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UEA
University of East Anglia

50 YEARS OF ENVIRONMENTAL SCIENCES

UEA ENV

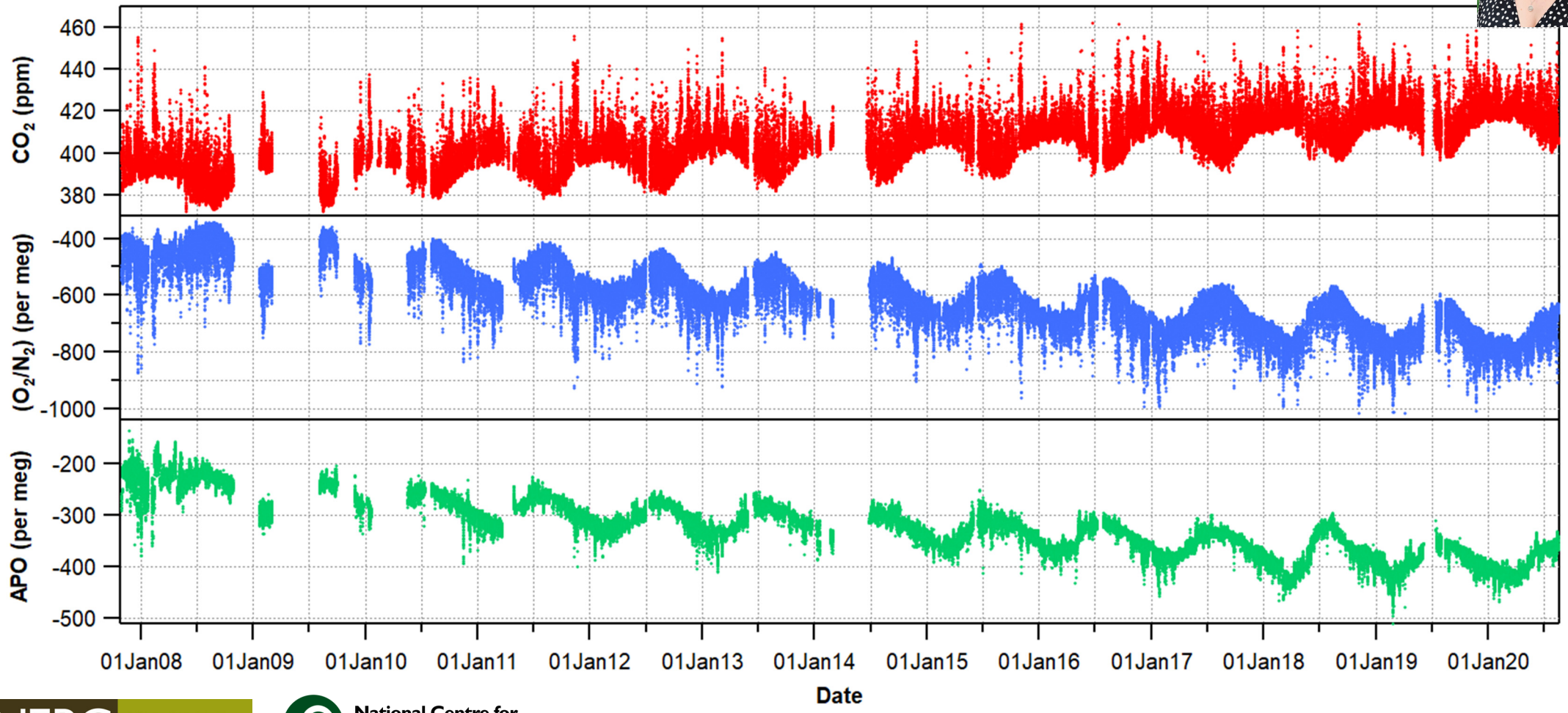
University of East Anglia

COAS
Centre for Ocean and Atmospheric Sciences

# Weybourne Atmospheric Observatory, UK (53°N)

(with support from Grant Forster, Alex Etchells, Thomas Barningham, Penelope Pickers and Phil Wilson)

