2018 ICOS OTC Workshop

7-9 March 2018

General Oceanics-KM Contros-ICOS OTC

General Oceanics Underway pCO_2 Uncertainty and Offset Analyses

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Geophysical Institute, UiB, Norway

Equations

From Pierrot et al. 2009

$$(pCO_2)^{wet}_{equT} = (xCO_2)^{dry}_{equT}\left[P_{equ} - pH_2O(CO_2, equT)\right] \quad (1)$$

$$(fCO_2)^{wet}_{equT} = (pCO_2)^{wet}_{equT} * exp\left\{\frac{\left[B(CO_2,equT)+2\left(1-(xCO_2)^{dry}_{equT}\right)^2\delta(CO_2,equT)\right]P_{atm}}{R*equT}\right\}$$
(2)

$$(fCO_2)^{wet}_{SST} = (fCO_2)^{wet}_{equT} * exp\{0.0423(SST - equT)\} \quad (3)$$

$$B(CO_2, equT) = -1636.75 + 12.0408 * equT - 3.27957 * 10^{-2} * equT^2 + 3.16528 * 10^{-5} * equT^3 \quad (4)$$

$$\delta(CO_2, equT) = 57.7 - 0.118 * equT \quad (5)$$

$$pH_2O(CO_2, equT) = exp\left\{24.4543 - 67.4509\left(\frac{100}{equT}\right) - 4.8489 ln\left(\frac{equT}{100}\right) -\right.$$

Parameters

Parameter	Range
P_{equ} and P_{atm}	1 atm
equT	0 to 40 °C
ΔT	0 to -2 °C
xCO_2	200 to 800 ppm
S	35 PSU
Standard Gases	250, 450, 600, 800 ppm

Parameter	High Uncertainty	Low Uncertainty
ΔP_{equ} and ΔP_{atm}	$2*10^{-3}$ atm	$5*10^{-4}$ atm
ΔequT and ΔSST	0.05 °C	0.02 °C
ΔxCO_2=ΔLI-COR	0.2 ppm	-
ΔS	0.5 PSU	-
ΔStandard Gases	0.27 ppm	0.15 ppm

Equations

$$(pCO_2)^{wet}_{equT} = ((xCO_2)^{dry}_{equT} \pm \Delta xCO_2)\left[(P_{equ} \pm \Delta P_{equ}) - pH_2O(CO_2, equT)\right] \quad (1)$$

$$(fCO_2)^{wet}_{equT} = (pCO_2)^{wet}_{equT} * exp\left\{\frac{\left[B(CO_2,equT)+2\left(1-((xCO_2)^{dry}_{equT} \pm \Delta xCO_2)\right)^2 \delta(CO_2,equT)\right](P_{atm} \pm \Delta P_{atm})}{R*(equT \pm \Delta equT)}\right\} \quad (2)$$

$$(fCO_2)^{wet}_{SST} = (fCO_2)^{wet}_{equT} * exp\{0.0423((SST \pm \Delta SST) - (equT \pm \Delta equT))\} \quad (3)$$

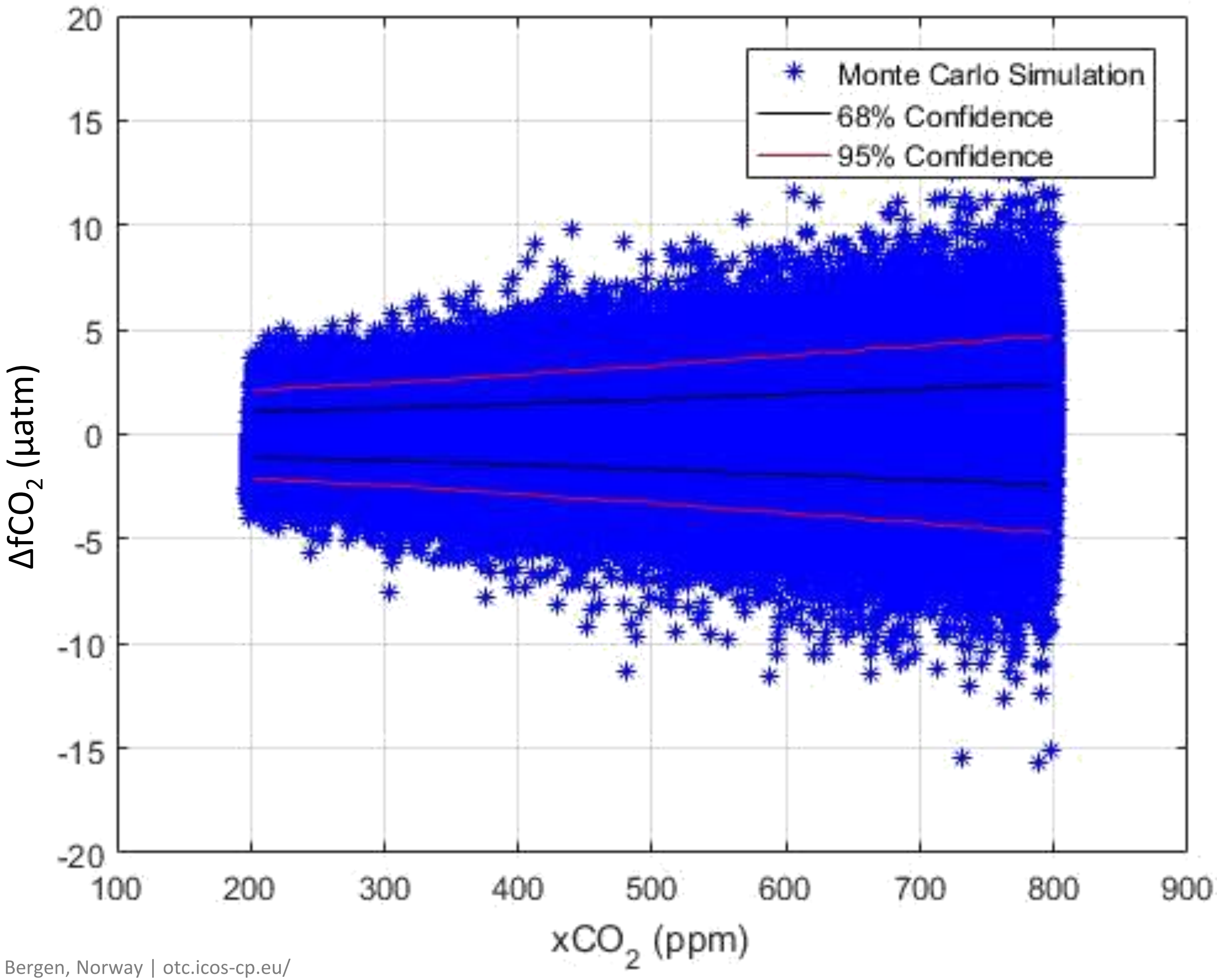
$$B(CO_2, equT) = -1636.75 + 12.0408 * (equT \pm \Delta equT) - 3.27957 * 10^{-2} * (equT \pm \Delta equT)^2 + 3.16528 * 10^{-5} * (equT \pm \Delta equT)^3 \quad (4)$$

$$\delta(CO_2, equT) = 57.7 - 0.118 * (equT \pm \Delta equT) \quad (5)$$

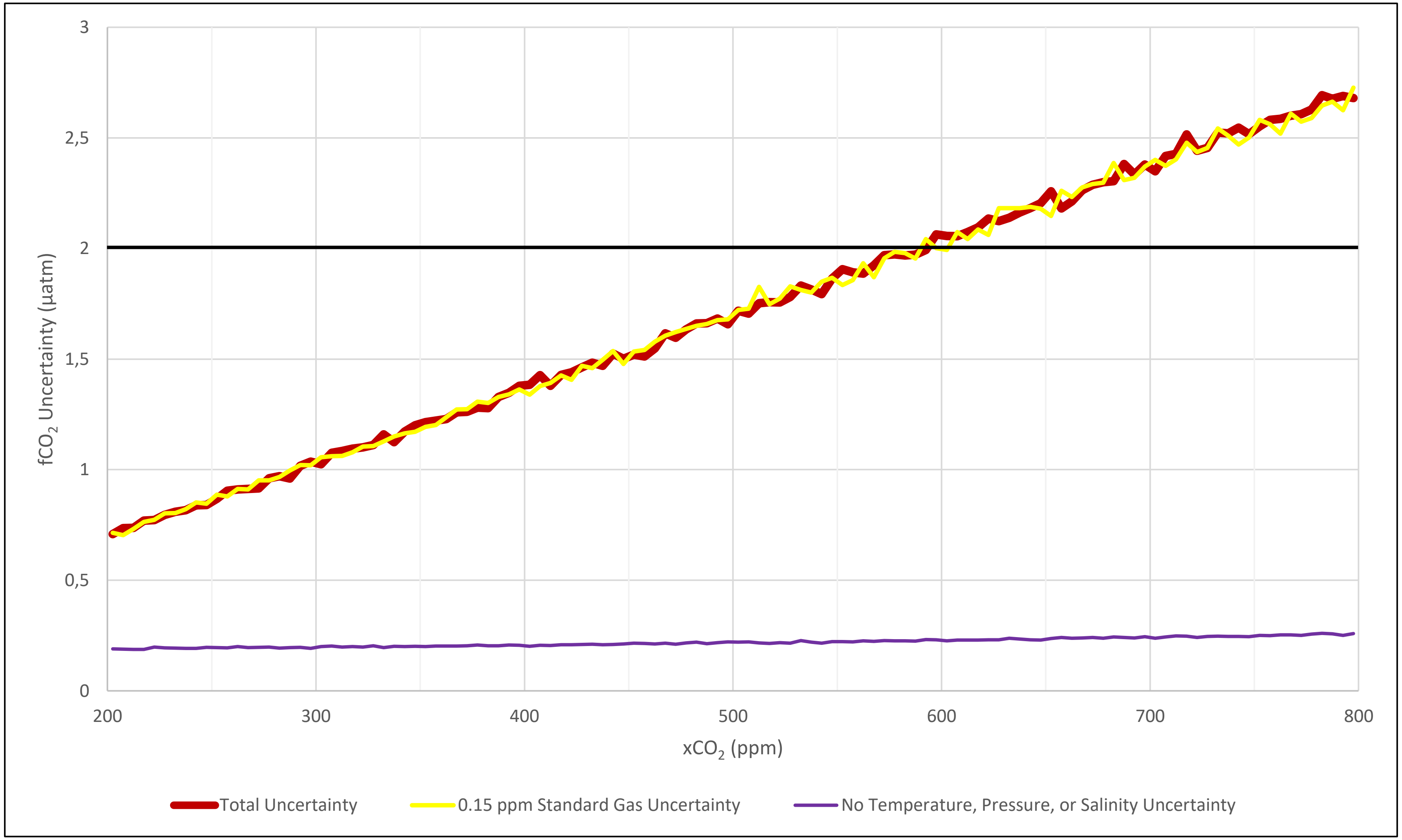
$$pH_2O(CO_2, equT) = exp\left\{24.4543 - 67.4509\left(\frac{100}{equT \pm \Delta equT}\right) - 4.8489 ln\left(\frac{equT \pm \Delta equT}{100}\right) - 0.000544 * (S \pm \Delta S)\right\} \quad (6)$$

Method

- Monte Carlo
  - Randomly selected uncertainty using a Gaussian Distribution
  - Compute $(fCO_2)_{SST}^{wet}$ with and without uncertainty
    - $\Delta(fCO_2)_{SST}^{wet}$=$((fCO_2)_{SST}^{wet})_{with\ Uncertainty} - ((fCO_2)_{SST}^{wet})_{without\ Uncertainty}$
  - Repeat 500000 times
    - $\Delta(fCO_2)_{SST}^{wet} = Standard\ Deviation\ of\ \{((fCO_2)_{SST}^{wet})_{with\ Uncertainty} -$

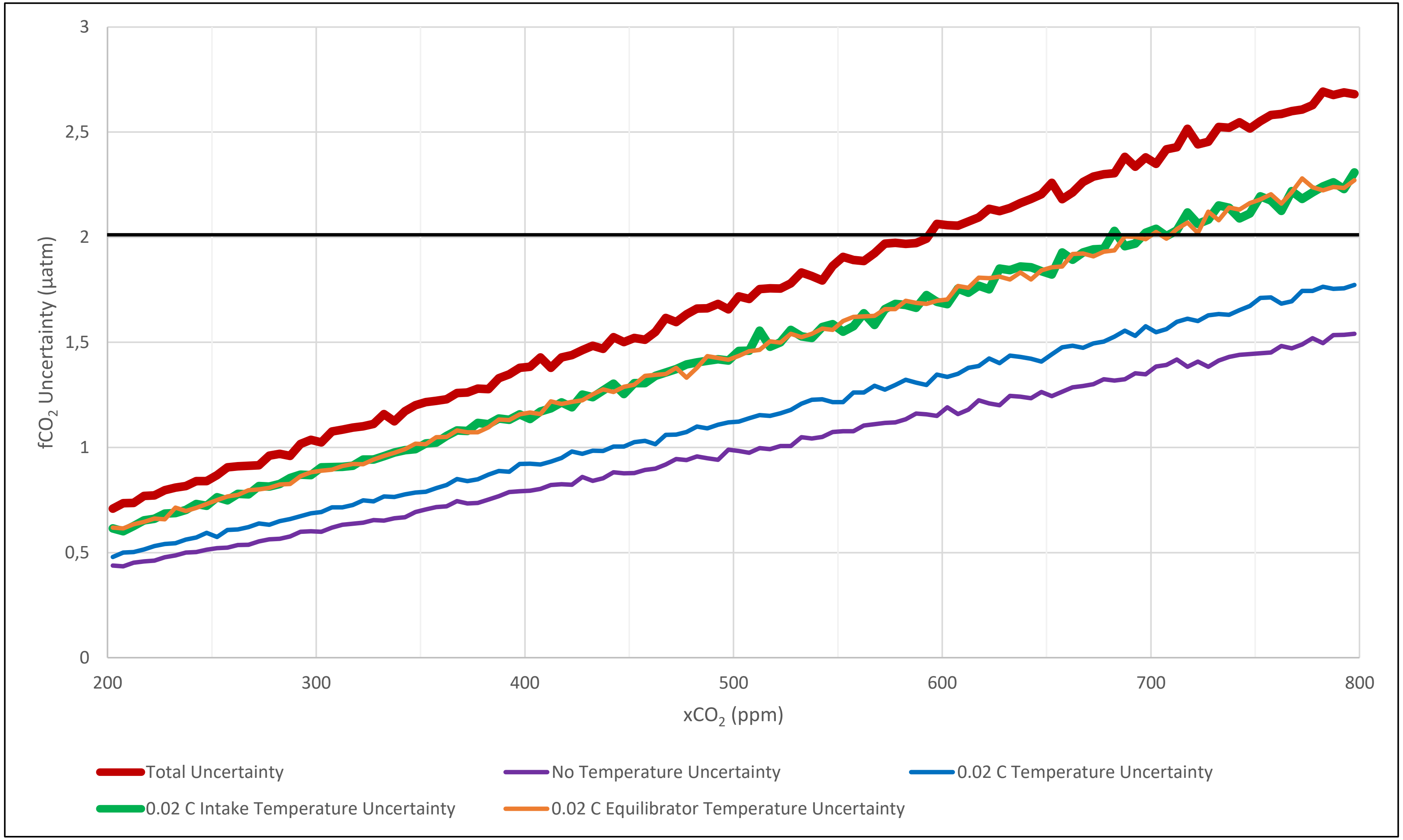

Monte Carlo Simulation
68% Confidence
95% Confidence
20
15
10
5
0
-5
-10
-15
-20
100
200
300
400
500
600
700
800
900
ΔfCO2 (µatm)
xCO2 (ppm)

Results



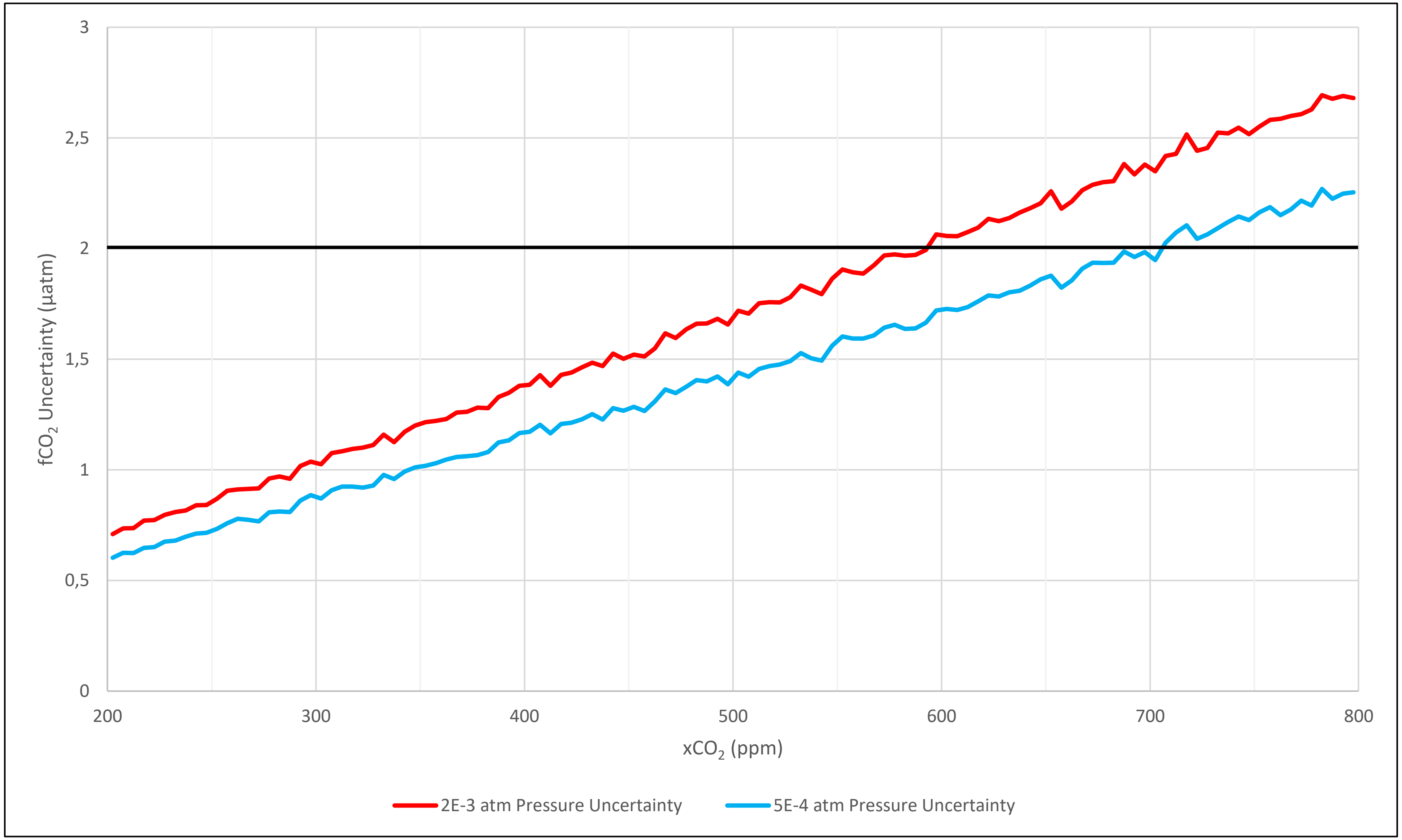
fCO$_2$ Uncertainty (µatm)
3
2,5
2
1,5
1
0,5
0
200
300
400
500
600
700
800
xCO$_2$ (ppm)
Total Uncertainty
0.15 ppm Standard Gas Uncertainty
No Temperature, Pressure, or Salinity Uncertainty

Results



fCO2 Uncertainty (µatm)
3
2,5
2
1,5
1
0,5
0
200
300
400
500
600
700
800
xCO2 (ppm)
Total Uncertainty
No Temperature Uncertainty
0.02 C Temperature Uncertainty
0.02 C Intake Temperature Uncertainty
0.02 C Equilibrator Temperature Uncertainty

Results



3
2,5
2
1,5
1
0,5
0
200
300
400
500
600
700
800
fCO2 Uncertainty (µatm)
xCO2 (ppm)
2E-3 atm Pressure Uncertainty
5E-4 atm Pressure Uncertainty

Continued Work

$$(pCO_2)^{wet}_{equT} = (xCO_2)^{dry}_{equT}\left[P_{equ} - pH_2O(CO_2, equT)\right]$$

$$(fCO_2)^{wet}_{equT} = (pCO_2)^{wet}_{equT} * exp\left\{\frac{\left[B(CO_2, equT) + 2\left(1 - (xCO_2)^{dry}_{equT}\right)^2 \delta(CO_2, equT)\right] P_{atm}}{R * equT}\right\}$$

$$(fCO_2)^{wet}_{SST} = (fCO_2)^{wet}_{equT} * exp\{(0.0423 \pm 0.0002)(SST - equT)\}$$

(SD, Takahashi et al 1993)

$$B(CO_2, equT) = -1636.75 + 12.0408 * equT - 3.27957 * 10^{-2} * equT^2 + 3.16528 * 10^{-5} * equT^3 \pm 2.314$$

(SD, Sengers et al 1971)

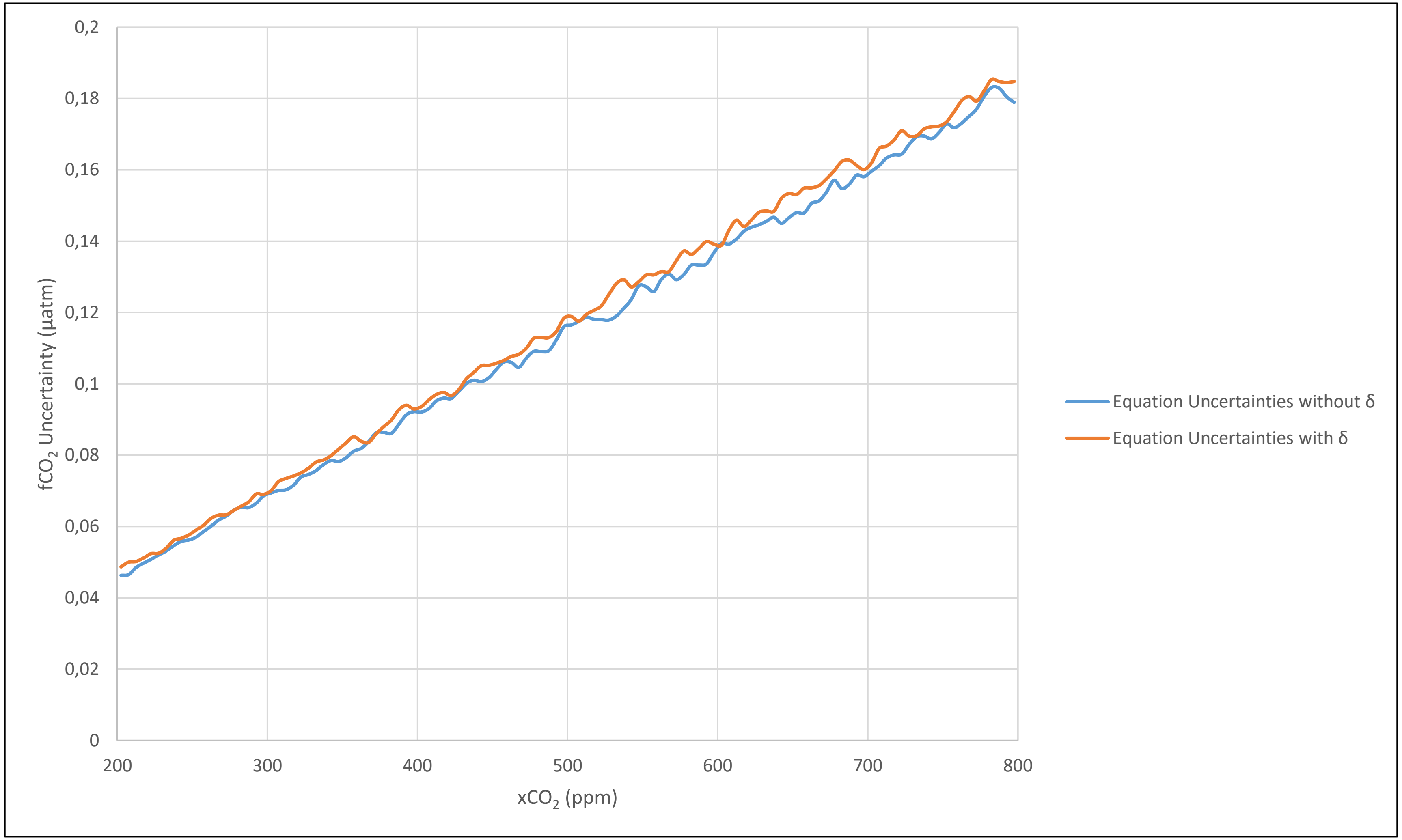
$$\delta(CO_2, equT) = 57.7 - 0.118 * equT \pm 3\%$$

(Estimate)

$$pH_2O(CO_2, equT) = exp\left\{24.4543 - 67.4509\left(\frac{100}{equT}\right) - 4.8489 ln\left(\frac{equT}{100}\right) - 0.000544 * S\right\} \pm 0.015\%$$

(SE, Weiss and Price 1980)

Preliminary Results



Standard Gas and Pressure Offset Analysis

Equations and Method

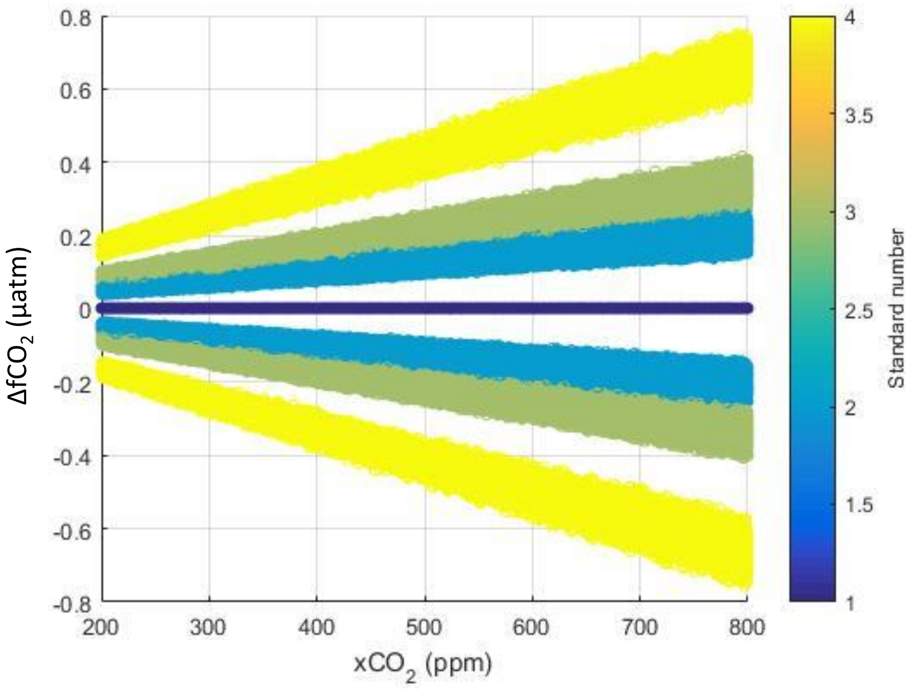
- Same equations as previous
- Offset one Standard Gas or Pressure measurement by specified amount
- Compute $(fCO_2)^{wet}_{SST}$ with and without offset
  - $Offset = ((fCO_2)^{wet}_{SST})_{with\ Offset} - ((fCO_2)^{wet}_{SST})_{without\ Offset}$
- Repeat over 500000 cycles

