Surface seawater biogeochemical measurements from long transects of the Atlantic by ships of opportunity

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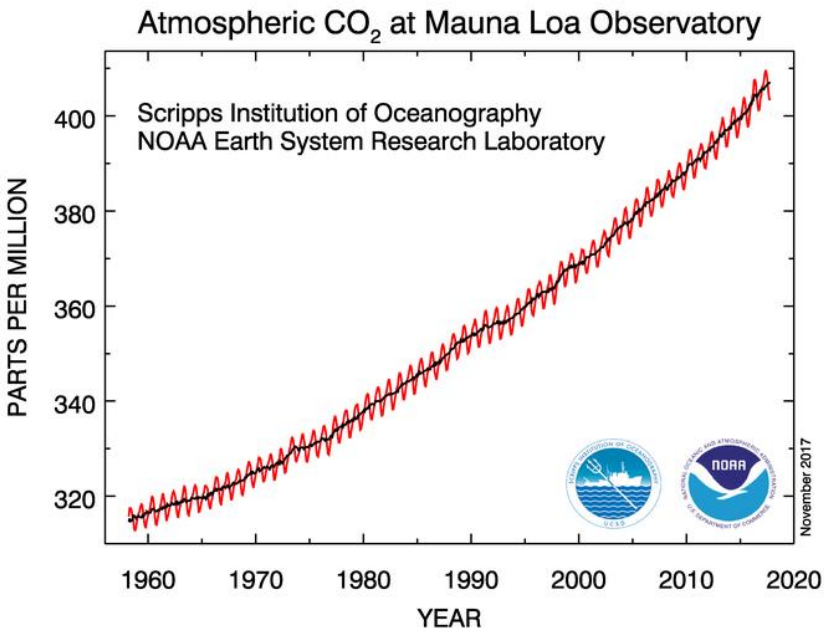
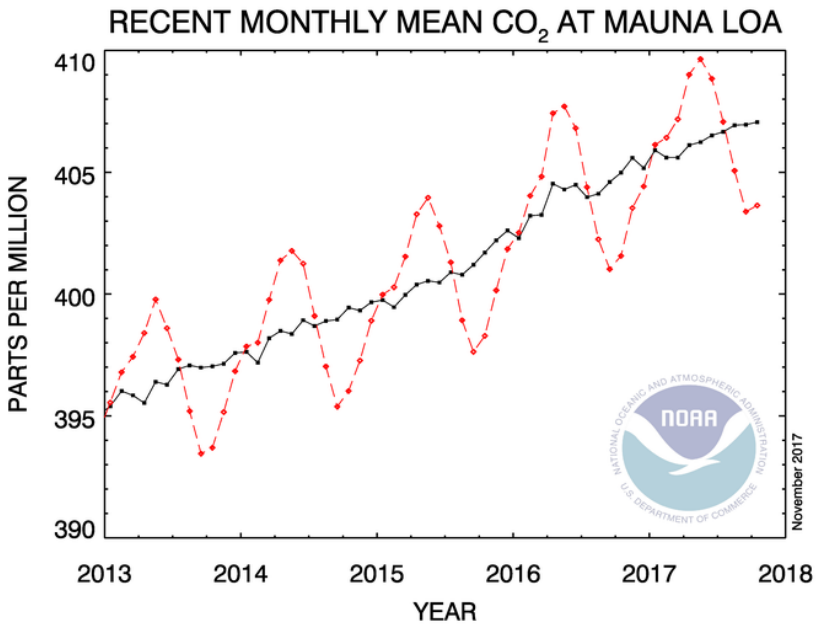
Natural Environment Research Council
noc.ac.uk
NERC Science of the Environment

Introduction

- pCO_2 atmospheric increase - includes natural variability and anthropogenic forcing

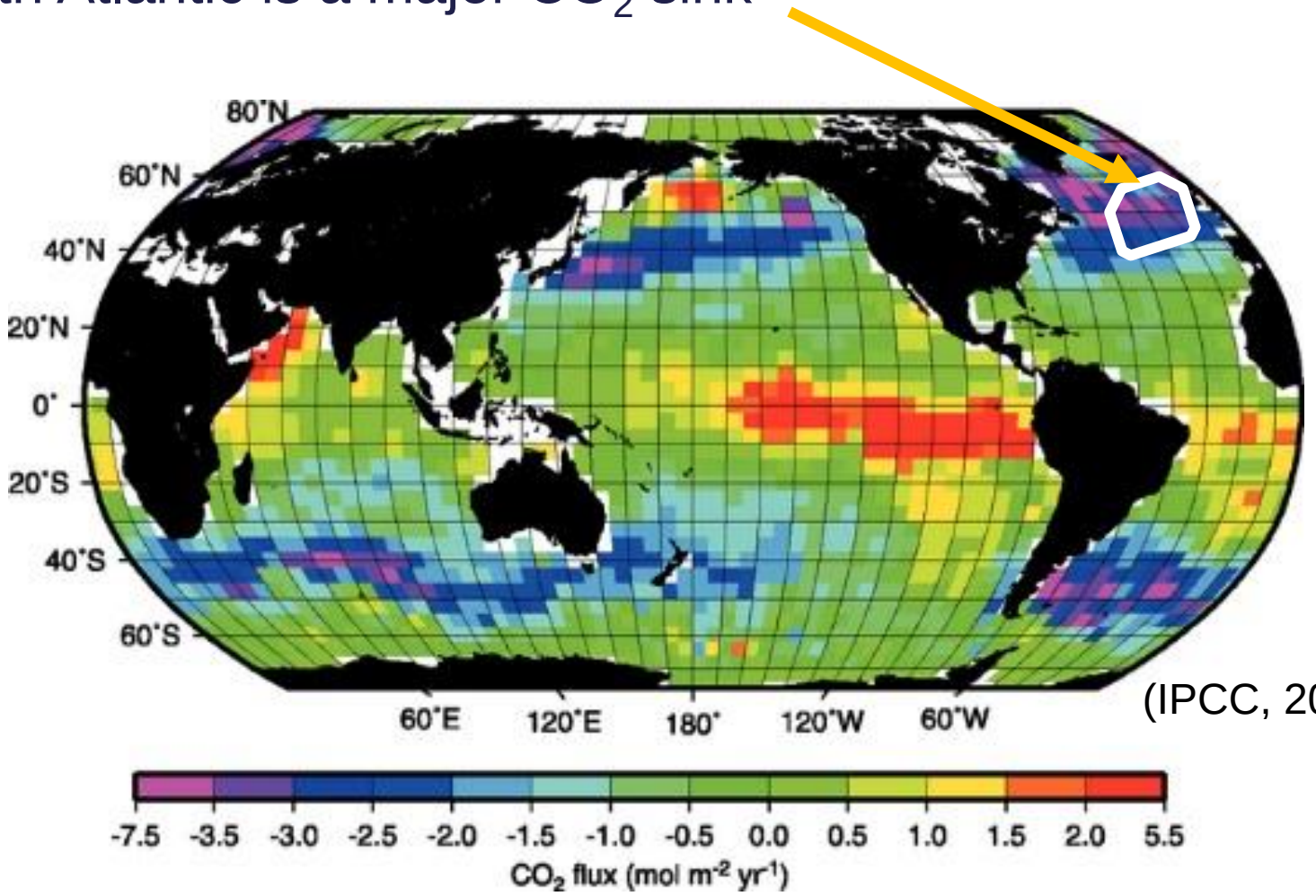




- ~27% has been taken up by the ocean, which results in decreasing pH (Ocean acidification)

(NOAA, 2017)

