Global Ocean Biogeochemistry Array (GO-BGC): Observing ocean chemistry and biology with Biogeochemical-Argo profiling floats

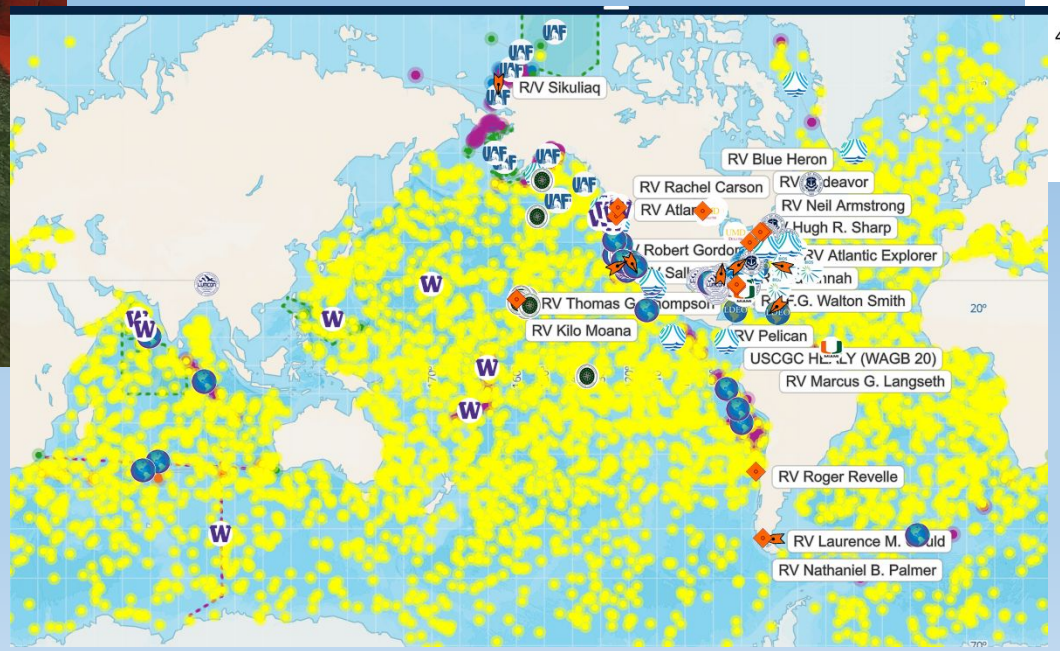
Kenneth S. Johnson
Monterey Bay Aquarium Research Institute
Moss Landing, CA, USA
johnson@mbari.org

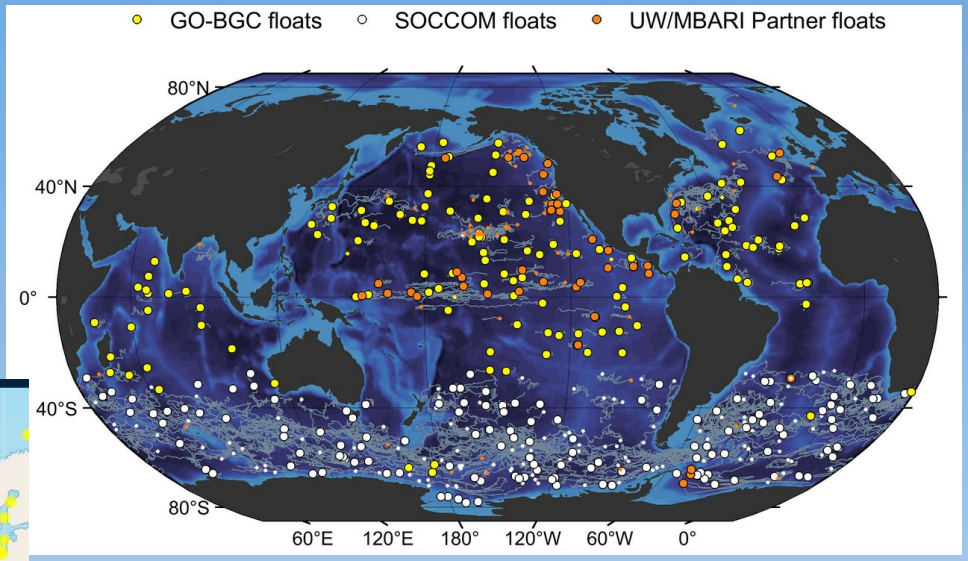
SOCCOM Unlocking the mysteries of the Southern Ocean

GO-BGC Global Ocean Biogeochemistry Array

This talk is about building a global array of profiling floats with chemical and biological sensors.

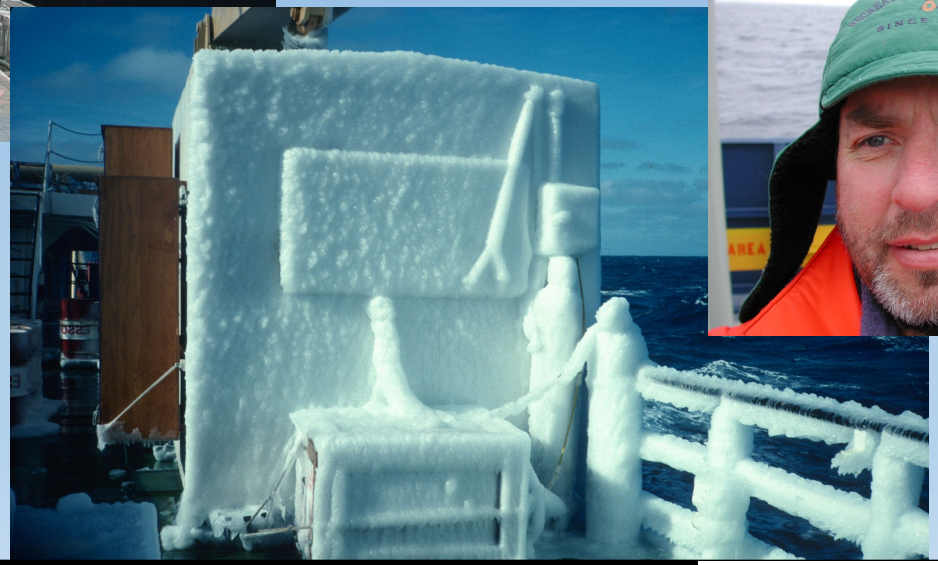
How does it relate to UNOLS?

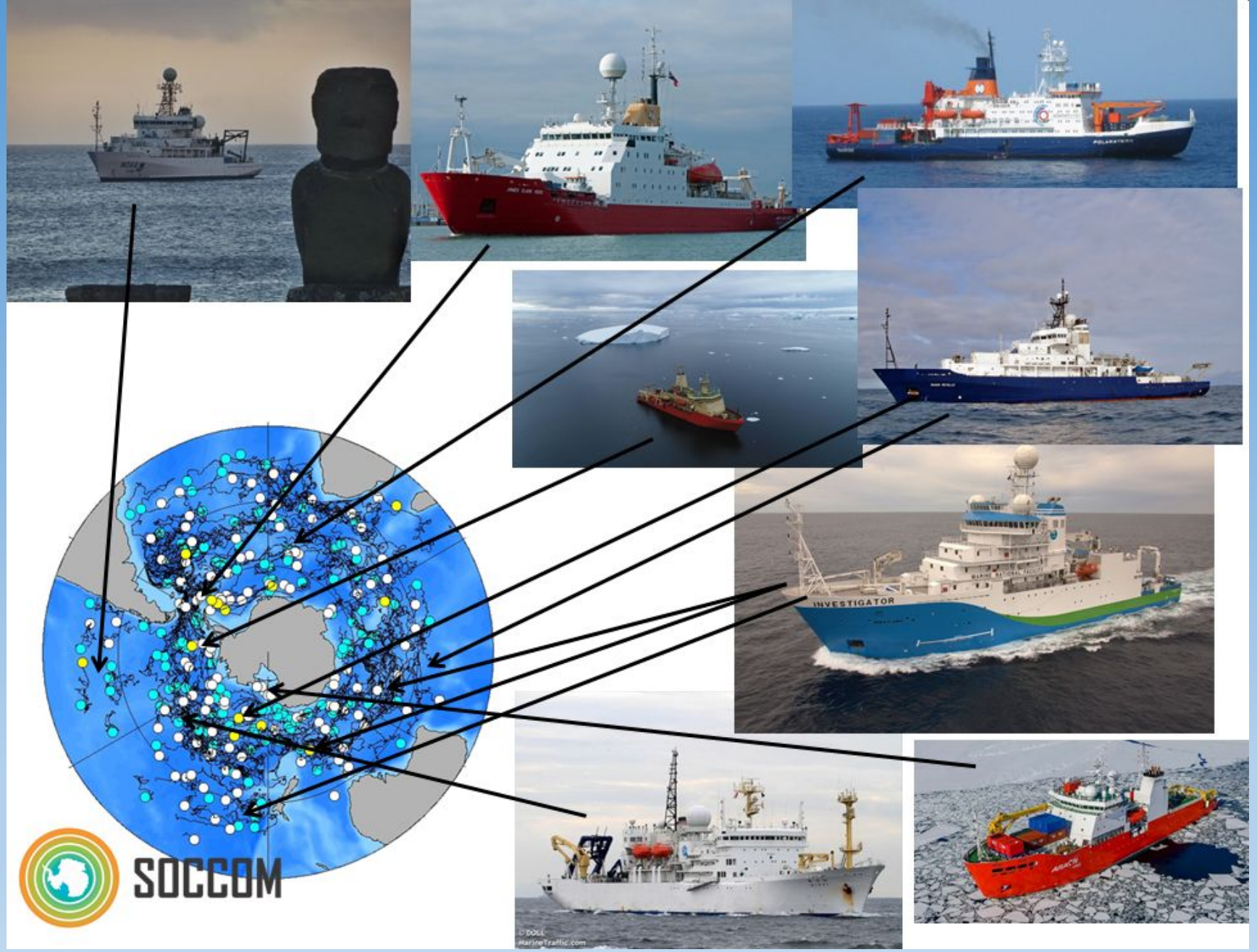




- UNOLS Fleet Improvement Committee 1990-1994
- UNOLS Chair 1994-1998

~18 months on UNOLS vessels: Cayuse, Velero IV, New Horizon, Sproul, Wecoma, Columbus Iselin, Point Sur, Atlantis II (and Alvin), Melville, Revelle, plus Navy, European, Canadian, MBARI ships





GO-BGC & SOCCOM rely on UNOLS!

Thompson, Revelle, Sally Ride, Kilo Moana, Atlantis, Armstrong, Sikuliaq, Palmer, Ron Brown

Australia, Canada, Germany, India, Japan, Korea, New Zealand, South Africa, Spain, Russia, United Kingdom

In the future, “vessels will be support, not monitoring platforms” Mel Briscoe, 2010.

Astronomers no longer go to the “observatory”. Data comes to them from the observatory - think Hubble Space Telescope.

What does a global, BGC-Argo array mean for UNOLS?

We can use ships more efficiently with a global network of sensors.

Process-oriented studies can be more focused.

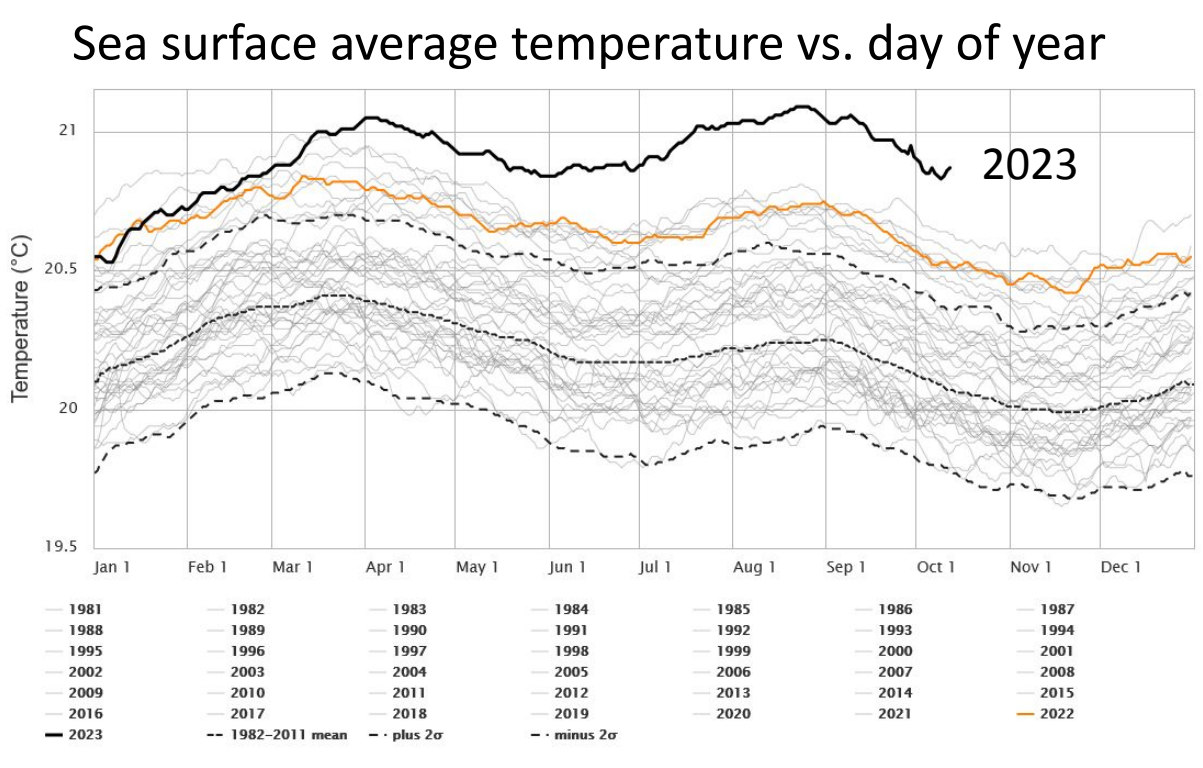
There will be an increasing amount of ancillary ship use to deploy platforms.

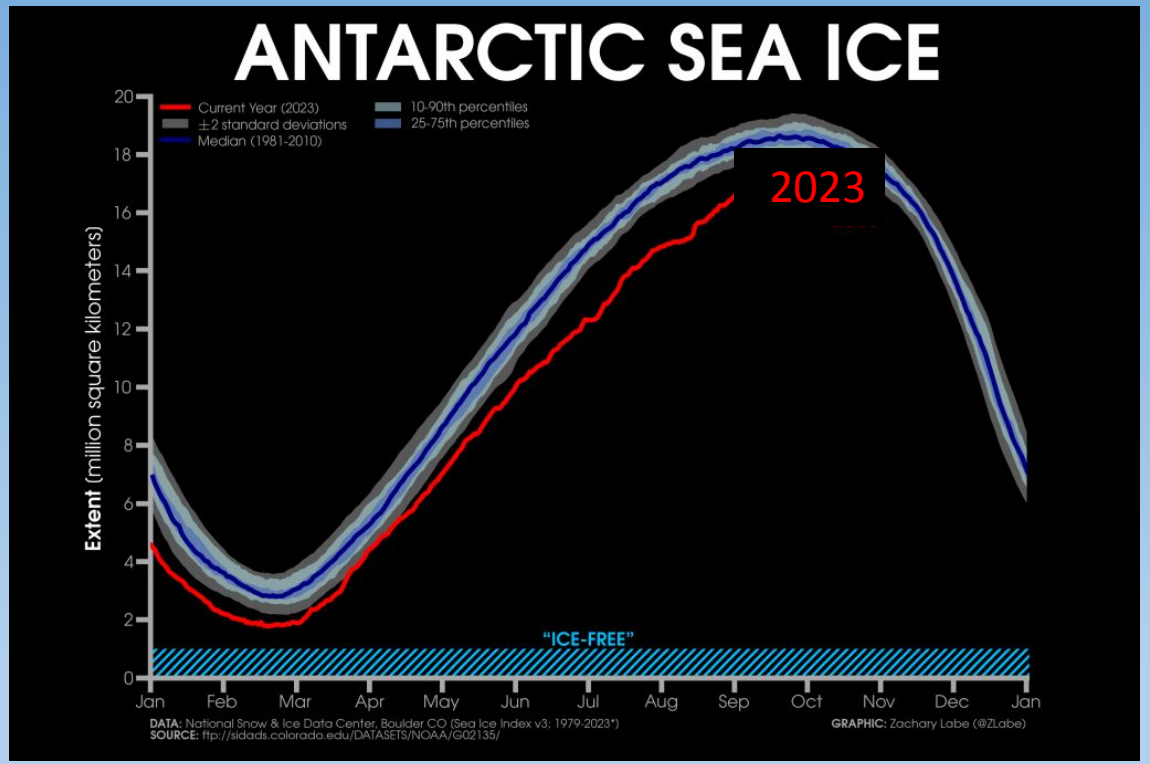
There may be a need for a new class of ships that just support deployments with reduced capital and operating costs.

There is an imperative to improve ocean observing!