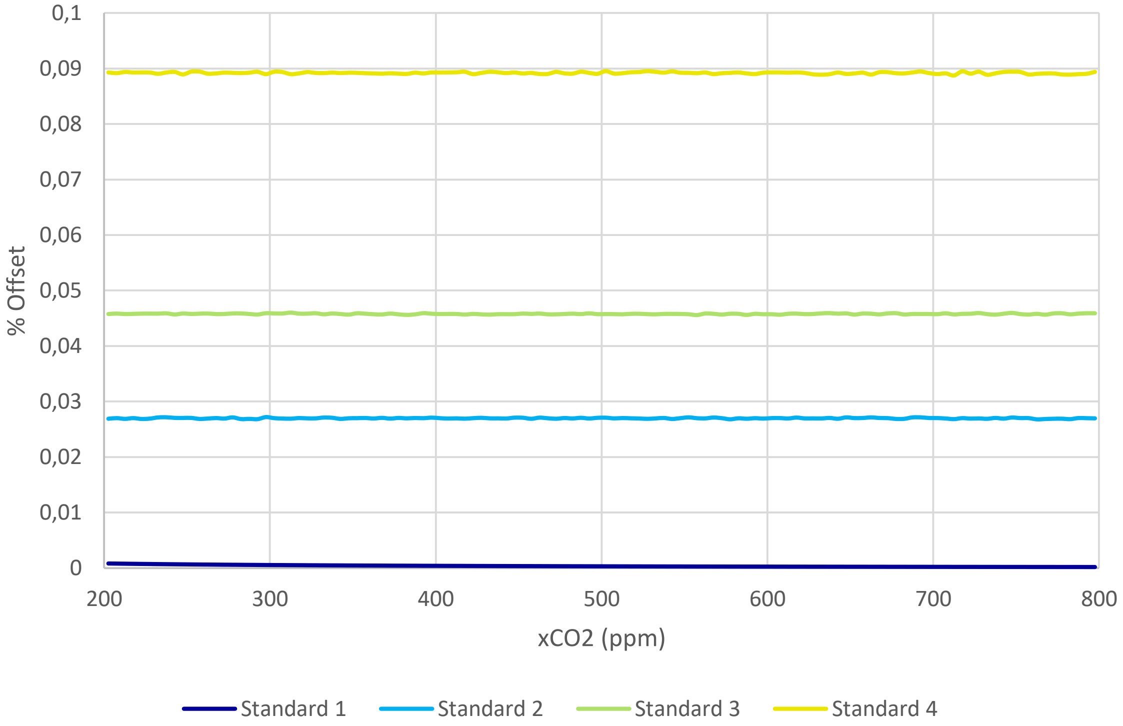
Data Ranges

Parameter	Range
P_{equ} and P_{atm}	1 atm
equT	0 to 40 °C
ΔT	0 to -2 °C
xCO_2	200 to 800 ppm
S	35 PSU
Standard Gas 1	0 ppm
Standard Gas 2	200 to 300 ppm
Standard Gas 3	350 to 500 ppm
Standard Gas 4	800 to 850 ppm

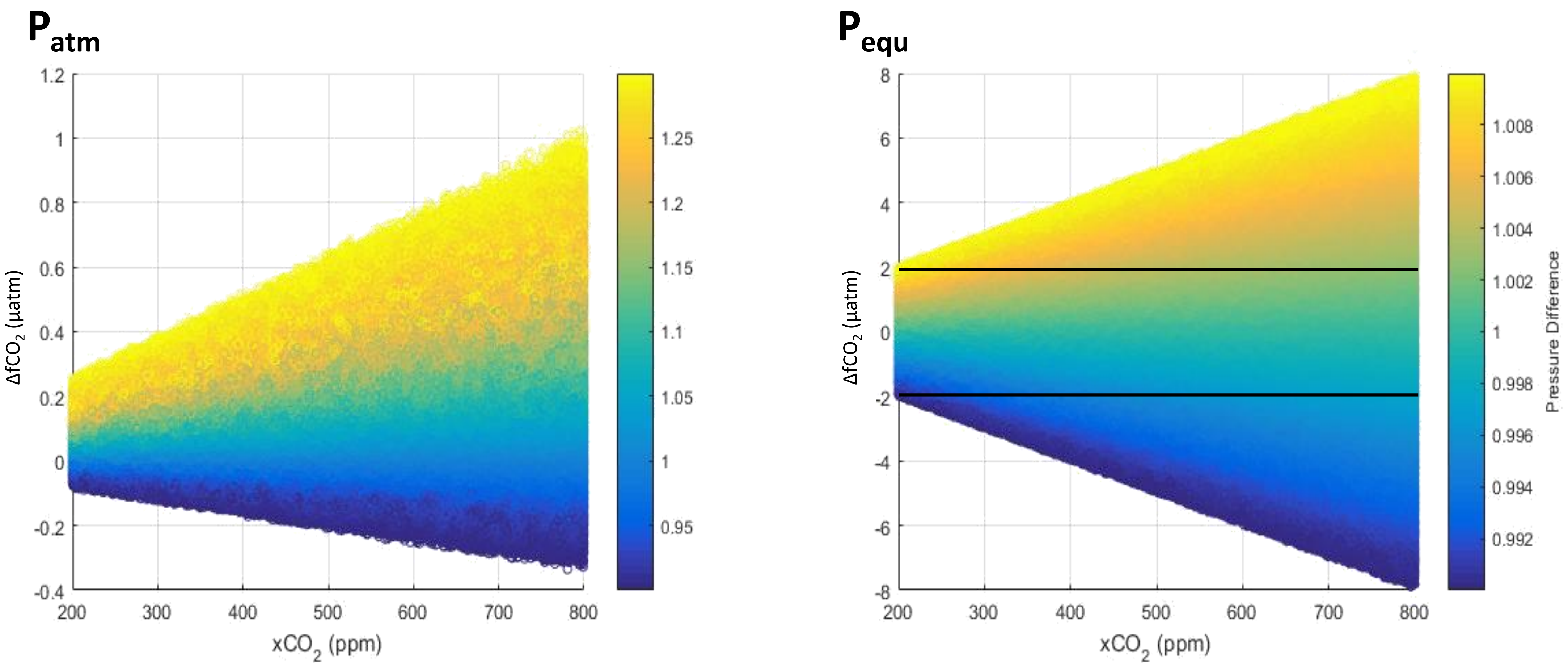
Parameter	Low Offset	High Offset
P_{atm}	0.9 atm	1.3 atm
P_{equ}	0.99 atm	1.01 atm
Standard Gas 1	0 ppm	1 ppm
Standard Gases	-1 ppm	1 ppm

Standard Gases



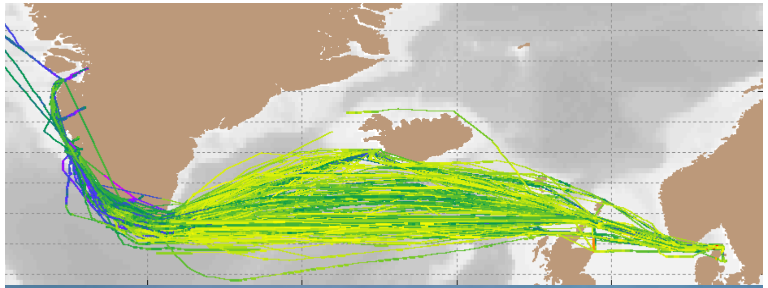


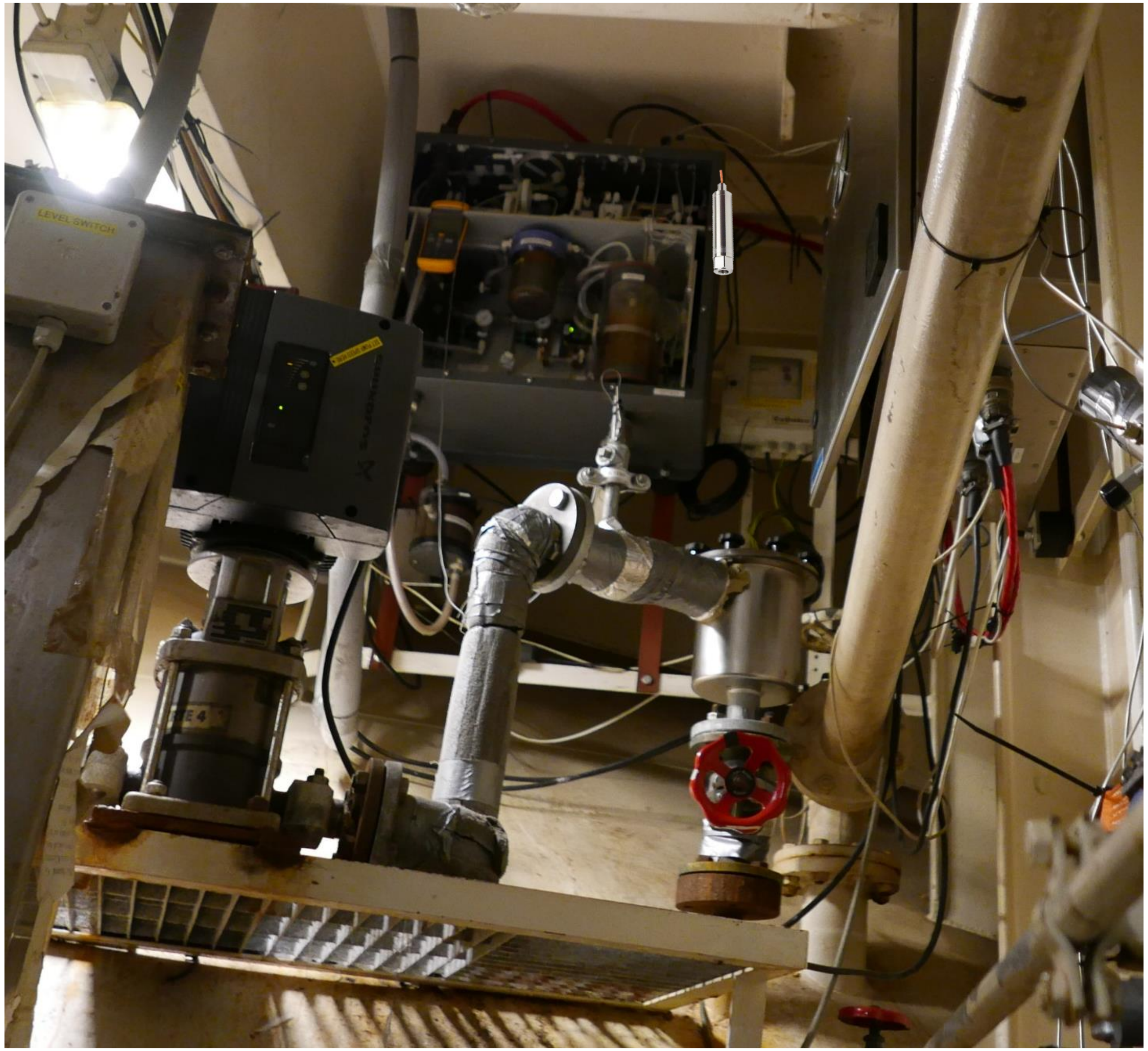
Pressure Offset



- Nuka Arctica

- GO system, Model 8050
- Licor 6262



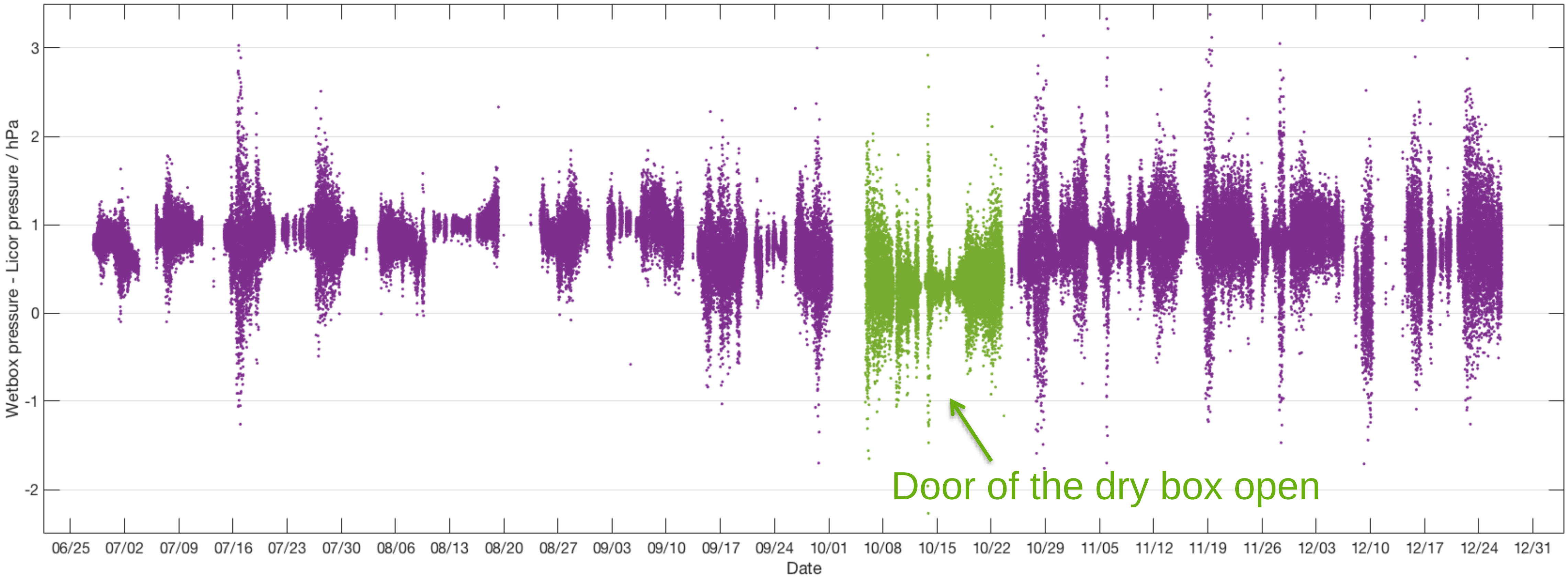


BJERKNES CENTRE for Climate Research

Installing a pressure sensor in the WetBox

Mean difference: 0.81 hPa

Mean difference (October): 0.33 hPa

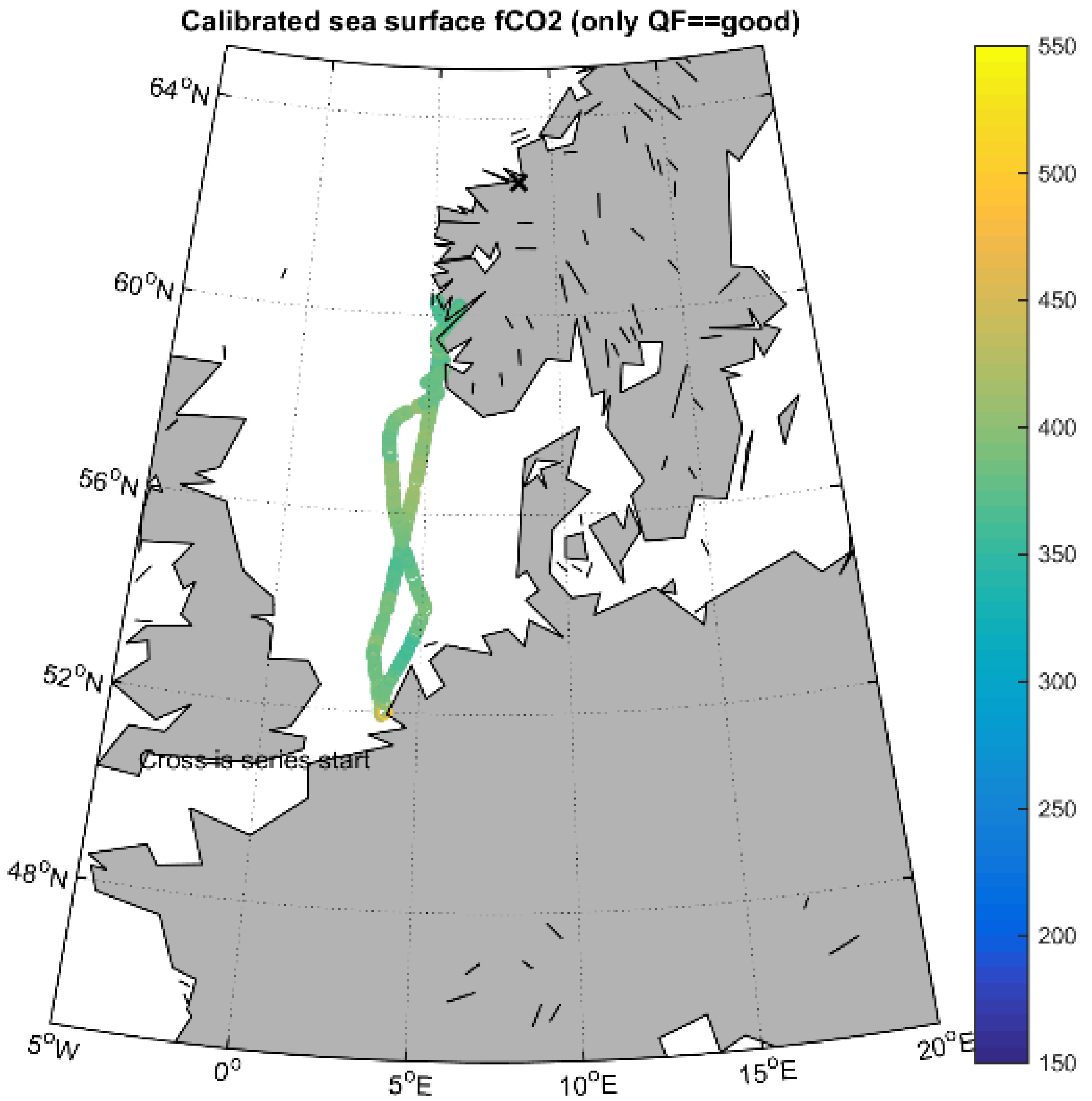


Trans Carrier

Sea-Cargo

Trans Carrier

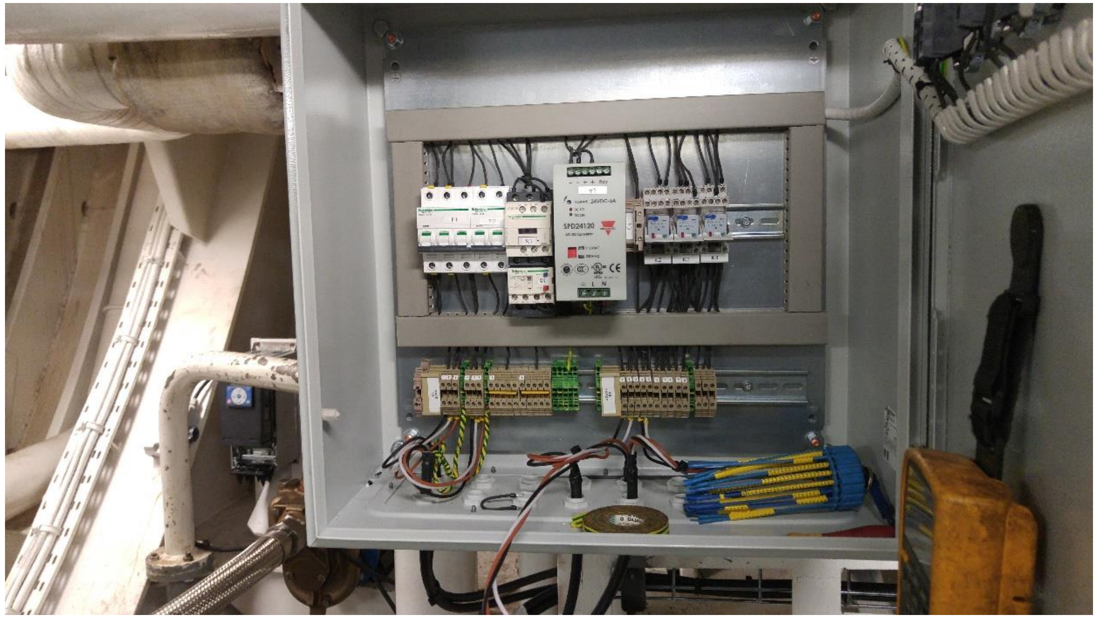
- Commercial ro-ro cargo vessel.
- Sailing between Bergen and Rotterdam.
- Costal/fjords in Norway, then crossing the North sea.
- 1 week round trip.

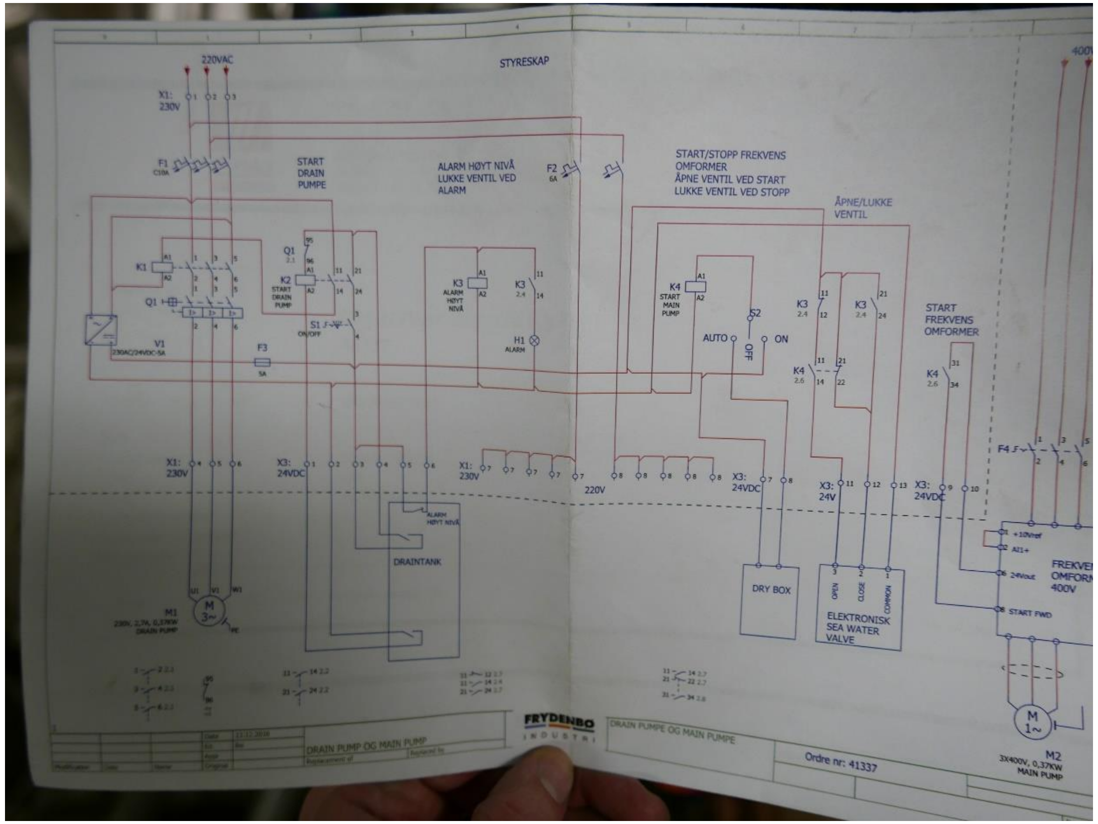


Removing old installation

Making and installing brackets

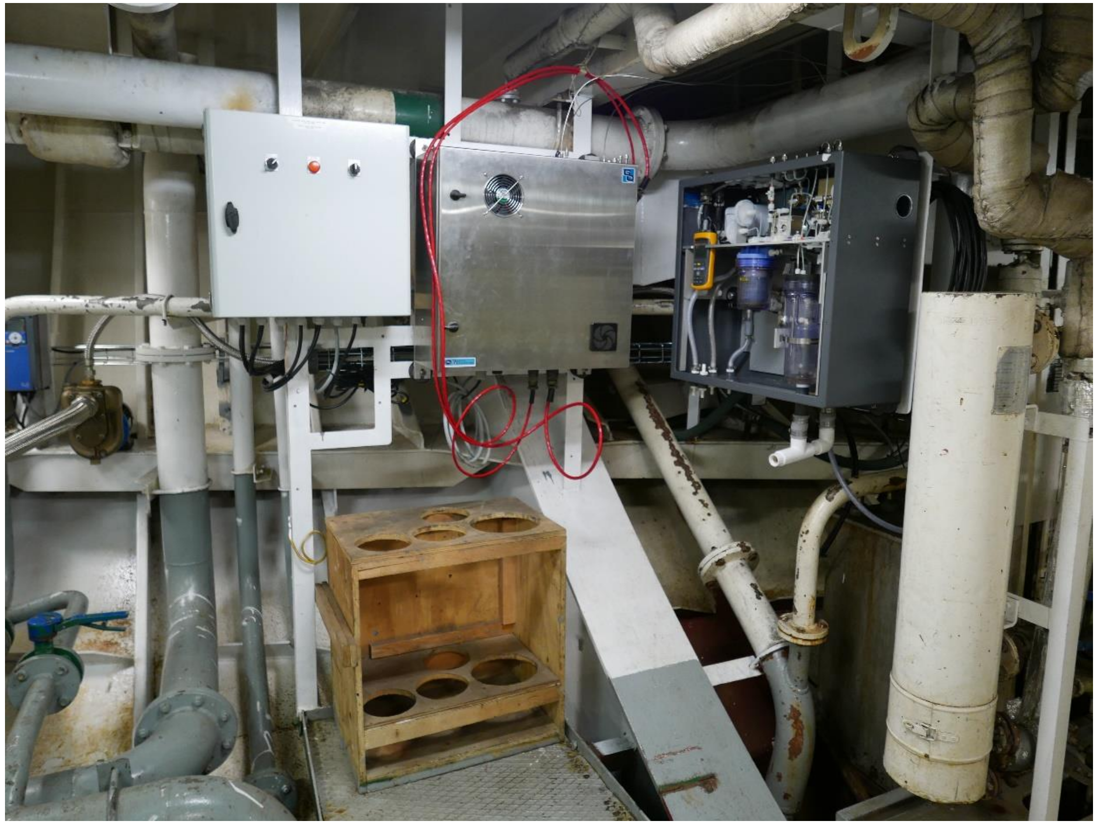
Electrical distribution





Water supply and drain

Box installation



The problems

Schedule

- Port call in Bergen Monday – Tuesday/Wednesday every week.

Schedule

- ~~Port call in Bergen Monday - Tuesday/Wednesday every week.~~
- Planned port call in Bergen every Sunday evening.
- Sometimes the port call in Bergen is cancelled.
- Notification about changes in schedule Friday afternoon or Saturday.

PPM-values

- Known standards were way off after zero-span.
- Spending much zero gas (STD1).

PPM-values

- Known standards were way off after zero-span.
- Spending much zero gas (STD1).

- Valco MPV had an internal problem with the TX-line. Causing the valve to receive commands, but failing to report its position back to the computer.
- This caused the MPV to move to position 1 (STD1) instead of stopping the flow (even position).

Water restriction

- Low water flow in system
- High flows when the water line was disconnected to locate the problem.

Water restriction

- Low water flow in system
- High flows when the water line was disconnected to locate the problem.

- Flow regulator in wet box did not open properly.
- Regulator was removed, and water flow is now controlled using the frequency converter and an external flow regulator.

Water pump

- Scraping sound when running on high speed.
- Several gaskets between motor and pump housing trying to prevent scraping.
- Could only run on low speed, not delivering enough water

- This occurred at the same time as the water restriction problem.

Tubing and pipes

- Flag state did not like flexible tubing

Water leak

- The flexible tubing was not made for sea water, so it started leaking.
- The supplier of the tubing could not come up with a solution, or supply adequate tubing or pipes.