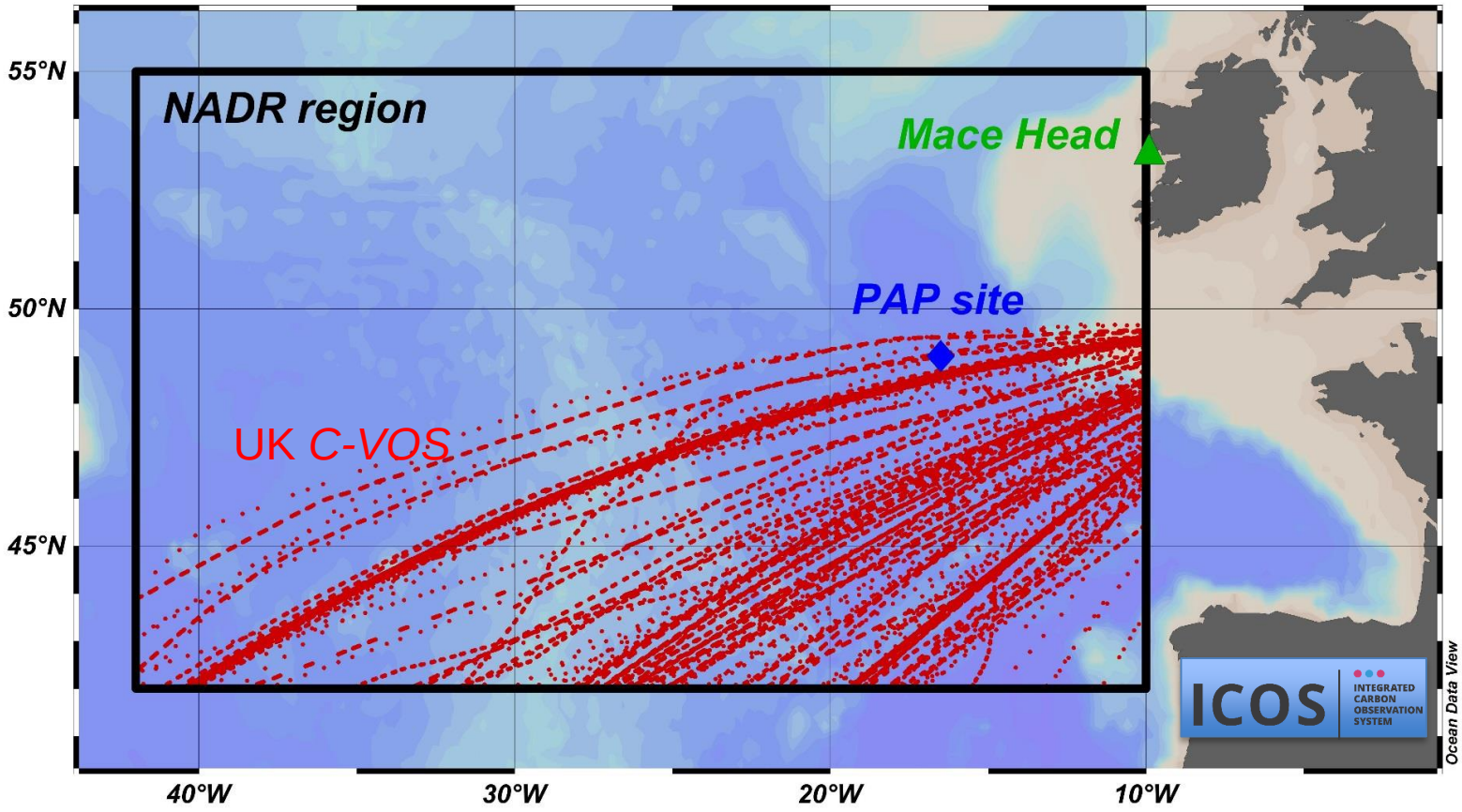
North Atlantic is a major CO_2 sink



(IPCC, 2007)

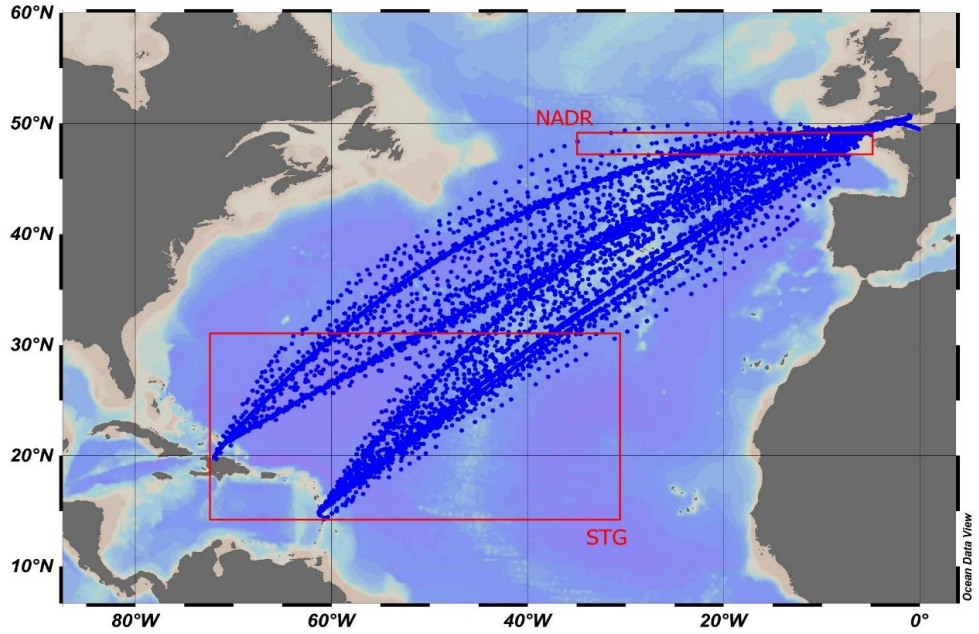
Temporal and spatial variability in CO_2 uptake into the ocean

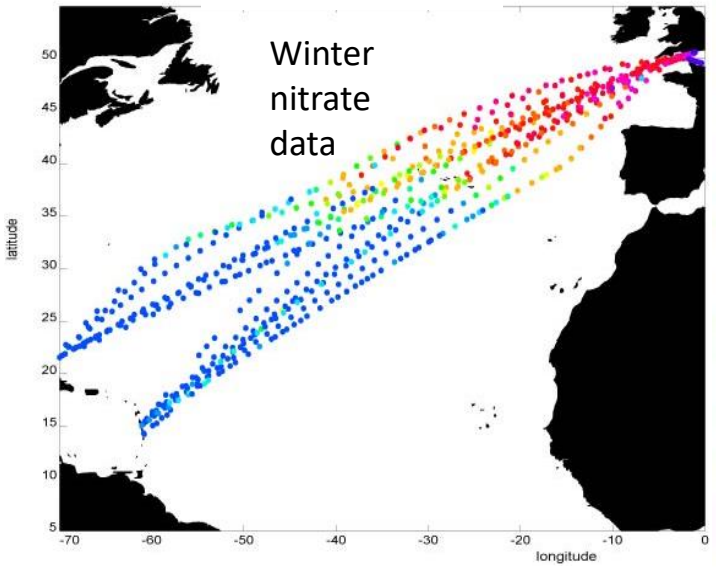
CO_2 data from SOO and fixed point observatories…

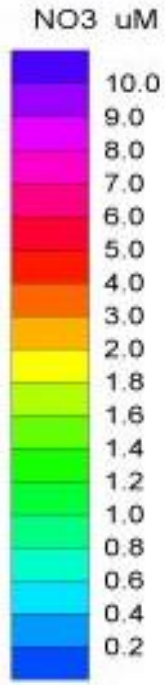


ICOS (Integrated Carbon Observing System)

1) UK-Caribbean ICOS Carbon-VOS transect







Since 2002 (4 ships)
Underway **pCO_2 equilibrator** system,
T/S and sampling for nutrients

ICOS Ocean Thematic Centre

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

noc.ac.uk

NERC SCIENCE OF THE ENVIRONMENT

2) Porcupine Abyssal Plain- ICOS Sustained Observatory

- Fixed point European open ocean observatory (4850m)
- Surface buoy 2002 –collaboration with Met Office (2010)
- **Membrane sensor pCO_2** along with O_2, pH, nitrate, T/S