Oceans are undergoing remarkable stresses:

- Warming • Acidification • Ice melt • Oxygen loss • Circulation changes
- Over fishing …

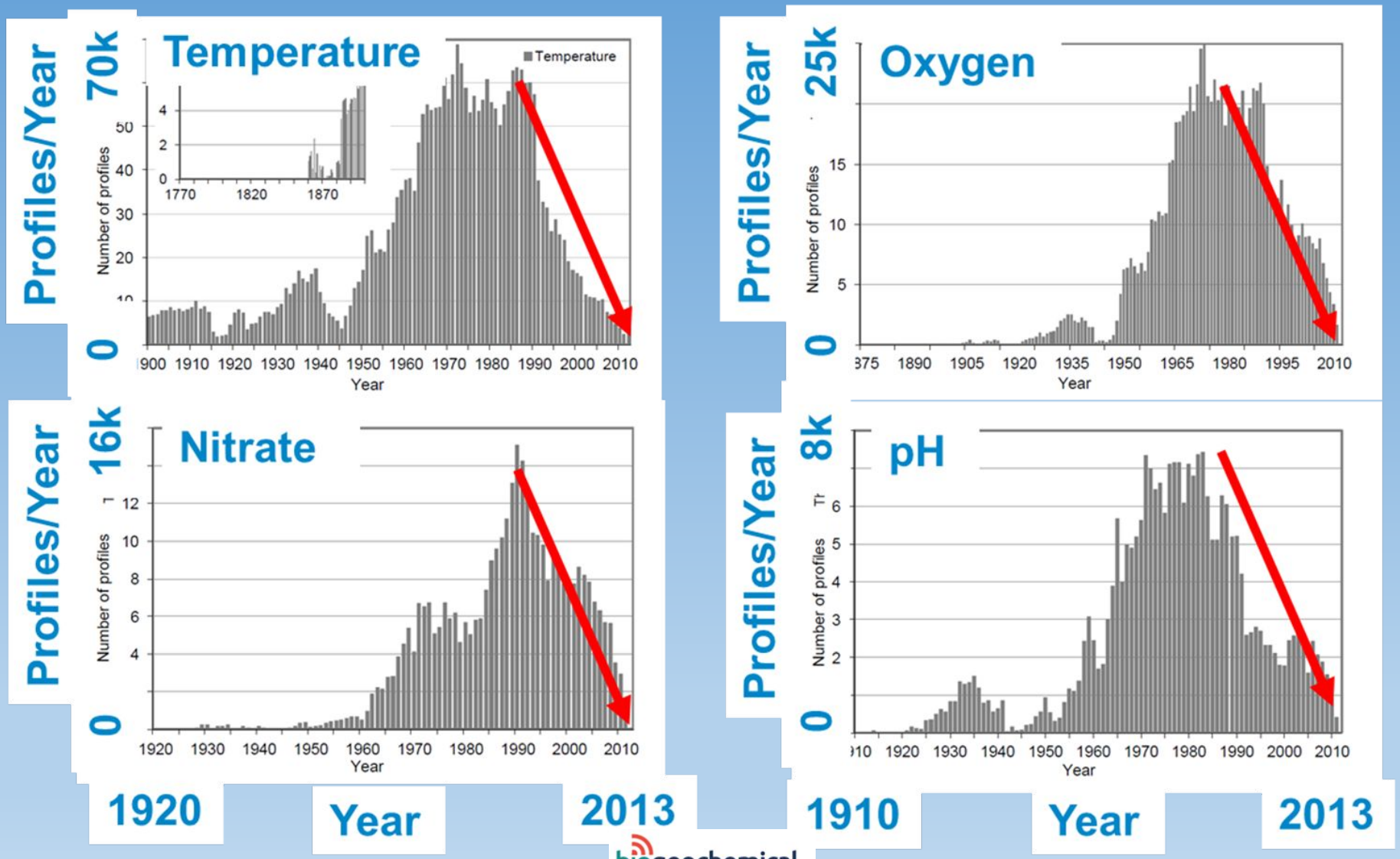




https://climatereanalyzer.org/clim/sst_daily/

https://zacklabe.com/antarctic-sea-ice-extentconcentration/

Yet the number of observations is decreasing.
Annual number of ship-based profiles (thousands) per year (NOAA World Ocean Atlas)



Boyer et al., 2013

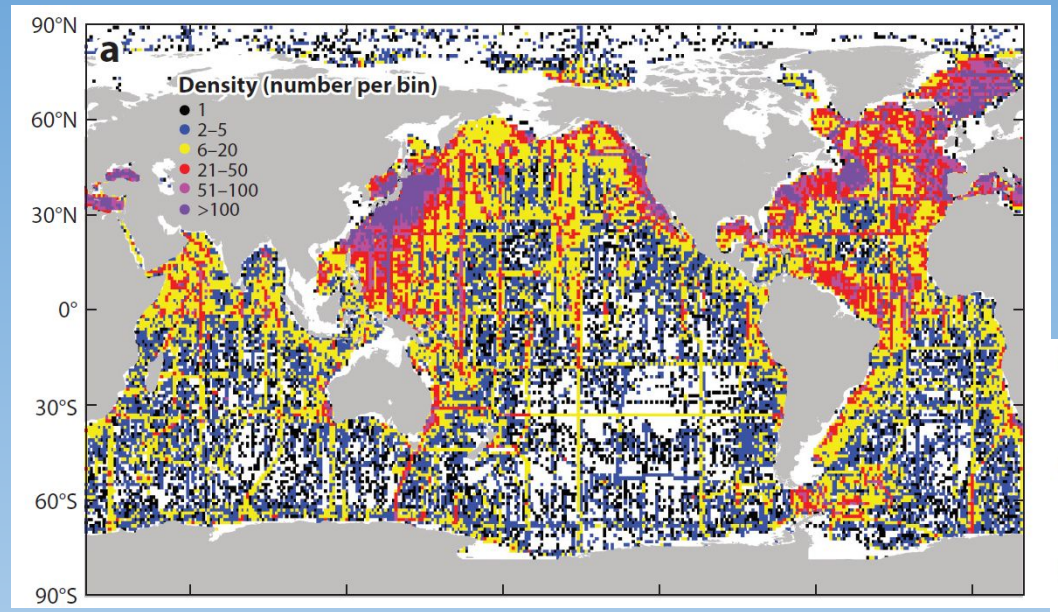
GO-BGC Global Ocean Biogeochemistry Array

biogeochemical Argo

SOCCOM

The Argo array has transformed physical oceanography!

Ships last 100 years



Annual Review of Marine Science

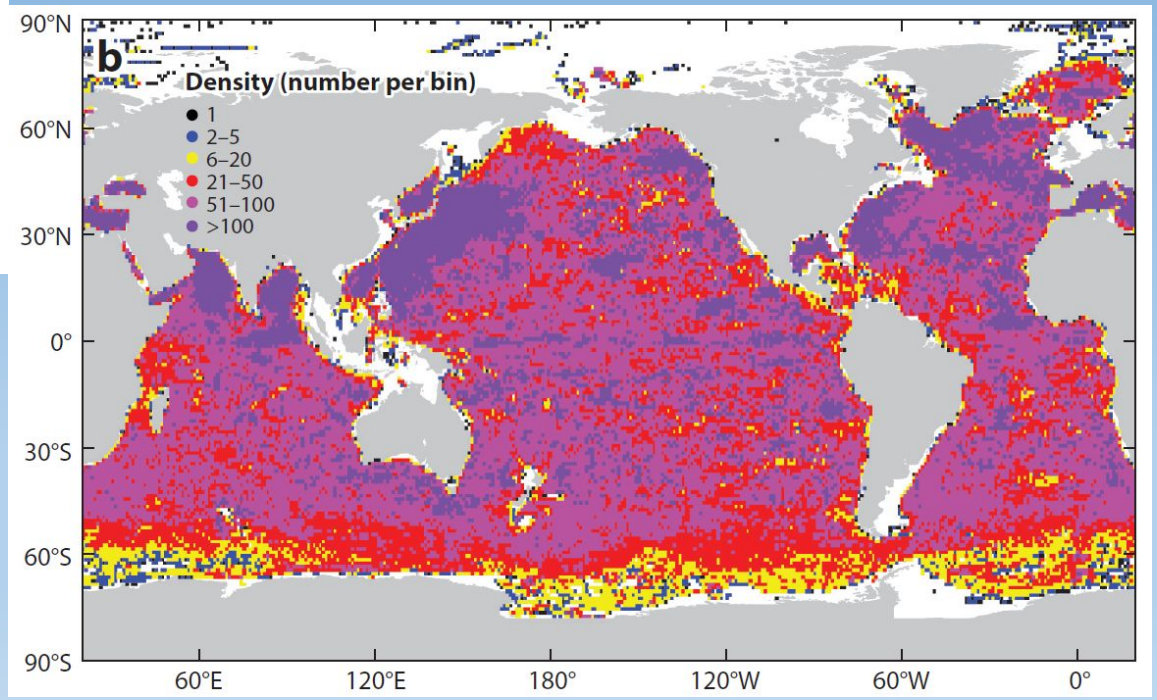
Argo—Two Decades: Global Oceanography, Revolutionized

Gregory C. Johnson,[1] Shigeki Hosoda,[2] Steven R. Jayne,[3] Peter R. Oke,[4] Stephen C. Riser,[5] Dean Roemmich,[6] Tohsio Suga,[7] Virginie Thierry,[8] Susan E. Wijffels,[3] and Jianping Xu[9]

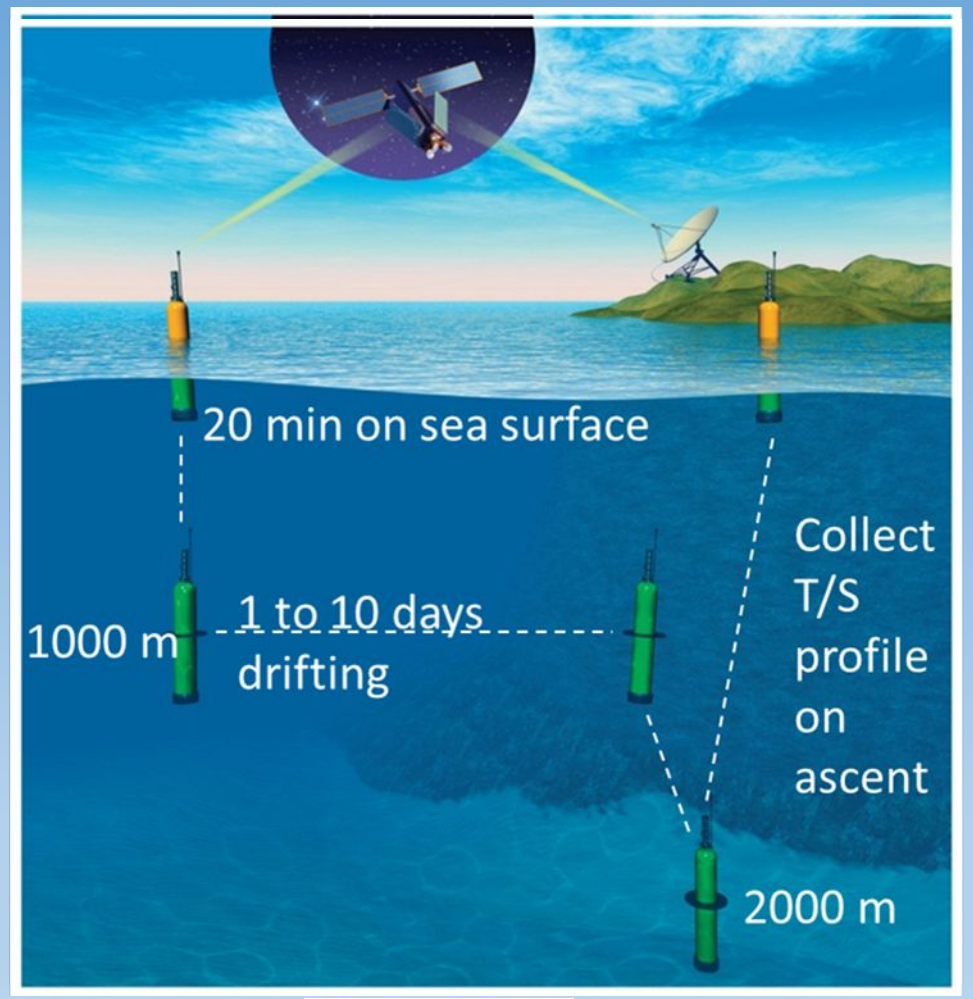
Number of temperature profiles to >1000 m per 1° x1° bin

1
2–5
6–20
21–50
51–100
>100

Argo floats last 21 years



We need a new approach to sustained ocean observations. Robotic observations with Biogeochemical-Argo!



Argo profiling floats with chemical & biological sensors

- Enough batteries for ~250 cycles from 2000 m to surface
- >5 year mean life at 1 cycle/10 days
- All data available within 24 hours without restriction

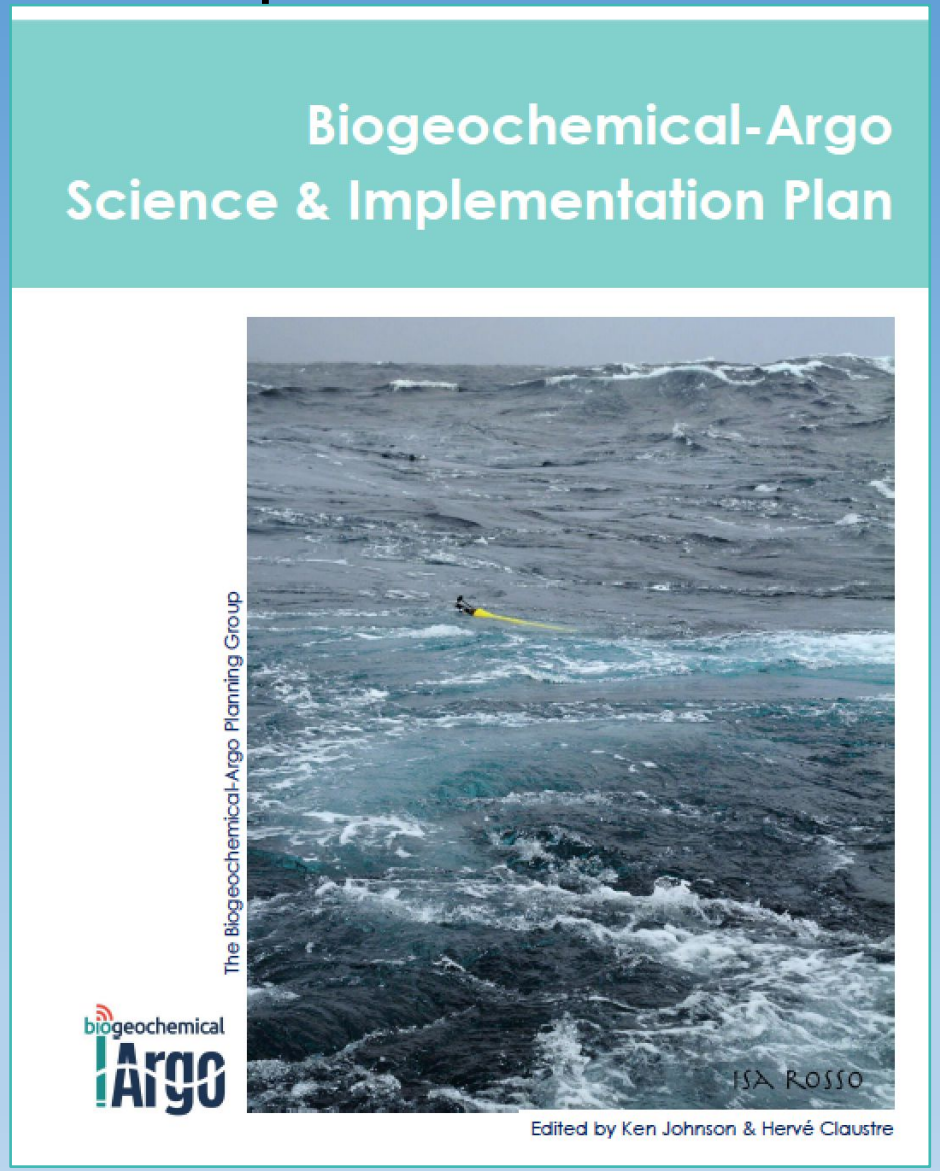
GO-BGC Global Ocean Biogeochemistry Array

biogeochemical Argo

SOCCOM

The 2016 Biogeochemical-Argo Science & Implementation Plan

- An international plan.
- 1000 profiling floats with
  - O_2, pH, NO_3^-, bio-optics
- Array size set by analysis of science requirements
- Data freely available in real-time.
- US provides 500 floats



http://biogeochemical-argo.org

biogeochemical Argo

An observing system simulation for Southern Ocean carbon dioxide uptake

Joseph D. Majkut, Brendan R. Carter, Thomas L. Frölicher, Carolina O. Dufour, Keith B. Rodgers and Jorge L. Sarmiento

Phil. Trans. R. Soc. A 2014 **372**, 20130046, published 2 June 2014

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
10.1002/2017JC012819

Special Section:
The Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) Project:

Observing System Simulation Experiments for an array of autonomous biogeochemical profiling floats in the Southern Ocean

Igor Kamenkovich[1], Angelique Haza[1], Alison R. Gray[2,3], Carolina O. Dufour[2,4], and Zulema Garraffo[5]

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
10.1002/2017JC013408

Special Section:

Correlation Lengths for Estimating the Large-Scale Carbon and Heat Content of the Southern Ocean

M. R. Mazloff[1], B. D. Cornuelle[1], S. T. Gille[1], and A. Verdy[1]

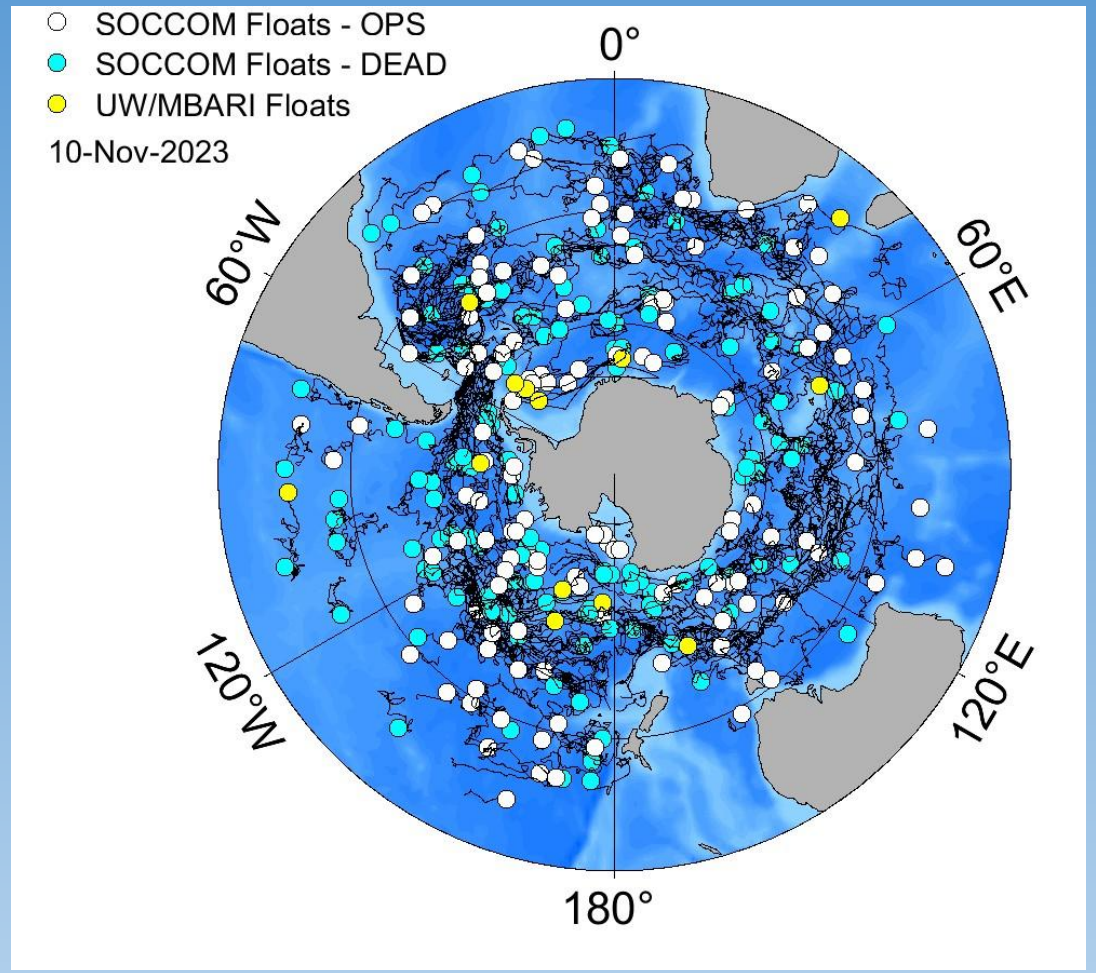
Biogeosciences, 18, 509–534, 2021
https://doi.org/10.5194/bg-18-509-2021

Biogeoscienc

Assimilating synthetic Biogeochemical-Argo and ocean colour observations into a global ocean model to inform observing system design

David Ford

Various assessments find that ~1000 floats, spread globally, greatly reduce uncertainty in BGC processes.



Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM):

- Initiated in 2014 with NSF OPP funding.
- Renewed for four years (2021-2024)
- 270 floats deployed, 138 active.
- Oxygen, pH, nitrate, bio-optical sensors
- 176 peer-reviewed papers
- SOCCOM-3 proposal in review

- https://soccom.princeton.edu

SOCCOM

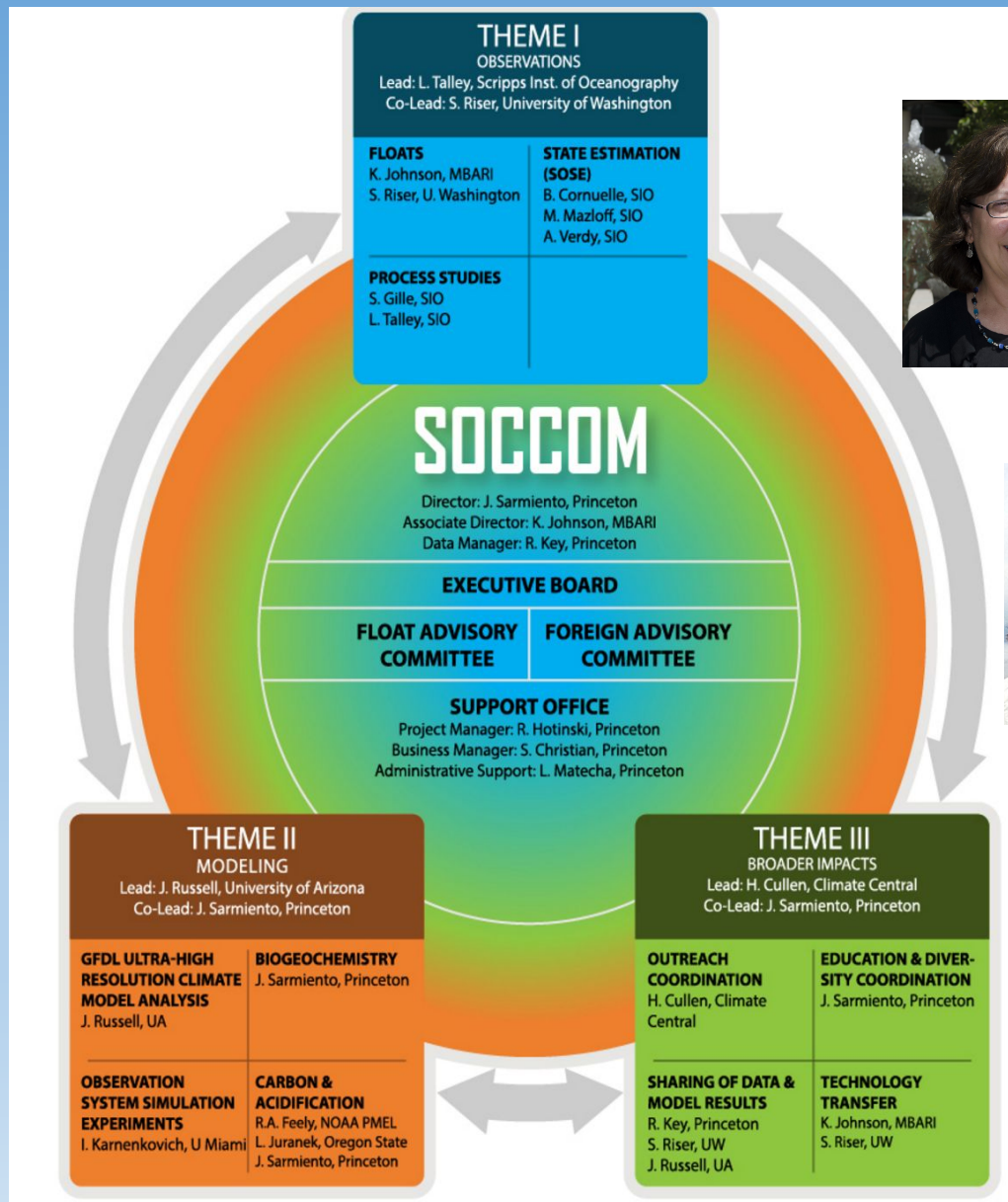
GO-BGC Global Ocean Biogeochemistry Array

Leadership

Director Emeritus
Jorge Sarmiento, Princeton

Acting Director
Ken Johnson, MBARI

Project Manager
Roberta Hotinski, Princeton



Theme I Observations

Lynne Talley
UCSD

Steve Riser
UW

Oscar Schofield
Rutgers

Theme II Modeling

Joellen Russell
U. Arizona

Matt Mazloff
SIO

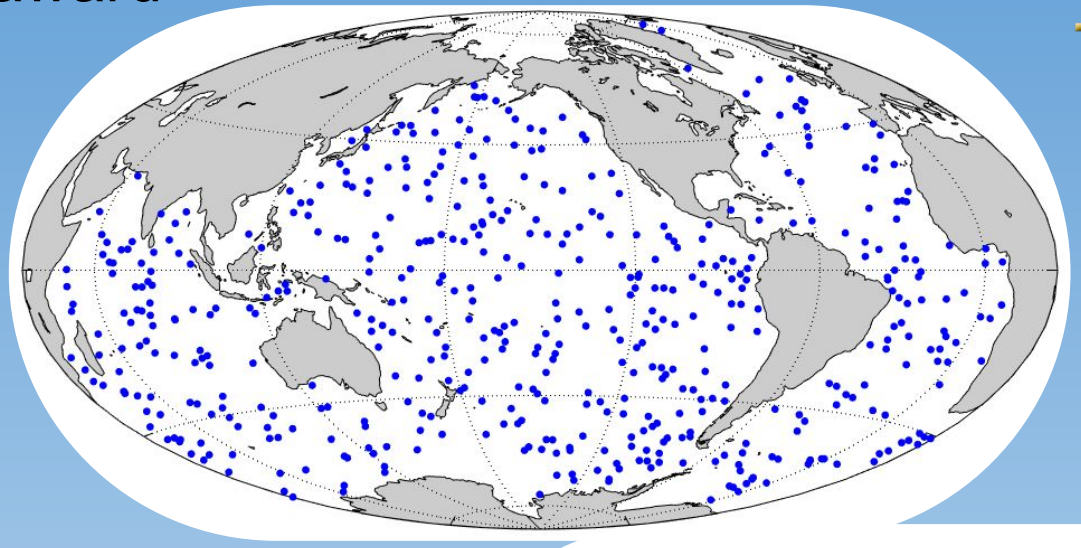
Curtis Deutsch
Princeton

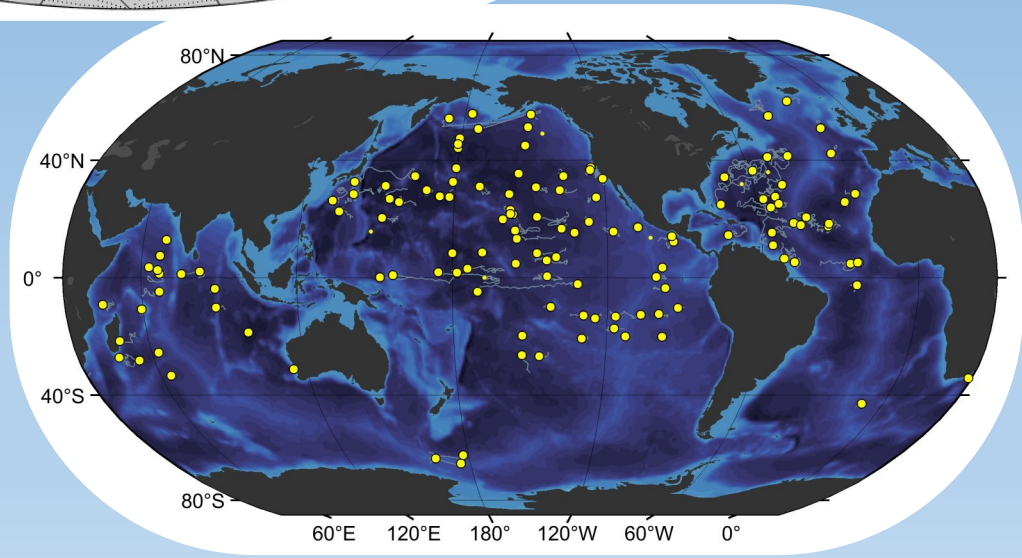
Theme III Broader Impacts

Heidi Cullen,
MBARI

Global Ocean Biogeochemistry (GO-BGC) Array:

- Oct. 29, 2020, NSF made a 5 year award for the GO-BGC Array
- 500 profiling floats GLOBALLY.
- O_2, NO_3^-, pH, bio-optics.
- Partner institutions:
  - Monterey Bay Aquarium Research Institute
  - University of Washington
  - Scripps Institution of Oceanography
  - Woods Hole Oceanographic Institution
  - Princeton University





Ken Johnson
MBARI

Steve Riser
UW

Lynne Talley
SIO

Susan Wijffels
WHOI

Jorge Sarmiento
Princeton

Heidi Cullen
MBARI

Yui Takeshita
MBARI

George Matsumoto
MBARI

Andrea Fassbender
NOAA

Sarah Purkey
SIO

Todd Martz
SIO

Alison Gray
UW

Roo Nicholson
WHOI

Roberta Hotinski
Princeton

GO-BGC
Executive
Team

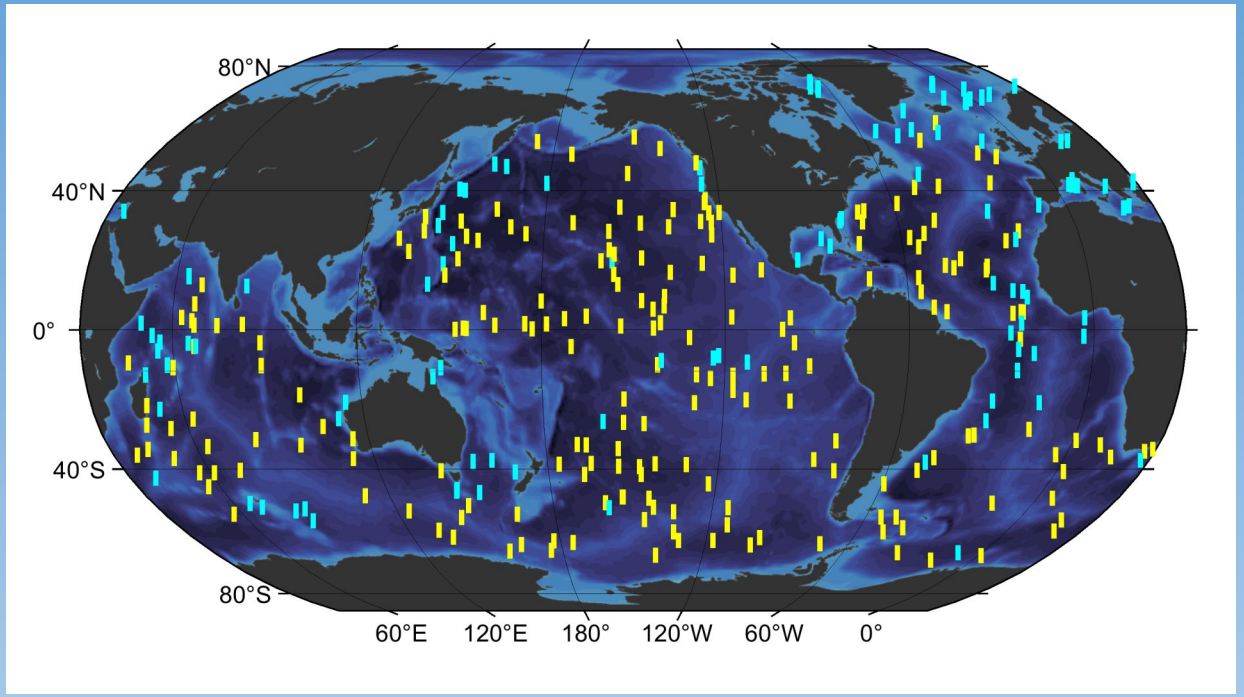
GO-BGC and Mid-Scale Research Infrastructure-2

MSRI is one of NSF's 10 Big Ideas

The Mid-scale RI-2 program will NOT support proposals that include the following:

- Pre-implementation research and development and other community or technical preparatory activities;
- Science research (except for validation of operational capability);
- Post-implementation research, operations, and maintenance; and
- General-purpose support systems and equipment that are not directly required for the implementation and eventual operation of the proposed infrastructure.

SOCCOM and GO-BGC are the primary US contributions to BGC-Argo.