## $CO_2$ (ppm), $O_2/N_2$ (per meg) and APO (per meg) records: 2007-2020




NERC SCIENCE OF THE ENVIRONMENT

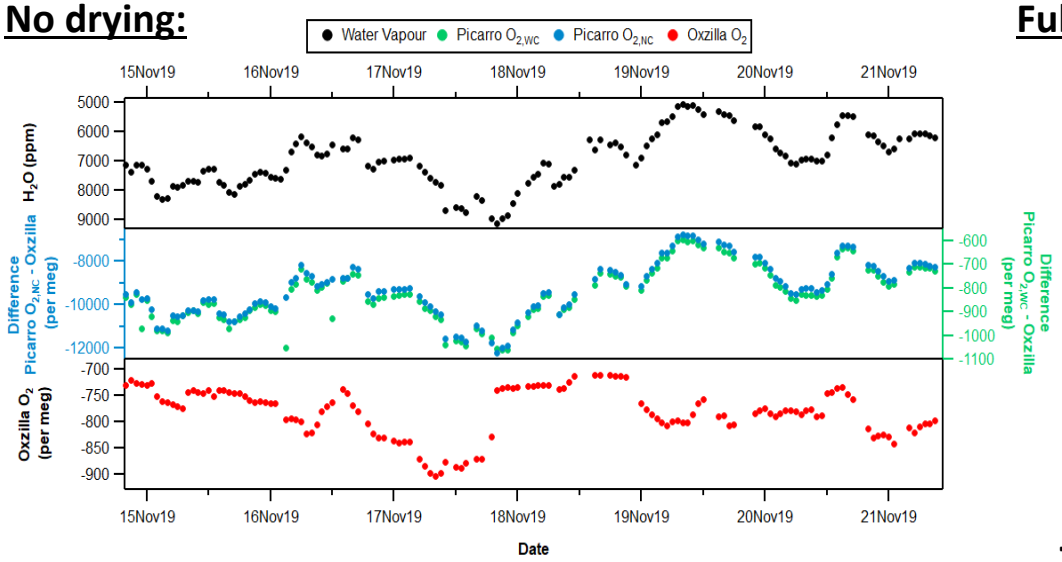
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

PICARRO

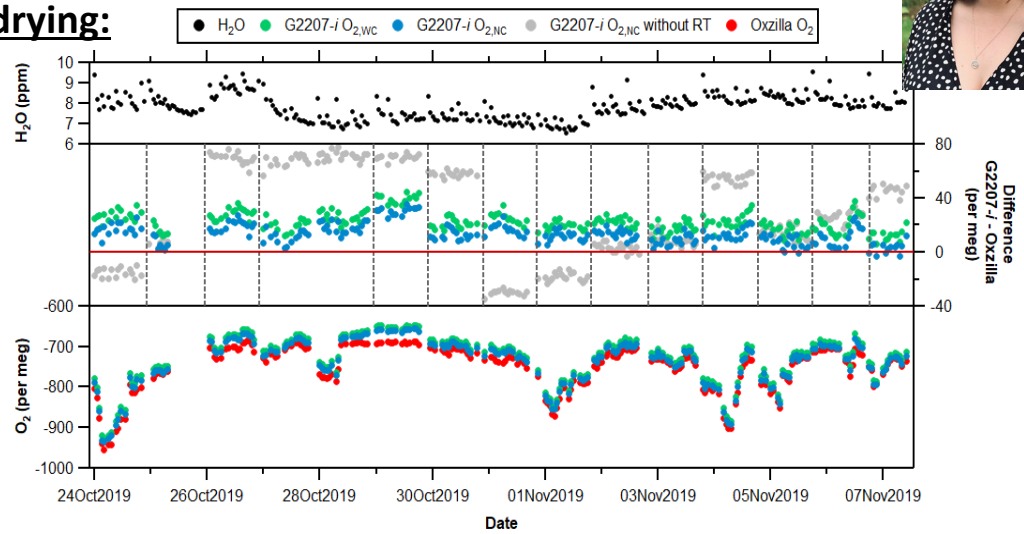
# Picarro Inc. G2207-*i* CRDS $O_2$ analyser

(in collaboration with Gregor Lucic and Magdalena Hofmann, Picarro Inc.)