Near real time data: noc.ac.uk/pap

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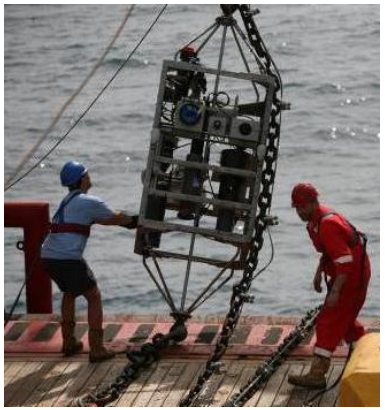
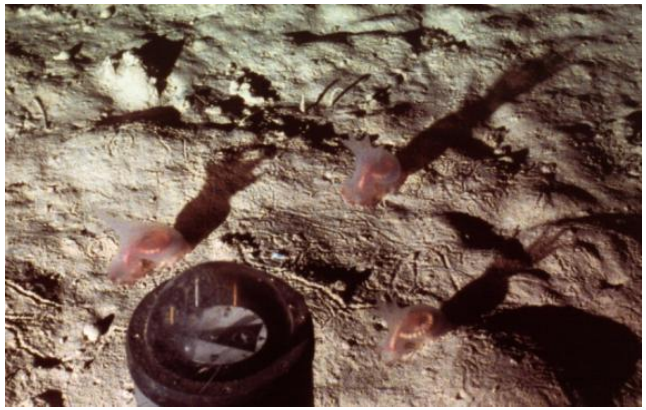
emso ERIC EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM

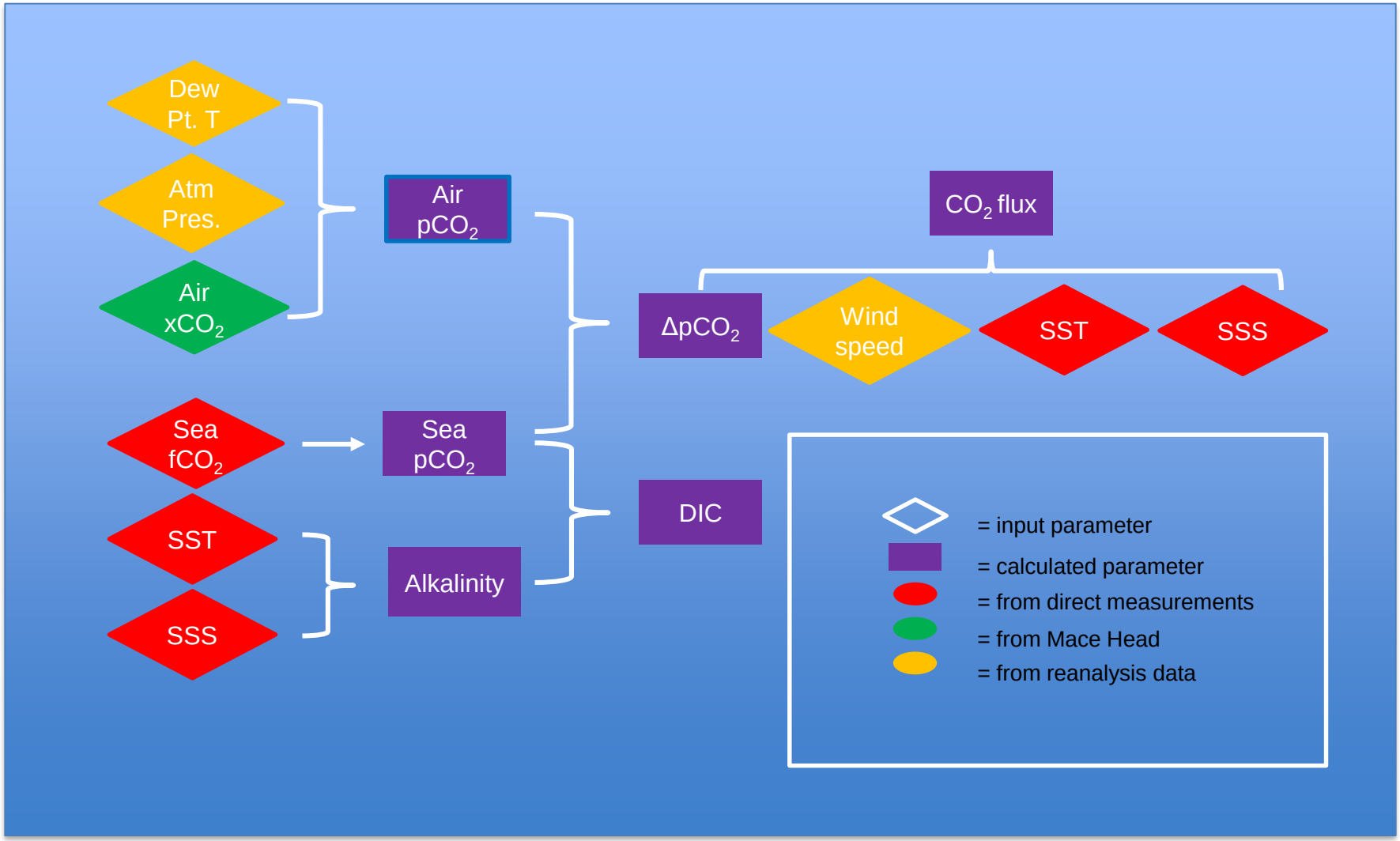
PAP

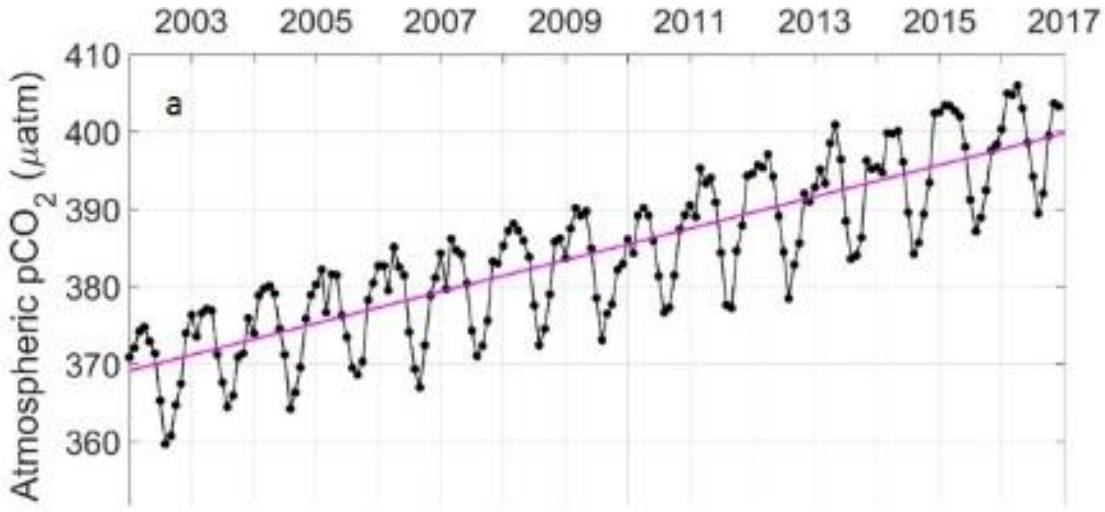
iFADO INNOVATION IN THE FRAMEWORK OF THE ATLANTIC DEEP OCEAN