4+ Sensor BGC Argo Floats
13-Nov-2023

Floats with 4 sensors: 54
Floats with 5 sensors: 239
Floats with 6 sensors: 45
MBARI floats in yellow

18 + nations deploying floats with 1 or more BGC sensors

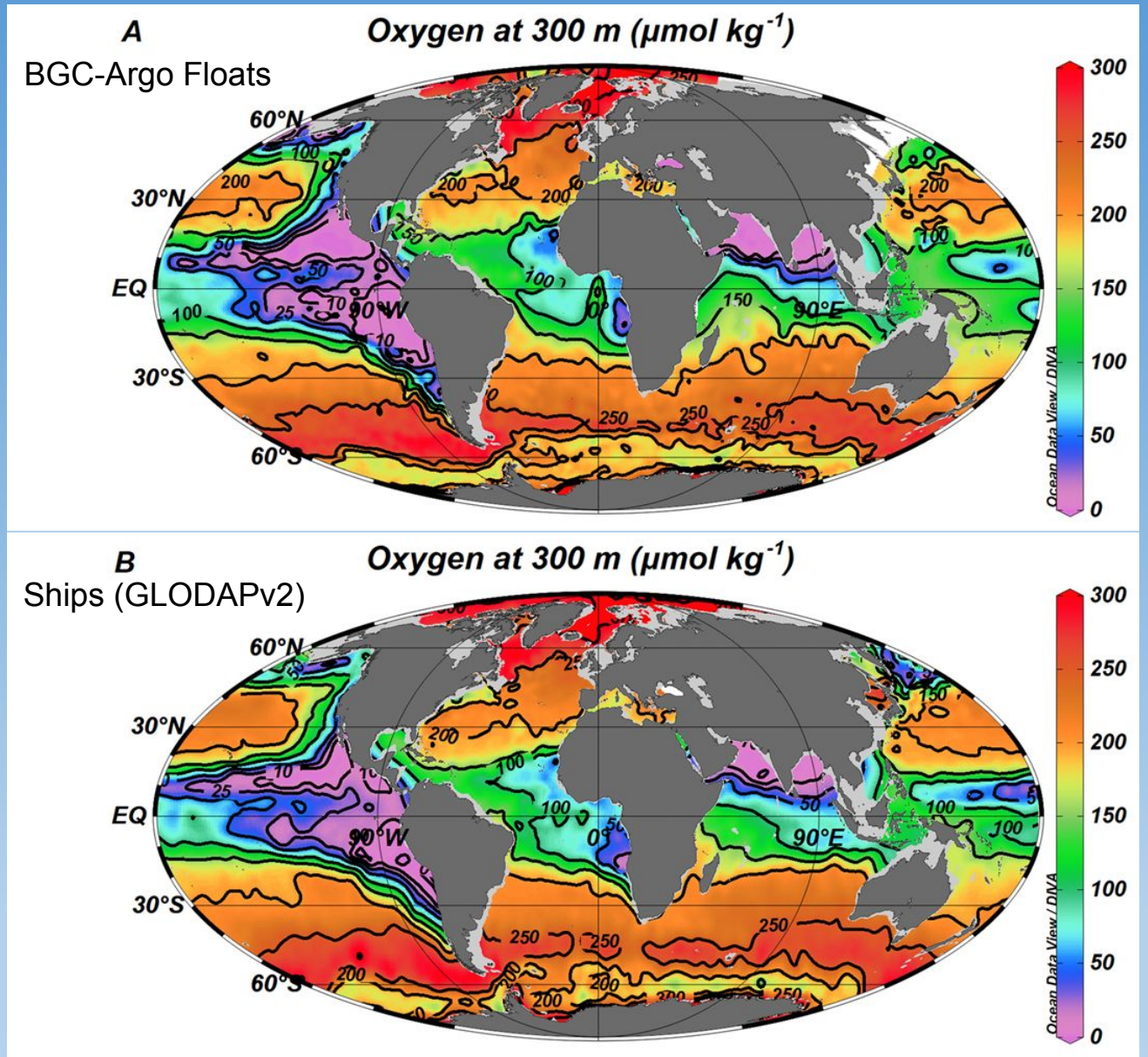
AUSTRALIA (12)	CHINA (21)	FRANCE (110)	IRELAND (2)	NORWAY (27)	UK (15)
BULGARIA (6)	EUROPE (21)	GERMANY (9)	ITALY (18)	POLAND (8)	USA (264)
CANADA (45)	FINLAND (3)	INDIA (8)	JAPAN (5)	SPAIN (1)	OTHER (2)

GO-BGC Global Ocean Biogeochemistry Array

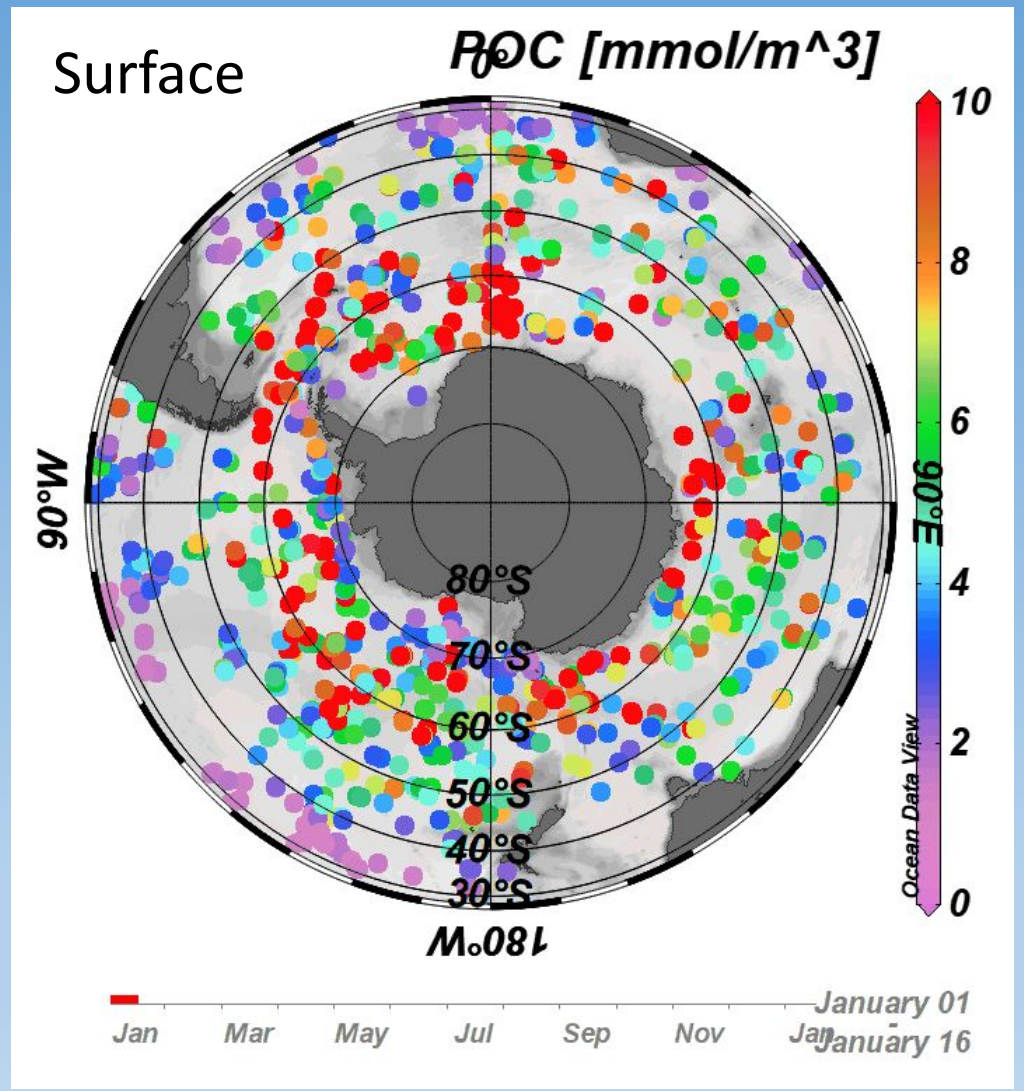
biogeochemical Argo

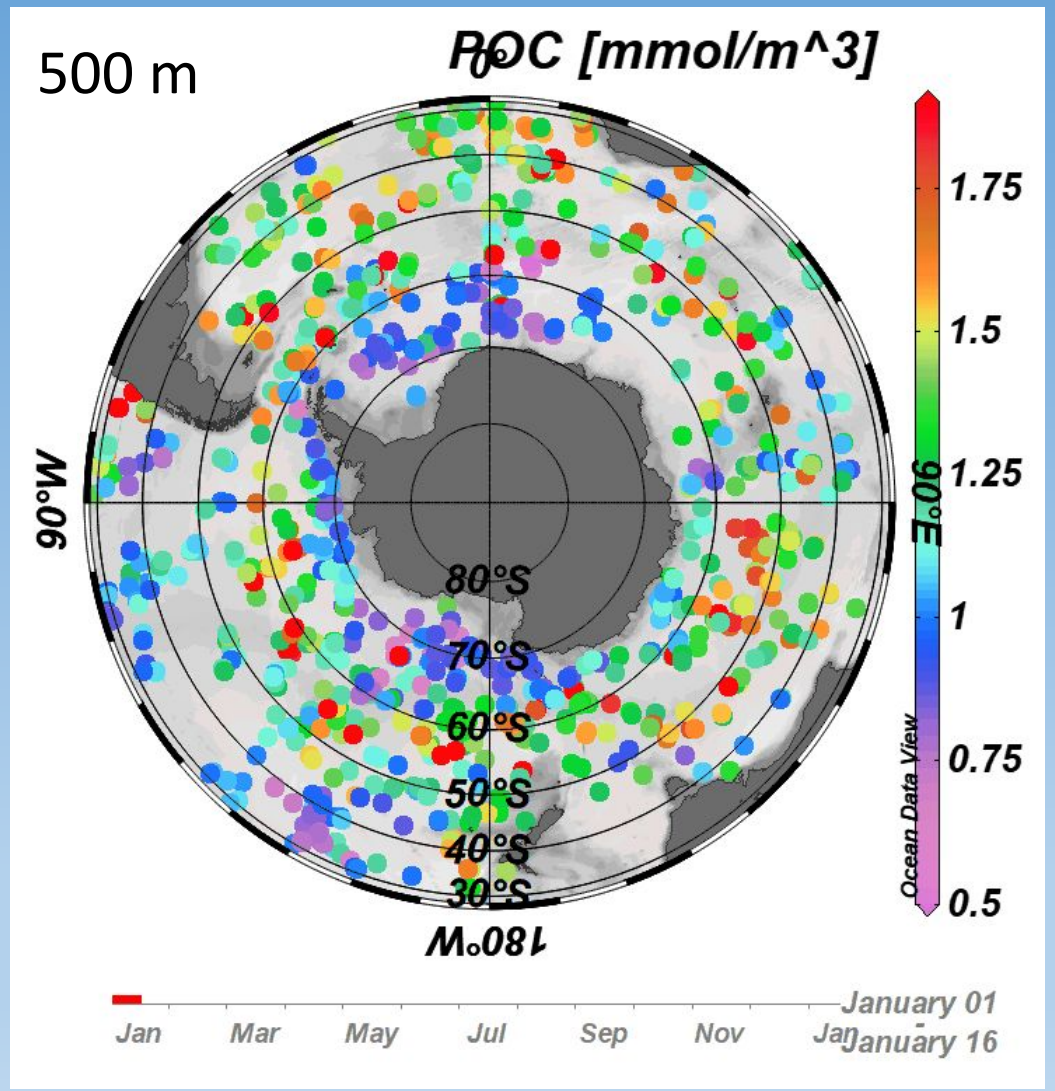
SOCCOM

BGC-Argo observations are nearly indistinguishable from high quality lab measurements, with greater temporal resolution.



BGC-Argo floats enable year-round observing not possible from ships

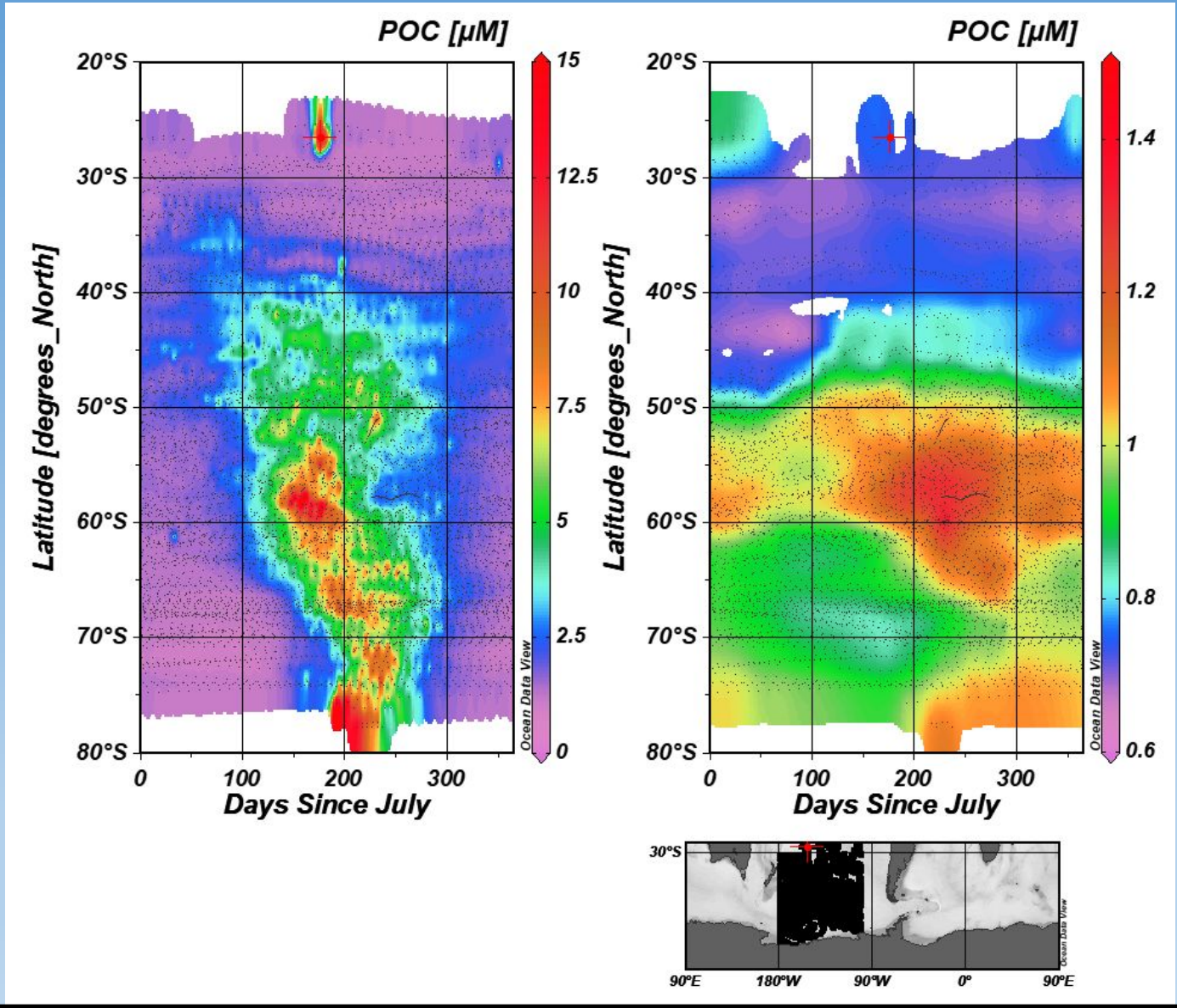




BGC-Argo floats provide a view into the ocean interior that is not possible with satellites

