquet, Philippe Ciais, Frederic Chevallier
  Philippe Peylin, Antoine Brechet, Hannah Allen
- TNO: Hugo Denier van der Gon
- UNIVBRIS: Matt Rigby, Hannah Chawner, Angelina Wenger
- RUG: Harro Meijer + postdoc
- UHEI/ICOS: Samuel Hammer, Ingeborg Levin
- ULUND: Marko Scholze, Carlos Gomez
- UT3: Claire Granier, Thierno Doumbia, Antonin Soulie
- WU: Ingrid Luijkx, Wouter Peters, Joram Hooghiem
- ETHZ: Lukas Wacker, Philip Gautschi

UHEI

RUG

UNIVBRIS



TEAM Work Package 3

• ECMWF:	Nicolas Bousserez + postdoc	(modelling)
• AGH:	Jaroslaw Necki	(measurements)
• LSCE:	Gregoire Broquet, Philippe Ciais, Frederic Chevallier Philippe Peylin, Antoine Brechet, Hannah Allen	(modelling)
• TNO:	Hugo Denier van der Gon	(modelling, flux databases)
• UNIVBRIS:	Matt Rigby, Hannah Chawner, Angelina Wenger	(modelling & measurements)
• RUG:	Harro Meijer + postdoc	(meas., APO data comp.)
• UHEI/ICOS:	Samuel Hammer, Ingeborg Levin	(meas., $^{14}CO_2$ data comp.)
• ULUND:	Marko Scholze, Carlos Gomez	(modelling)
• UT3:	Claire Granier, Thierno Doumbia, Antonin Soulie	(modelling, flux databases)
• WU:	Ingrid Luijkx, Wouter Peters, Joram Hooghiem	(modelling & measurements)
• ETHZ:	Lukas Wacker, Philip Gautschi	(measurements)

Tasks Work Package 3: task 3.1

- **Task 3.1** **$^{14}CO_2$ and APO data collection and intensified use of existing infrastructure** (**lead: UHEI & RUG**)
- **Task 3.1.a** **Global APO (RUG) and $^{14}CO_2$ (UHEI) database**
- **Task 3.1.b** **Intensive $^{14}CO_2$ and APO observation year in Europe (UHEI, RUG, UNIVBRIS, AGH, ETHZ)**

★ Extension of the ICOS CRL $^{14}CO_2$ sample processing capacity (ETHZ, UHEI)
★ New stations: continuous APO Cabauw (RUG, WU), ICOS flasks at: Bialystok (AGH), Heathfield (UNIVBRIS)
★ Additional $^{14}CO_2$ measurements from new and archived samples by Scripps
★ Integrated $^{14}CO_2$ samples for MHD, IZO and ALT (UHEI)

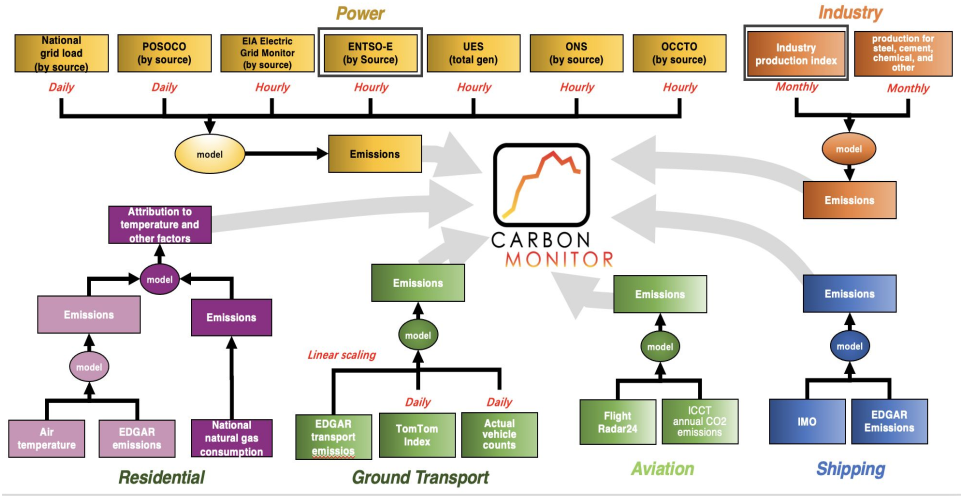
Tasks Work Package 3: task 3.2

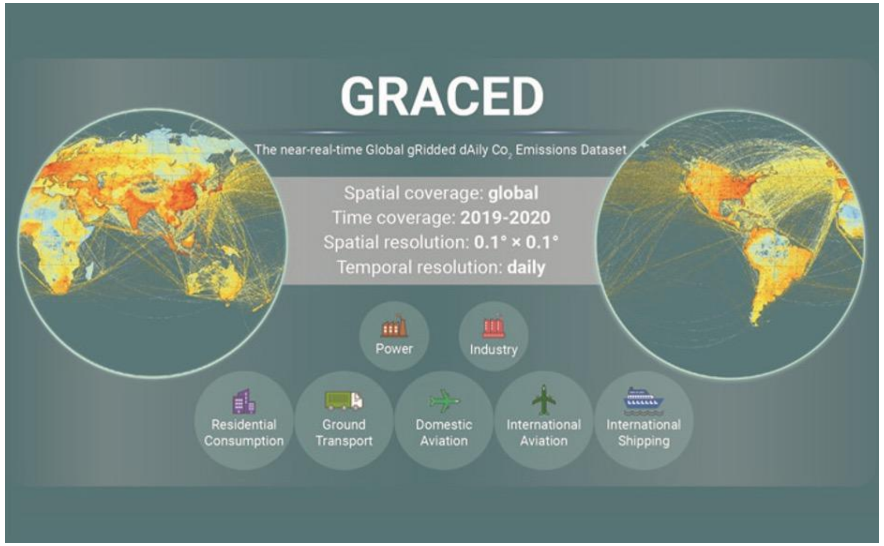
- **Task 3.2** **APO and $^{14}CO_2$ flux databases** (lead: TNO & ULUND)
- **Task 3.2.a** **Collection of $^{14}CO_2$ flux products**