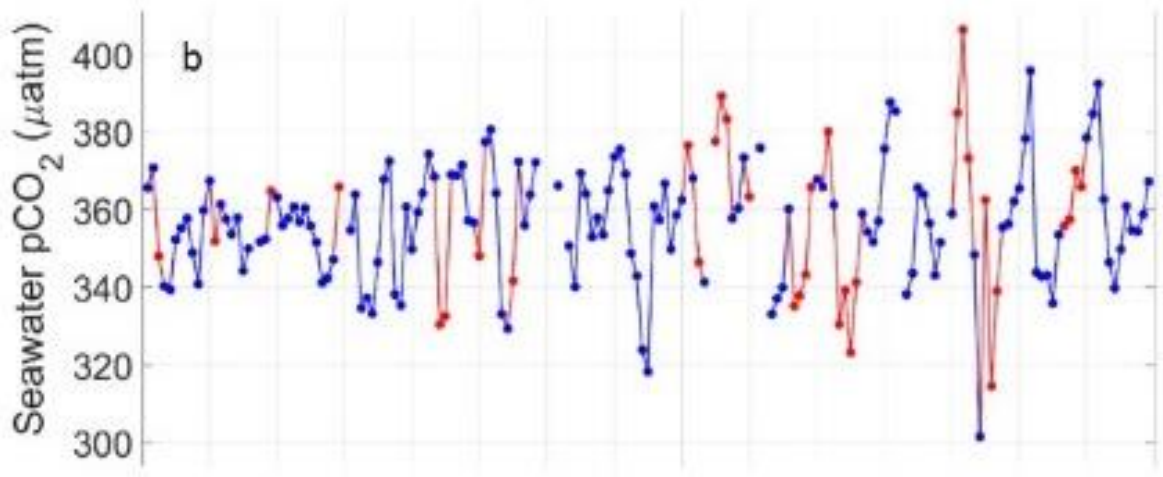
…to calculate North Atlantic CO_2 flux



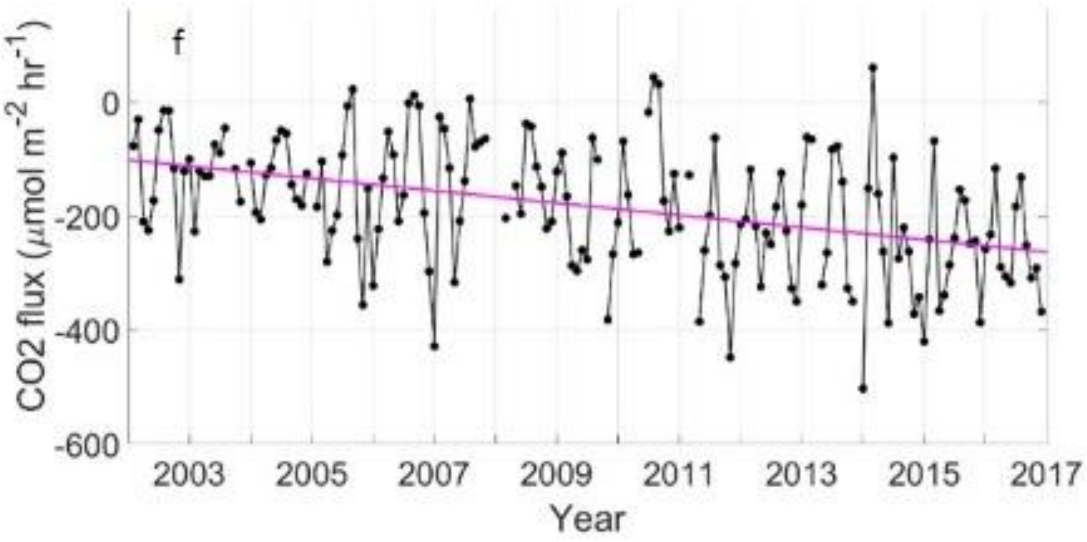


Atmospheric pCO_2 yearly trend: 2.04 ± 0.097 µatm

Seawater pCO_2: **no trend**, but <u>increasing variability</u>



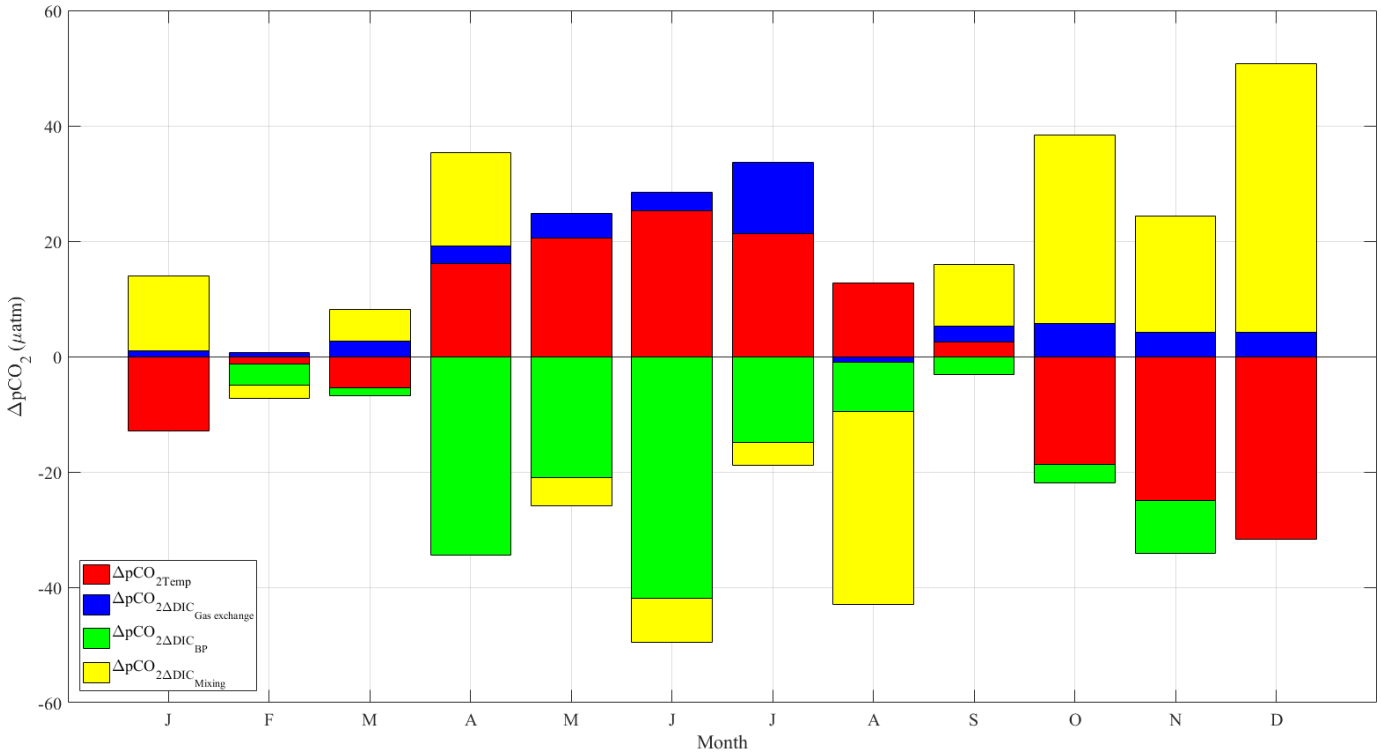
Under-saturation of CO_2 throughout the year at PAP



CO_2 flux yearly trend: -10.76 ± 1.82 → stronger sink

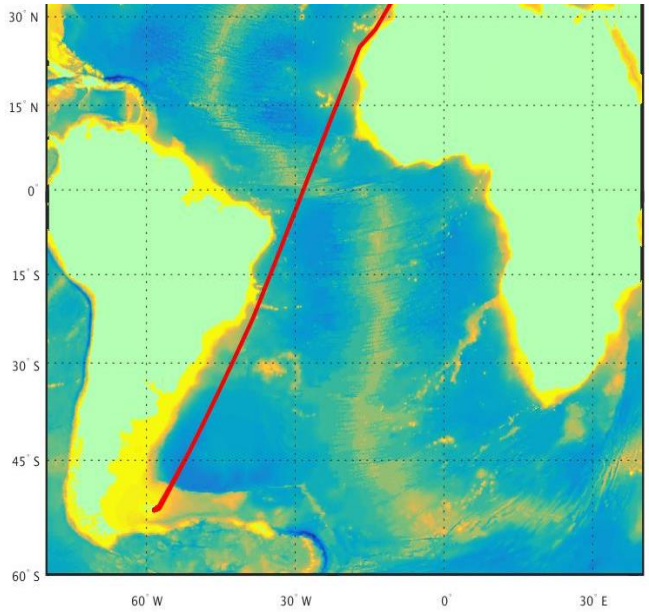
Use ancillary data: to understand how the CO_2 sink works

pCO_2 annual cycle NADR: Showing the influence of temperature, mixing, productivity and **gas exchange**.