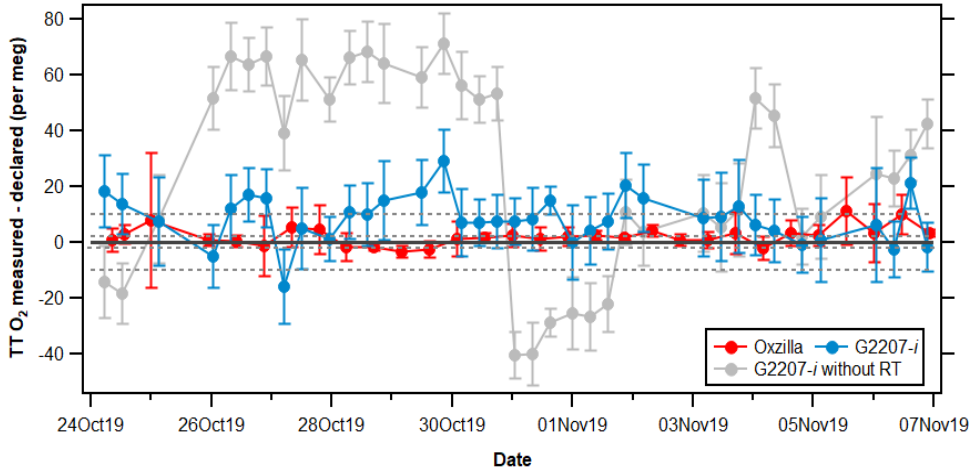
## No drying:




## Full drying:

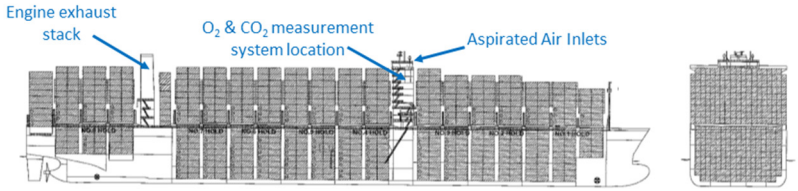



## Target Tank results:



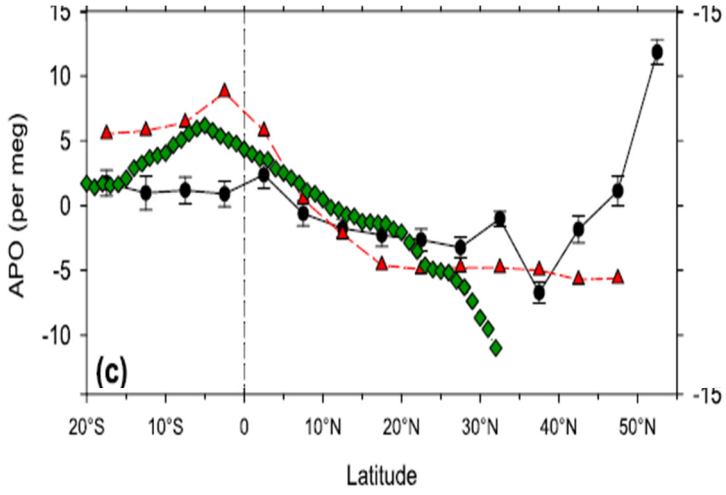

- Allan deviation: Precision of 4.8 per meg after 5 minutes; 2.5 per meg after 1 hour averaging.
- Maximum peak-to-peak drift over 24 hours, with 1 hour averaging: ~5.8 per meg.
- Water correction function is not good enough, Picarro are investigating this.
- Based on TT results with full drying, repeatability: ± 11.66 ± 2.87 per meg; compatibility: 9.97 ± 6.71 per meg.