  Terrestrial and oceanic $^{14}CO_2$ disequilibrium fluxes (LPJ-GUESS & C-TESSEL/ECLAND, ULUND, WP4), cosmogenic production (Wang, 2016 by LSCE), emissions from nuclear reactors and reprocessing plants (RADD with updates by LSCE)

- **Task 3.2.b** **Global and regional APO inventories**

  APO fluxes for fossil and biofuels, based on TNO_GHGco and GRACED (TNO, LSCE)





https://carbonmonitor-graced.com/

Tasks Work Package 3: task 3.2

- **Task 3.2.c Ocean APO fluxes**

  ECCO2 and NEMO O_2, N_2 and CO_2 fluxes (UNIVBRIS)

- **Task 3.2.d Future emission scenarios**

  Based on SSPs from IPCC AR6 for the coming decade for CO_2, $^{14}CO_2$ and APO (UT3)

Tasks Work Package 3: task 3.3

- **Task 3.3 Global scale modelling and inversions (lead WU & LSCE)**

  Assessing large-scale constraints on fossil fuel CO_2 emissions from $^{14}CO_2$ and APO with focus on 2004-2024 for North America and Europe, where inventories are relatively robust. Additionally, we will run future scenarios 2020-2030 to test against changing emission landscape.

Modelling systems:

- CTE-TM5 (WUR)
- CIF-LMDZ (LSCE)
- TM5-4DVAR $^{14}CO_2$ (ULUND)
- Working towards OpenIFS (WUR/ECMWF)

Tasks Work Package 3: task 3.4

- **Task 3.4 Regional scale modelling and inversions** (**lead ULUND & UNIVBRIS**)
- **Task 3.4.a Regional European inversions**

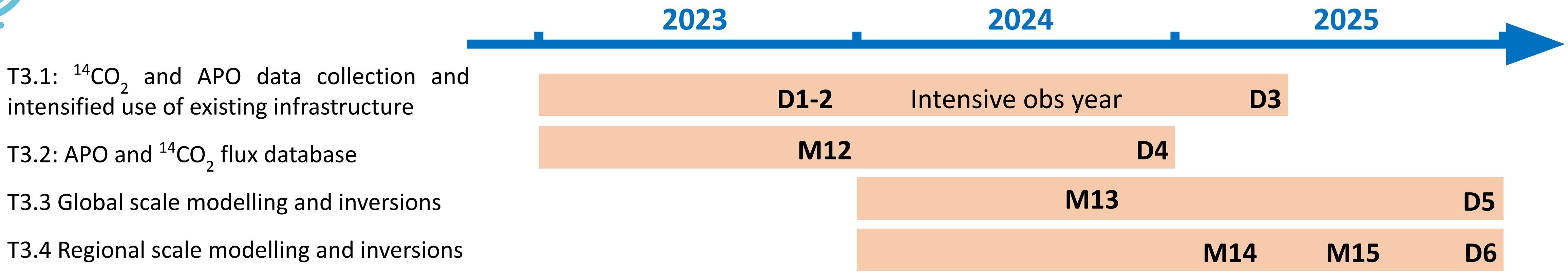
  Focussing on the added value of the observations collected in the intensive year 2024, from the ICOS flask samples at 14 stations and the continuous APO observations

  Modelling systems:
  - CTE-TM5 (WUR)
  - CIF-LMDZ (LSCE)
  - NAME- HBMCMC (UNIVBRIS)
  - LUMIA (ULUND)

- **Task 3.4.b Site-level attribution**

  CTE and NAME will assess specifically the added value of continuous APO observations compared to flask APO and $^{14}CO_2$ observations, focussing on UK-NL, plus development of a metric to test the skill of the systems to detect fossil fuel dominated plumes or by specific sectors

DELIVERABLES AND TIMELINE



D3.1	Database of existing $^{14}CO_2$ measurements	M9	Lead UHEI
D3.2	Database of existing APO measurements	M9	Lead RUG
D3.3	Final APO and $^{14}CO_2$ measurement datasets from the 1-year intensive observations in Western Europe	M28	Lead UHEI
M12	First version of the APO and $^{14}CO_2$ flux databases with an exhaustive coverage of all types of fluxes including intermediate products	M10	
D3.4	Final and complete version of the APO and $^{14}CO_2$ flux databases	M24	Lead TNO
M13	First 20-year global inversions assimilating APO and $^{14}CO_2$	M20	
D3.5	Estimates of the annual fossil fuel CO_2 emissions at the continental to national scales over a decade and recommendations for the implementation of global scale APO and $^{14}CO_2$ data assimilation in the CO2MVS	M36	Lead WU
M14	Regional inversion systems set-up for intensive observation year	M26	
M15	Development of metric for the assessment of the added value of continuous APO	M30	
D3.6	Analysis of the FFCO2 emissions at national scale in Western Europe in 2024 and recommendations for the implementation of regional scale APO and $^{14}CO_2$ data assimilation in the CO2MVS	M36	Lead UNIVBRIS

Focus point first year

- Extending $^{14}CO_2$ measurement capabilities
- Continuous APO measurements to be set up at Cabauw
- $^{14}CO_2$ and APO measurement databases
- Preparation flux databases
- Preparations modelling setups

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THANK YOU

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