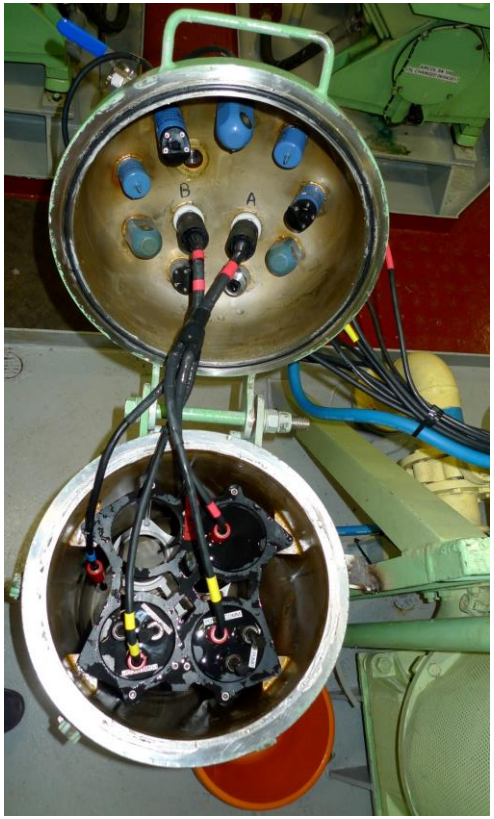
Submitted PiO, 2019

A new (May 2018) carbon VOS on the *MV Maersk Raleigh* provides South Atlantic transects (**UK to the Falkland's**) of biogeochemical data including CO_2



MV Maersk Raleigh Seasonal measurements N to S Atlantic

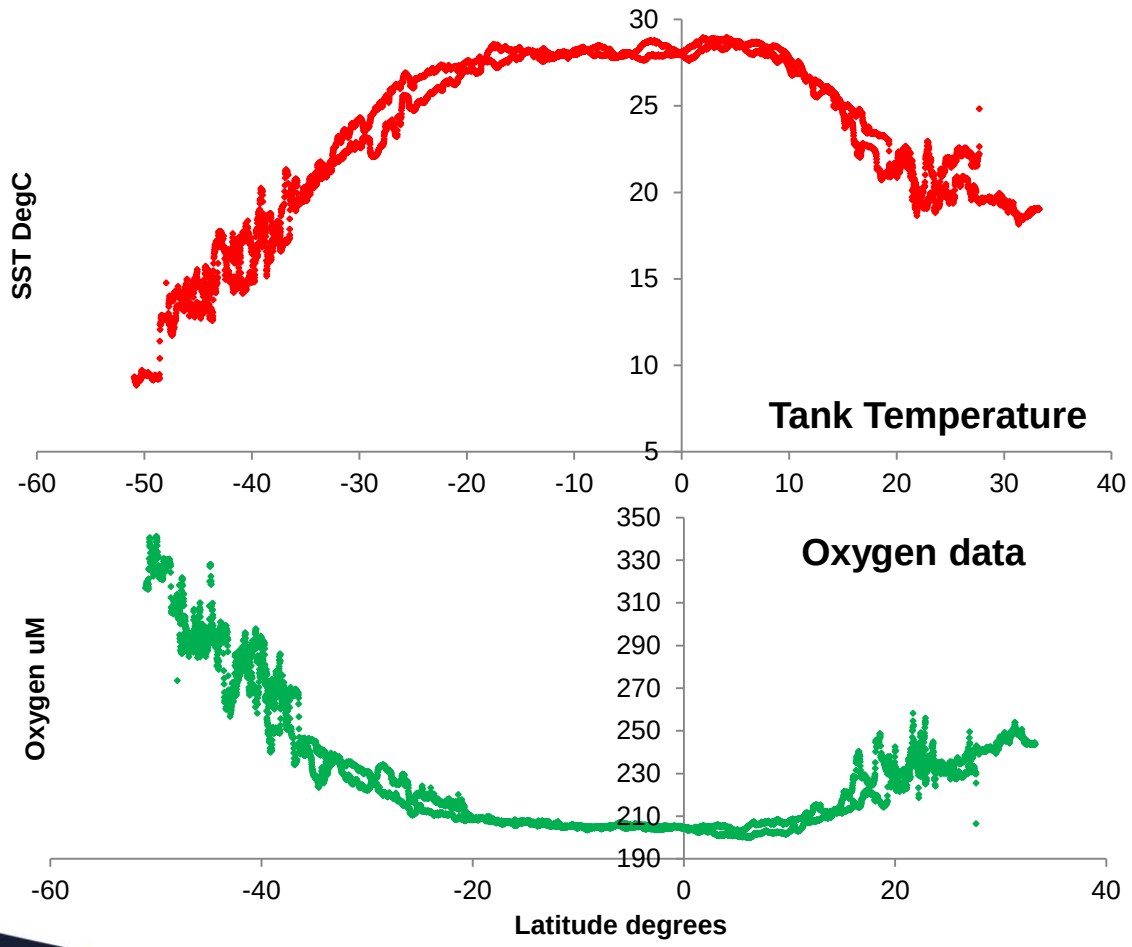
Membrane sensor pCO_2 plus sensors for O_2, chl-fluorescence, T/S + meteorological data



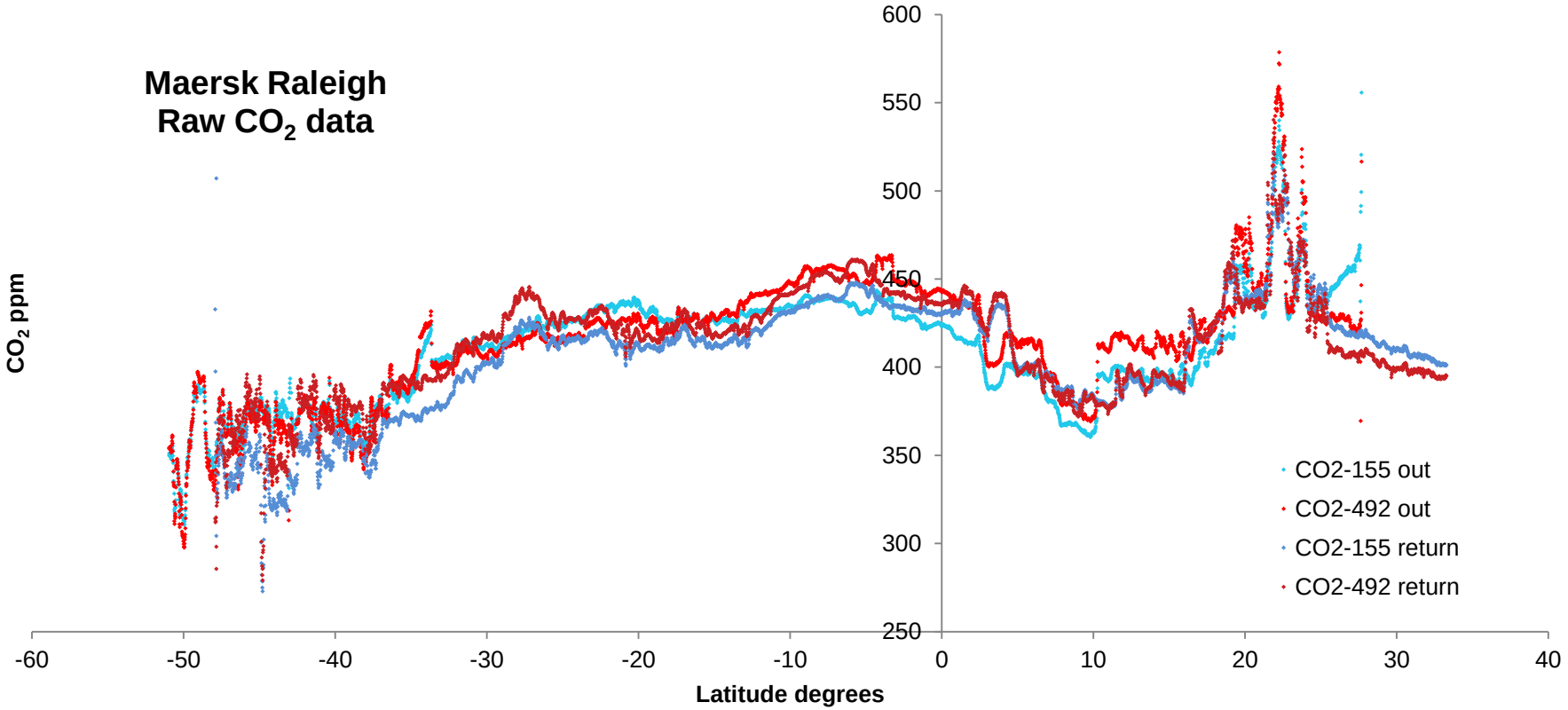
Daily DIC/TA, salinity, nutrient sampling