# The Cap San Lorenzo container ship

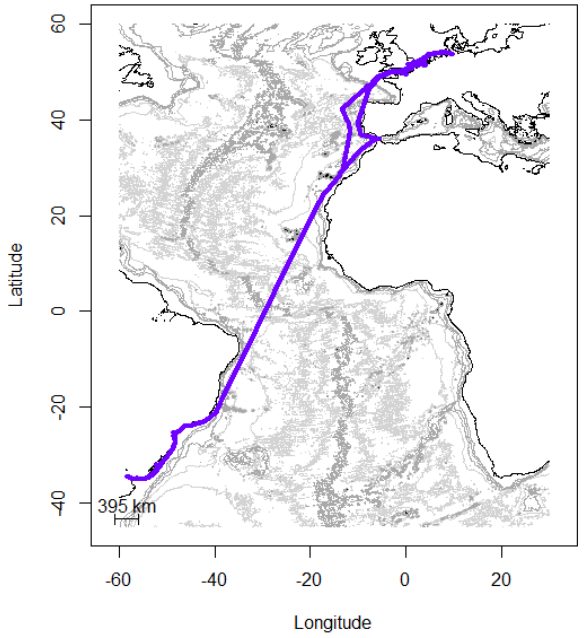

## In situ measurements of atmospheric $O_2$ and $CO_2$ reveal an unexpected $O_2$ signal over the tropical Atlantic Ocean

Penelope A. Pickers[1], Andrew C. Manning[1], William T. Sturges[1], Corinne Le Quéré[2], Sara E. Mikaloff Fletcher[3], Philip A. Wilson[1], and Alex J. Etchells[1]




- Pickers et al., GBC, 2017.
- **Black** – our observations (2015-2017 mean).
- **Red** – TM3 transport model results .
- **Green** – Pacific equivalent (observations; Tohjima et al., 2015).

- Technical and logistical issues in latter years, including covid-19.



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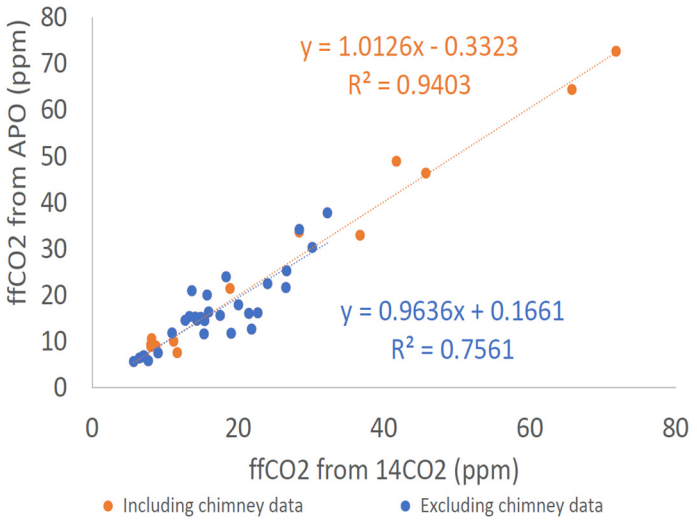
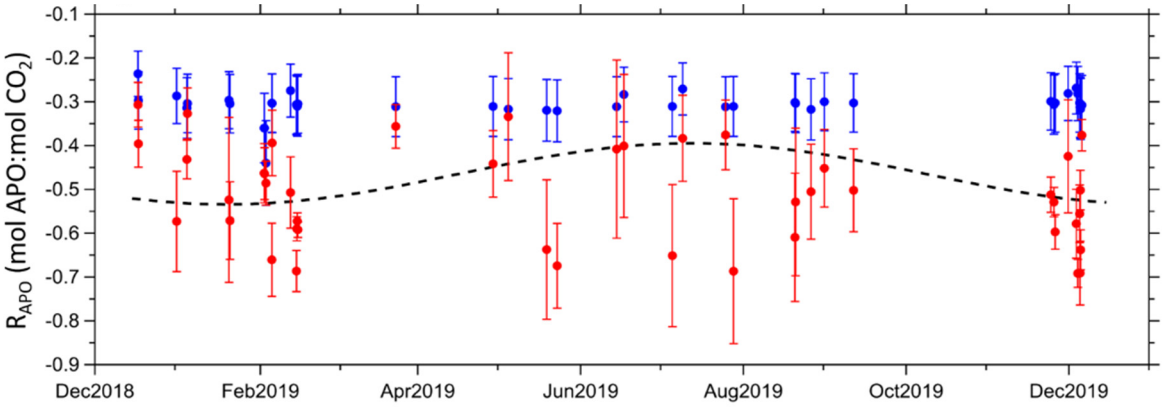
# $^{14}C$- and APO-derived $ffCO_2$ in Heidelberg

$$ffCO_2(APO) = \frac{APO_{measured} - APO_{background}}{R_{APO}}$$

where $R_{APO}$ is the APO:$CO_2$ ratio for fossil fuel combustion.