- At the same time the water pump started leaking, probably due to the need of several gaskets.

Water leak

- Crew made a solid pipe to replace the leaking flexible tube.
- Water pump was replaced on warranty.

Just in: Drain tank flooding

- Drain pump running continuously
- Drain tank flooding
- System stopped by ship crew

- We hope the ship will come to Bergen this Sunday.


SEA-CARGO
TRANS CARRIER
NASSAU
TRANS CARRIER
NASSAU

Katharina Seelmann, PhD student

Test and evaluation of the Contros HydroFIA® TA system in field

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

GEOMAR

Who am I?

PhD student in the chemical oceanography department at the GEOMAR Helmholtz-Centre for Ocean Research Kiel

- Working group:
  Observational Chemical Oceanography (PI: Prof. Arne Körtzinger)

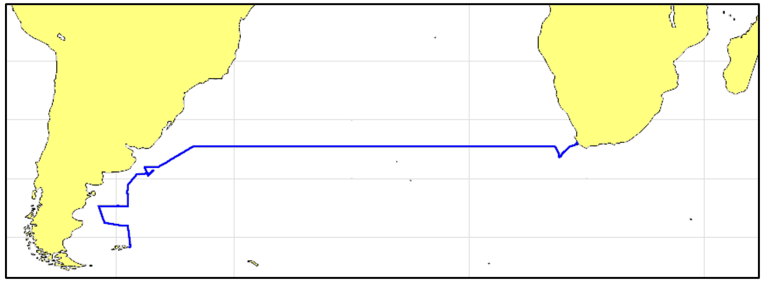
Main aim of my thesis

- Production of valid and comparable results with the Contros HydroFIA® TA system during an autonomous long-term installation on a North Atlantic VOS (voluntary observing ship) line

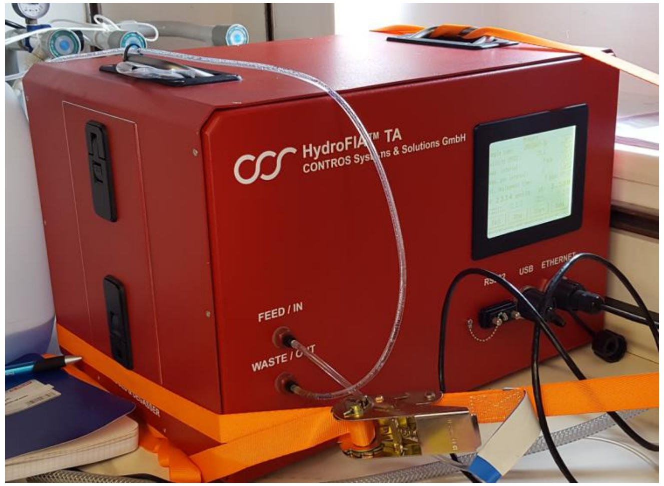
- Before:
  - ➢ Comprehensive testing of the analyser regarding to the behaviour under semi-continuous measurement condition

First evaluation cruise: M133

- Research cruise on RV Meteor (M133)
- 15.12.2016 – 13.01.2017
- From Cape Town, South Africa to Stanley, Falkland Islands



- Measurement conditions:
  - ➢ Installed in bypass to a continuous underway seawater stream (filtered with a 50 µm flow-through filter)
  - ➢ Calibration only at the start of the cruise with CRM
  - ➢ Measurement interval: 7 minutes



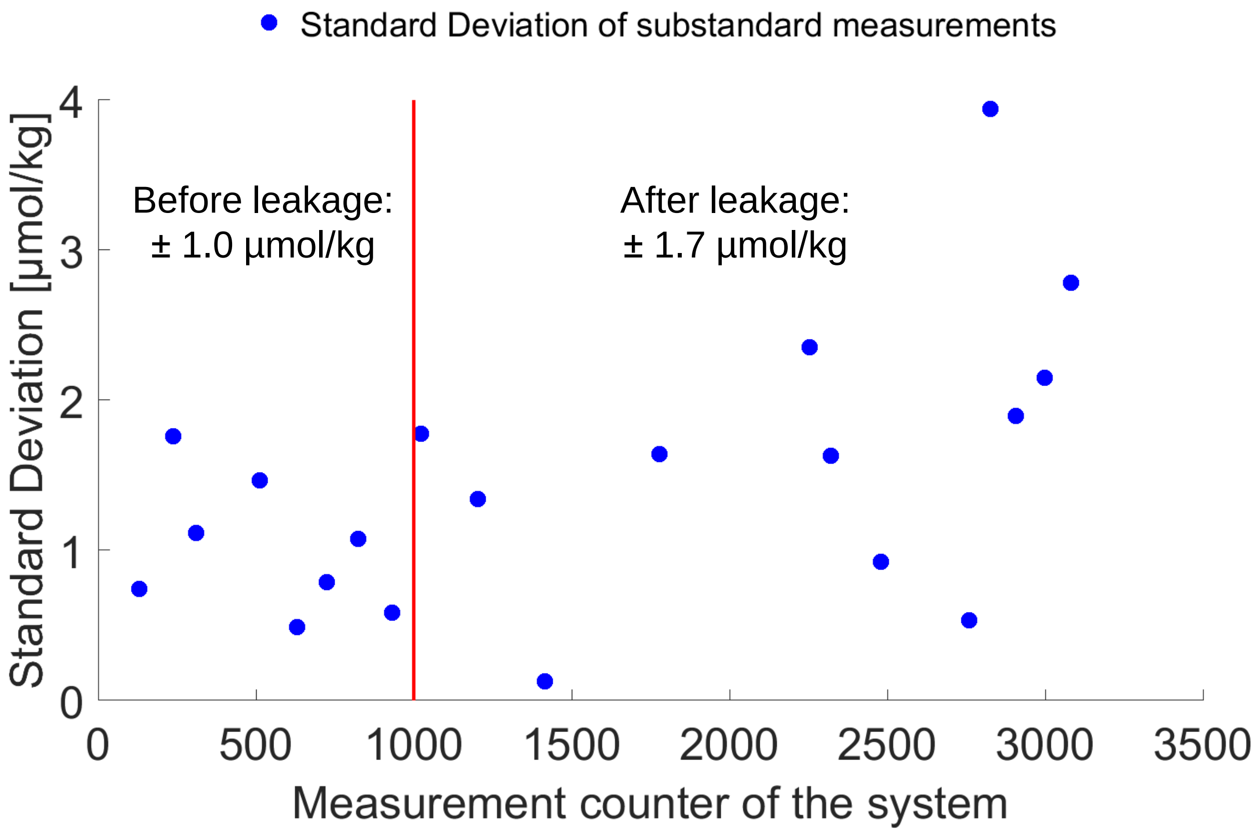
First evaluation cruise: M133

- Overall 3358 measurements
  - ➢ 2702 underway measurements
- Daily substandard measurements for precision monitoring
- Regular CRM measurements and collecting of discrete samples for accuracy monitoring

- Problem:
  - ➢ Around1000 measurements → leakage in the degasser unit

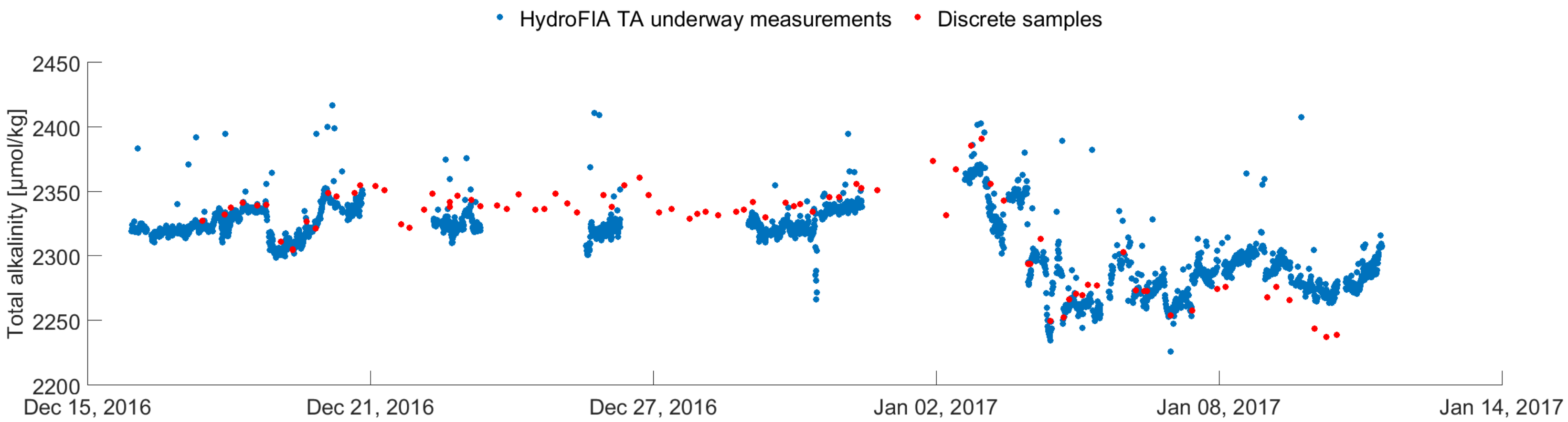
First evaluation cruise: M133

- Precision evaluation: Averaged standard deviation = **± 1.5 µmol/kg**



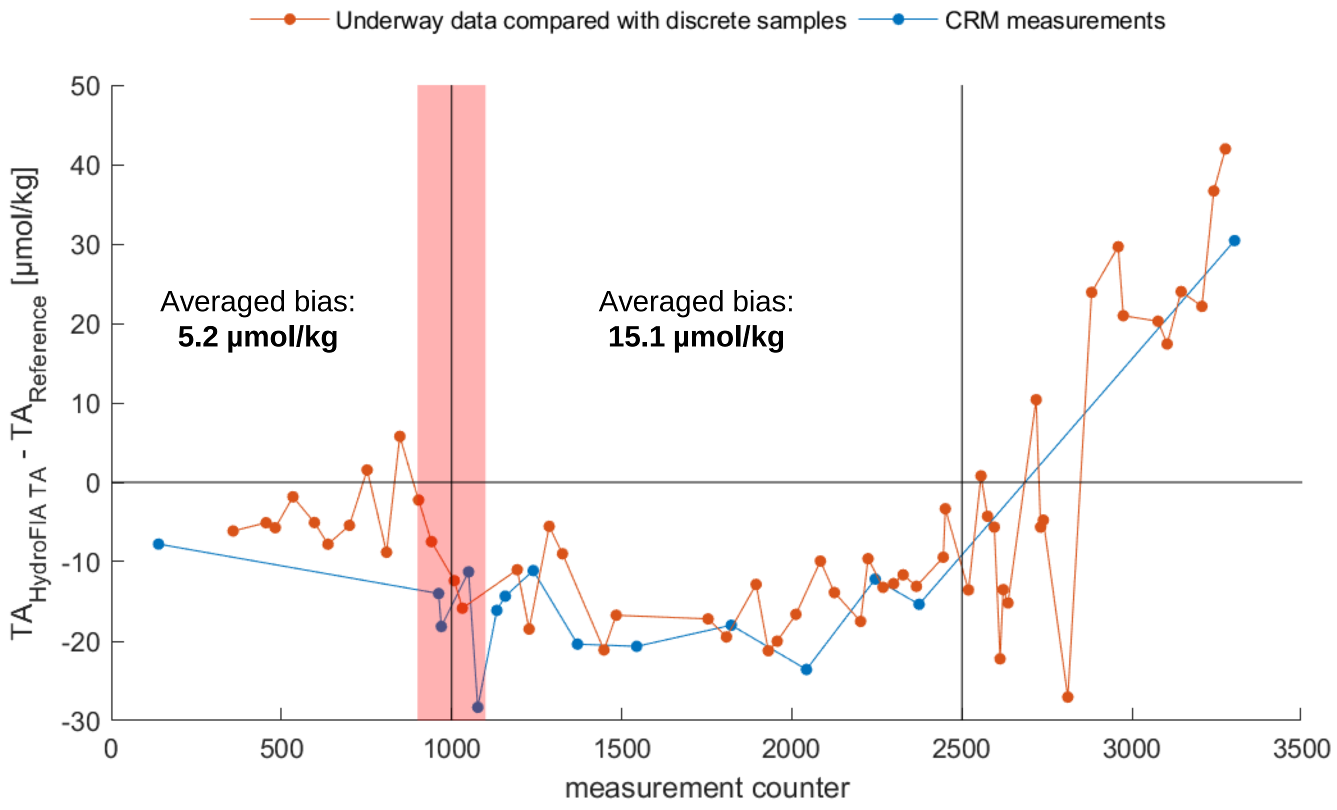
First evaluation cruise: M133

- Accuracy evaluation:



First evaluation cruise: M133

- Accuracy evaluation:



First evaluation cruise: M133

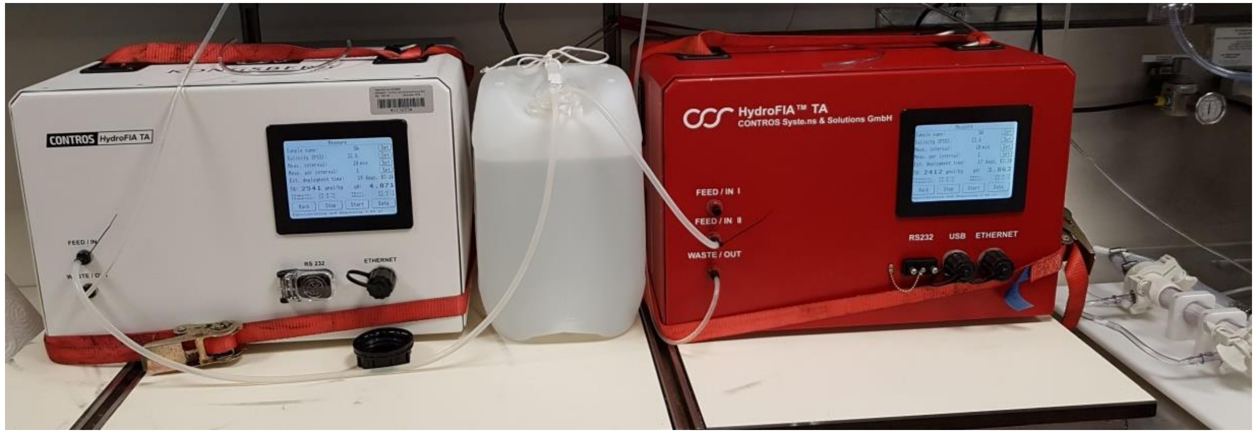
Main finding from M133:

- Daily quality insurance measurements are mandatory

- Second evaluation cruise without leakage was necessary

Second evaluation cruise

- MSM68/2 on RV Maria S. Merian (From Emden, Germany to Mindelo, Cape Verde)
- 03.11. – 14.11.2017
- Final evaluation of the data still in progress



VOS line

- With the findings of the two evaluation cruises
  - ➢Install the system on board of the container vessel for autonomous long-term measurements

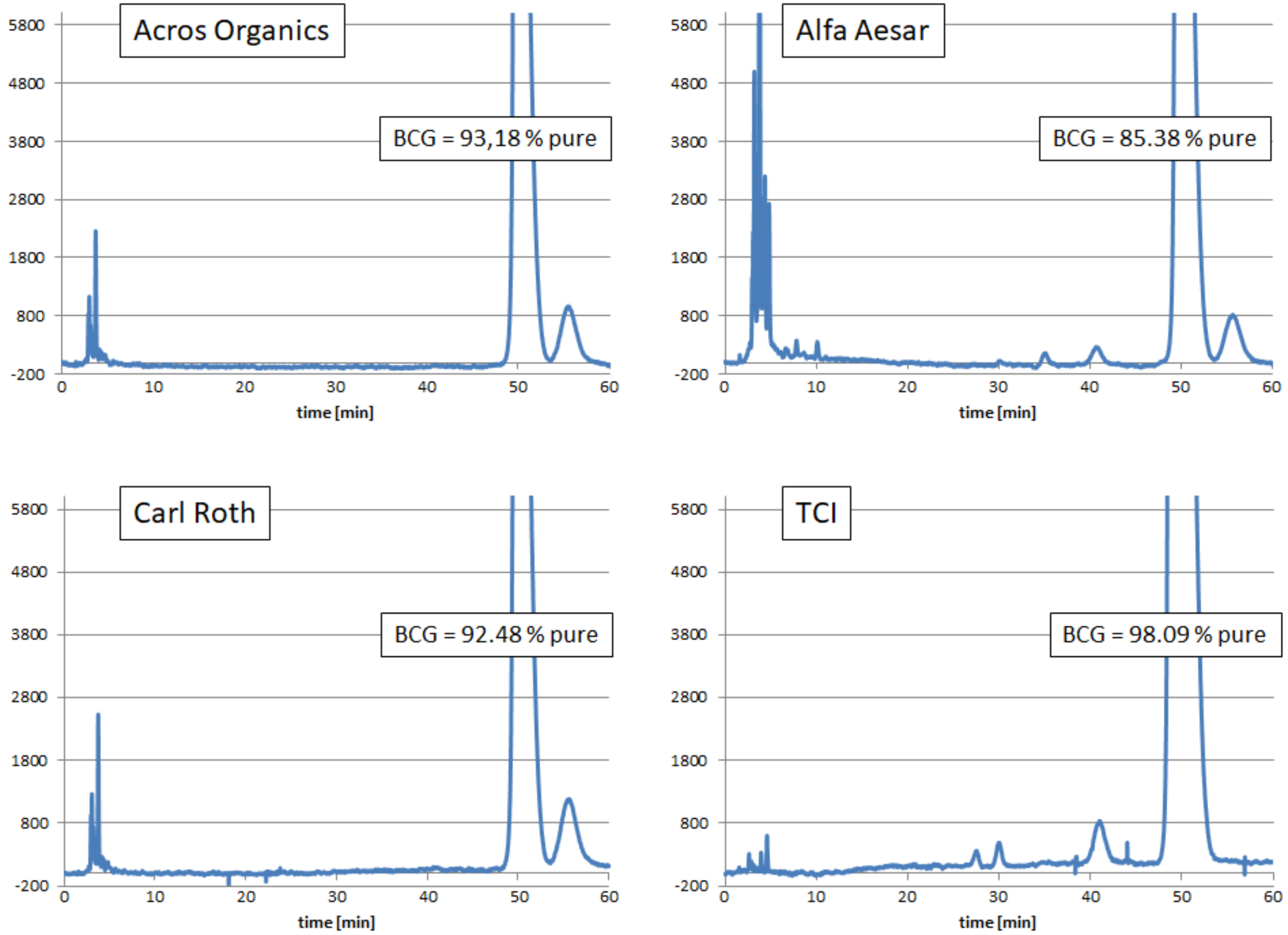
Bromocresol green purification

- Developing of a preparative and analytical HPLC method similar to a existing method for meta-cresol purple [(1)]
  - ➢ **Is there a possible improvement for the TA measurements?**

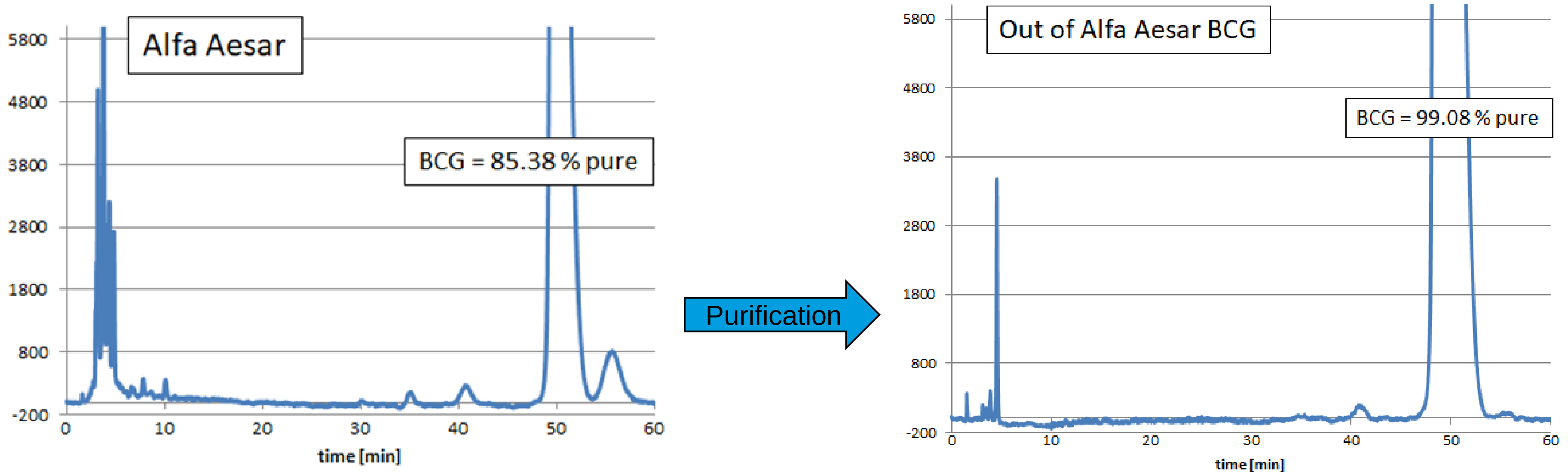
- Analyse BCG from different vendors with this method
- First purification of BCG

(1) Purification and Characterization of meta-Cresol Purple for Spectrophotometric Seawater pH Measurements, Xuewu Liu, Mark C. Patsavas, and Robert H. Byrne, *Environmental Science & Technology* **2011** 45 (11), 4862-4868

Bromocresol green purification



Bromocresol green purification



- Purity improvement of 14%
- Next steps:
  - ➢Purification of TCI BCG
  - ➢Spectrophotometric measurements
  - ➢Measurements with the HydroFIA® TA system

ICOS | INTEGRATED CARBON OBSERVATION SYSTEM

ICOS Data Management – the way towards operational oceanography

Benjamin Pfeil, Steve Jones, Camilla Stegen Landa, Jonas Fagnastøl Henriksen, Rocio Castano Primo

ICOS Ocean Thematic Centre / Bjerknes Climate Data Centre

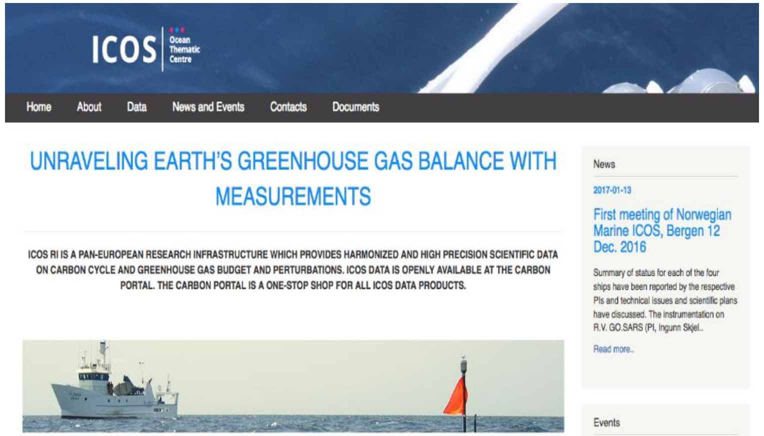
Bjerknes Centre for Climate Research

BCDC Bjerknes Climate Data Centre

Bjerknes Centre for Climate Research

The Ocean Thematic Centre

ICOS Ocean Thematic Centre



Home | About | Data | News and Events | Contacts | Documents

UNRAVELING EARTH'S GREENHOUSE GAS BALANCE WITH MEASUREMENTS

ICOS RI IS A PAN-EUROPEAN RESEARCH INFRASTRUCTURE WHICH PROVIDES HARMONIZED AND HIGH PRECISION SCIENTIFIC DATA ON CARBON CYCLE AND GREENHOUSE GAS BUDGET AND PERTURBATIONS. ICOS DATA IS OPENLY AVAILABLE AT THE CARBON PORTAL. THE CARBON PORTAL IS A ONE-STOP SHOP FOR ALL ICOS DATA PRODUCTS.

News

2017-01-13

First meeting of Norwegian Marine ICOS, Bergen 12 Dec. 2016

Summary of status for each of the four ships have been reported by the respective PIs and technical issues and scientific plans have discussed. The instrumentation on R.V. GO.SARS (PI, Ingunn Skjel..

Read more..

Events

2017-01-13

Joint ICOS OTC and MSA meeting

The yearly joint ICOS OTC and MSA meeting will be held in Bergen 1-3 March 2017.

Welcome to the ICOS OTC website

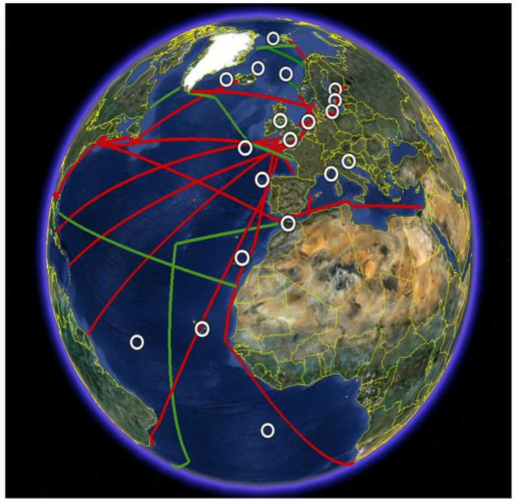
The Ocean Thematic Centre (OTC) is one of four central facilities within the European research infrastructure Integrated Carbon Observation System (ICOS RI). The marine elements of the ICOS RI provides the long-term oceanic observations required to understand the present state and predict future behaviour of the global carbon cycle and climate- relevant gas emissions. The oceanic sink currently offsets approximately 25% of CO_2 emissions from human activities. Oceanic net air-sea CO_2 fluxes of the Atlantic are a large proportion of the net global marine flux, together with CH_4 and N_2O fluxes.

OTC coordinate and support the European network of Monitoring Stations Assembly (MSA) in the North Atlantic, Nordic Seas, Baltic and the Mediterranean (Fig. 1). OTC cooperates with the International Ocean Carbon Coordination Project (IOCCP) to cover the global ocean observing systems, such as Voluntary Observing Ships (VOS), Fixed Ocean Stations (FOS), Repeat Ocean Sections (ROS), Marine Flux Towers (MFT) and new technologies.

OTC builds on expertise and results
gained during previous and current EU-funded science projects (CAVASSOO, CARBOOCEAN, CARBOCHANGE, Euro-Sites, FixO3 and ATLANTOS). In addition, as the observation of marine carbon cycle is of global concern, OTC works with the global observing community to develop global monitoring (e.g. Pfeil et al., 2013; Bakker et al., 2014).