Near real time data

MV Maersk Raleigh SST and O_2 data



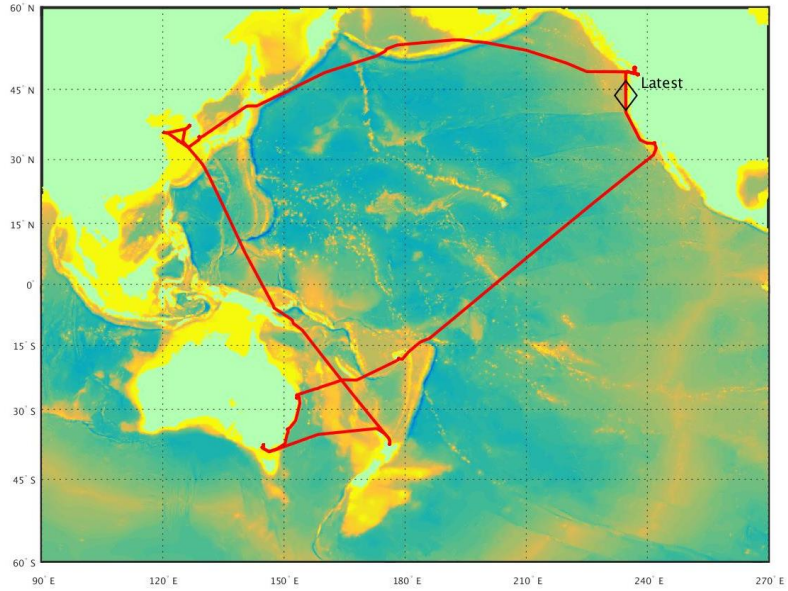
MV Maersk Raleigh CO_2 data



To do: validate measurements using daily DIC/TA sample data

Similar sensors used on other NOC routes….

www.snoms.info Real time data from the Pacific China Navigation/ Swire and the new Maersk routes



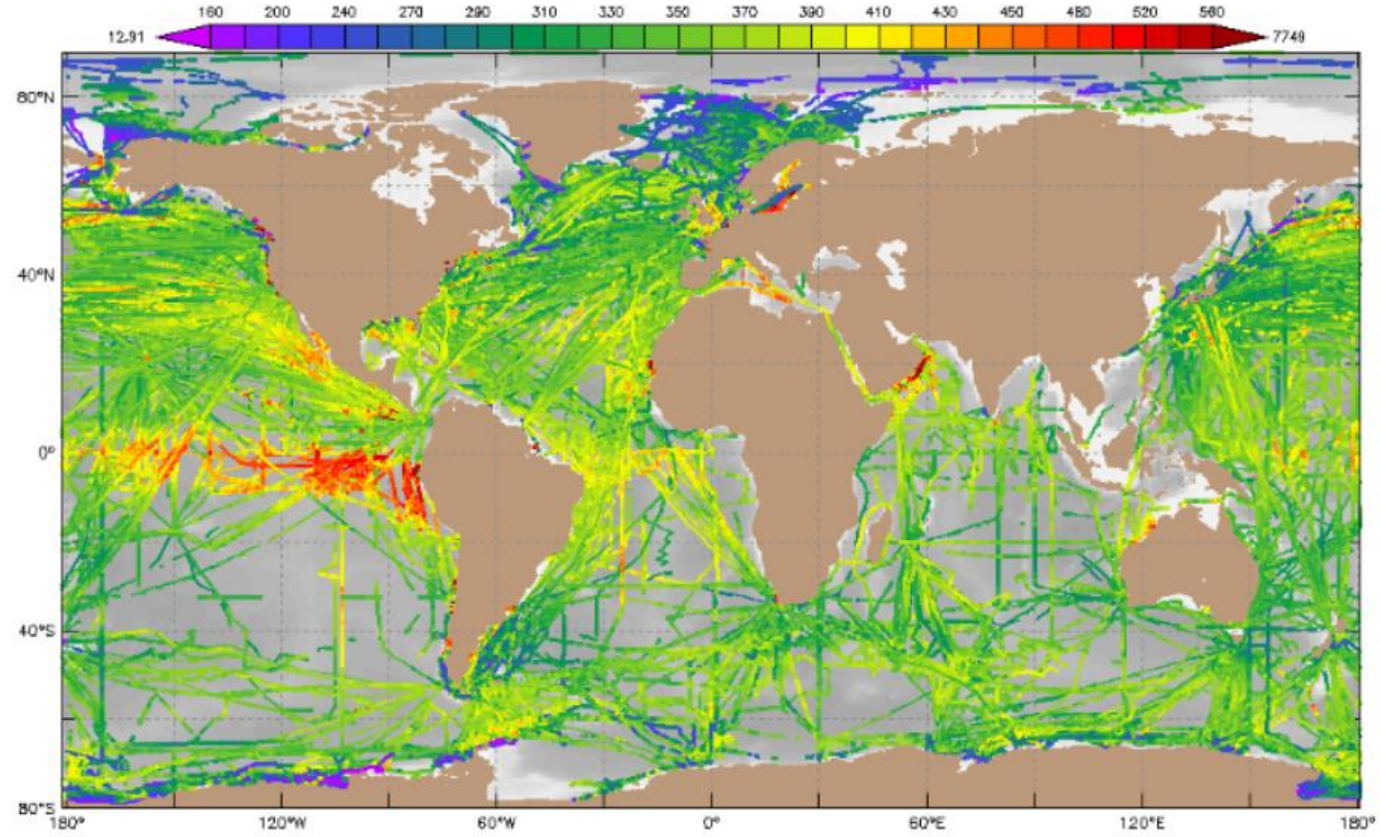
CHINA NAVIGATION

SWIRE

Support from SWIRE for travel, instrumentation and students

SWIRE TRUST

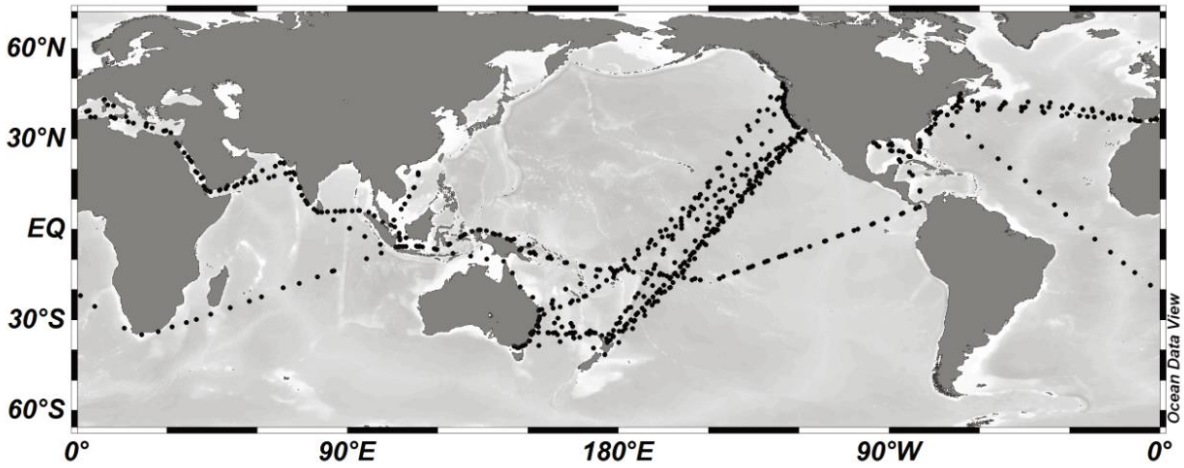
All data to the Surface Ocean CO_2 Atlas