- Challenging station! V. hetererogenous local fossil fuel sources, and complex topography and micro-meteorology.
- $R_{APO}$ shows high variability because of proximity to local sources. $^{14}C$-calibrated ratios in agreement with TNO database, but not with COFFEE database.
- When using an accurate mean $R_{APO}$ value, there is no inherent bias between $^{14}CO_2$ and APO-based $ffCO_2$ estimates. APO is not as precise as $^{14}CO_2$ (because of $R_{APO}$-related variability), but it is accurate overall and provides continuous (hourly $ffCO_2$ estimates).



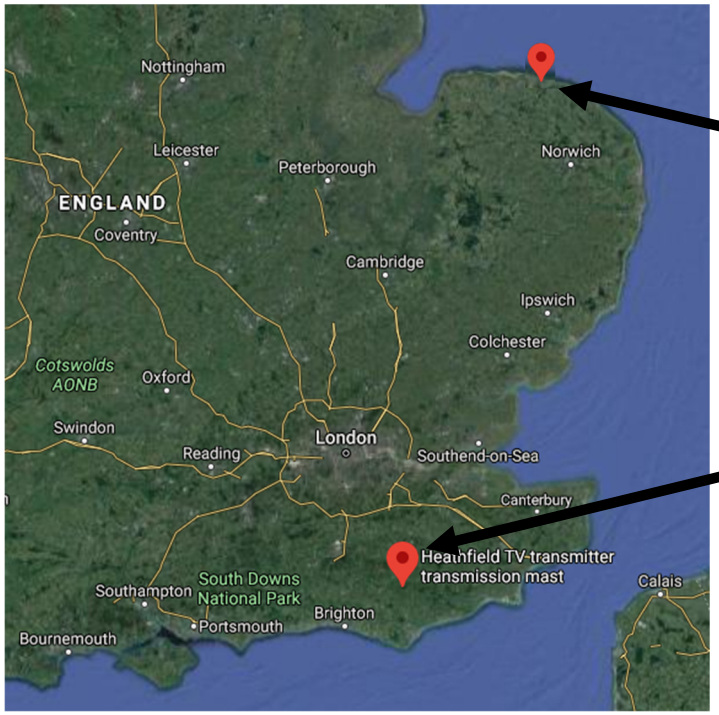

$R_{APO}$ based on COFFEE database

$R_{APO}$ from TNO database (preliminary estimate)

$R_{APO}$ based on $^{14}CO_2$ measurements

ICOS Central Analytical Laboratory

# Upcoming in 2020-2021:
# $^{14}C$- and APO-derived $ffCO_2$ at the Heathfield tall tower

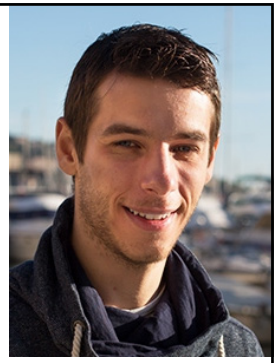



Weybourne Atmospheric Observatory, Norfolk (measurements from 15 metres)

Heathfield Tall Tower, Sussex (measurements from 100 metres)

- Continuous $O_2$ and $CO_2$ installation in autumn 2020; $^{14}CO_2$ flask sampler installation in early 2021.
- More remote from local $ffCO_2$ sources than Heidelberg, so we anticipate less $R_{APO}$ variability, and therefore more precise $ffCO_2$ estimates.