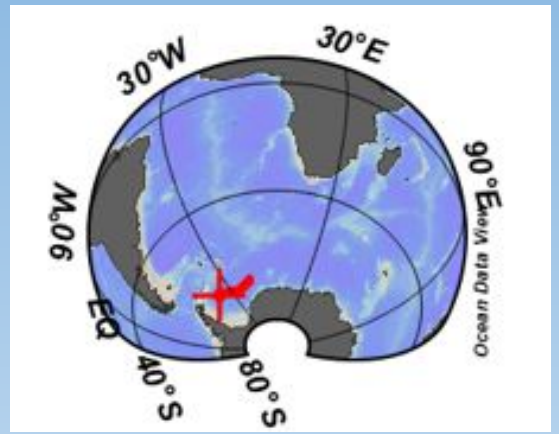
Surface

500 m

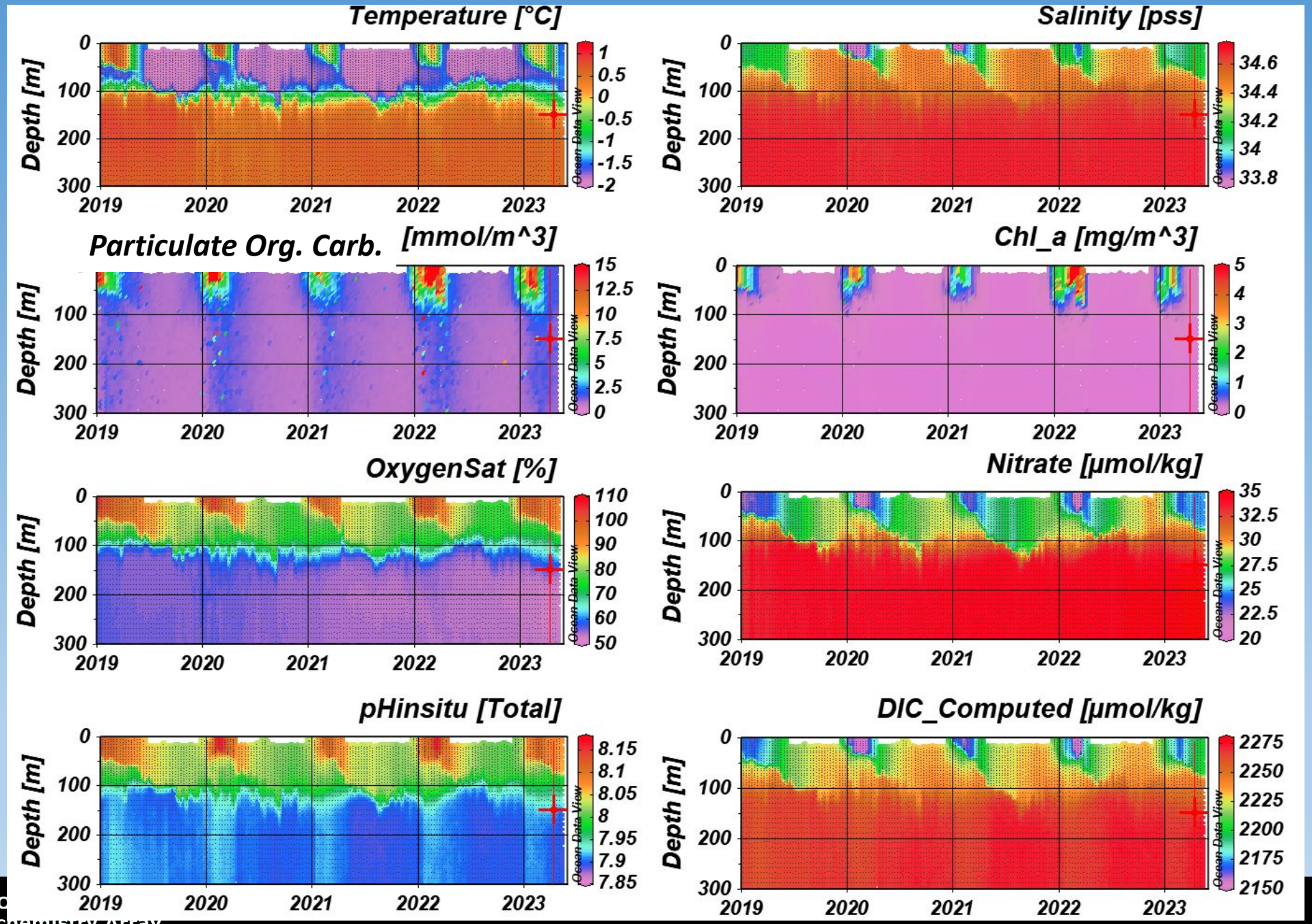


Floats can operate in the harshest environments, providing unequalled datasets.

Float 11090/WMO 5905995 in the seasonal ice zone of the Weddell Sea

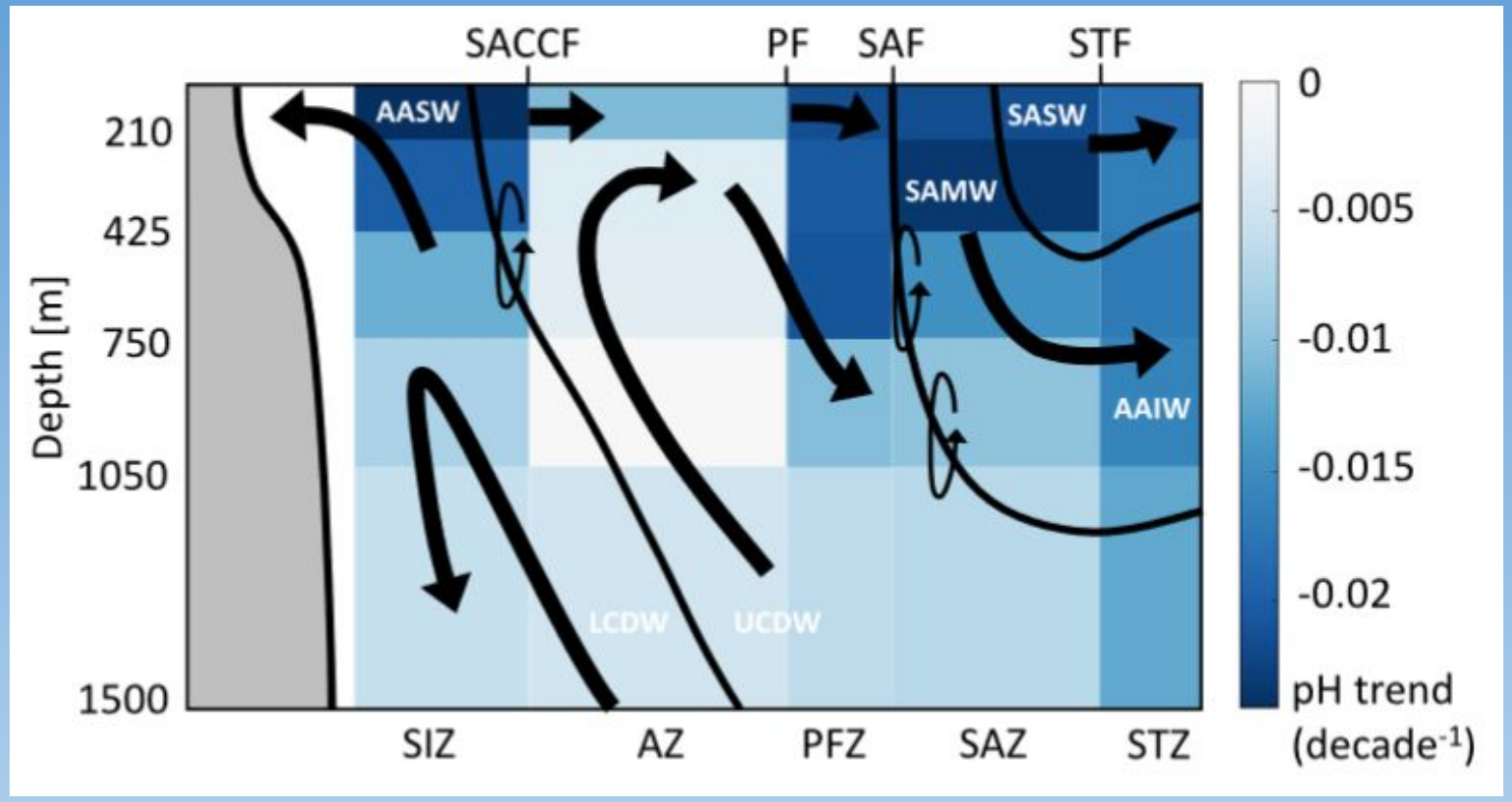


SOCCOM



Float data enables long-term change to be observed across the open ocean

Zonal mean acidification rate consistent with the overturning circulation of the Southern Ocean



JGR Oceans

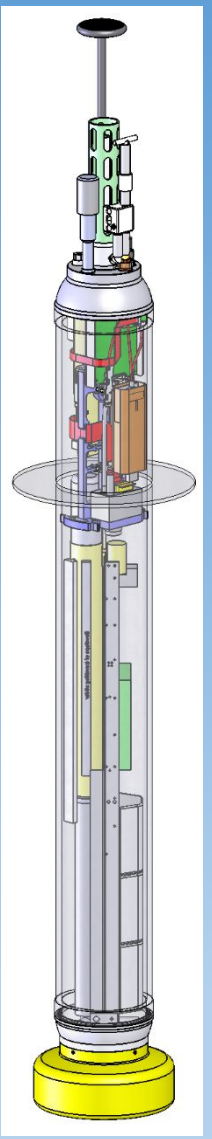
RESEARCH ARTICLE
10.1029/2022JC019530

Key Points:

- We present a novel 12-month Southern Ocean pH mapped product,

Southern Ocean Acidification Revealed by Biogeochemical-Argo Floats

Matthew R. Mazloff[1], Ariane Verdy[1], Sarah T. Gille[1], Kenneth S. Johnson[2], Bruce D. Cornuelle[1], and Jorge Sarmiento[3]

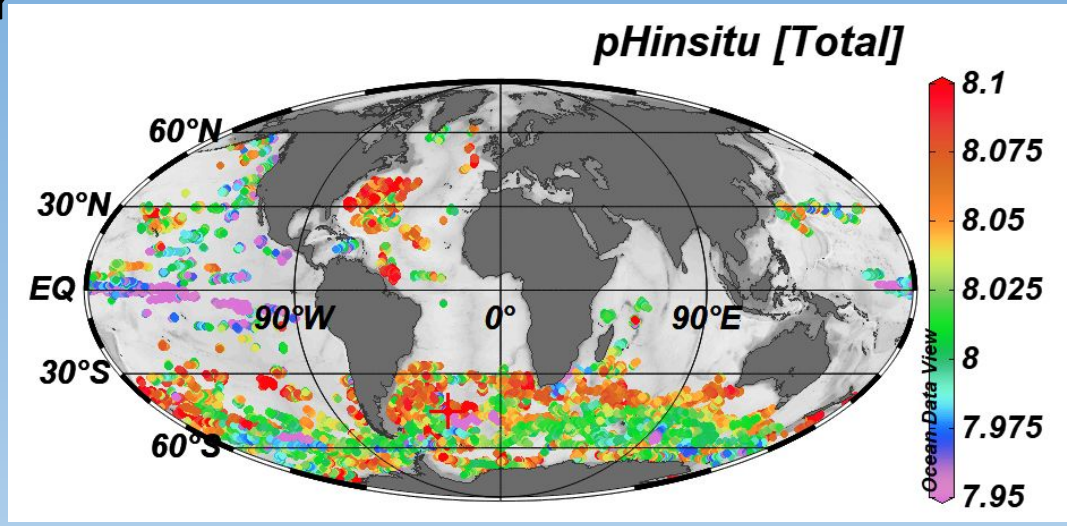


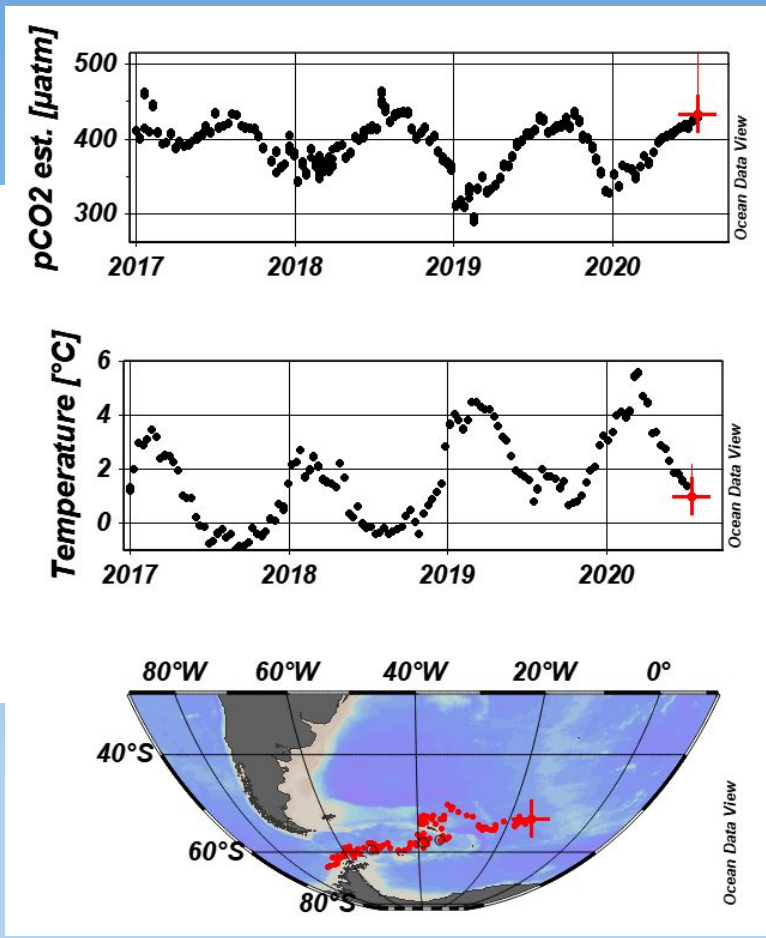
BGC-Argo floats with pH sensors can provide an estimate of pCO_2.

Ion Sensitive Field Effect Transistor pH sensor

Calculating surface ocean pCO_2 from biogeochemical Argo floats equipped with pH: An uncertainty analysis

N. L. Williams[1], L. W. Juranek[1], R. A. Feely[2], K. S. Johnson[3], J. L. Sarmiento[4], L. D. Talley[5], A. G. Dickson[5], A. R. Gray[4], R. Wanninkhof[6], J. L. Russell[7], S. C. Riser[8], and Y. Takeshita[3]





WMO 5904856

Global Biogeochemical Cycles

Research Article | Open Access

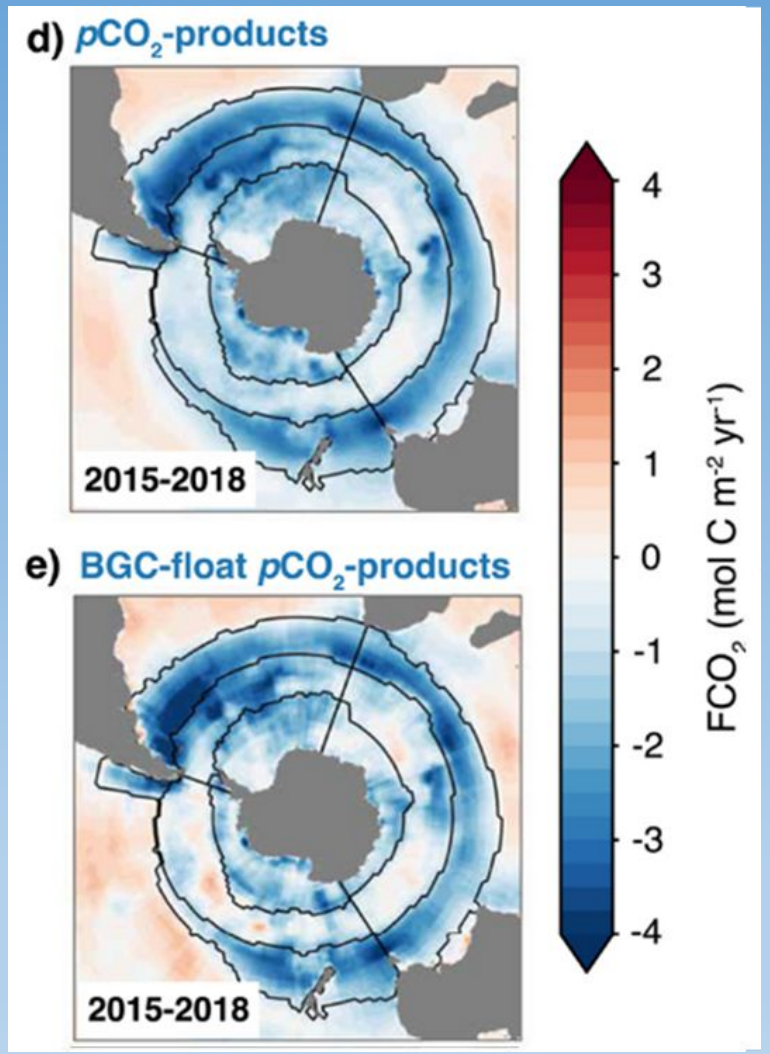
The Southern Ocean Carbon Cycle 1985–2018: Mean, Seasonal Cycle, Trends, and Storage

Judith Hauck, Luke Gregor, Cara Nissen, Lavinia Patara, Mark Hague, Precious Mongwe, Seth Bushinsky, Scott C. Doney, Nicolas Gruber, Corinne Le Quéré, Manfredi Manizza, Matthew Mazloff, Pedro M. S. Monteiro, Jens Terhaar ... See fewer authors

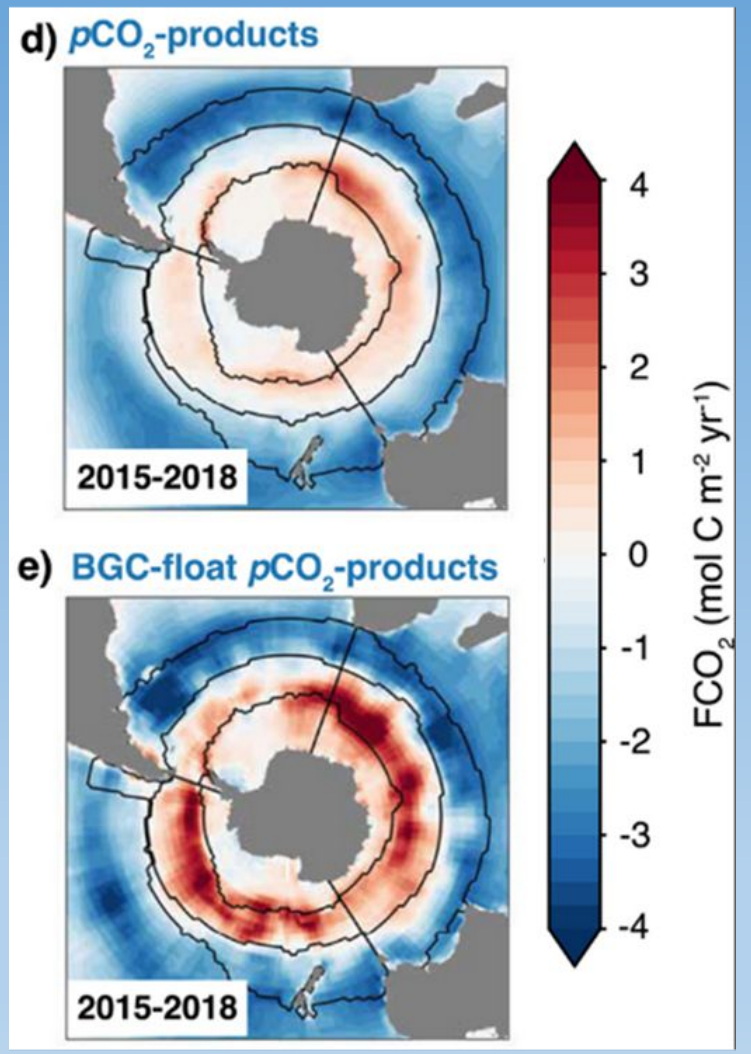
pCO_2 – products are Machine Learning (Neural Networks) products fitted to SOCAT (Shipboard) pCO_2 observations

Almost all SOCAT data is summer time.