In some regions there are still gaps in data coverage
Small, relatively cheap systems required

www.socat.info

Assessment of a membrane-based pCO_2 sensor



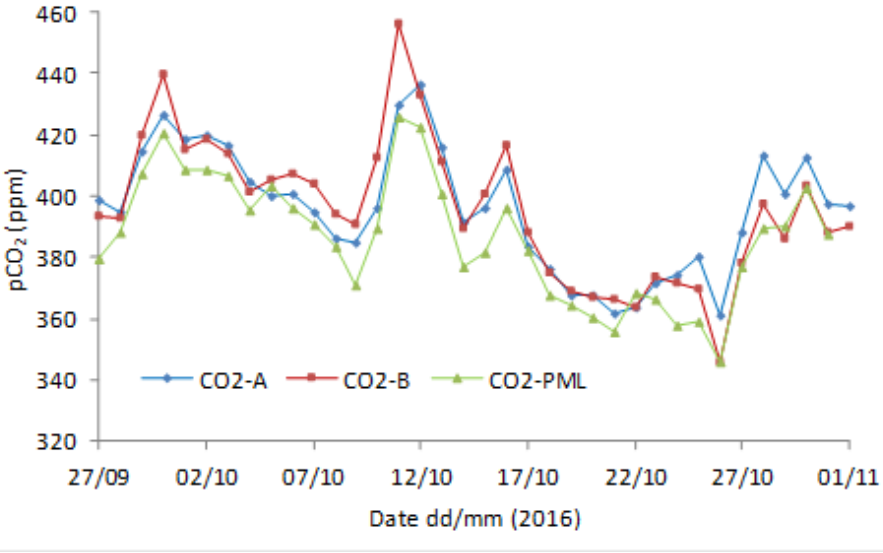
Tests on various platforms to review autonomous sensor reliability

	Application	Mode	Time length	Reference	Difference from the reference	
					direct output	corrected output*
ACT	mooring test	in situ	16-day	calculation from pH and TA	8.7 ± 14.1	0 ± 7.4
SNOMS	SOO observation	underway	several months	calculation from DIC and TA	(-4 to 24) ± (4 to 13)	0 ± 6.5
				calibrated equilibrator system		2.6 ± 6.7
Aquatron	laboratory test	underway	2 months	calibrated equilibrator system	0.5 ± 8	
PAP	mooring deployment	in situ	several months	calculation from DIC and TA	7.3 ± 10	

* corrected by the carbonate calculation

Jiang et al., L&O methods, 2014

Membrane sensor and Equilibrator system comparison



Inter-calibration on AMT (2016) showed good agreement

Equlibrator/Licor system.
4 gas standards
measured daily

Pro-Oceanus membrane sensors with auto zero and annual gas standards

AtlantOS

As part of ICOS

Under the European **ICOS we are arranging a wider inter-comparison of methods to measure carbonate variables (April 2020)**

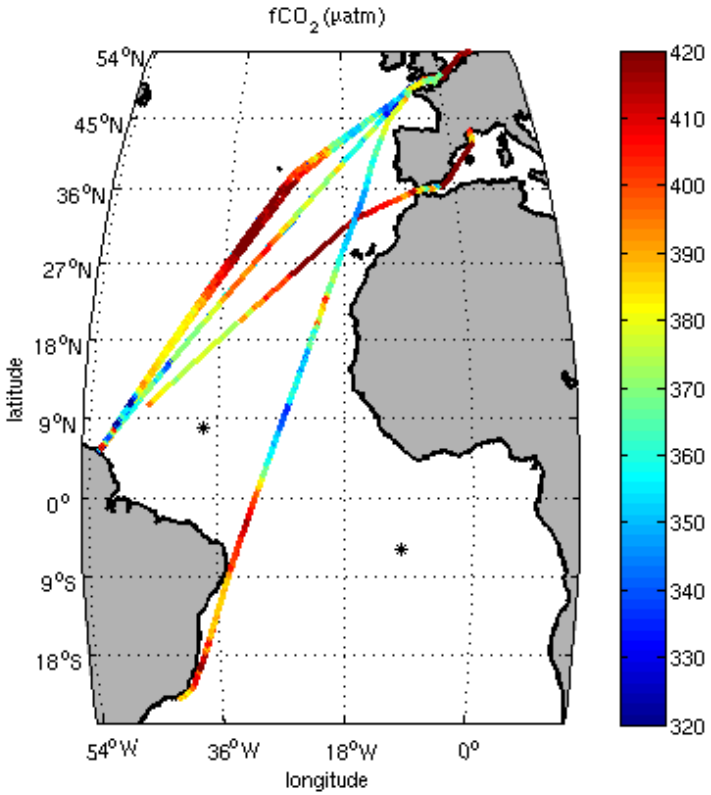
ICOS: preparing a **brochure** and a **web-searchable database**

- for the shipping industry
- with information about our global sea surface pCO_2 observational network

ICOS “cookbook”

- for scientific / technical / engineering staff
- with information about the installation of a measuring system on-board a commercial ship

National funding as part of ‘CLASS’
Climate linked Atlantic Sector Science



Atlantic data from PAP and the carbon-VOS routes will be used for CO_2 flux calculations to identify **regional and inter-annual variations** in the ability of the ocean to act as a carbon sink

projects.noc.ac.uk/class/

Climate Linked Atlantic Sector Science (CLASS) 2018-2023, £22M

Prof. Angela Hatton, PI
Dr. Penny Holliday, Science Coordinator

NATIONAL CAPABILITY

WORLD-LEADING ENVIRONMENTAL SCIENCE SUPPORTING NATIONAL STRATEGIC NEEDS

AT LEAST NATIONAL AND DECADAL TIME-SCALES

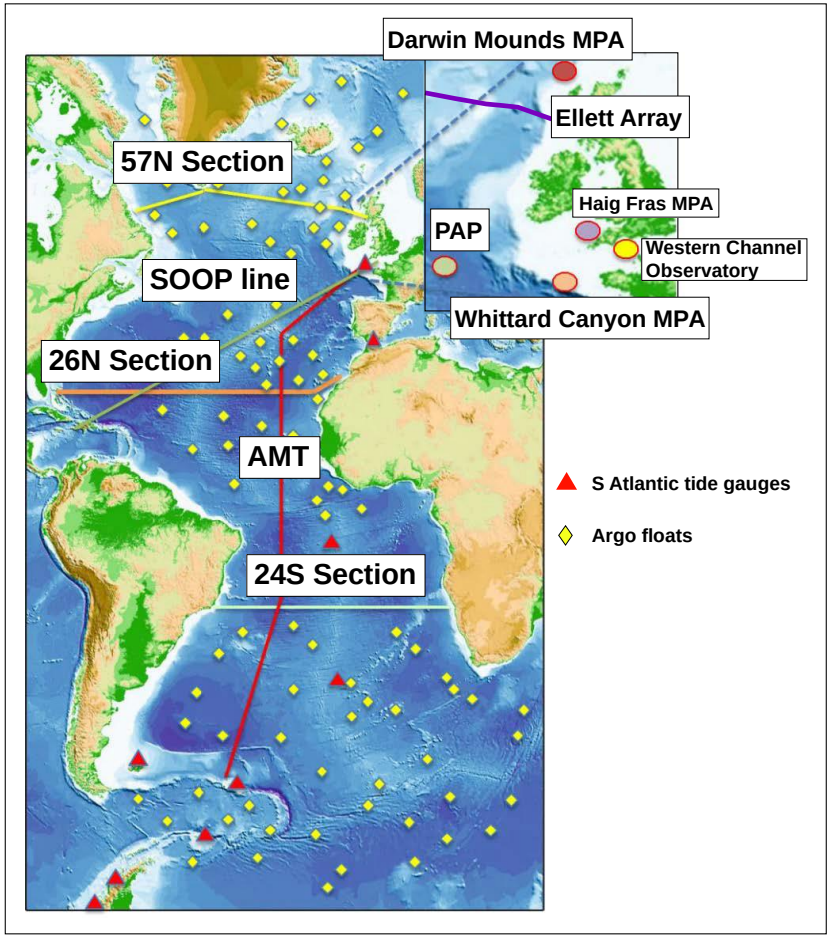
projects.noc.ac.uk/class/

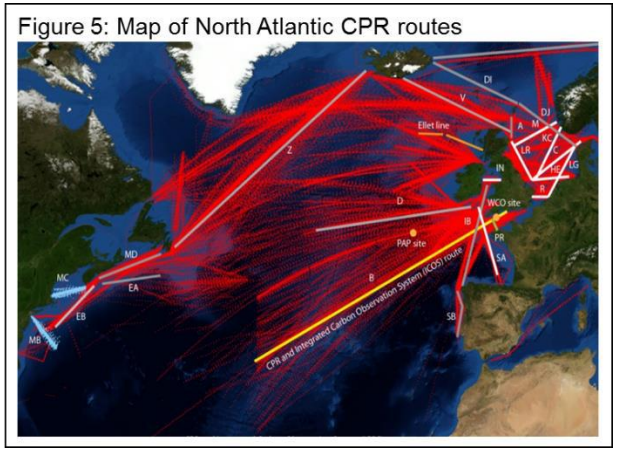
*CLASS will deliver the **knowledge** and **understanding** of the Atlantic Ocean system that society needs to make evidence-based decisions regarding ocean management*