# An observation-based global APO budget



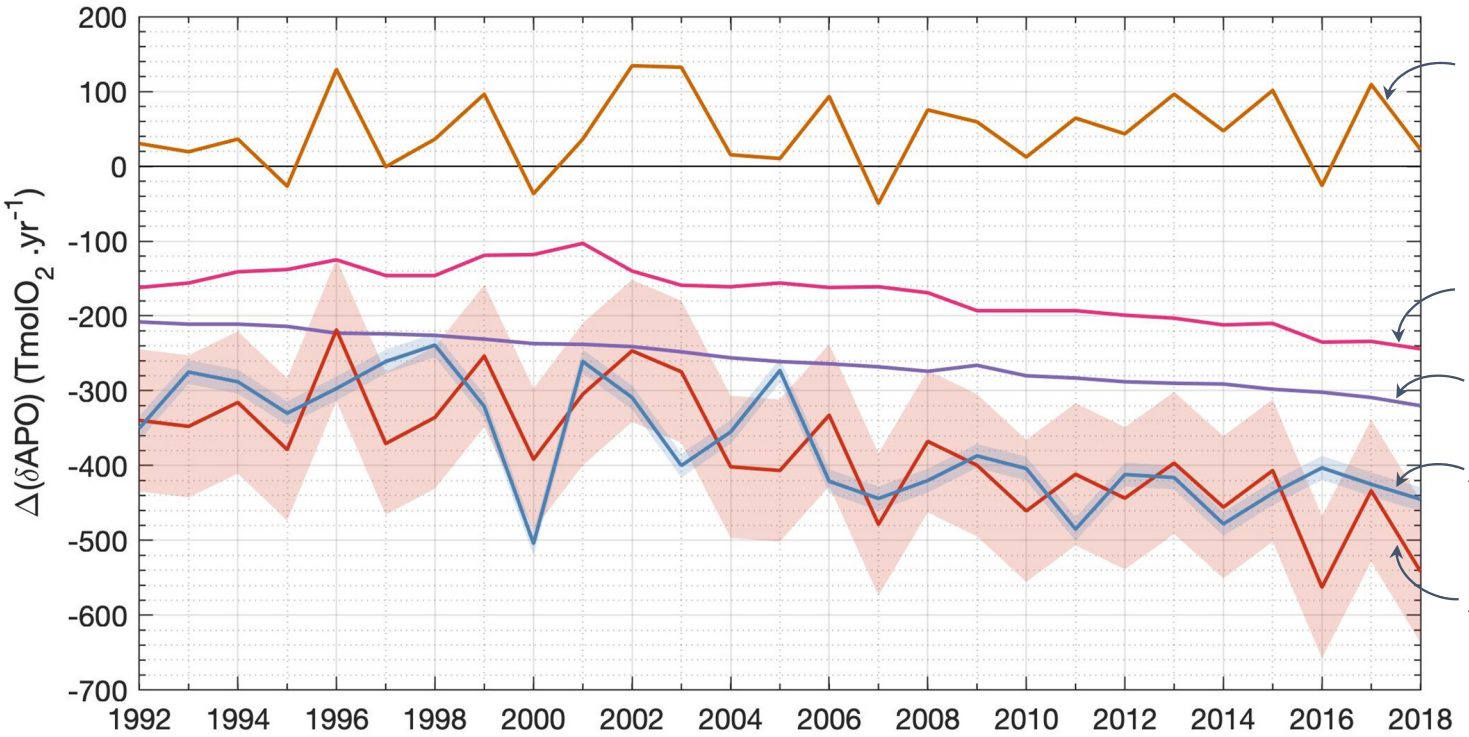
$\boldsymbol{APO}_{\text{measured}}$ : Air samples from the Scripps $O_2$ Program with weightings from *Hamme and Keeling (2008)*

$$\boldsymbol{APO}_{\text{estimated}} = (-\alpha_F + \alpha_B)\boldsymbol{F} - \alpha_B \boldsymbol{O} + \boldsymbol{Z}$$

Fossil fuel burning
Global Carbon Project

Oceanic $CO_2$ sink
Interpolated surface ocean $pCO_2$ measurements
(Jena-MLS, MPI-SOMFFN, CMEMS)

Oceanic $O_2$ source
Warming-induced outgassing, used change in ocean heat storage datasets
(Cheng et al., Ishii et al., NCEI)