Summer



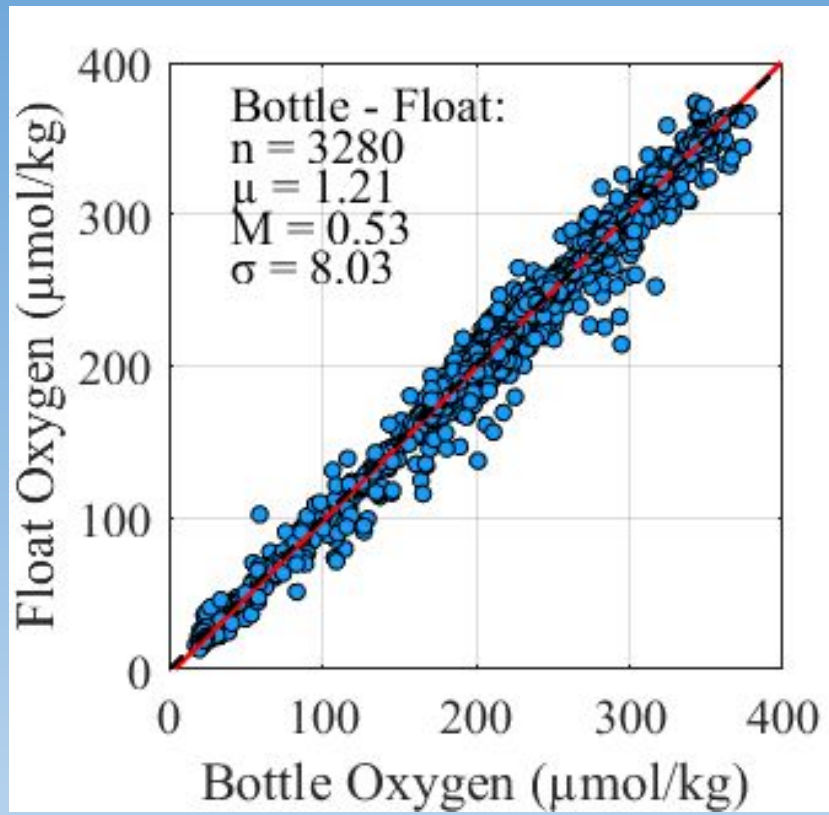
Winter

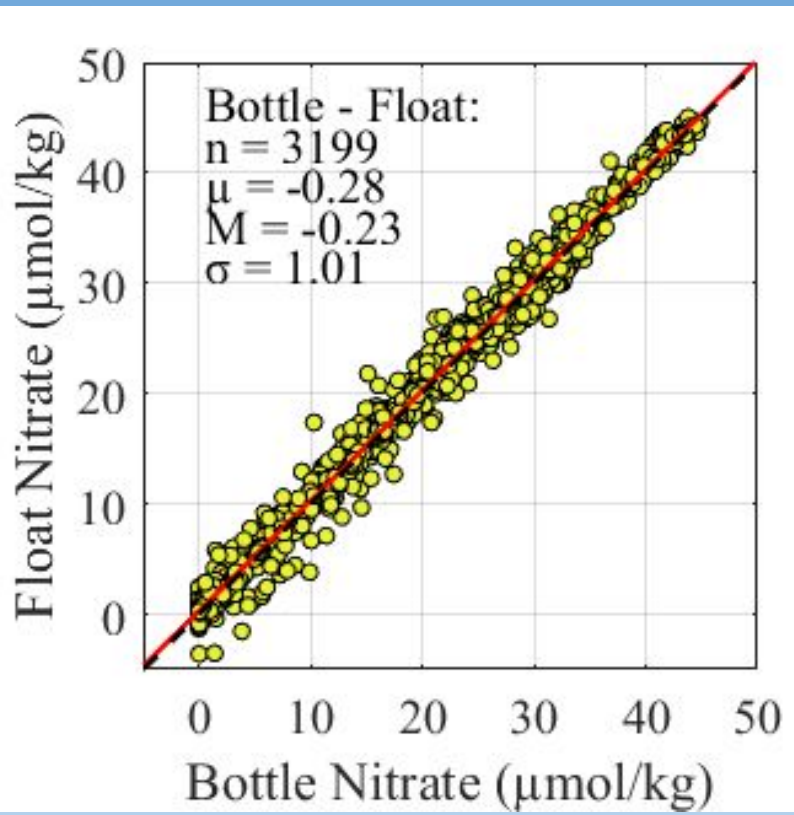


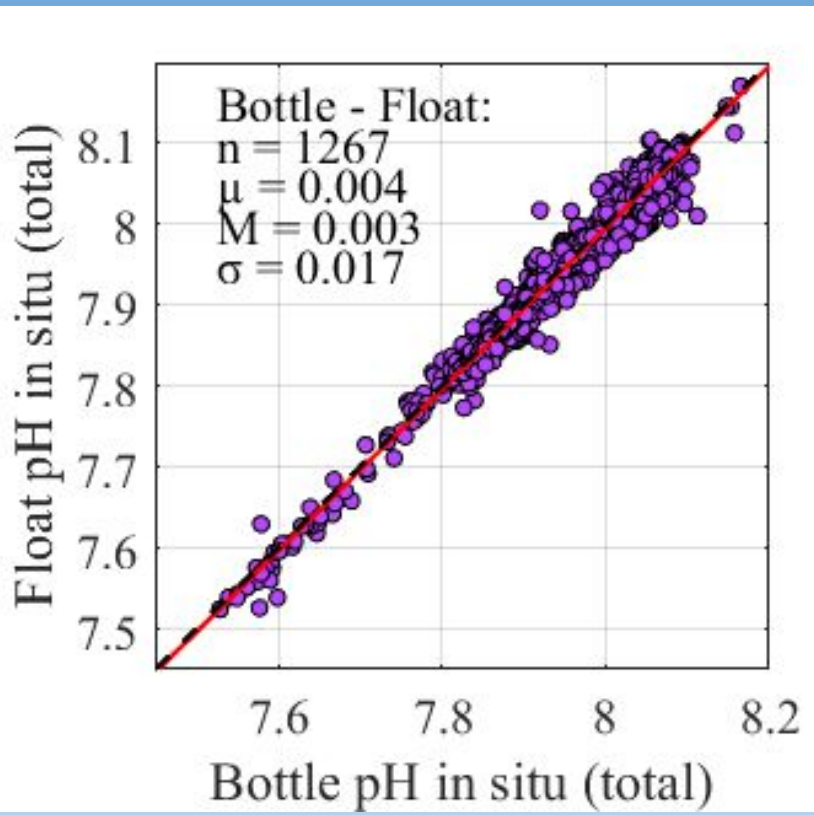
GO-BGC Data quality

DMQC methods follow Maurer et al (2021)

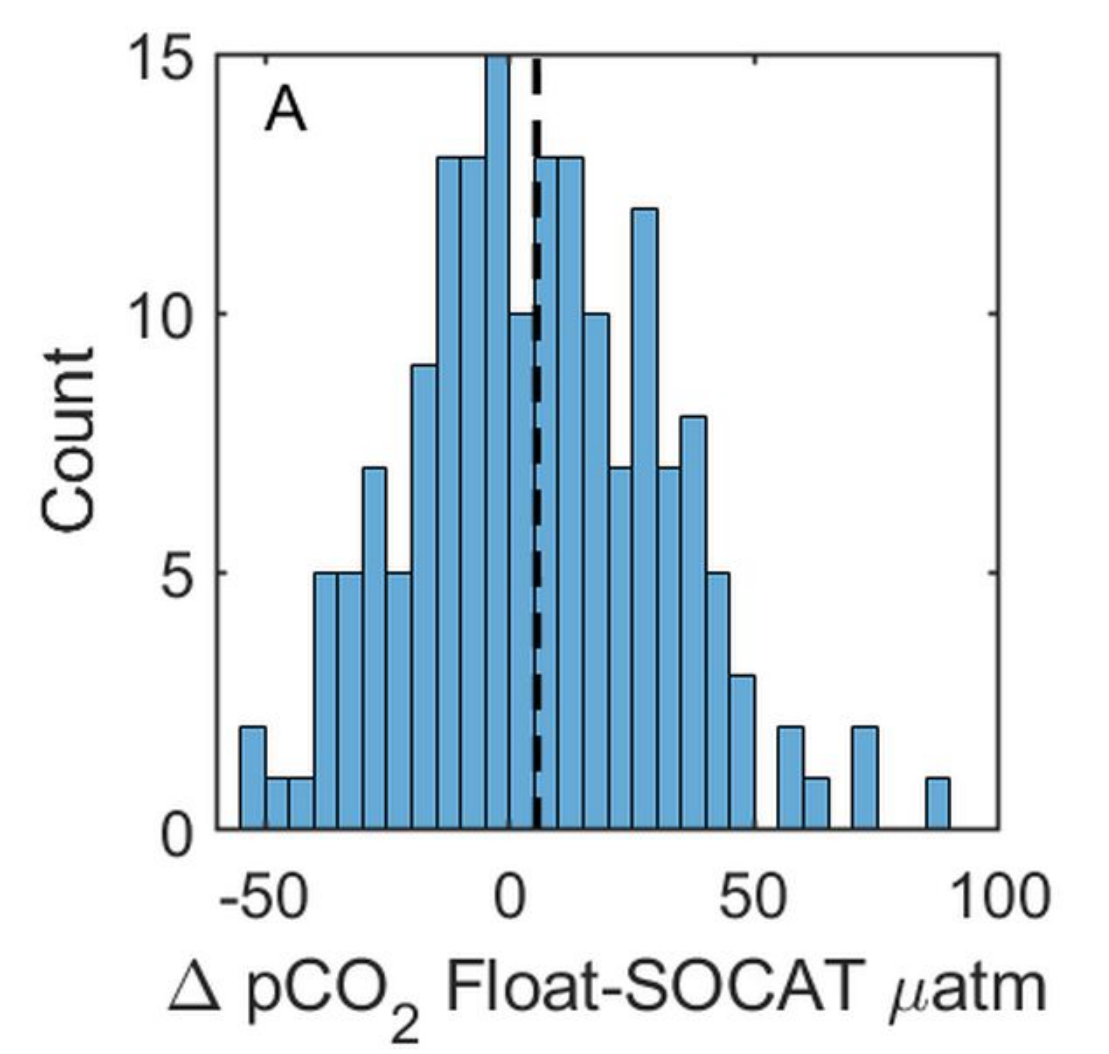
Ship-board data is essential to validate float observations. Opportunistic contributions from GO-SHIP are key.



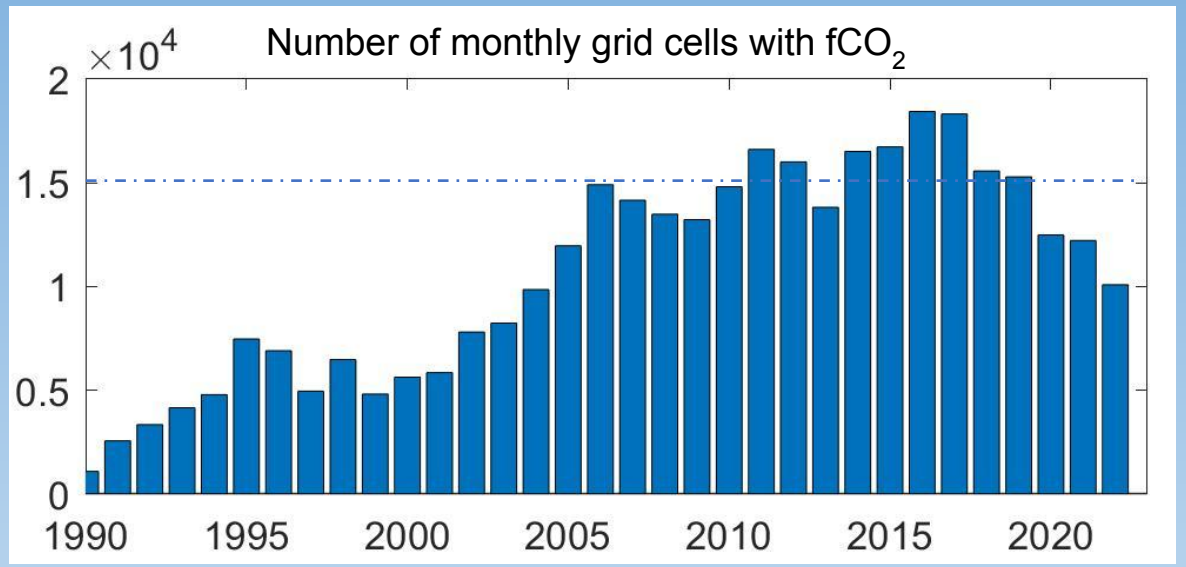




Underway observations from ships are essential to validate the pCO2 from floats.



SOCAT version 2023: An alarming decline in the ocean CO_2 observing capacity
Dorothee Bakker



UNOLS vessels have dozens of cruises with pCO_2 in the R2R, but almost none gets into the SOCAT database used for science analysis.

R2R
ROLLING DECK TO REPOSITORY

683 Results Download Table

View: Data Sets Cruises

Only display results in current map view

« 1 2 3 4 5 »

Results per Page

Mercator North Pola

SHOW ON MAP	CRUISE	VESSEL	DEVICE	DOI	RAW DATA
	AR31-C	Armstrong	pCO2 GeneralOceanics 8050	10.7284/137327	
	AR34A	Armstrong	pCO2 GeneralOceanics 8050	10.7284/144794	
	AR34B	Armstrong	pCO2 GeneralOceanics 8050	10.7284/144790	
	AR35-01	Armstrong	pCO2 GeneralOceanics 8050	10.7284/135629	
	AR35-02	Armstrong	pCO2 GeneralOceanics 8050	10.7284/135666	
	AR35-03	Armstrong	pCO2 GeneralOceanics 8050	10.7284/135721	
	AR35-04	Armstrong	pCO2 GeneralOceanics 8050	10.7284/144943	
	AR35-05	Armstrong	pCO2 GeneralOceanics 8050	10.7284/135791	
	AR37	Armstrong	pCO2 GeneralOceanics 8050	10.7284/135758	

SOCAT Data Viewer

Data Collections Update Plot <

One Plot Annotations

Plot Options

90 N

180 W 180 E

80 S

Start date/time: 1957 Jan 01

End date/time: 2022 Dec 31

Maps

Latitude-Longitude

Line Plots

Time

My selections:

(x) WOCE_CO2_water = 2

(x) fCO2_recommended != NaN

(x) platform_name = (?i).*armstrong.*

Print... Link... Animate Correlation Viewer Google Earth Show Values Export to Desktop Application Save As...