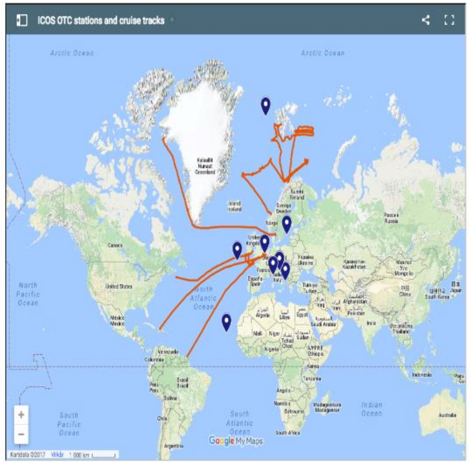
https://otc.icos-cp.eu/

Marine observation routes and stations



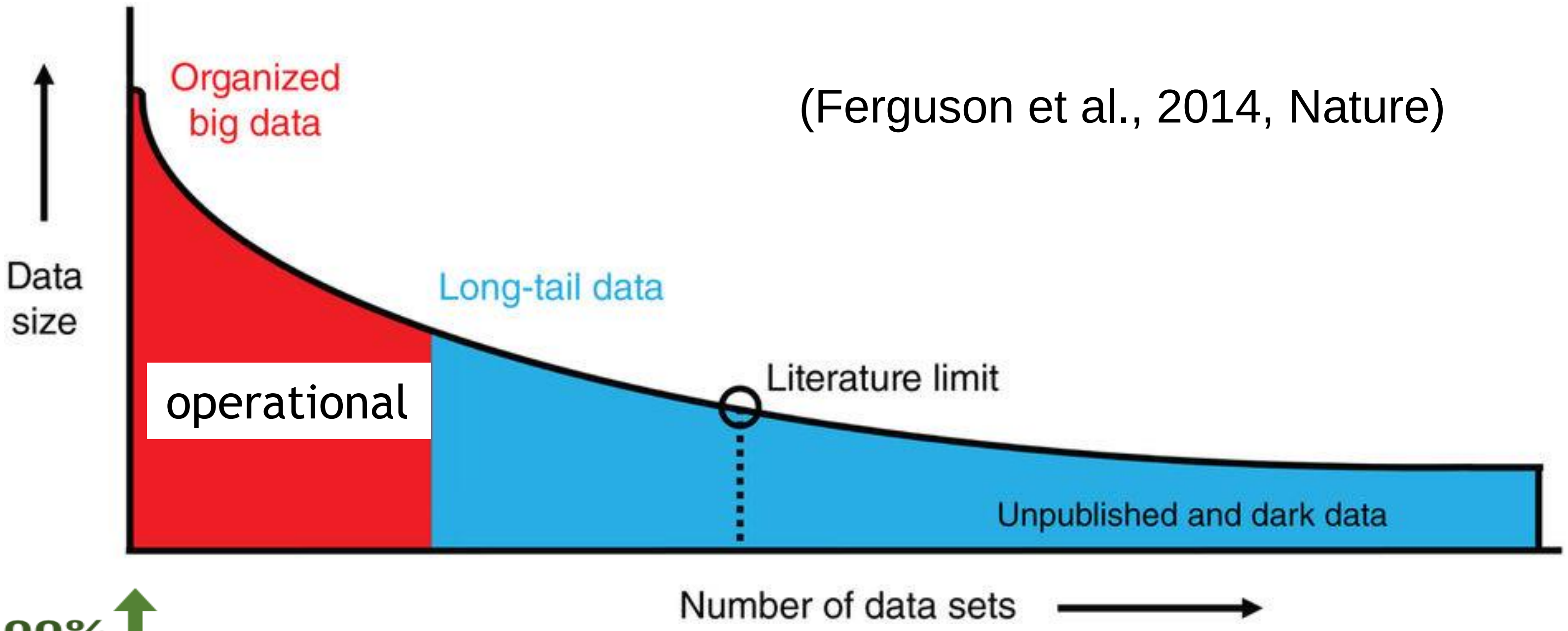
The suggested network of stations for the ocean-network: Cicles - Fixed Ocean Stations, Red lines – Ships of Opertunites and Green lines – Repeat Section. In addition, new technologies like floats and gliders will be implement when relaiable and robust autonomous sensors for the purpose is developed.

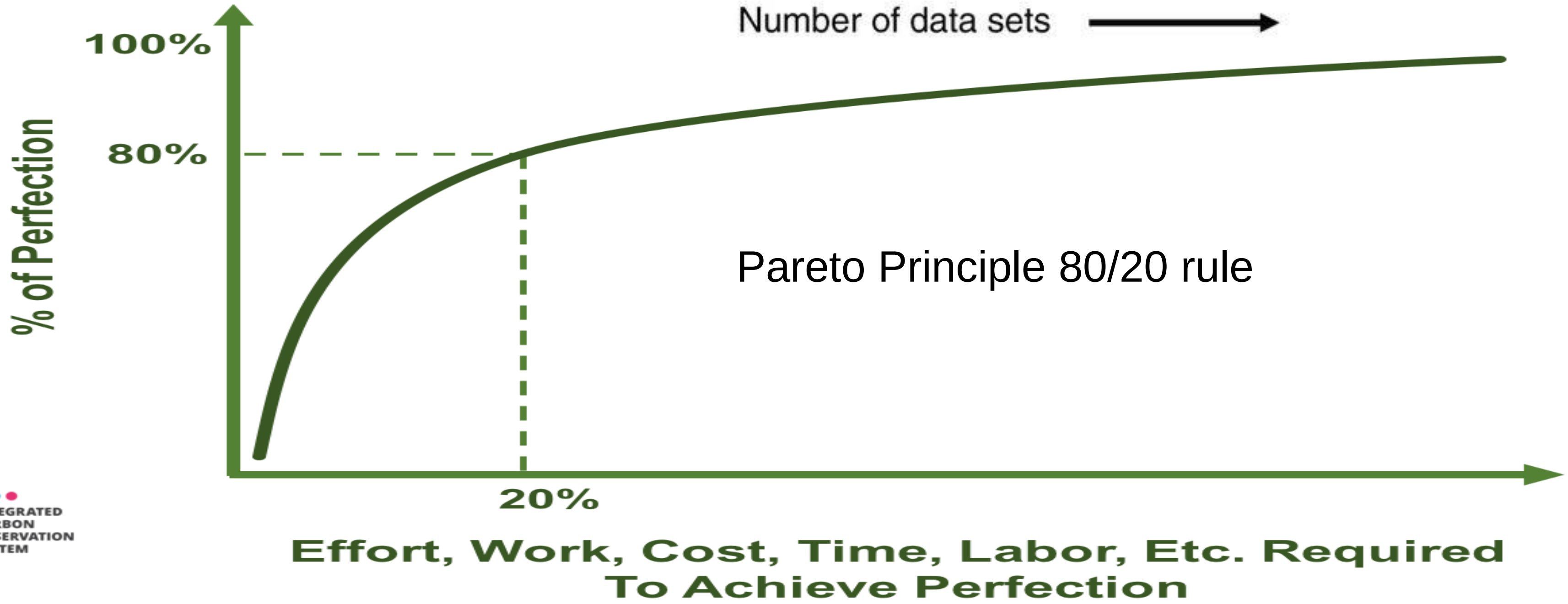
- The goal in 2013
- About 35 stations
- Future Vision about 50 stations



- The reality in 2017
- 21 station ready to be labelled
- 21 passed step 1 and ready for step 2

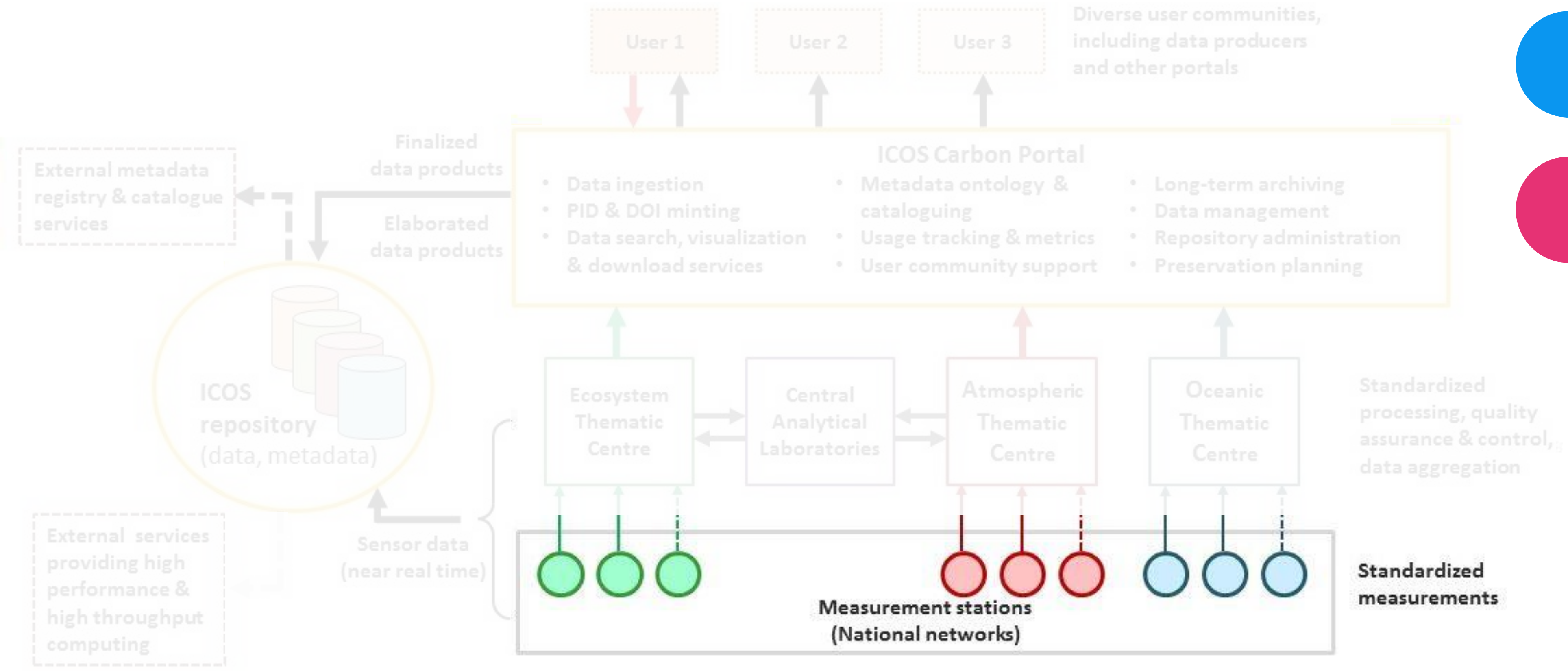
Challenges





ICOS INTEGRATED CARBON OBSERVATION SYSTEM

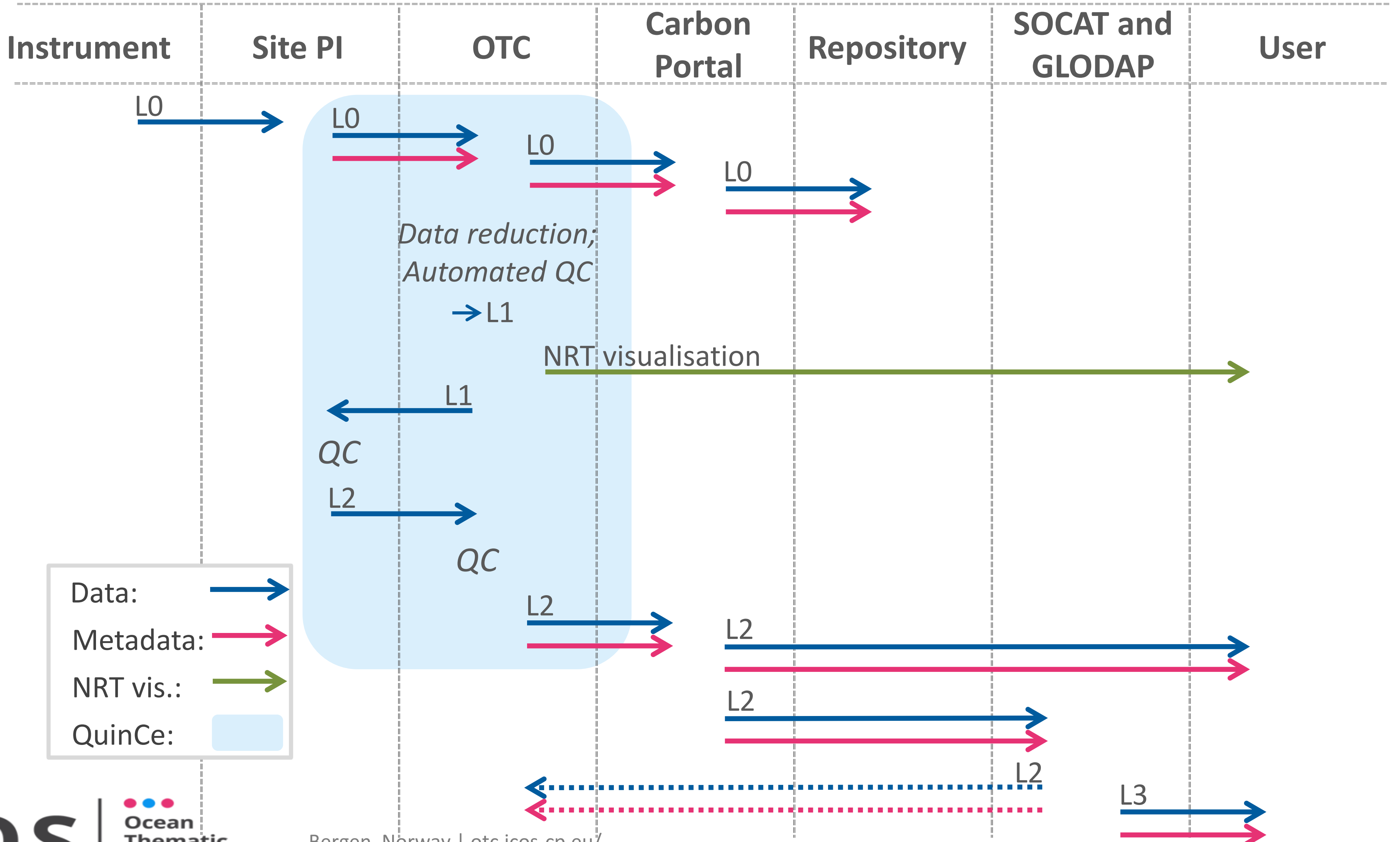
General Overview



Data Levels

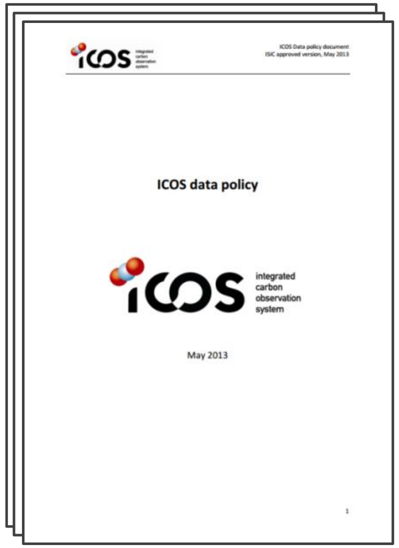
- **Level 0:** raw sensor output
- **Level 1:** gone through data reduction and automatic QC
- **Level 2:** final data set, QCed by PI
- **Level 3:** external data products using ICOS data

Data Lifecycle Within OTC



Data Policy

… takes into account the overall European legal framework related to access, sharing, protection and re-use of environmental data, information and databases


ICOS data policy

May 2013

https://otc.icos-cp.eu/node/16

All ICOS data, metadata and ICOS data products are

- public = open to all users
- made available with minimum time delay
- made available with minimum and whenever possible no cost

Data License

Creative Commons 4.0 BY

You are free to:

Share — copy and redistribute the material in any medium or format

Adapt — remix, transform, and build upon the material

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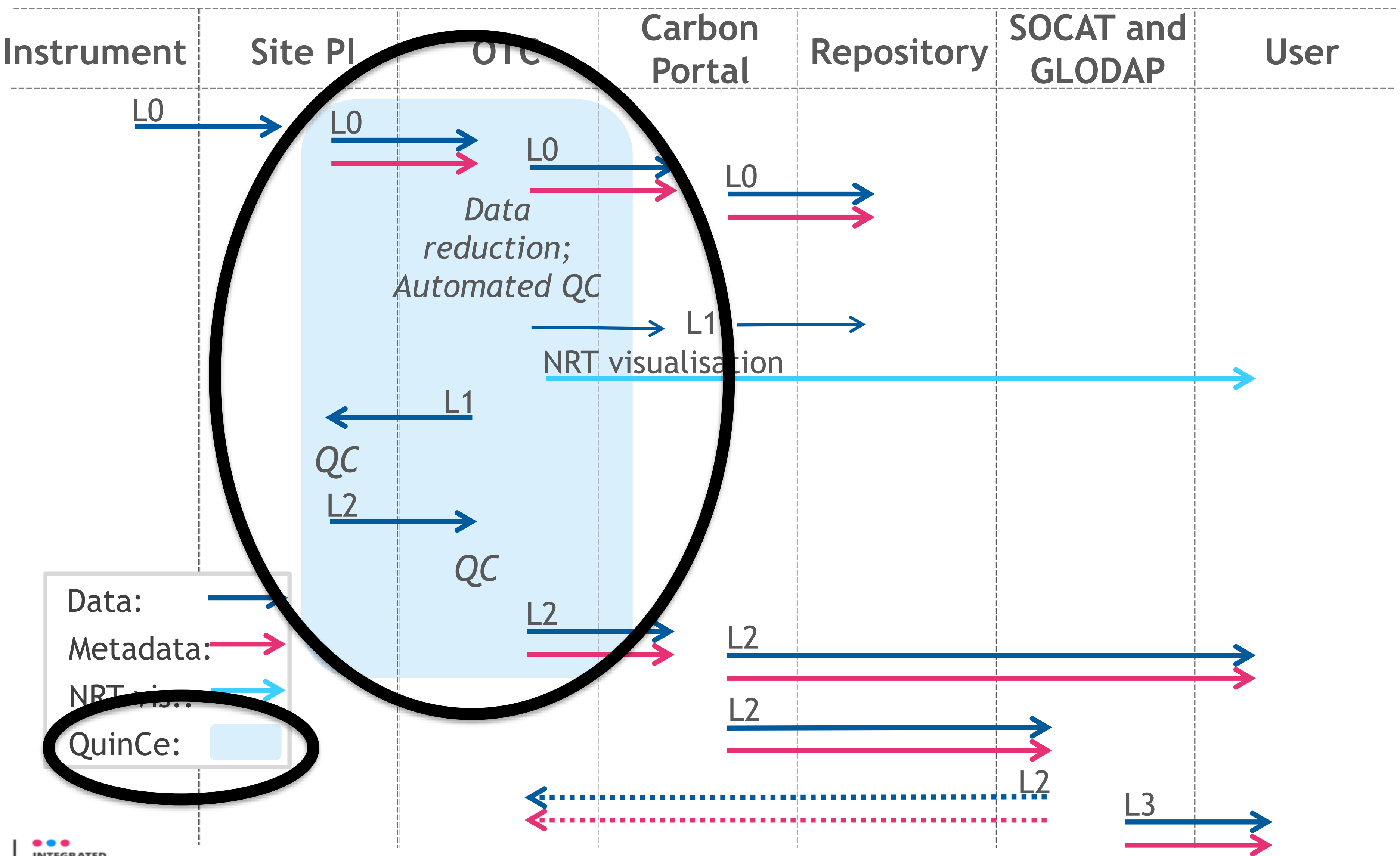
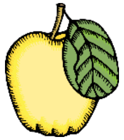
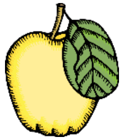
Data Lifecycle Within OTC





Data reduction and quality control software QuinCe: Features

- Web applications (runs through the browser = no Matlab or R expertise needed)
- Ingests raw data (streaming and delayed mode)
- Follows SoPs and approved routines (Pierrot el al.)
- Automatic data reduction with calibration, gas standards and automated initial QC
- Offers manual QC tools for visualising and flagging
- Standardised tools for data processing (consistency and documentation) -> become operational
- Currently underway pCO2 but will be extended to pH



Data reduction and quality control software QuinCe

- about longitudinal studies of drift
- long-term performance (feedback to producers)
- Archives data and calibration information

Opens up for:

- Online training
- Standardized data treatment outside ICOS
- Collaboration outside the ICOS network (strong interest e.g. EuroGOOS, CMEMS, SDC)

Global Ocean Biogeochemistry Data Management

Benjamin Pfeil
IOCCP SSC member responsible for data and information management
Bjerknes Climate Data Centre @ University of Bergen

GOA-ON

Global Ocean Acidification Observing Network

The Global Ocean Acidification Observing Network (GOA-ON) is a collaborative international approach to document the status and progress of ocean acidification in open-ocean, coastal, and estuarine environments, to understand the drivers and impacts of ocean acidification on marine ecosystems, and to provide spatially and temporally resolved biogeochemical data necessary to optimize modeling for ocean acidification.

Home | **References/Reports** | **GOA-ON Activities** | **Interactive Map** | **Network Members** | **Governance/Contact** | **Pier2Peer**

Approach and G

Detailed information about th
background, design, implemen
data strategy can be found he

Global Ocean Acidification Ob
Network: Requirements and G
Plan (JA Newton, RA Feely, EE
Williamson, J Mathis)

GOA-ON high-level goals:

Goal 1 - Improve our understand
OA conditions:

- Determine status and s
temporal patterns in ca
chemistry, assessing th
of response to ocean a
- Document and evaluate

* * What's New * *

An International Effort

67
GOA-
N.
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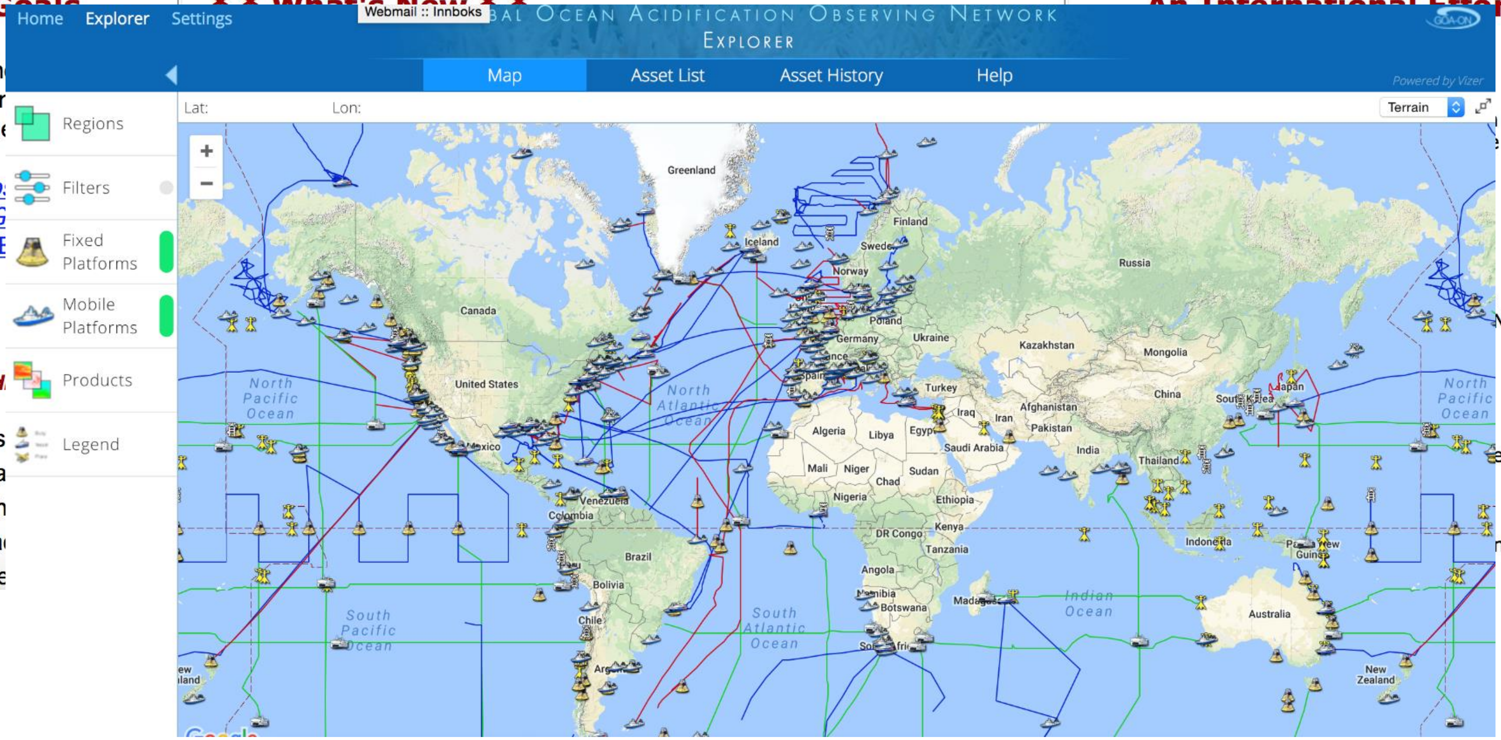
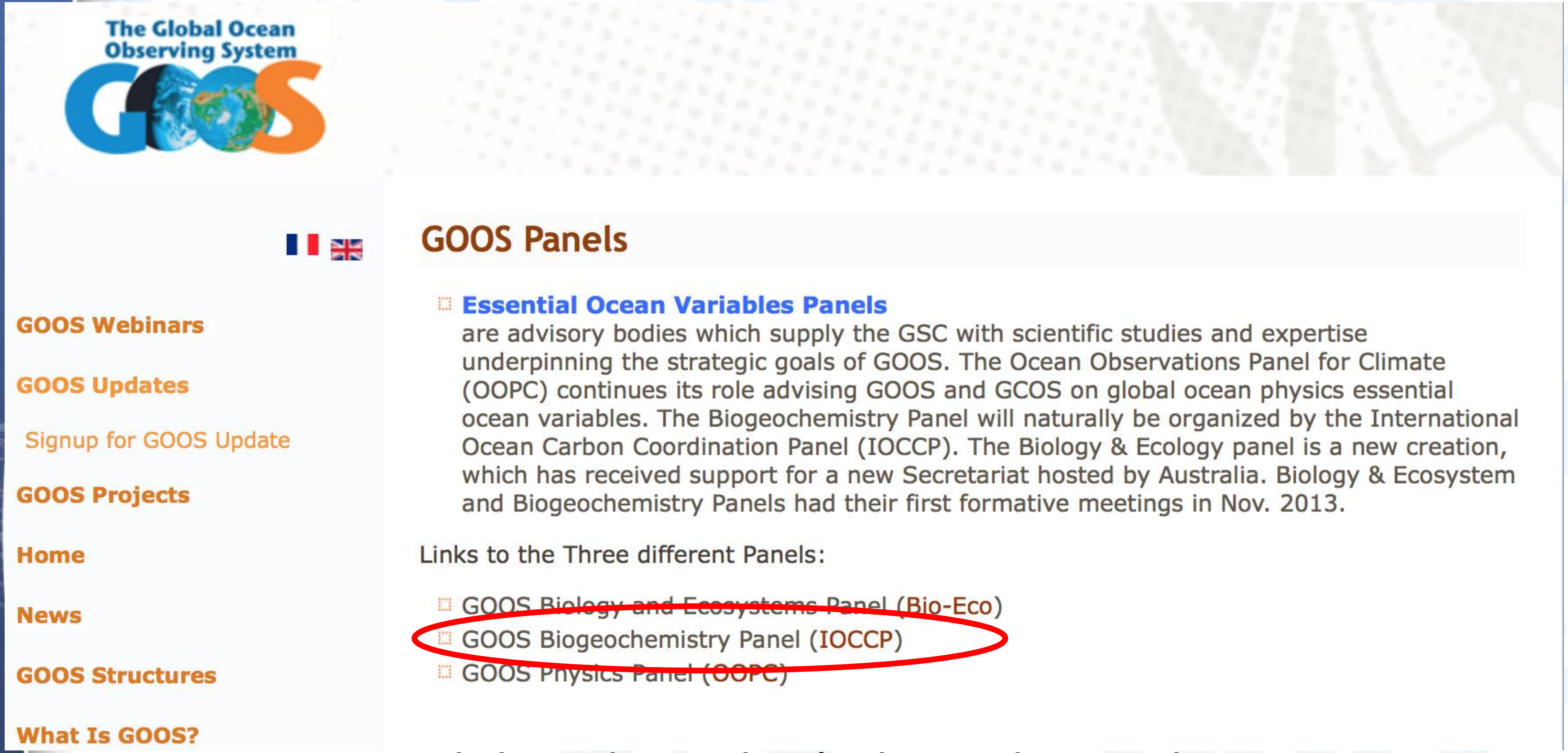