$\boldsymbol{Z} \approx \boldsymbol{\gamma} \times$ Heat Flux

Corrected for $Z_{N2}$ and N deposition

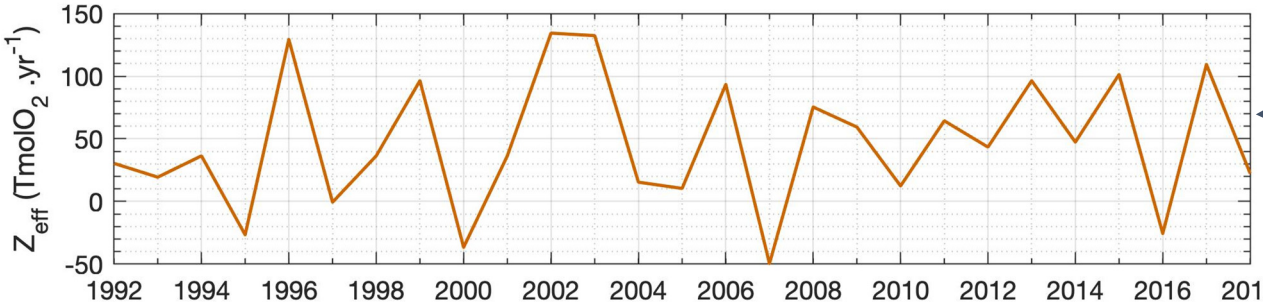
"Observations"

Budget Imbalance

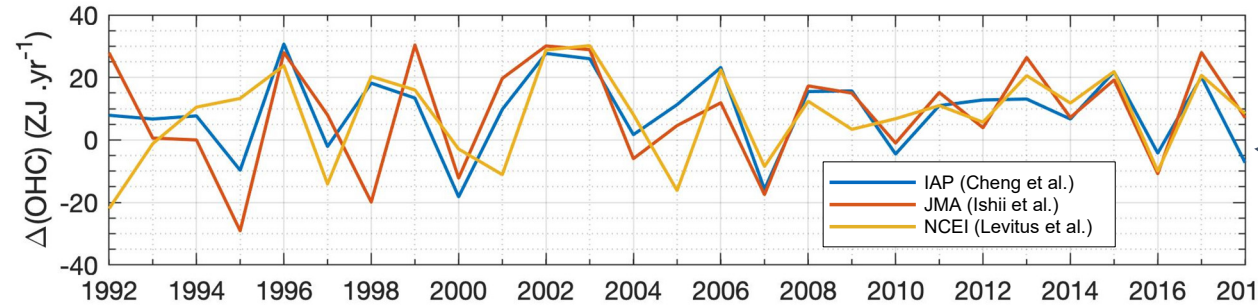
–23 TmolO2 $yr^{-1}$

Climate-Carbon Interactions in the Current Century

# Interannual variabilities in oceanic $O_2$ exchanges

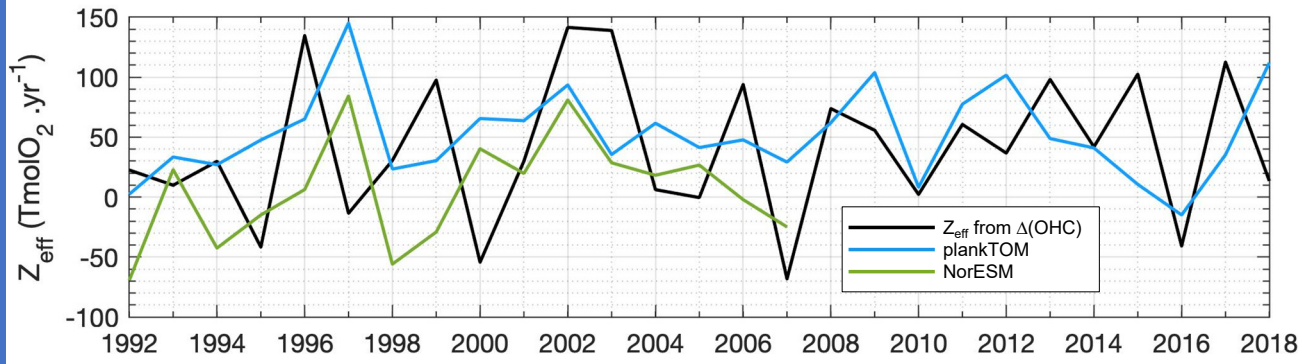



Estimated interannual variability of $\boldsymbol{Z}$…




…annual changes in ocean heat storage

$\boldsymbol{Z} \approx \boldsymbol{\gamma} \times \Delta(\mathrm{OHC})$

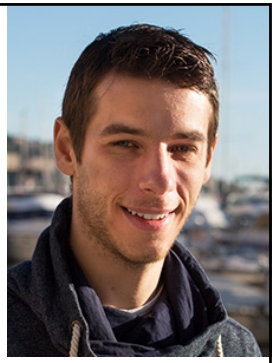



Study the interannual variability of APO and evaluate global ocean biogeochemistry models :