DATA SET: SOCAT v2023 Data Collection

OPeNDAP URL: https://data.pmel.noaa.gov/socat/erddap/tabledap

LAS 8./PyFerret 7.6 NOAA/PMEL

Print + fCO2 recommended

80°N

40°N

0°

40°S

No Data Available

R2R

ROLLING DECK TO REPOSITORY

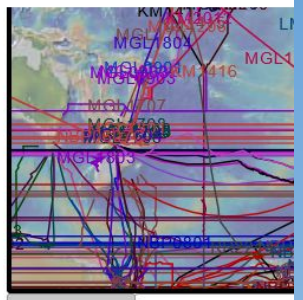
683 Results Download Table

View: Data Sets Cruises

Only display results in current map view

« 24 25 26 27 28 »

Results per Page



Mercator

SHOW ON MAP	CRUISE	VESSEL	DEVICE	DOI
☐	NBP2113	Palmer	pCO2 *LDEO pCO2*	
☐	NBP2202	Palmer	pCO2 *LDEO pCO2*	
☐	NBP2205	Palmer	pCO2 *LDEO pCO2*	
☐	RR2213	Revelle	pCO2 *GeneralOceanics 8050*	
☐	RR2214	Revelle	pCO2 *GeneralOceanics 8050*	
☐	RR2301	Revelle	pCO2 *GeneralOceanics 8050*	
☐	RR2302	Revelle	pCO2 *GeneralOceanics 8050*	

Data that does migrate to SOCAT seems to only come from GO-SHIP cruises where there is a science PI responsible.

SOCAT Data Viewer

Data Collections | Update Plot | One Plot | Annotations | Plot Options

Print... | Link... | Animate | Correlation Viewer | Google Earth | Show Values | Export to Desktop Application | Save As... | Table of Datasets | Thumbnails

DATA SET: SOCAT v2023 Data Collection

VARIABLE: fCO_2 recommended (µatm)

01-Jan-1957 00:00 to 31-Dec-2022 00:00

OPeNDAP URL: https://data.pmel.noaa.gov/socat/erddap/tabledap

- 16 trajectories shown
- Data subsampled for efficiency (explanation)
- Where fCO2_recommended is valid
- Where WOCE CO2 water is 2
- Where platform name is (?i).*revelle.*

LAS 8./PyFerret 7.6 NOAA/PMEL

142.73 N | 75.59 W | 75.59 W | 37.27 S

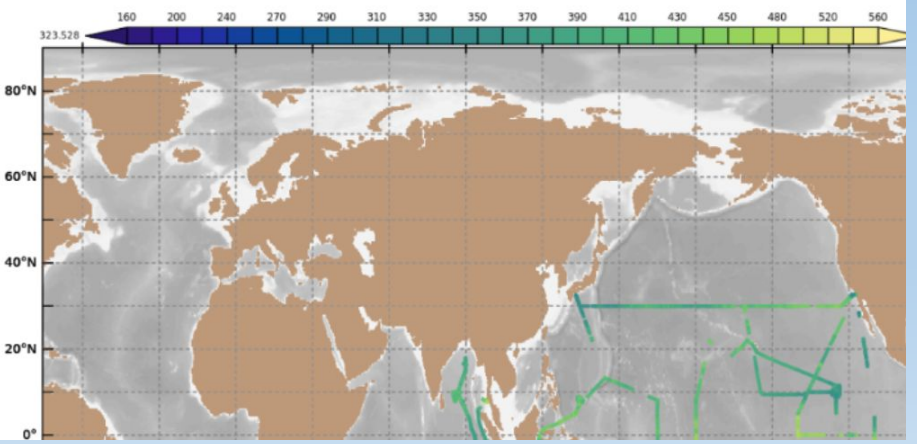
Start date/time: 1957 Jan 01

End date/time: 2022 Dec 31

Maps: Latitude-Longitude

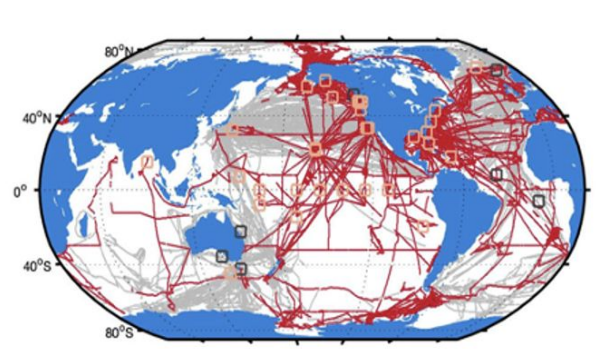
Line Plots: Time

Print | fCO2 recommended

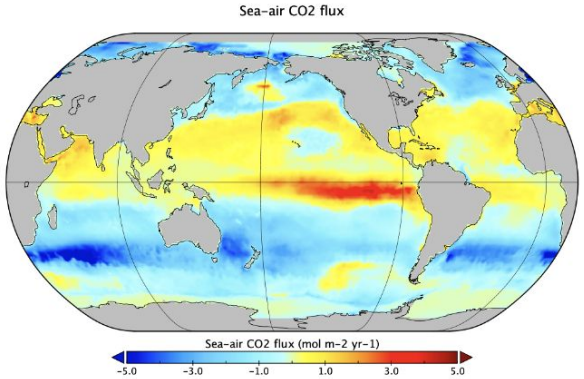


Surface CO_2 Measurements from Research Vessels (UNOLS) Opportunities (rik.wanninkhof@noaa.gov)

- Automated surface water CO_2 measurements (Underway pCO_2) are the cornerstone of global air-sea CO_2 flux estimates
- As part of SOCONET, measurements will be increased with uniform high-quality data to improve products and product delivery to meet the WMO-Greenhouse-Gas watch (G3W) deliverables
- **Research vessels are uniquely positioned to contribute**:
  - -Onboard expertise: Marine technicians
  - - Required infrastructure (scientific seawater line, thermosalinographs, MET sensors, internet controlled, laboratory environments)
  - - Sampling of data in sparse regions of the ocean
- **Value added**: Observations can be used for checks/validation of other data (e.g. BGC Argo) and contribute to many contemporaneous biogeochemical studies (O_2/Ar, NCP, plankton)
- Several (≈4) of the new RVs are being outfitted with state-of-the art systems (General Oceanics)



Current measurements
Red NOAA



Example of product: Fluxes for July 2020

Outputs of G³W

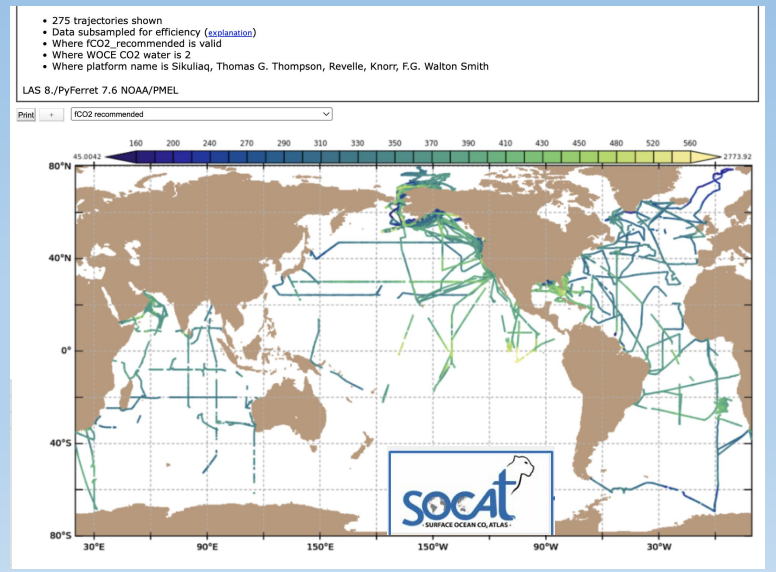
- ✓ Monthly GHG net fluxes with 1x1 degree horizontal resolution and a maximum delay of one month;
- ✓ Other policy-relevant output.

G3W objectives

Surface CO_2 Measurements from Research Vessels (UNOLS) Challenges

- Automated underway pCO_2 instruments are complex
- Require training in operation
- Systems need routine maintenance and checks (≈ 20 minutes/day)
- Systems require extra attention for startup and shutdown (≈ 4 hours each cruise)
- Requires shoreside support for assistance in more complex issues
- Data reduction, quality control, and submission requires special expertise
- Oversight is beneficial

Systems have successfully operated on UNOLS vessels (e.g Thompson, Walton Smith, Sikuliac, Revelle) on GO-SHIP and coastal cruises by the NOAA SOOP-CO_2 program



UW pCO_2 data from UNOLS ships in SOCAT

Setup of GO system on the *Walton Smith*

SOCONET
SURFACE OCEAN CO2 OBSERVING NETWORK

Surface CO_2 Measurements from Research Vessels (UNOLS) Approach, Requirements and Resources (rik.wanninkhof@noaa.gov)

Approach:

- Follow example of NOAA Ship *Ronald H Brown*: operations since 1998
- Close interaction of marine techs on ship with shoreside experts
- Marine techs take responsibility of operations at sea
- Shoreside experts responsible for remote assistance, data reduction, QC and delivery
- Uniform instrumentation and infrastructure

Requirements:

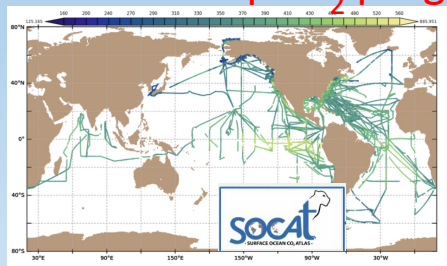
- Dedication and commitment from all parties
- Support from home institutions and command of ships
- Interaction between marine techs on ships and shoreside experts (communal knowledge)

Resources:

- Instrument and infrastructure (≈ $150 K) (already available on several UNOLS RVs)
- Annual maintenance (≈ $10-20 K)
- Personnel time total ≈ 1 mo/yr marine tech ; 1-3 mo/yr shoreside expert for support and data reduction

NOAA's SOOP-CO_2 group interested in collaborating in a UNOLS UW pCO_2 program

UW pCO_2 data from over 200 cruises from the BROWN have been submitted to SOCAT



SOCONET - SURFACE OCEAN CO_2 OBSERVING NETWORK

Rik Wanninkhof, NOAA AOML (rik.wanninkhof@noaa.gov)

Todd Martz, SIO (trmartz@ucsd.edu) has expressed interest

nature geoscience

ARTICLES

Unexpected winter phyt
North Atlantic subpolar

L. Lacour[1]*, M. Ardyna
and D. Iudicone[2]

nature

LETTERS

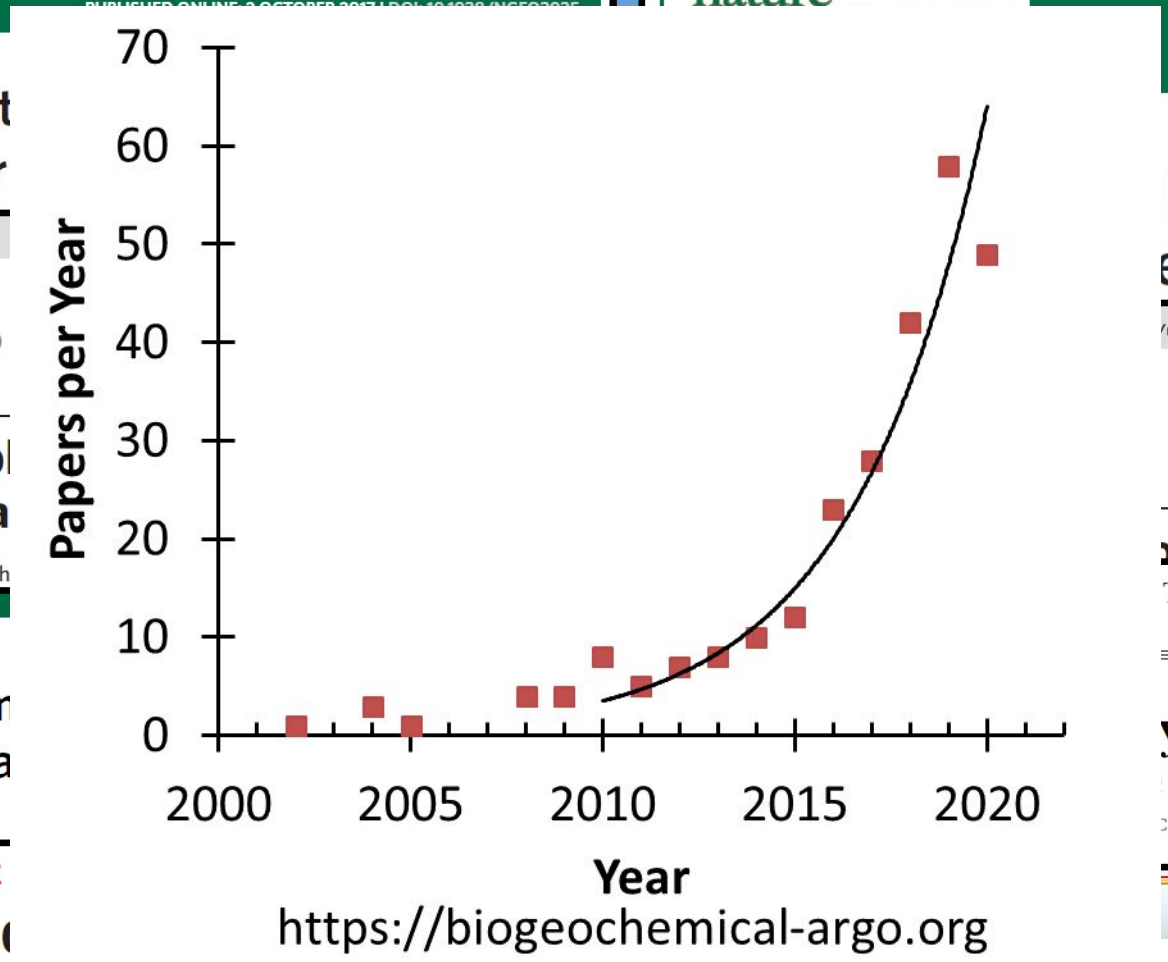
Nitrate suppl
the North Pa

Kenneth S. Johnson[1], Steph

nature geoscience

Importance of wind and m
chemical and physical cha
Ocean

Ben Bronselaer[1,2,3]*, Joelle
John P. Dunne[2], Richard A.



CARBON CYCLE

Major role
biological sequestration of CO_2 by the oceans

Nathan Briggs[1,2]*, Giorgio Dall'Olmo[3,4], Hervé Claustre[2]

nature

PUBLISHED ONLINE: 26 SEPTEMBER 2016 | DOI: 10.1038/NGEO2818

LETTERS

input to the mesopelagic
e seasonal mixed-layer pump

/nature06441 nature

LETTERS

on of oxygen in the subtropical ocean

T U R E | www.nature.com/nature

https://doi.org/10.1038/s41586-019-1294-0

ynyas linked to
cli

. Riser[1], C

nature COMMUNICATIONS

ARTICLE

Check for updates

https://doi.org/10.1038/s41467-020-16931-0 OPEN

Remote assessment of the fate of phytoplankton in the Southern Ocean sea-ice zone

Sébastien Moreau[1,2✉], Philip W. Boyd[2] & Peter G. Strutton[2,3]

ARTICLE

DOI: 10.1038/s41467-017-02143-6 OPEN

Floats with bio-optical sensors reveal what processes trigger the North Atlantic bloom

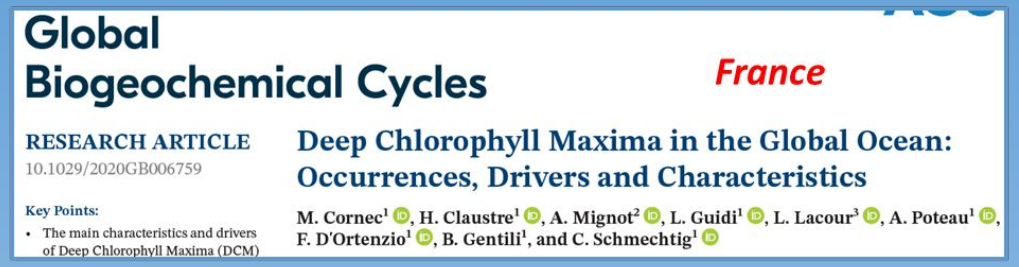
Mignot[1,2], R. Ferrari[1] & H. Claustre[2]

GO-BGC Global Ocean Biogeochemistry Array

biogeochemical Argo

SOCCOM

GO-BGC & SOCCOM data are freely available in real time


Global Biogeochemical Cycles

France

RESEARCH ARTICLE
10.1029/2020GB006759

Deep Chlorophyll Maxima in the Global Ocean: Occurrences, Drivers and Characteristics

Key Points:
- The main characteristics and drivers of Deep Chlorophyll Maxima (DCM)

M. Cornec[1], H. Claustre[1], A. Mignot[2], L. Guidi[1], L. Lacour[3], A. Poteau[1], F. D'Ortenzio[1], B. Gentili[1], and C. Schmechtig[1]


nature COMMUNICATIONS

Australia

ARTICLE

https://doi.org/10.1038/s41467-020-16931-0 OPEN

Remote assessment of the fate of phytoplankton in the Southern Ocean sea-ice zone

Sébastien Moreau[1,2✉], Philip W. Boyd[2] & Peter G. Strutton[2,3]


nature geoscience

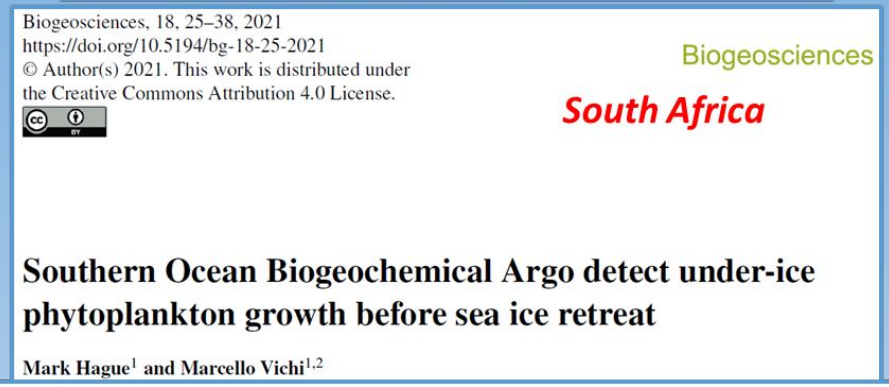
United Kingdom

LETTERS

PUBLISHED ONLINE: 26 SEPTEMBER 2016 | DOI: 10.1038/NGEO2818

Substantial energy input to the mesopelagic ecosystem from the seasonal mixed-layer pump

Giorgio Dall'Olmo[1,2,3*], James Dingle[1], Luca Polimene[1], Robert J. W. Brewin[1,2] and Hervé Claustre[4]

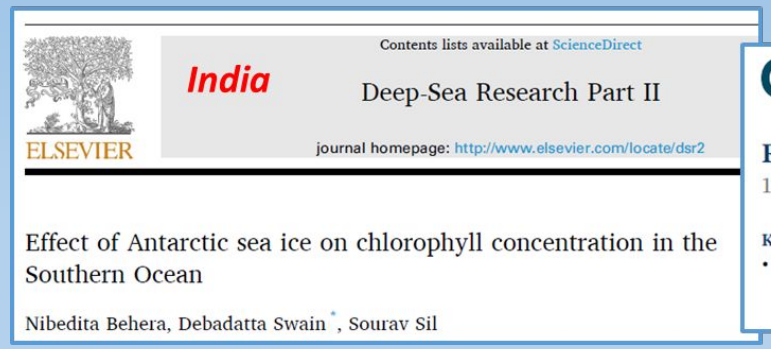

Biogeosciences, 18, 25–38, 2021
https://doi.org/10.5194/bg-18-25-2021
© Author(s) 2021. This work is distributed under the Creative Commons Attribution 4.0 License.