Framework for Ocean Observing

Approved governance structure

GOOS Steering Committee



(Observing technologies and networks,
Variable focus: data and products, synthesis, link to models)

IOCCP SSG

Chair
Toste Tanhua (Germany)

Underway pCO_2:
Rik Wanninkhof (USA)

Surface CO_2 Data:
Kim Currie (New Zealand)

Repeat Hydrography:
Masao Ishii (Japan)

Ocean Interior Data:
Are Olsen (Norway)

Time Series Networks:
Laura Lorenzoni (US)

Instruments and Sensors:
Todd Martz (US)

Data Management:
Benjamin Pfeil (Norway)

Nutrients
Michio Aoyama (Japan)

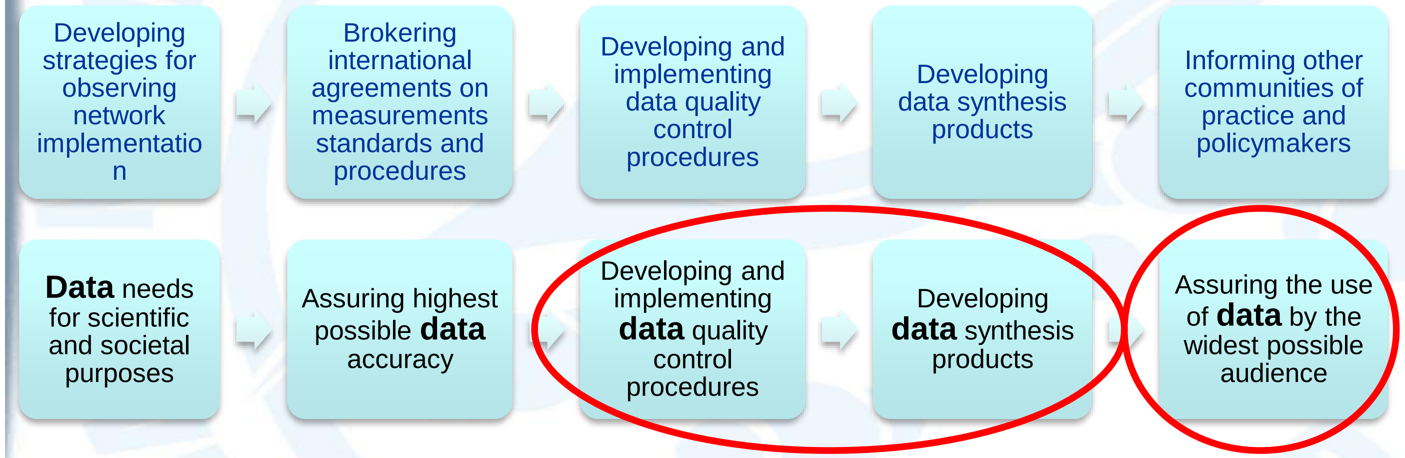
Ocean Acidification
Richard Feely (USA)

SOLAS/IMBER:
Andrew Lenton (Australia)
Niki Gruber (Switzerland)

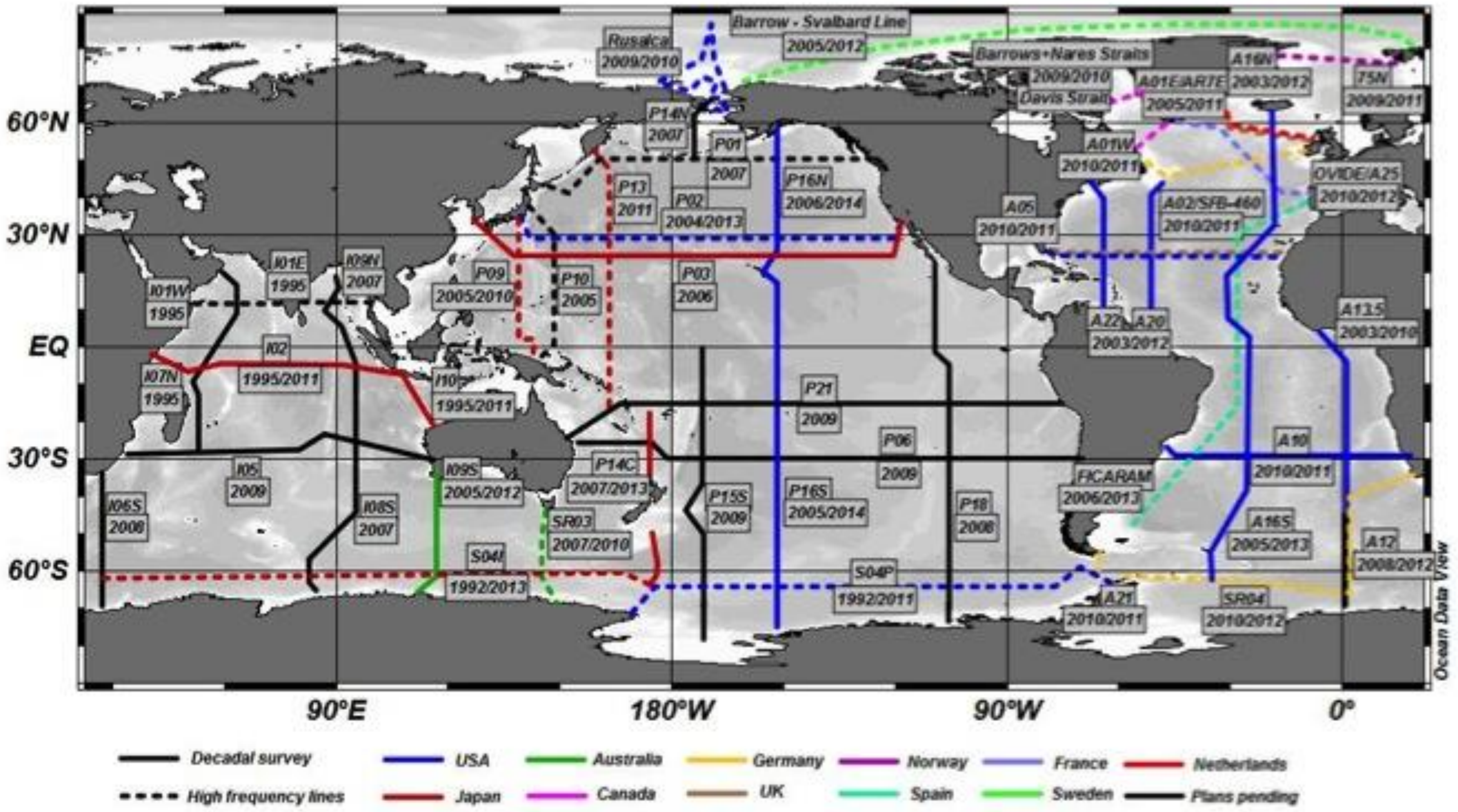
Project Director:
Maciej Telszewski (Poland)

IOCCP Mission and Field of Expertize

The IOCCP promotes the development of a global network of observations for marine biogeochemistry through technical coordination and communication services, international agreements on standards and methods, and advocacy and links to the global ocean observing system. In each of the fields of our interest (left) IOCCP follows the following scheme:

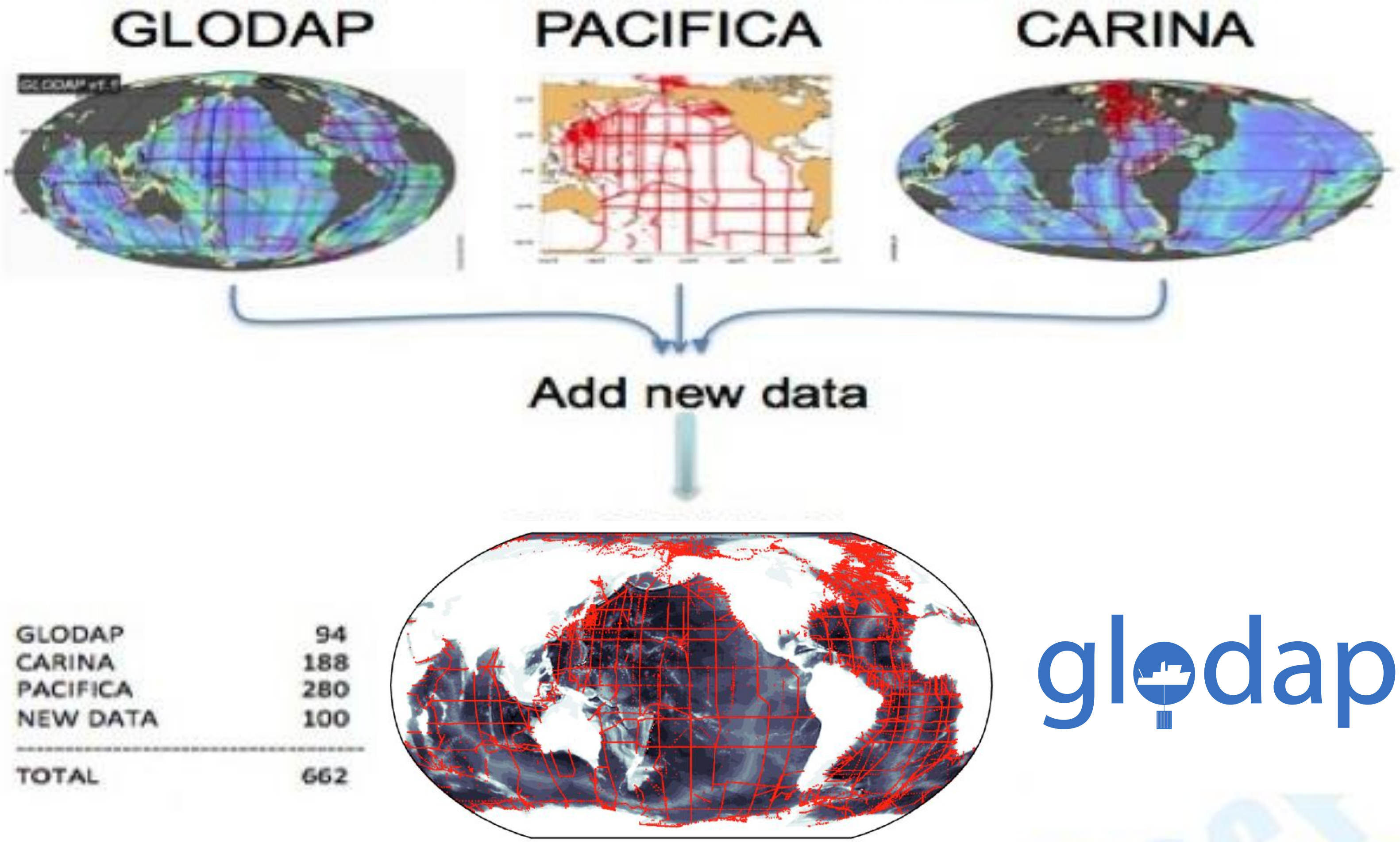


IOCCP Major Activities – Hydrographic Sections



Source: CDIAC

IOCCP Major Activities – Hydrographic Sections

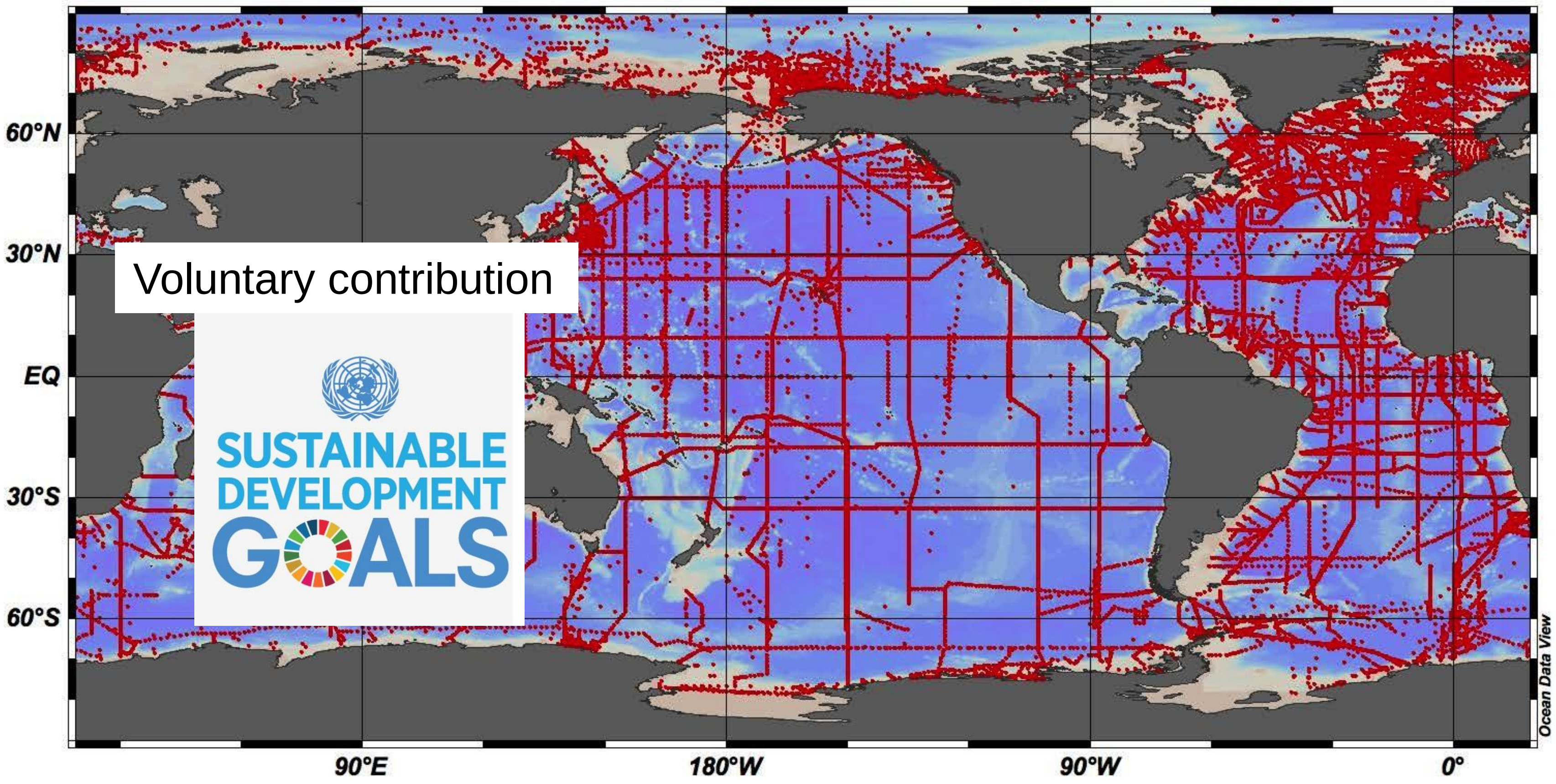


GLODAP	94
CARINA	188
PACIFICA	280
NEW DATA	100
TOTAL	662

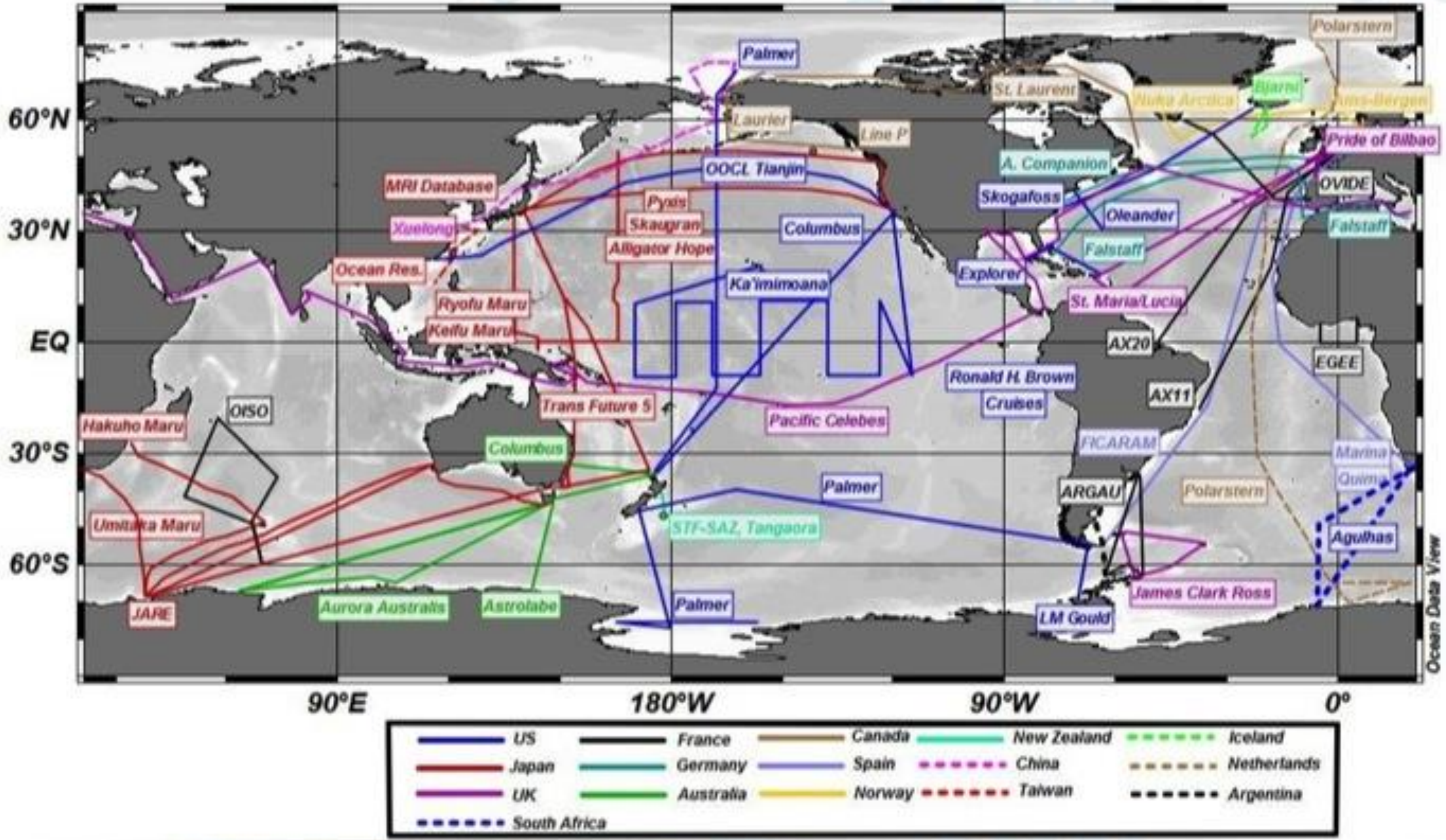
glodap v2

glodap v2

GLODAPv2 Map (45,475 stations)

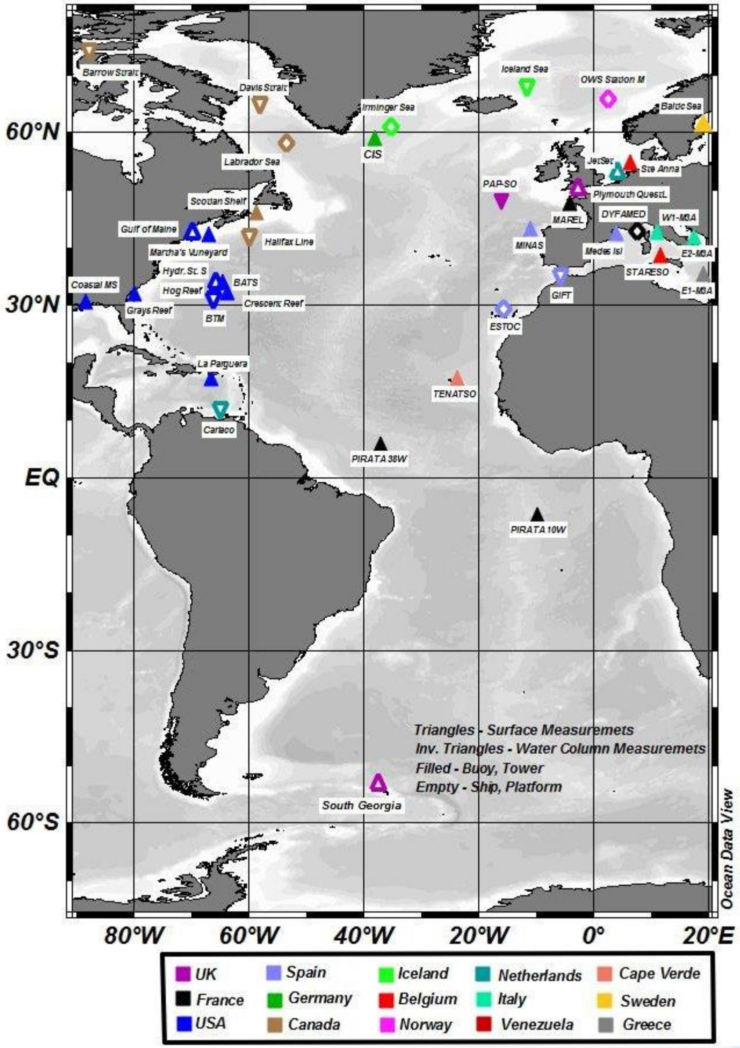


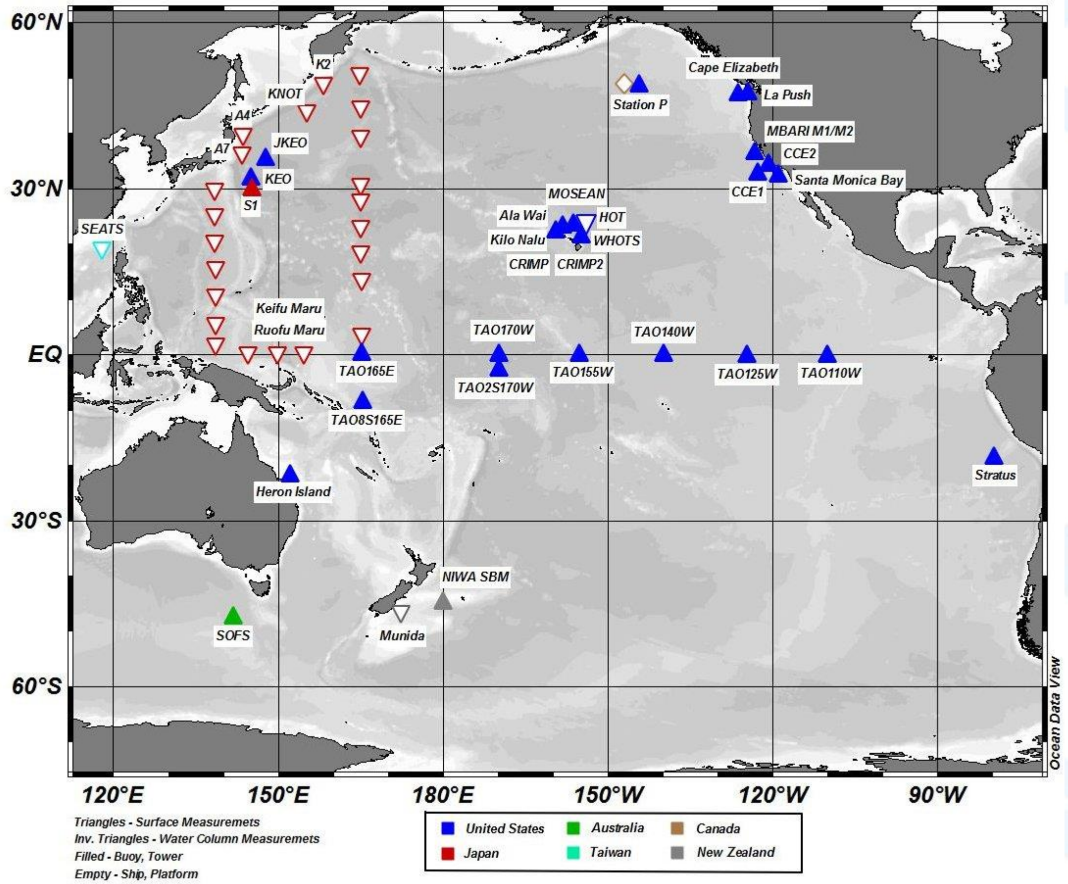
IOCCP Major Activities – Surface Ocean



Source: CDIAC

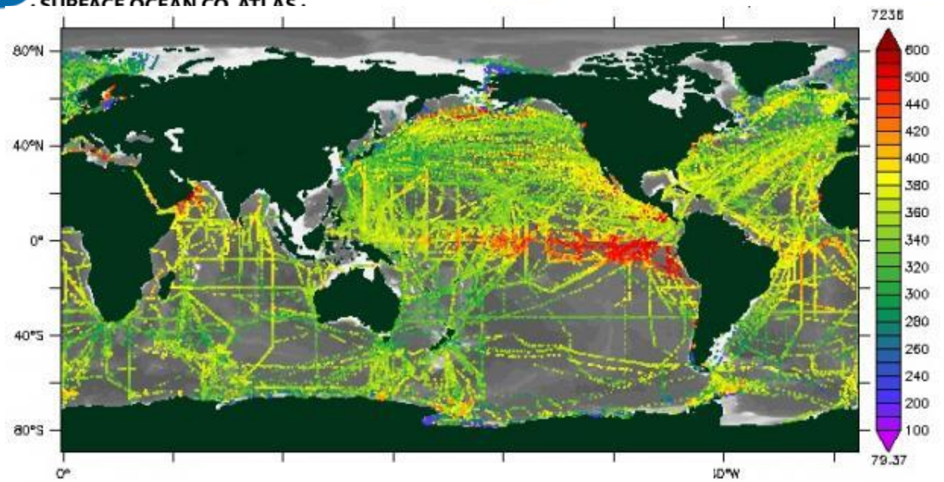
IOCCP Major Activities – Time Series stations