Models provide global and regional $\boldsymbol{O}$ and $\boldsymbol{Z}$

→ Are they in the expected range of values?

→ Evaluate regional contributions



Climate-Carbon Interactions in the Current Century

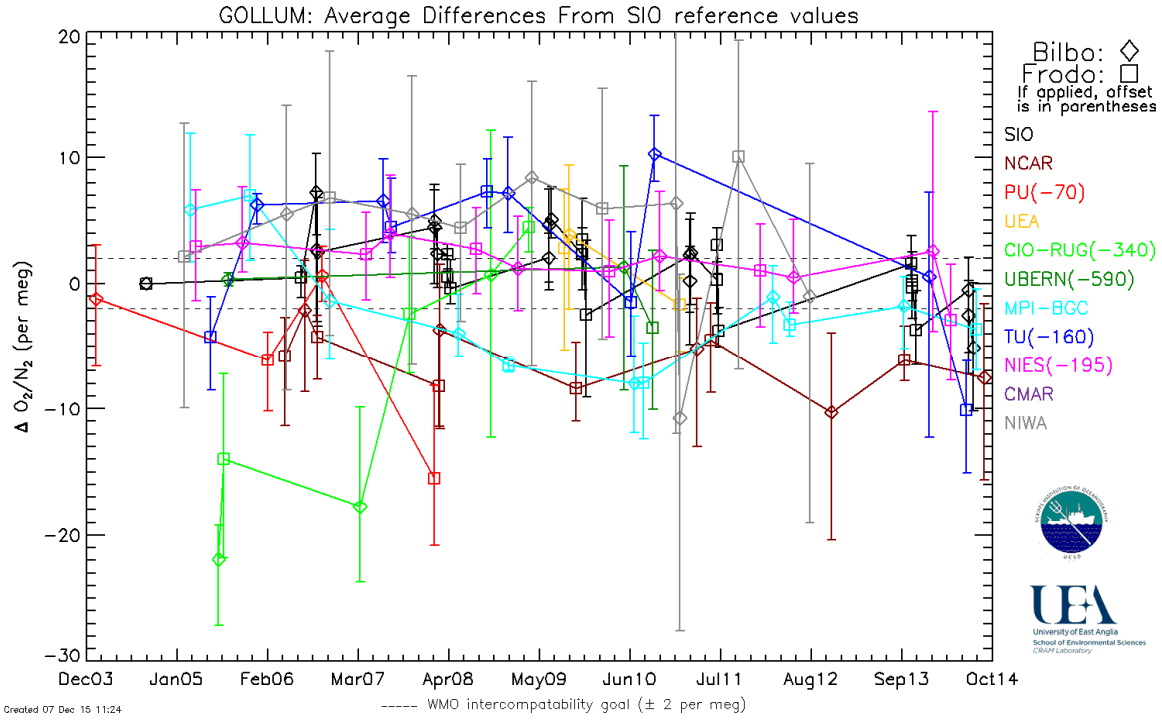
University of East Anglia
School of Environmental Sciences
CRAM Laboratory

# GOLLUM

Global Oxygen Laboratories Link Ultra-precise Measurements

Home | Rotations (PDF) | Shipping Certificates | Participants (PDF) | Stations Map

## Crude summary of all results, 2003-2014




- $O_2$ community suffers from lack of a WMO Central Calibration Laboratory.
- GOLLUM goes a small way to addressing this lack, via repeated intercomparisons of 6 high-pressure cylinders by all participating $O_2$ laboratories.
- Program halted at end of 2014 owing to empty cylinders.
- About to restart, thanks to new cylinders from Scripps.