- **Underpinning activities (observations, models, technology)**
  - this is 'next stage' for long-term, large-scale activities
- **Science Programme (20%)**
- **Engagement with stakeholders**

Sustained Ocean Observations

Multi-decadal records from coast to deep ocean, surface to seafloor





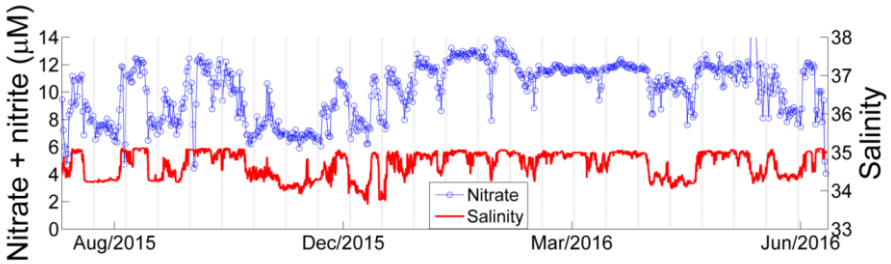
- **Physical, biological and chemical data**
- **All data quality controlled and open access**
- **Contributing data and leadership to international networks and systems**

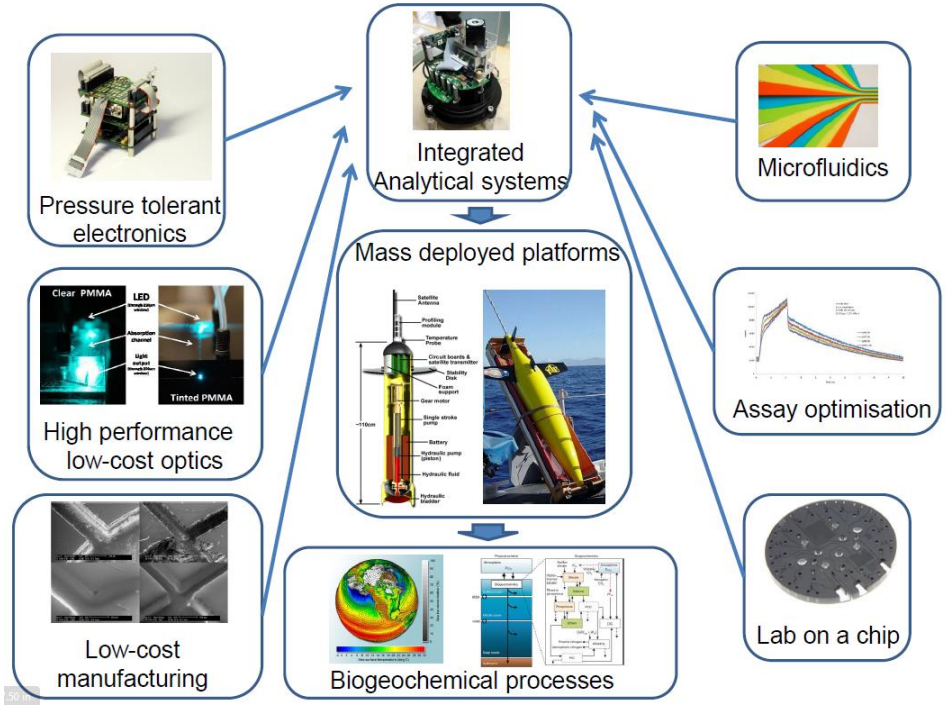
Technology Innovation

Sensors and systems for robotic sensing of the ocean

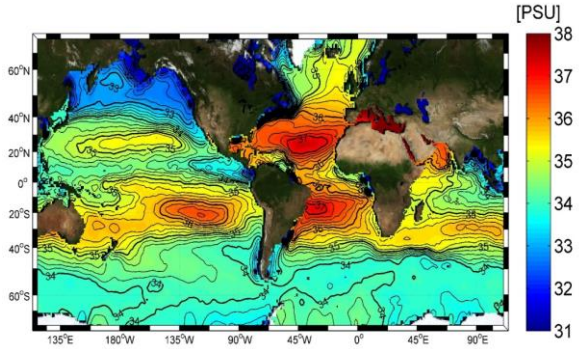
Sensors – for key climate parameters with technology gaps

- Methane
- pH and Total Alkalinity:
- Flow cytometer
- Molecular sampler - eDNA

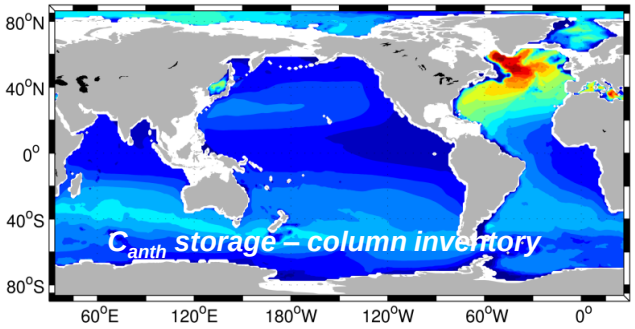




Understanding the Changing Atlantic Ocean

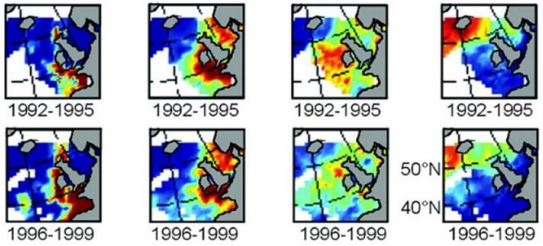


What is the current state of the hydrological cycle and how will changes in ocean salinity impact it into the future

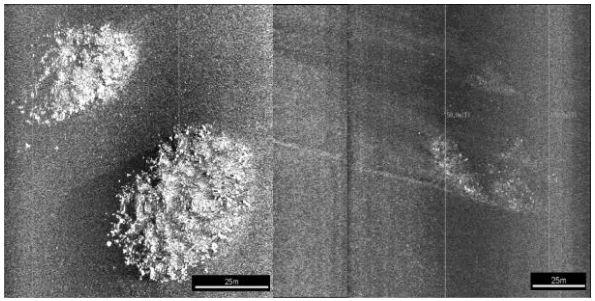


How physical and biological uptake, transfer and storage of carbon in the deep ocean interact to determine the Atlantic CO_2 sink and how this will this change in the future

How the natural and anthropogenic drivers of basin and decadal changes are altering the Atlantic ecosystem, and consequences for ecosystem functioning and services



How structure, diversity and productivity of biological communities are changing in response to abrupt or episodic disturbance events compared to natural change



Stakeholder Engagement

International	Programmes	Gov. Agencies	Training
e.g. GOOS, GO-SHIP, ICOS, IPCC, ARGO, NEMO	e.g. RAPID, OSNAP, ATLANTOS, EMSO, COMICS, Blue Coast	e.g. Met Office, CEFAS, MS, AFBI, EA, JNCC	NERC Doctoral Training Programmes, Universities

CLASS provides resources for **underpinning activities** on long time scale (5-10 years)

Expectations: engaging with the range of international coordination efforts

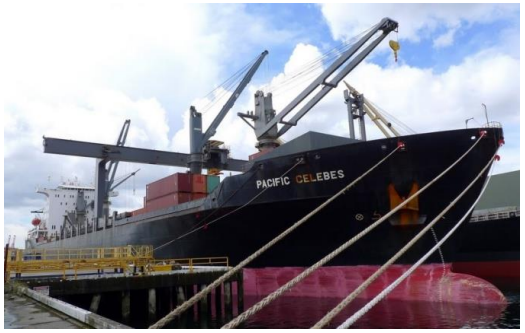
community leverages additional science funding to build on underpinning activities

interaction between UK and devolved government agencies

making national capability resources open to universities & other organisations

So work continues …

Measurements of sea surface pCO_2 and related parameters continue across the Atlantic to achieve a **better understanding of the controlling mechanisms on the carbon cycle**





Thank you for listening!

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