Source: CDIAC

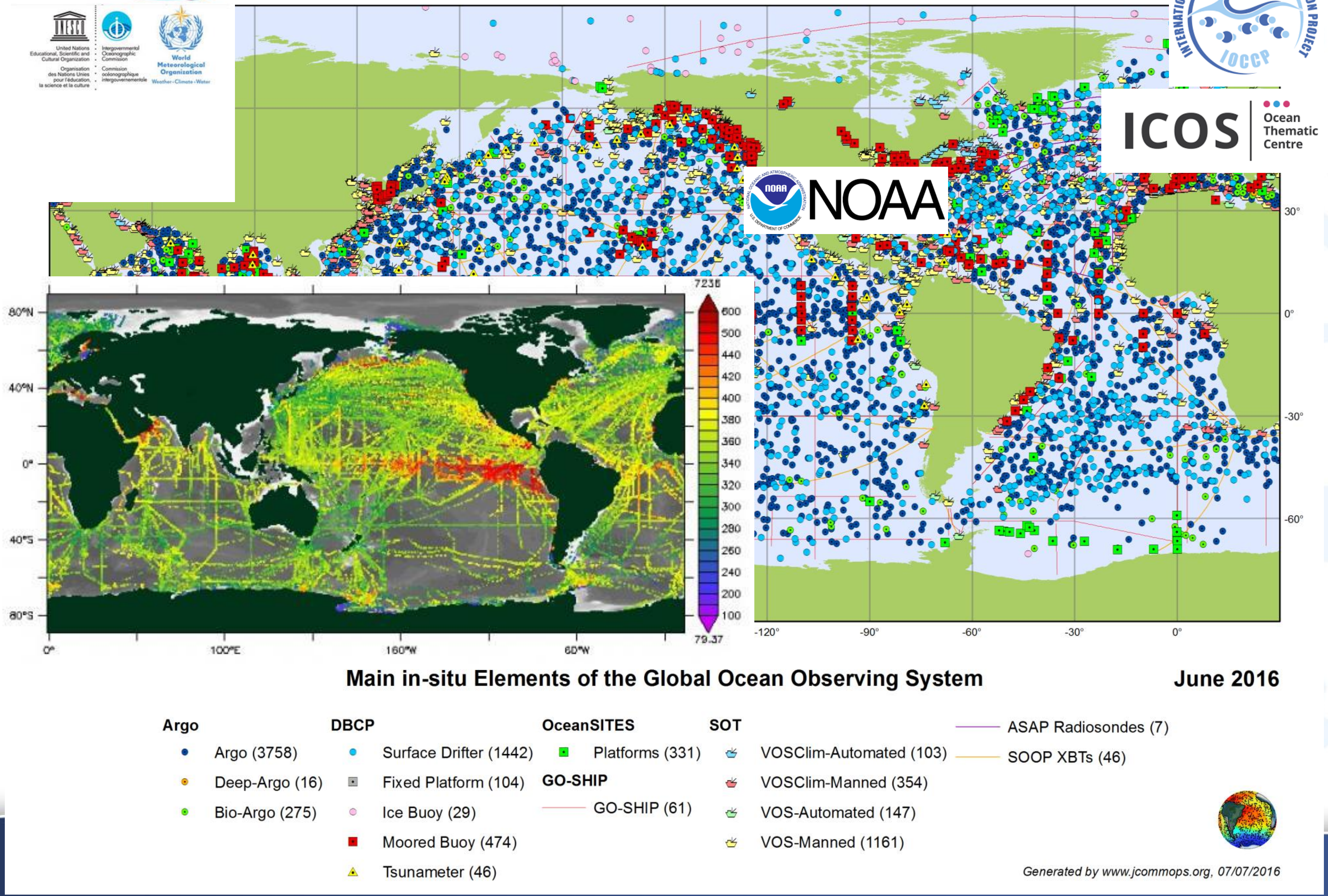
Surface Ocean CO2 Atlas



Voluntary contribution

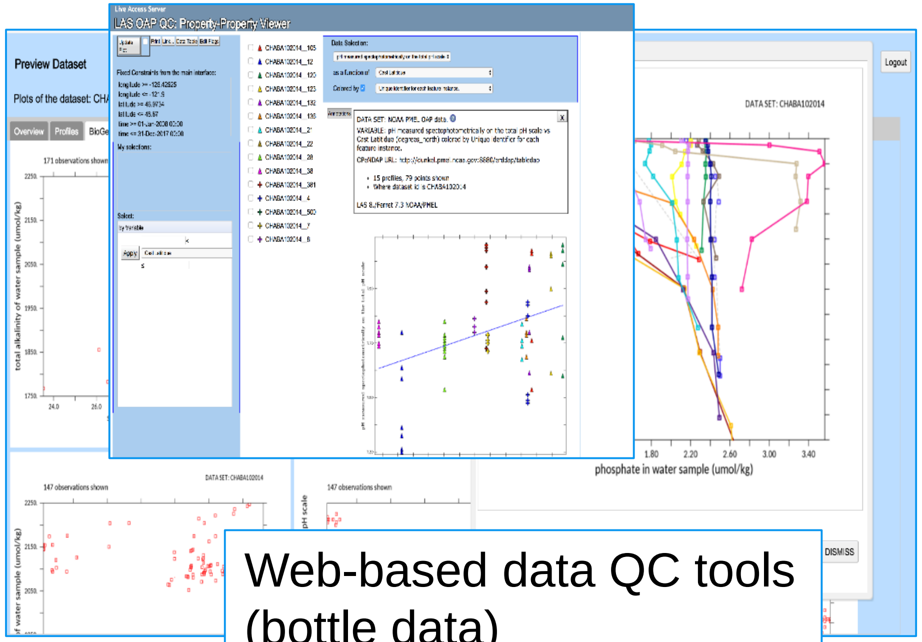
- SOCATv5 released in 2017
- Consists of 20 million fCO_2 data on > 4800 cruises covering the years 1957-2016
- Data from SOOP/VOS, RVs, fixed ocean time-series, buoys,
- Prominent users: Global Carbon Project (GCP) and Intergovernmental Panel on Climate Change (IPCC)
- DM infrastructure supported by NOAA and ICOS OTC (RINGO)

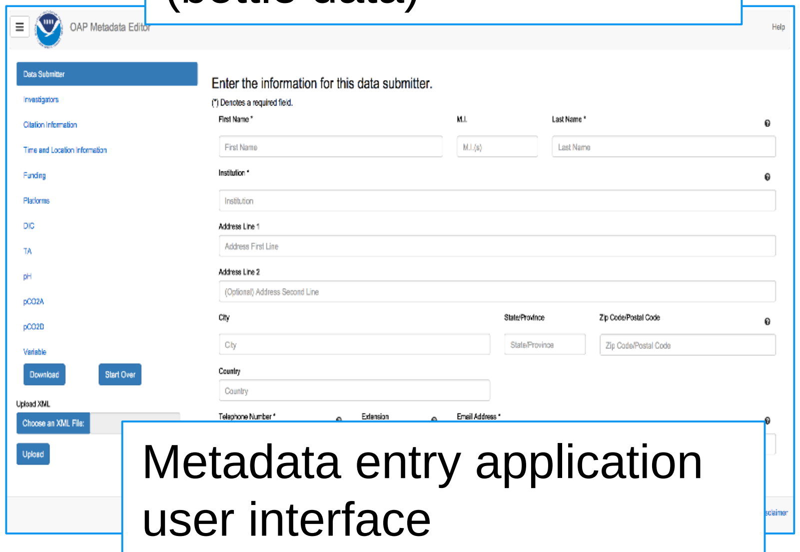
Surface ocean CO2 reference network



US-European collaboration

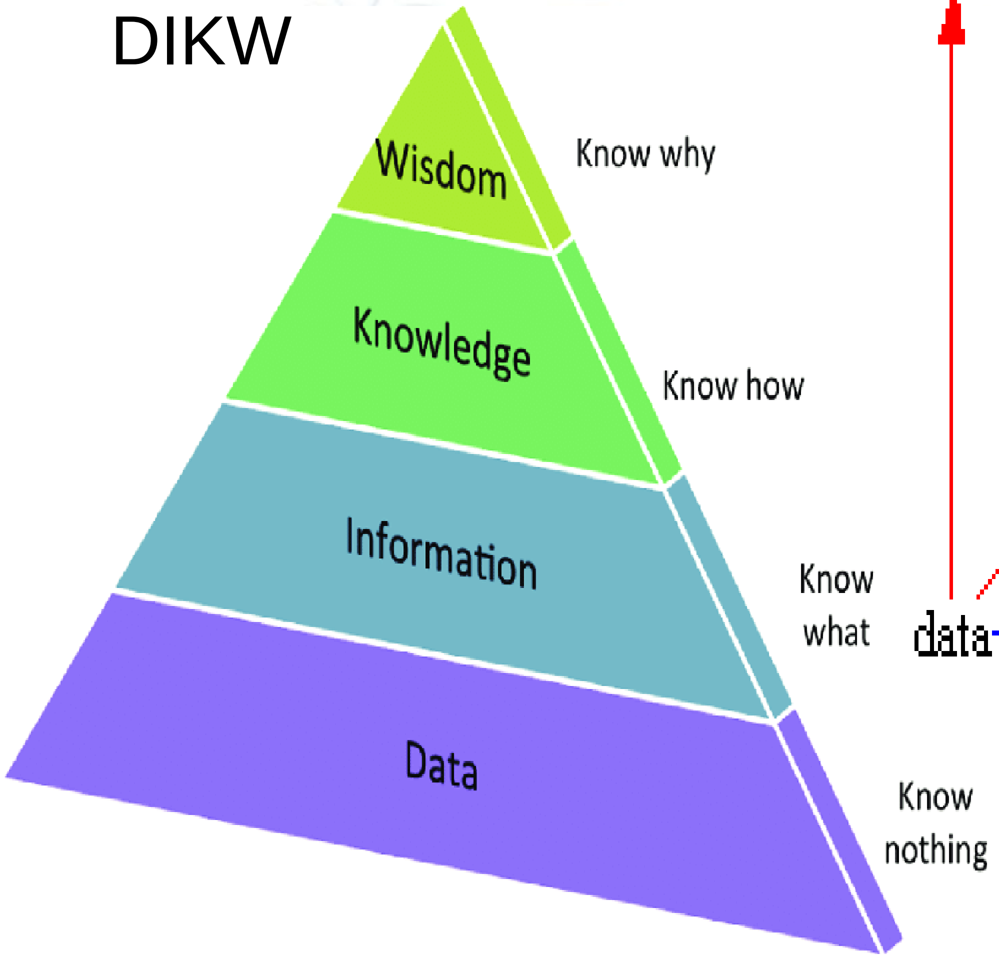
- close collaboration ***NOAA PMEL Data Integration Group*** and ***ICOS OTC***
- develop processes to provide homogeneous bgc data management and QC capabilities
- OAP and ICOS efforts are complementary, with overlap where required to better serve regional groups
- ICOS will adopt the OA metadata entry application as developed by NCEI and NOAA/PMEL



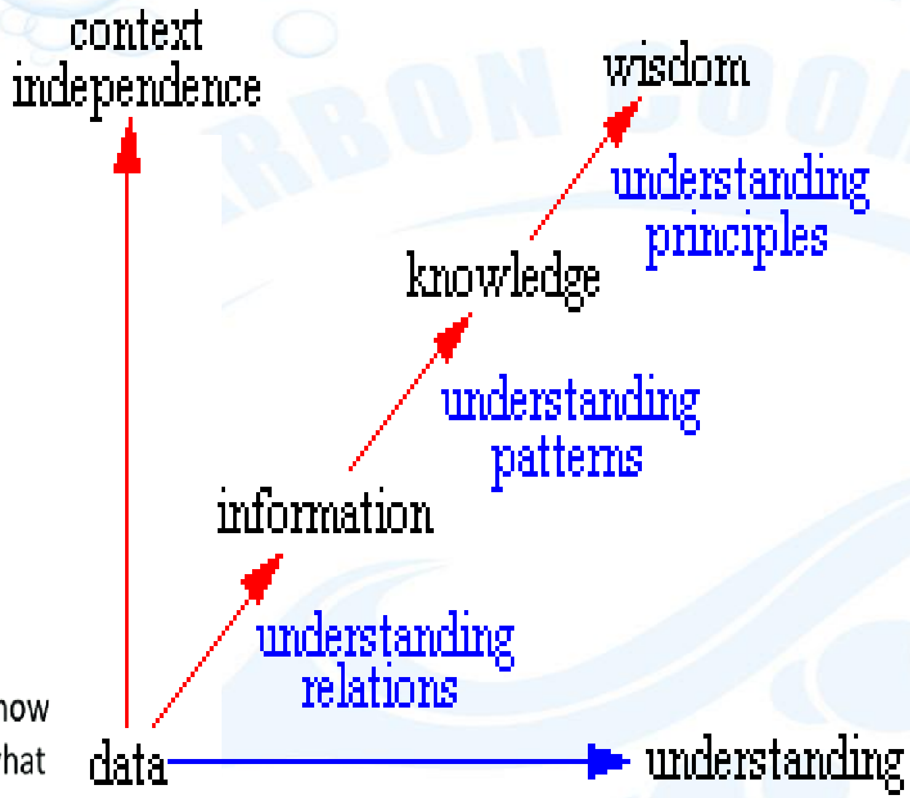


Societal Challenges

DIKW



Compiled based on Ackoff, R. L. (1989). From data to wisdom. *Journal of Applied Systems Analysis, 16*(1), 3-9. and Zeleny, M. (1987). Management support systems: towards integrated knowledge management. *Human Systems Management, 7*(1), 59-70.



Key: Systematic approach for the aggregation and integration of data
Driving force for making operational data management efforts

CO_2 IN AIR MEASUREMENTS:

INTEGRATING WITH THE ATC ??

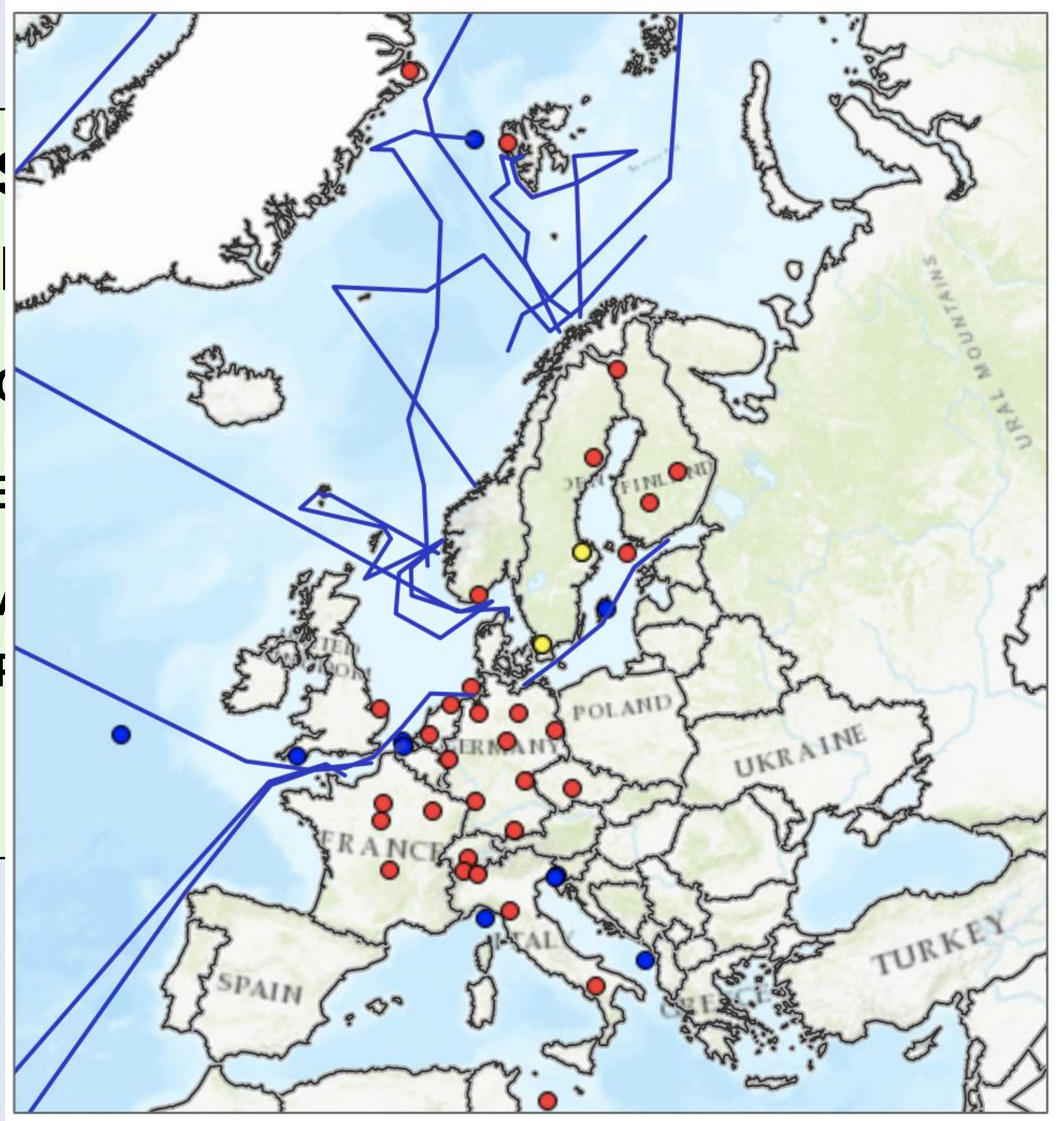
A: RATIONALE

B: TASK 3.2 OF RINGO

C: ATC CONFORMITY REQUIREMENTS

ARGUMENTS
MEASUREM

- AREAS DIFFI
- VERY UNIQUE
- INSTRUMENTA ALREADY IN F



The Problems

- Historically, atmospheric measurements on RV and VOS driven by wish for Performance Control or local ΔpCO_2
- Not tuned for best atm. measurement
- Usually no assessment of Accuracy and precision (QC)
- Requires installation of air line
- At the cost of water measurement frequency
- NOWHERE conform to ICOS ATC STANDARDS

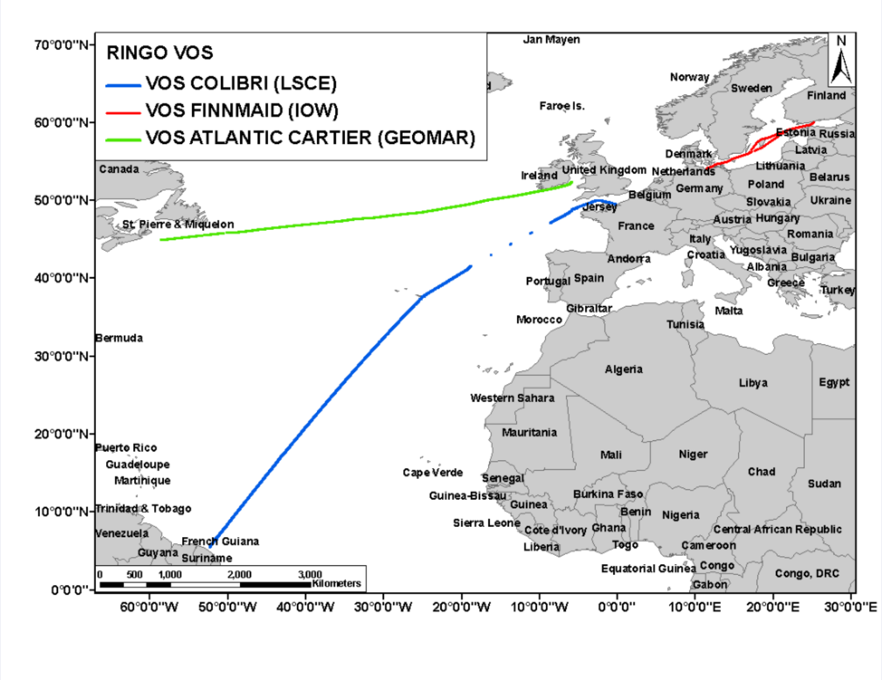
RINGO | Readiness of ICOS for Necessities of Integrated Global Observations

TASK 3.2.

Improving atmospheric measurements on Voluntary Observing Ships (VOS)

Rationale:

- Spatial vs. temporal coverage
- Not covered by atm. station grid
- <u>Potential value for improved inverse modeling</u>



THREE COMLEMENTARY TEST LINES

VOS Finnmaid (IOW)

Baltic (Lübeck – Helsinki)

- *easy to access,*
- *surrounded by ICOS atm. station network*
- *aim for „easy to move“-unit*

VOS COLIBRI (LSCE)

France – French Guiana

- *undersampled equatorial Atlantic*
- *extreme range of external conditions*

VOS ATLANTIC SAIL (GEOMAR)

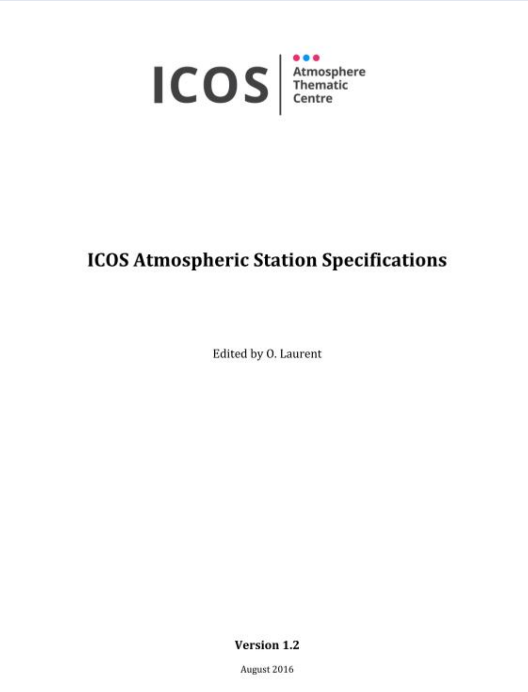
English Channel – Westwards

- *Attempt to use instrumentation also used for water measurements*
- *Cost optimization*

(MPI JENA, CAL. and ATC)

Consulting during construction phase, assembly of flask sampler, provision of calibration gases, assessment of added value through inverse modelling runs

Technological requirements for atmospheric measurements.


ICOS Atmosphere Thematic Centre

ICOS Atmospheric Station Specifications

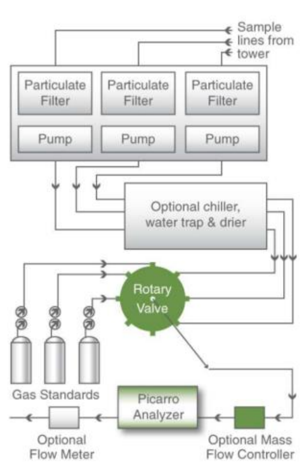
Edited by O. Laurent

Version 1.2

August 2016

Atmospheric Station:

- typically consists of a set of integrated analyzers
- that reside in a shelter with an
- air intake system **in ideal position**
- that collects air on a mast.



ATC approach:

to achive a homogeneous dataset:

- standardization of equipment,
- measurement protocol & data processing of
- associated Atmospheric Stations (AS).

Gregor Rehder and the IOW ICOS team

Continuous measurements - recommendations

Component	Guaranteed Specification Range	Precision[1] *Std. dev. (1-σ); 1' / 60' average raw data*	Repeatability[2] *Std. dev. (1-σ); 10' average raw data*
CO_2	350 - 500 ppm	< 50 ppb / 25 ppb	< 50 ppb
CH_4	1700 - 2900 ppb	< 1 ppb / 0.5 ppb	< 0.5 ppb
N2O	300 - 400 ppb	< 0.1 ppb / 0.05 ppb	< 0.1 ppb
CO	30 - 1000 ppb	< 2 ppb / 1 ppb	< 1 ppb

Test conditions : dry air; room temperature : 20 °C ± 2°C; room pressure: atmospheric pressure with a natural variation.

[1] Measuring a gas cylinder (filled with dry natural air) over 25 hours; first hour rejected (stabilization time).

[2] Measuring alternately a gas cylinder (filled with dry natural air) during 30 minutes and ambient air (not dried) during 270 minutes over 72 hours. Statistics based on the last 10 minute average data of each 30 minute cylinder gas injection (first 20 minutes rejected as stabilization time).

Table 3 : Gas analyzer performance required by ICOS (as of August 2016)

Brand	Model	Species	ICOS Compliance CO_2	ICOS Compliance CH_4	ICOS Compliance CO	Eligibility Conditions
PICARRO	G1301	$CO_2/CH_4/H_2O$	•	•	-	
PICARRO	G2301	$CO_2/CH_4/H_2O$	•	•	-	
PICARRO	G2401	$CO_2/CH_4/CO/H_2O$	•	•	•	With ICOS specifications
LGR	907-0015	$CO/N_20/H_2O$	-	-	•	Precaution with Δ temperature
LGR	913-0015 (EP)	$CO/N_20/H_2O$	-	-	•	

• : ICOS Compliant - : Not applicable

Table 4: list of continuous gas analyzers meeting the ICOS specifications (as of August 2016)

Calibration and target gas requirements

Set of 3 Calibration and 2 Target Gases

- all by CAL
- VERY unusual range for the atm community
- recommended to be stored horizontally
- Cylinder: 6061 Aluminum cylinder manufactured by Luxfer UK
- Cylinder valve: Rotarex membrane valve (D200 type with PCTFE seat).
- Pressure regulator fitting: DIN 14 by preference, CGA 590 also possible

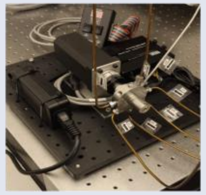
2015		CO_2		CH_4		CO		N_2O	
	Trend	≈ +2.5 ppm/yr		≈ +5 ppb/yr		≈ 0 ppb/yr		≈ +1 ppb/yr	
	Site	Bckgnd	Peri-urban	Bckgnd	Peri-urban	Bckgnd	Peri-urban	Bckgnd	Peri-urban
3 CAL set	CAL 3	450	470	2100	2200	250	400	340	345
	CAL 2	415	420	1950	1970	150	200	330	333
	CAL 1	380	380	1800	1800	60	60	320	320
4 CAL set	CAL 4	450	470	2100	2200	250	400	340	345
	CAL 3	420	430	2000	2060	175	200	335	337
	CAL 2	400	410	1900	1930	100	100	330	330
	CAL 1	380	380	1800	1800	60	60	320	320
	LTT	450	470	2100	2200	250	400	340	345
	STT	400		1900		100		330	
	STWS	400		1900		100		330	

Table 12: Values of the mole fractions recommended for the gas cylinders.

Continuous measurements - recommendations

– **Shelter** *enclosed mounting rack, air-conditioned (+/- 2° C, adapted to on-site conditions, beware of overheating / condensation effects!)*

– **Air-sampling & -distribution system** *for different inlet lines / cylinders recommended: VICI Valco model EMT2SD***



– **Time server** *helps with time stamp to identify origin of gas analyzed*

– **Pressure regulators** *two models accepted:*

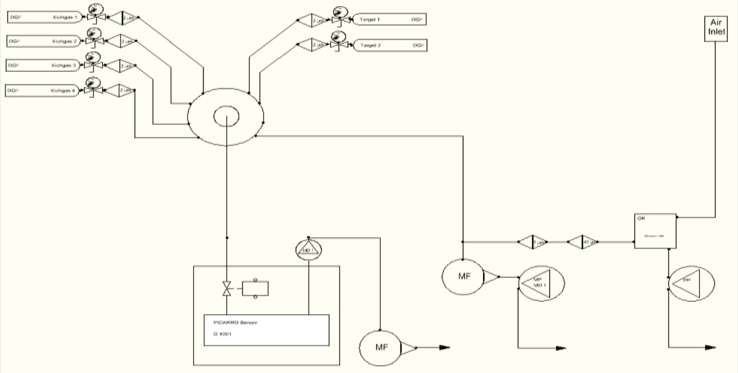
- *SCOTT MODEL 14 M-14C (or -14B) Nickel-plated brass.*
- *TESCOM Serie 64-3400 stainless steel electropolished, PCTFE valve seat & stainless steel high purity gas pressure gauge.*

– **Tubing** *Synflex 1300 (EATON), alternatively: stainless steel tubing*
Attention: outdoor/indoor delta T → risk of water condensing!
Diameter & flushing flow rate → residence time ideally < 1 minute, e.g. ¼" Synflex tubing (<40m), flushing flow rate around 5-10 SLPM.

*** Alternatives possible after proving its suitability (dead volume, material compatibility, absence of leakages), best to contact ATC for guidance.*

Continuous measurements - recommendations

– **Plumbing recommendations** *no standardized Architecture imposed, but station PI may best contact ATC for guidance, station designs can be provided if requested.*



Example of station design by ATC, one sample height

– **Sampling line** *required to continuously flush the line, with pump) for each line or a shared pump or blower. Lines at best in* ***one single piece!***

At least the following additional sampling lines are required:

- *one dedicated sampling line at highest sampling height for the travelling instrument*
- *a spare sampling line at each sampling height for quality control purpose*

→*allows swapping lines when one is obstructed.*

- *rain guard for each sampling air inlet, additional filters recommended.*
- *Dryer (peltier, fridge etc.) in the sampling line recommended.*

– **Station ancillary data** *automated monitoring of mandatory station ancillary data:*

- *flushing flow rate each tubing*
- *instrument flow rate*
- *room temperature*

…however, the data will always be processed by ATC !

The weather station

In order to characterize the weather conditions at the ambient air sampling site, ICOS requires monitoring of the following meteorological parameters:

- barometric pressure
- relative humidity
- air temperature
- wind direction
- wind speed

Variable	*Range* [1]	*Resolution*[2]	*Mode of measurement*[3]	*Required measurement uncertainty* [4]	*Sensor time constant* [5]	*Output average time* [6]	*Achievable uncertainty* [7]
Wind speed	0 to 75m/s	0.5m/s	Averaging	0.5m/s [0m/s; 5m/s] 10% [5m/s; 75m/s]	Distance Constant	2 and 10min	**0.5m/s [0m/s; 5m/s]** **10% [5m/s; 75m/s]**
Wind direction	0 to 360°	1°	Averaging	5°	1s	2 and 10min	**5°**
Temperature (Air)	-80 to +60°C	0.1°C	Instantaneous	0.3K [-80°C; -40°C] 0.1K]-40°C; +40°C] 0.3K]+40°C; +60°C]	20s	1min	**0.2 K**
Relative humidity	0 to 100%	1%	Instantaneous	1%	40s	1min	**3%**
Barometric pressure	500 to 1080hPa	0.1hPa	Instantaneous	0.1hPa	20s	1min	**0.3 hPa**

Table 5: WMO operational measurement uncertainty requirements and instrument performance (Annex 1.B of WMO-N. 8 -*Guide to Meteorological Instruments and Methods of Observation*, 7th Ed.)

Take Aways and Points for Discussion

– Clear Documentation and requirements for ATC-conform measurements

- Digesting data from different source would need a paradigm shift at ATC

- Make up your mind why atm. Measurements on the ship are taken, and who will use it

- There is a mismatch in the appreciation of atm. Measurments between OTC (Class 1 criterion) and ATC

- MORE AFTER RINGO TP3.2 IMPLEMENTATION

- ??? Peripheral Package (close to GO-Dry Box)

Gregor Rehder and the IOW ICOS team

ICOS OTC Workshop, March 2018, Bergen

The Team

Gregor Rehder

Oliver Schmale

Bernd Schneider

Jens Müller

Bernd Sadkowiak

Michael Glockzin

Acknowledgements

BALTIC GAS

ICOS integrated carbon observation system

Thanks to our collegues from SYKE

Petri Maunula
Seppo Kaitala

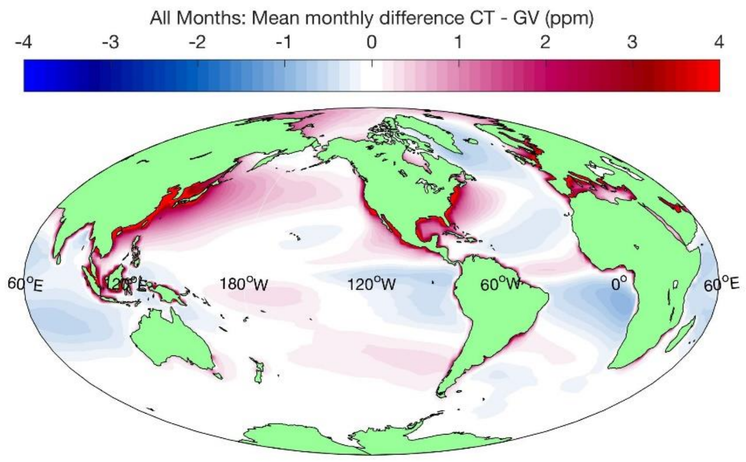
and FINNLINES

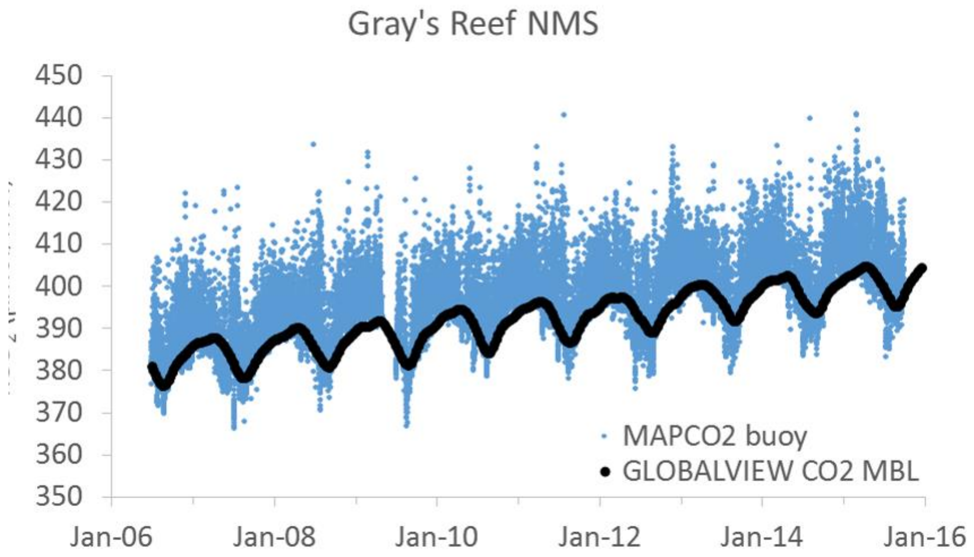
Improving the ΔpCO_2 estimates

Impacts of regional patterns of atmospheric CO_2 on ocean uptake

- For ΔpCO_2 we use zonal averaged (y,t) atmospheric CO_2 values

Carbon Tracker (3D)- Globalview-CO_2(2D)

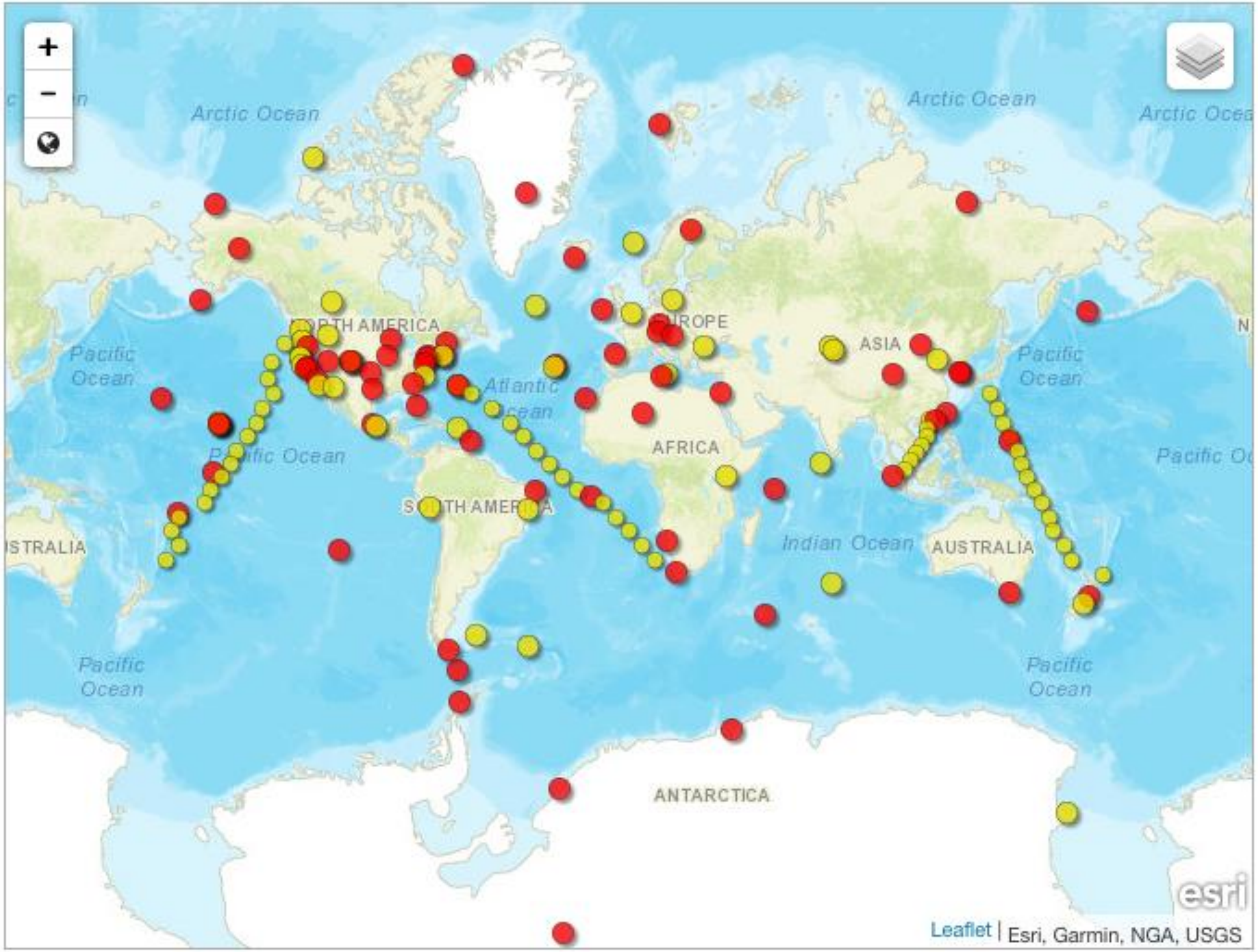


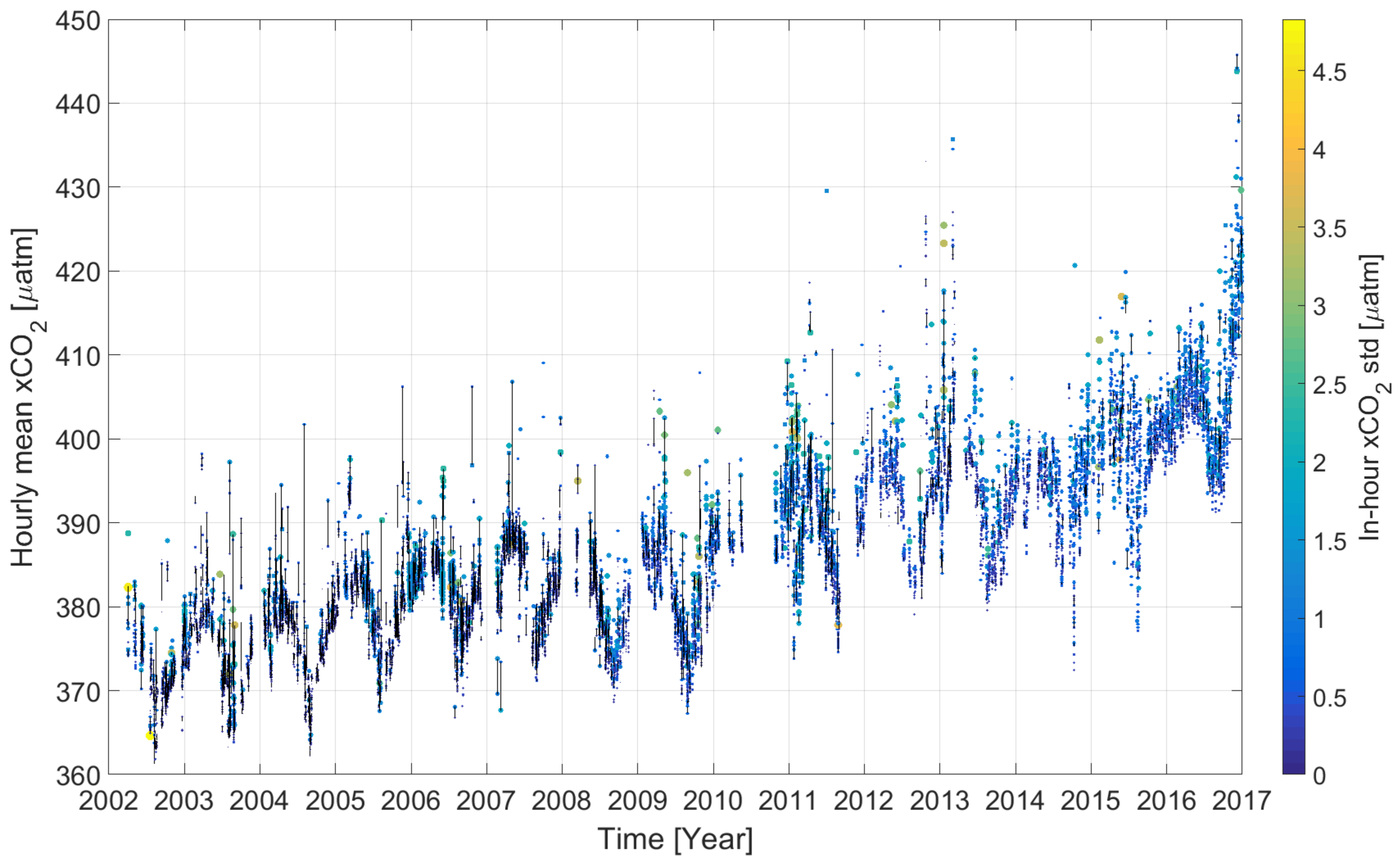


Ships and Mooring instruments provide precise CO_2 estimates.
Need to validate these for:

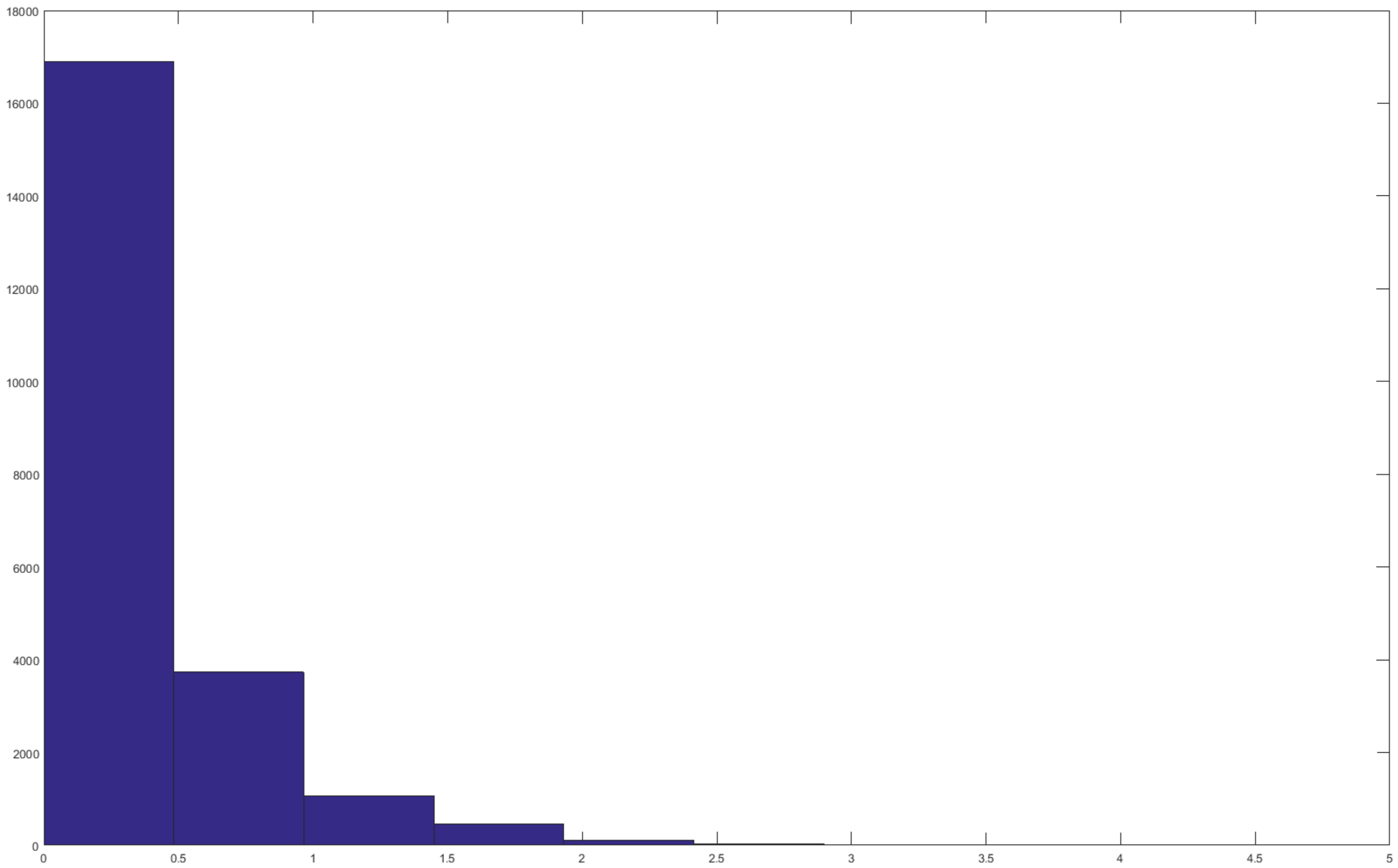
- Better air-sea CO_2 flux estimates
- Validation atmospheric transport models
- Validation of satellite sensors (OCO)

Cooperative flask sampling stations ESRL/GMD





Hourly mean xCO_2 [μatm]
450
440
430
420
410
400
390
380
370
360
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
Time [Year]
In-hour xCO_2 std [μatm]
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

DATA SET: SOCAT v5 Data Collection

VARIABLE: fCO_2 recommended (μatm)

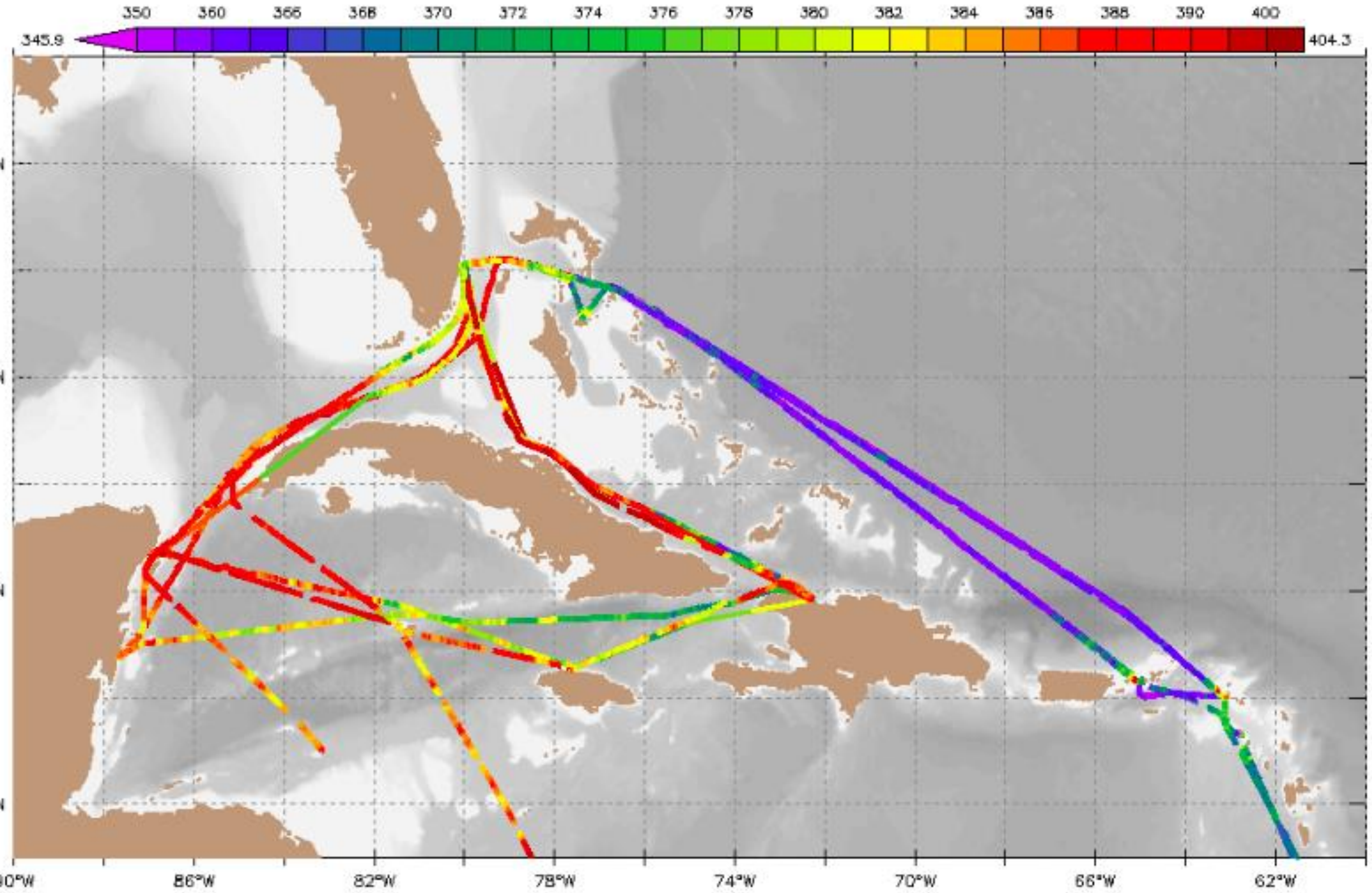
01-Jan-2017 00:00 to 31-Dec-2017 00:00

OPeNDAP URL: http://ferret.pmel.noaa.gov/socat/erddap/tabledap

- 9 trajectories, 17126 points shown
- Where fCO2_recommended is valid
- Where WOCE CO2 water is 2

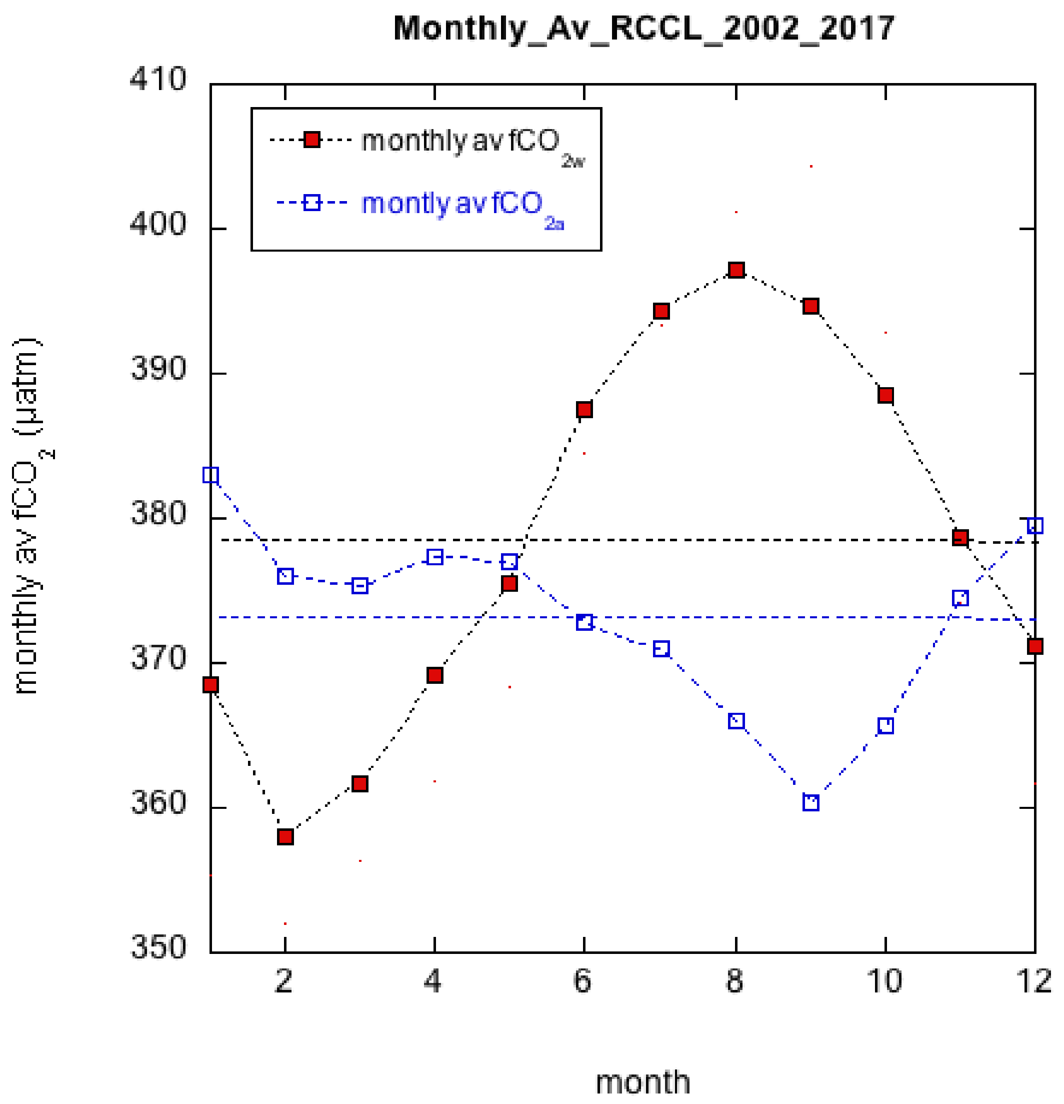
LAS 8./Ferret 7.31 NOAA/PMEL

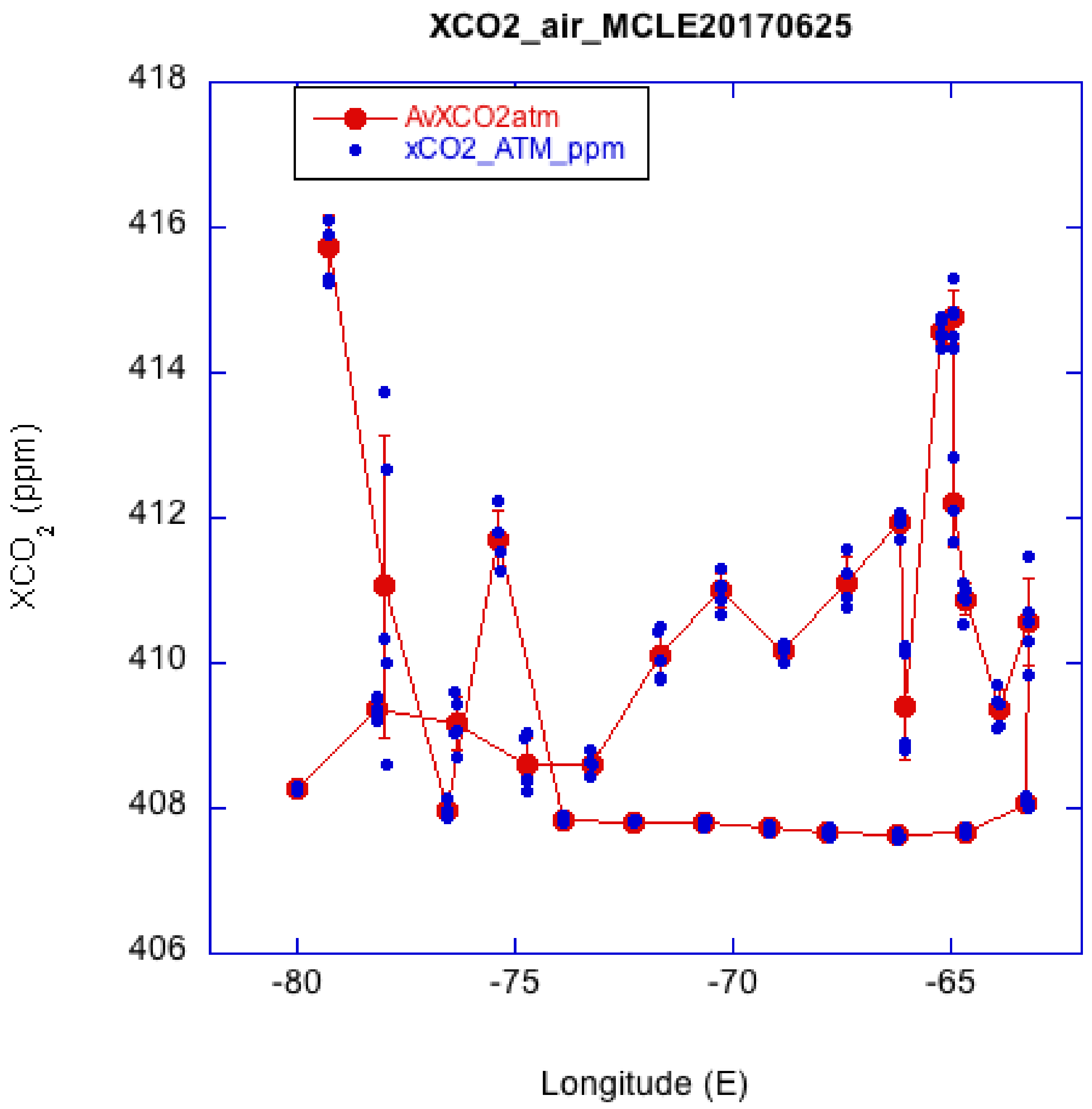
Print + fCO2 recommended

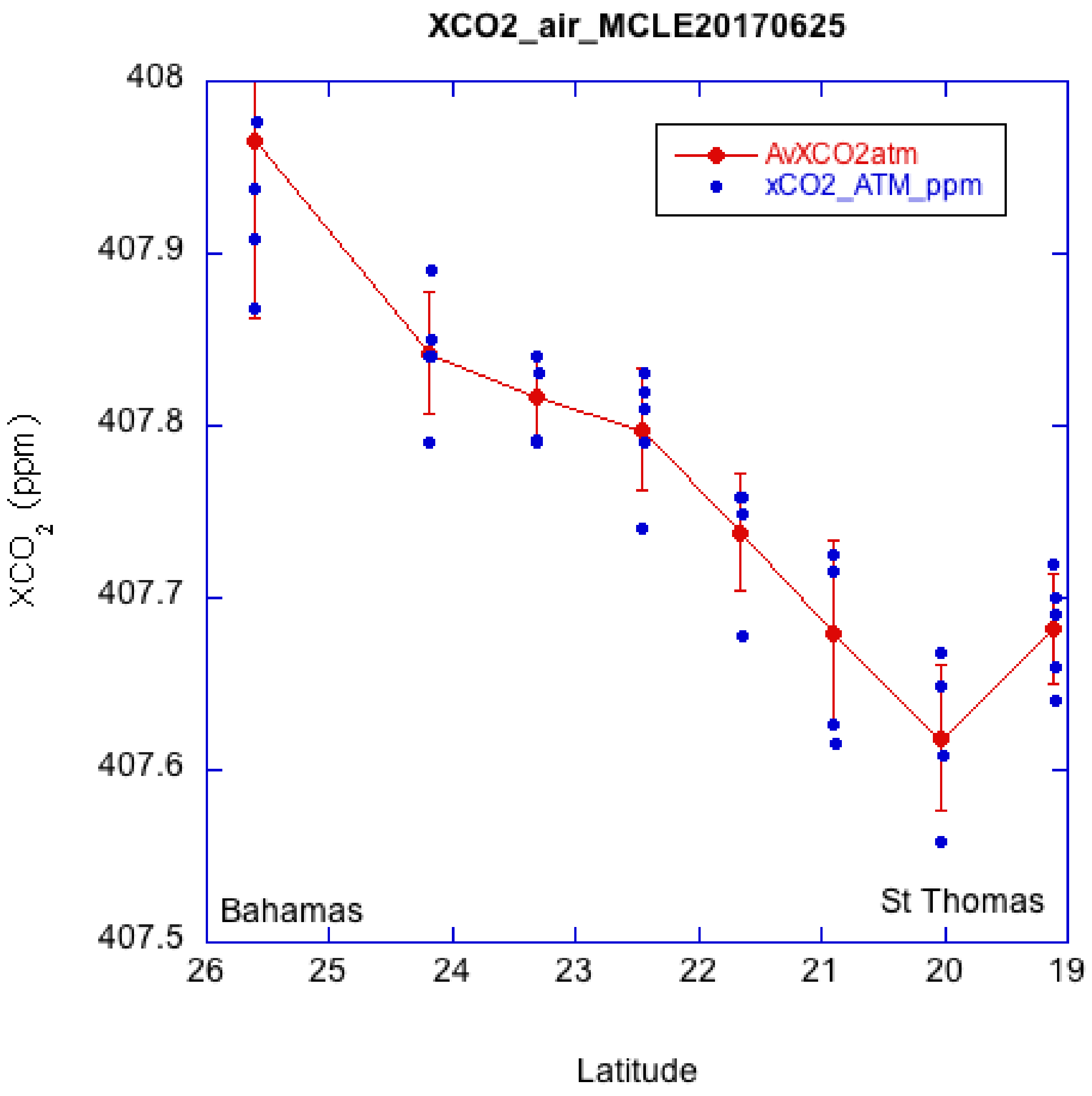


ΔpCO$_2$ Caribbean Sea

Seasonal cycle of pCO$_{2w}$ in opposite phase and greater than seasonal cycle pCO$_{2air}$

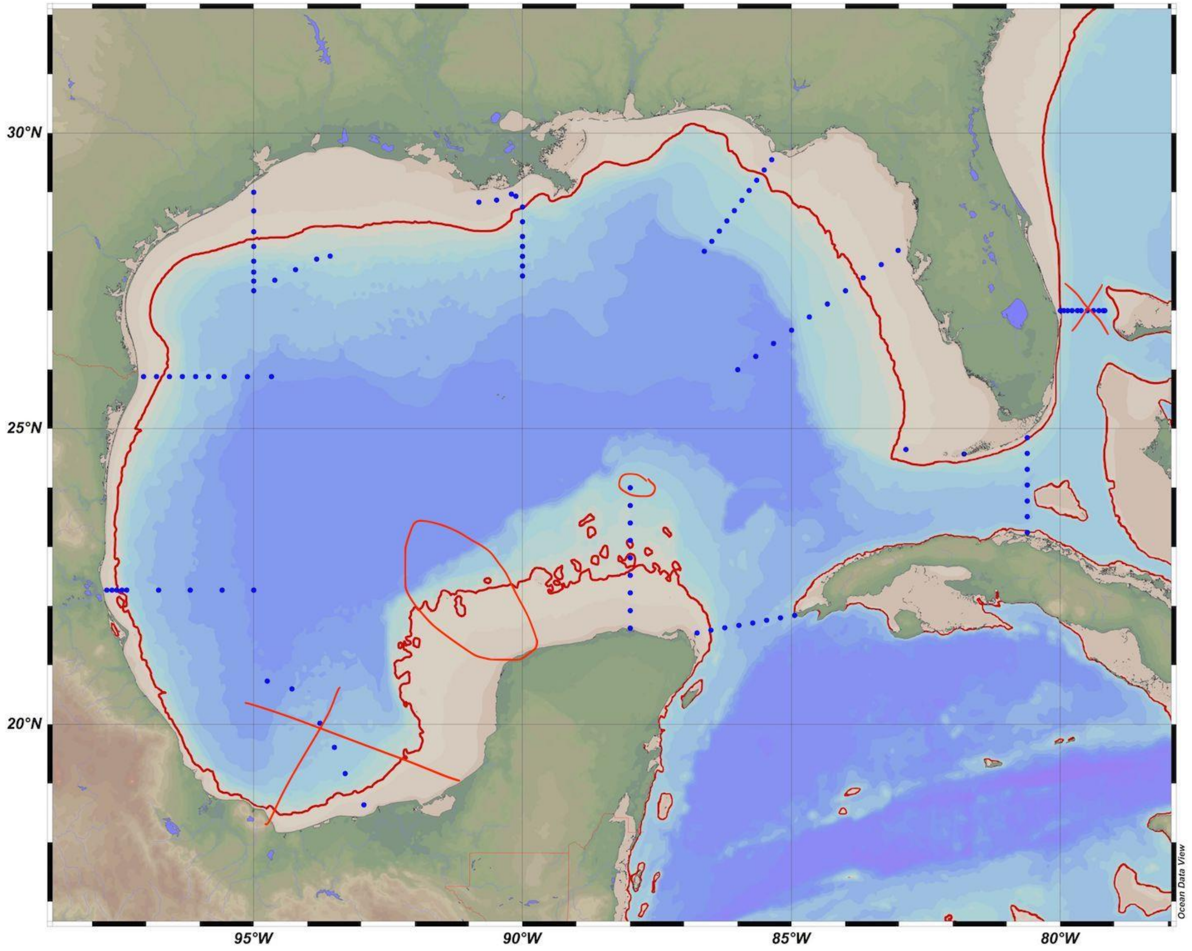


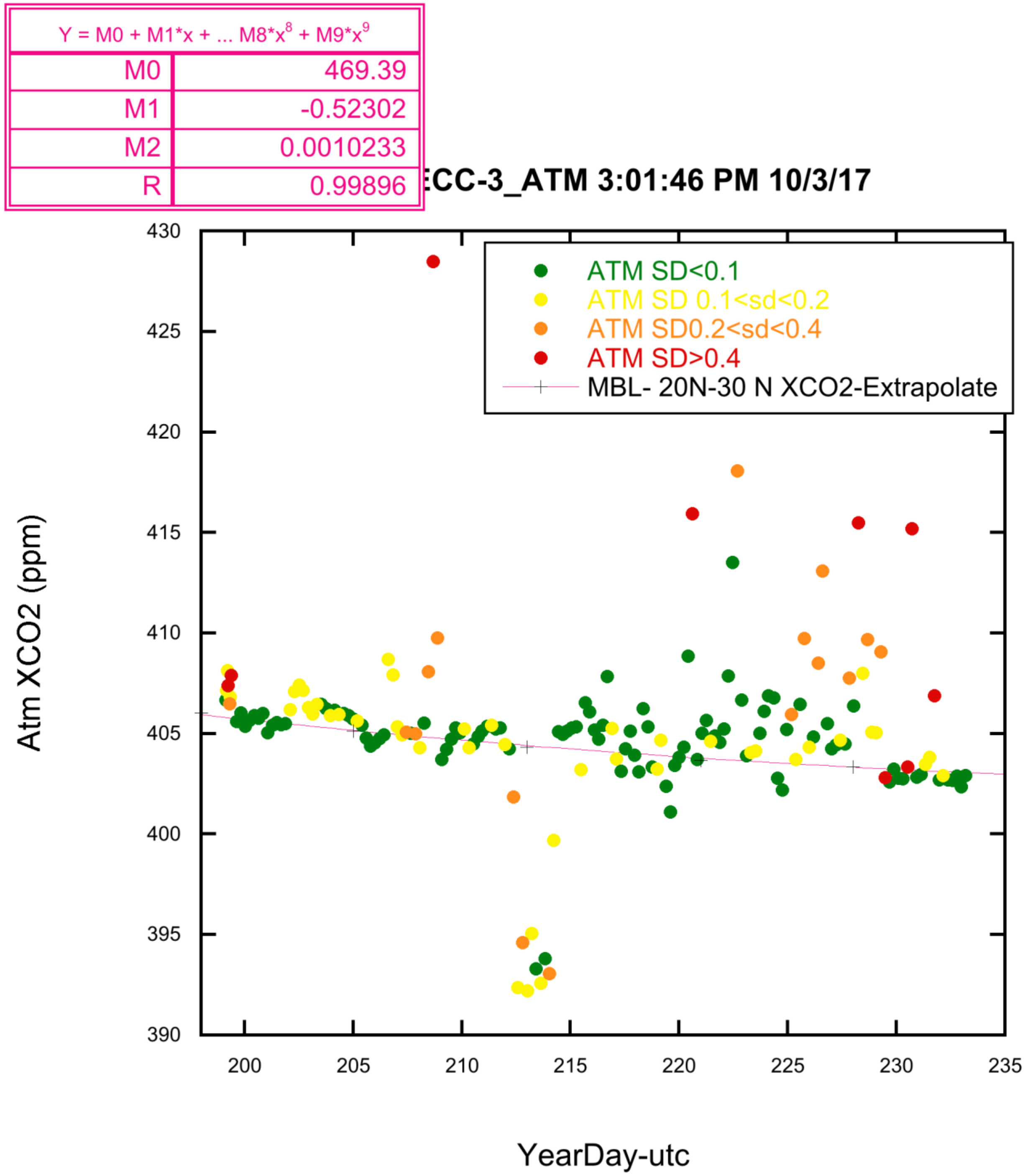

XCO2_air_MCLE20170625
AvXCO2atm
xCO2_ATM_ppm
418
416
414
412
410
408
406
-80
-75
-70
-65
XCO2 (ppm)
Longitude (E)



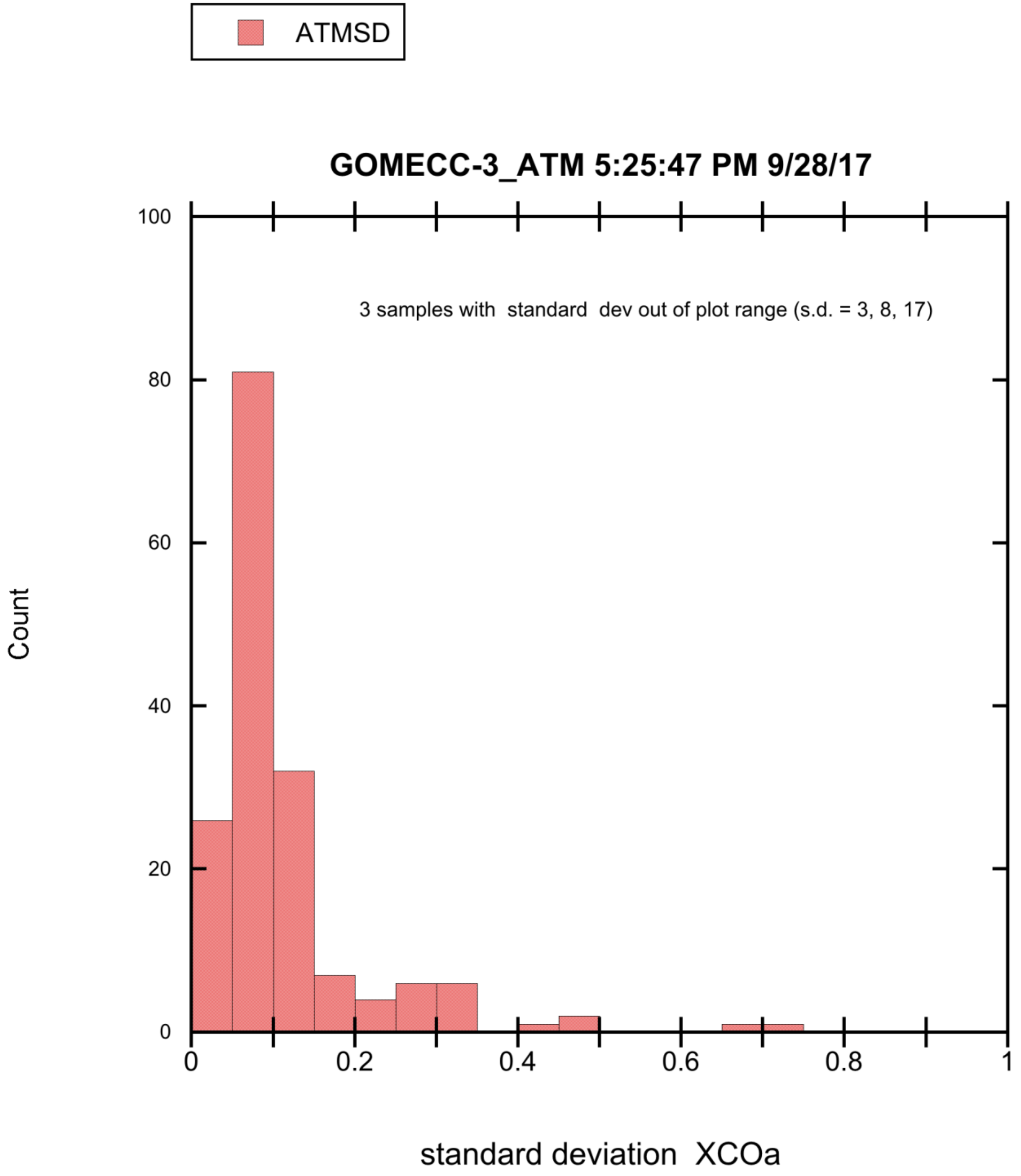
XCO2_air_MCLE20170625
XCO$_2$ (ppm)
Latitude
AvXCO2atm
xCO2_ATM_ppm
Bahamas
St Thomas
408
407.9
407.8
407.7
407.6
407.5
26
25
24
23
22
21
20
19

GOMECC-3 July 2017

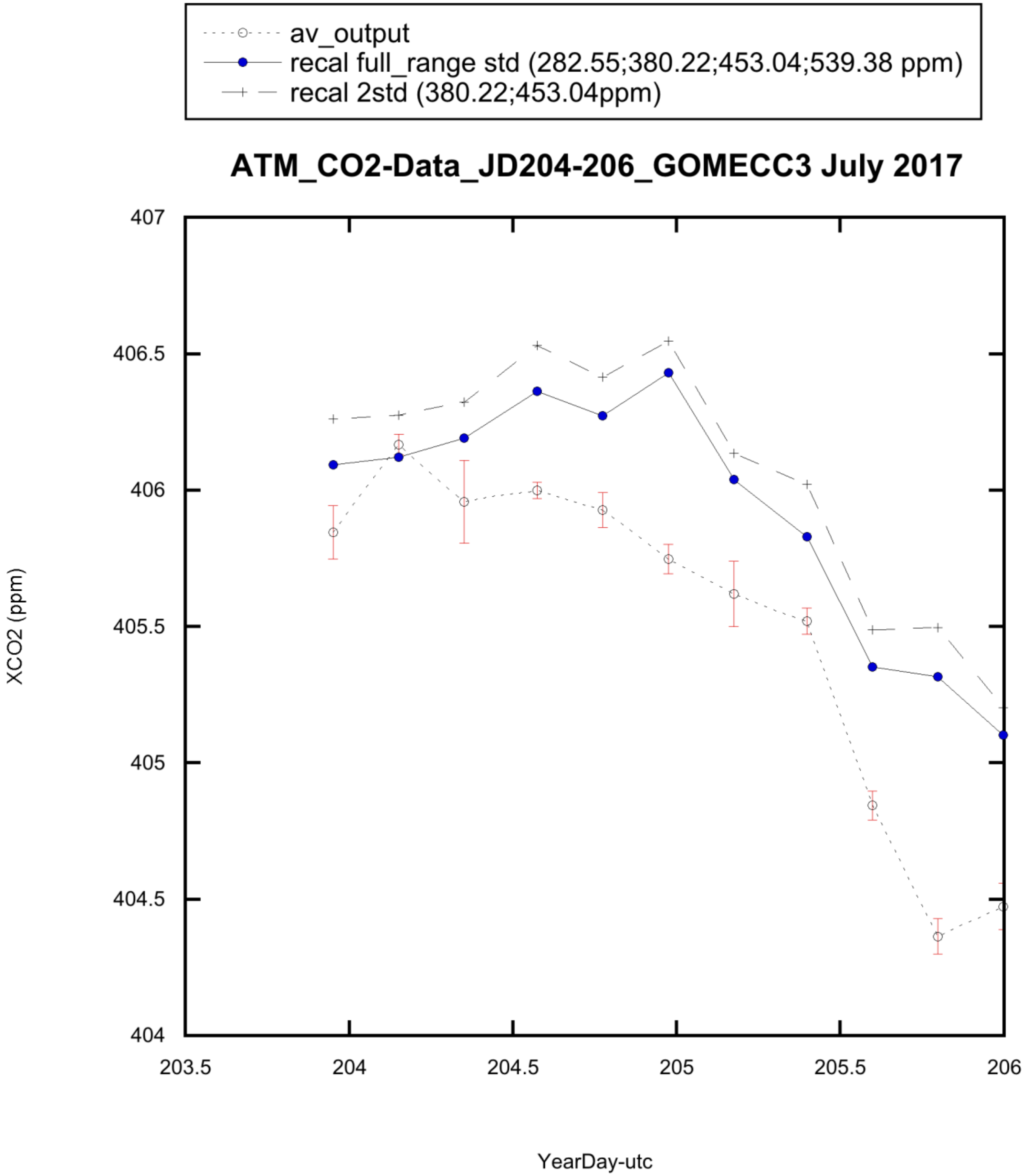




Y = M0 + M1*x + ... M8*x8 + M9*x9
M0 469.39
M1 -0.52302
M2 0.0010233
R 0.99896
ECC-3_ATM 3:01:46 PM 10/3/17
ATM SD<0.1
ATM SD 0.1<sd<0.2
ATM SD0.2<sd<0.4
ATM SD>0.4
MBL- 20N-30 N XCO2-Extrapolate
Atm XCO2 (ppm)
YearDay-utc
430
425
420
415
410
405
400
395
390
200
205
210
215
220
225
230
235

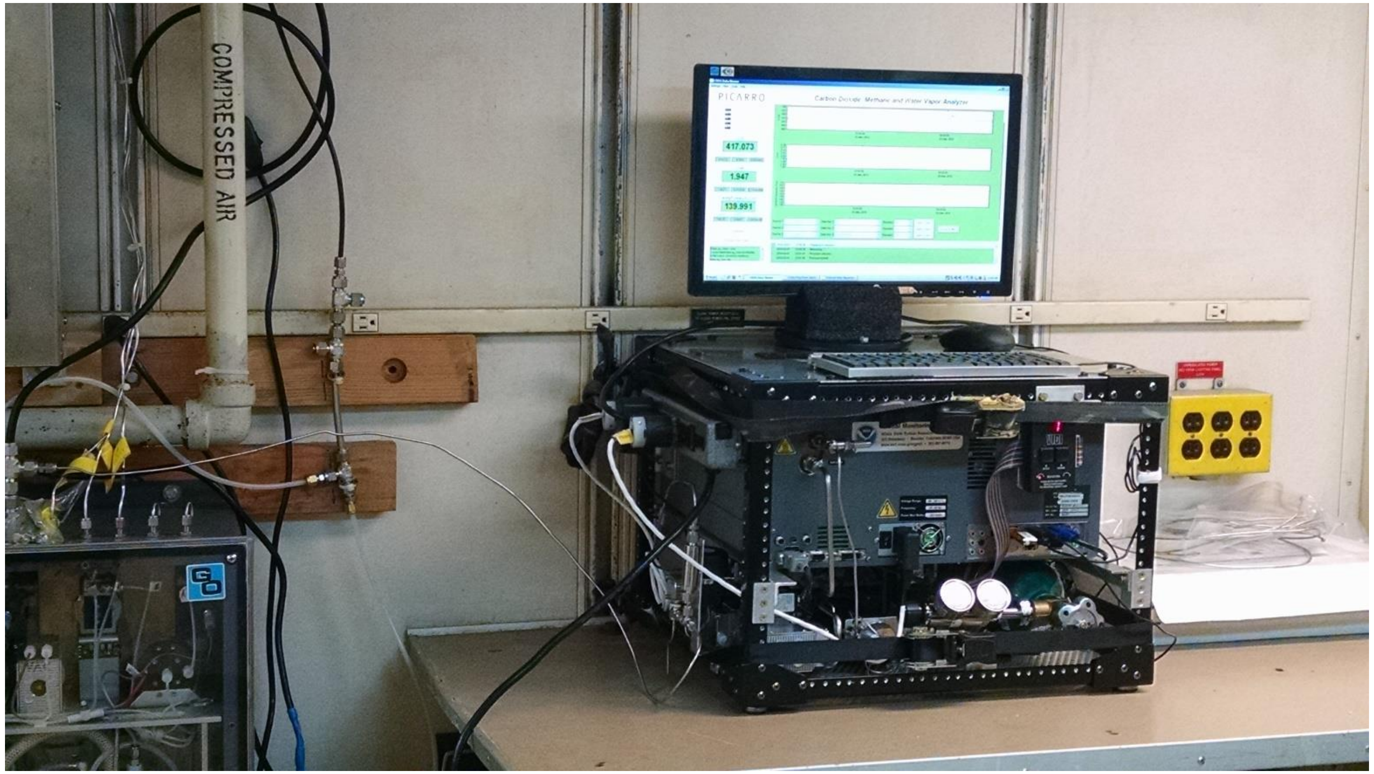


ATMSD
GOMECC-3_ATM 5:25:47 PM 9/28/17
3 samples with standard dev out of plot range (s.d. = 3, 8, 17)
100
80
60
40
20
0
Count
0
0.2
0.4
0.6
0.8
1
standard deviation XCOa



av_output
recal full_range std (282.55;380.22;453.04;539.38 ppm)
recal 2std (380.22;453.04ppm)
ATM_CO2-Data_JD204-206_GOMECC3 July 2017
XCO2 (ppm)
407
406.5
406
405.5
405
404.5
404
203.5
204
204.5
205
205.5
206
YearDay-utc

Transportable System (ESRL/GMD) on NOAA SHIP BROWN



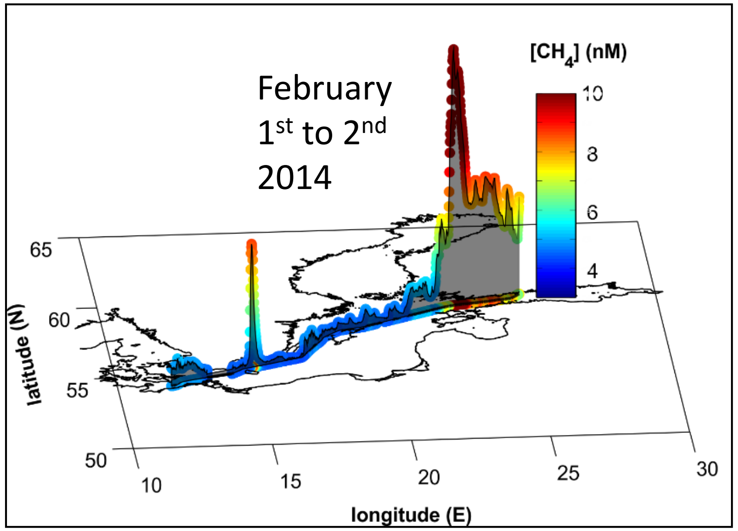
Considerations of the Response Time of Equilibration Systems

A: General

REMEMBER ….

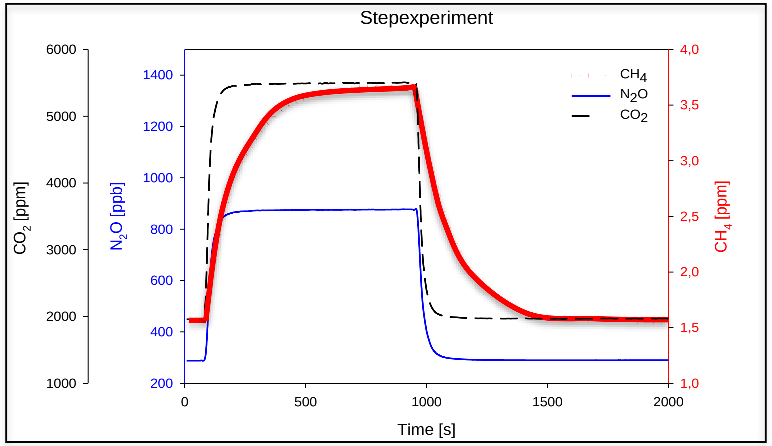
•Sparingly soluble gases equilibrate slower

•In particular methane distribution can be patchy with small small scale differences



- **Response time: system-dependent**
- **For τCH_4 / τCO_2 : ~ 25 to 3**

(Webb et al., 2016)



•Equilibrator always in disequilibrium

(Johnson et al., 1999)

$$C_{e(t)} = \left(C_i - \frac{C_W}{\alpha}\right) e^{-\left(\frac{t}{\tau_1}\right)} + \frac{C_W}{\alpha}$$

So what is a correct value?

- **Implications for "Quality Goals", i.e. SOCAT, ICOS (remember talks by Truls and Dorothee)**