Biogeosciences

South Africa

Southern Ocean Biogeochemical Argo detect under-ice phytoplankton growth before sea ice retreat

Mark Hague[1] and Marcello Vichi[1,2]


ELSEVIER

Contents lists available at ScienceDirect

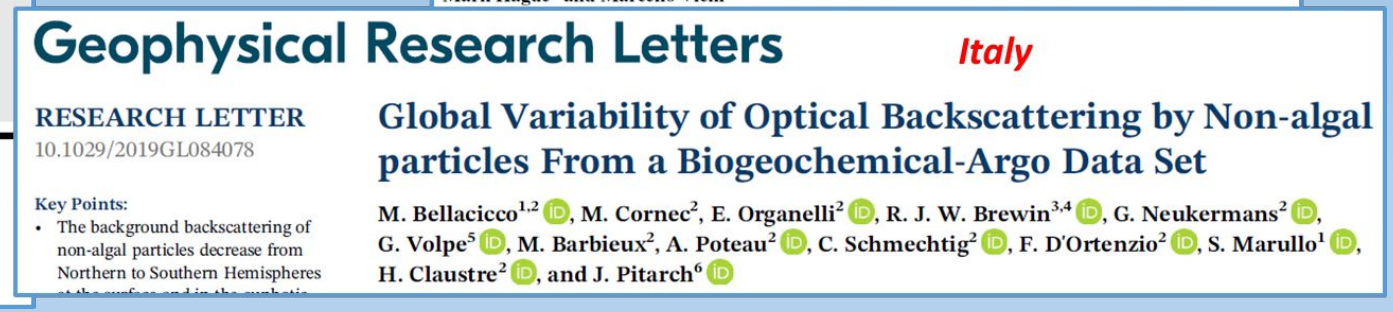
India

Deep-Sea Research Part II

journal homepage: http://www.elsevier.com/locate/dsr2

Effect of Antarctic sea ice on chlorophyll concentration in the Southern Ocean

Nibedita Behera, Debadatta Swain *, Sourav Sil


Geophysical Research Letters

Italy

RESEARCH LETTER
10.1029/2019GL084078

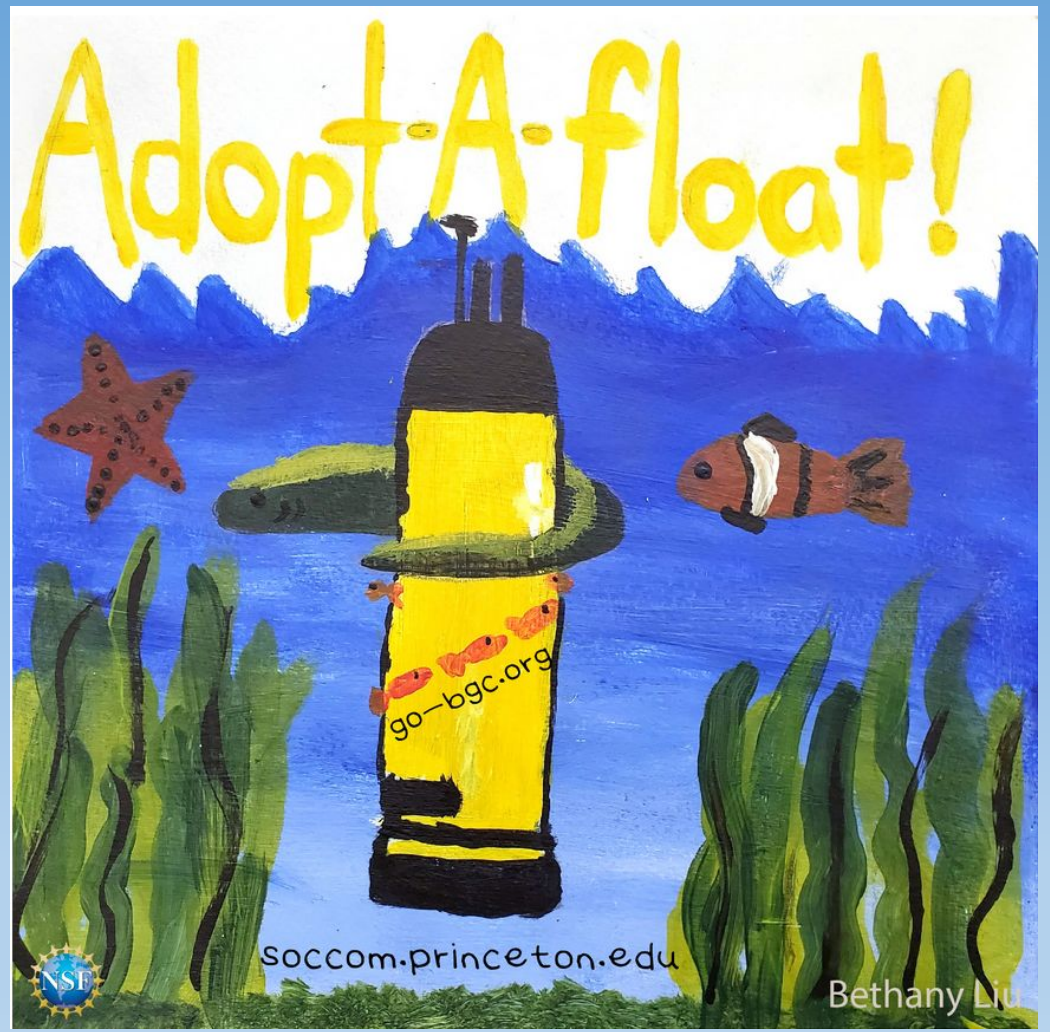
Global Variability of Optical Backscattering by Non-algal particles From a Biogeochemical-Argo Data Set

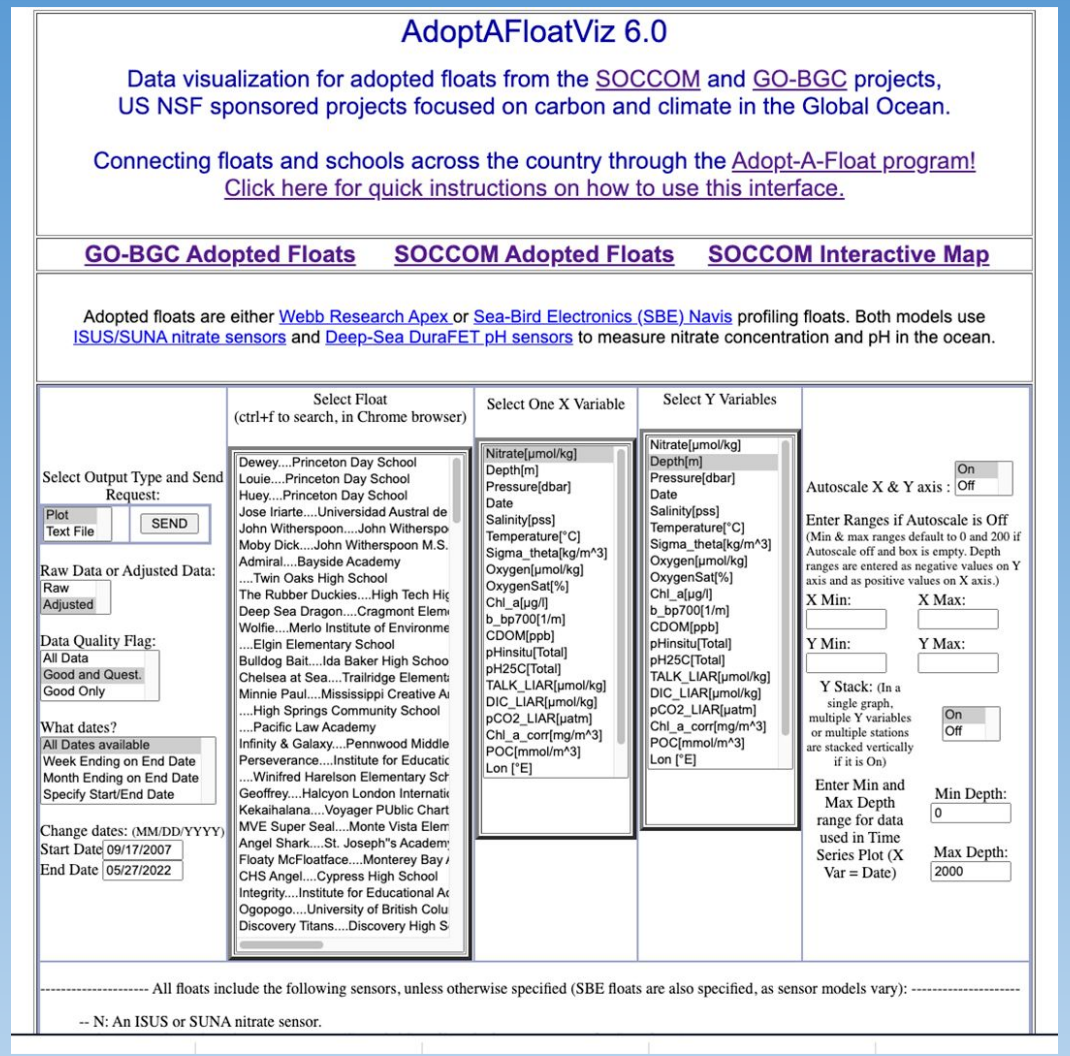
Key Points:
- The background backscattering of non-algal particles decrease from Northern to Southern Hemispheres

M. Bellacicco[1,2], M. Cornec[2], E. Organelli[2], R. J. W. Brewin[3,4], G. Neukermans[2], G. Volpe[5], M. Barbieux[2], A. Poteau[2], C. Schmechtig[2], F. D'Ortenzio[2], S. Marullo[1], H. Claustre[2], and J. Pitarch[6]

GO-BGC Outreach Efforts

- **MATE Floats! In the ROV Challenge**
  - Marine Advanced Technology and Education (MATE) II
- **Adopt-a-Float Program**
  - each float is paired with a classroom
- **Educator Workshops**
  www.mbari.org/EARTH
- **Researcher Workshop - June 28/30**
- **MakerSpace (UCSD-SIO)**





Schools in 45 states, many countries have adopted floats.

ADOPT A FLOAT

GO-BGC Global Ocean Biogeochemistry Array

MBARI

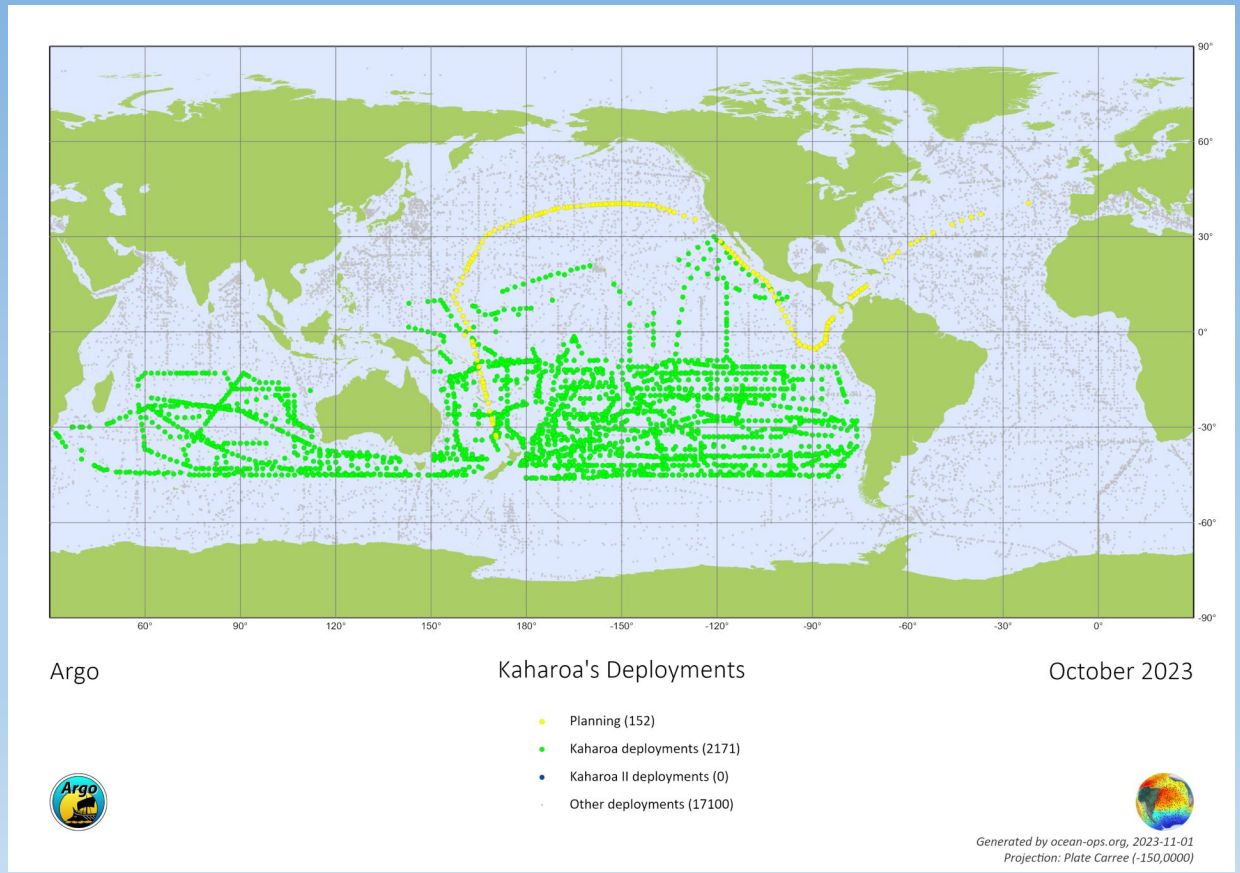
SOCCOM

In the future, “vessels will be support, not monitoring platforms” Mel Briscoe, 2010.

A new class of ships can be small to control costs.

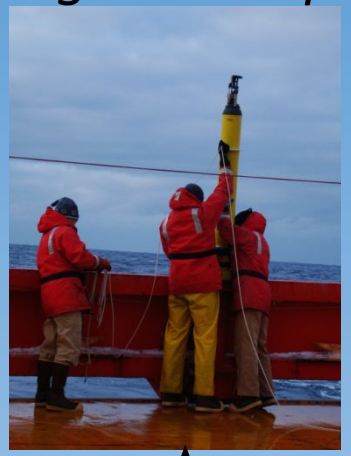
E.g., 28 meter R/V Kaharoa has deployed more than 2000 Argo floats.

36 m Kaharoa II replacement is in construction that will enable deployments further south.



First science mission of MBARI's new R/V David Packard will be deployment of GO-BGC profiling floats on its delivery voyage (Feb. 2024)

GO-BGC, SOCCOM, BGC-Argo are at the cross-roads of ocean observing. They make observing with ships and satellites better. They don't replace them.



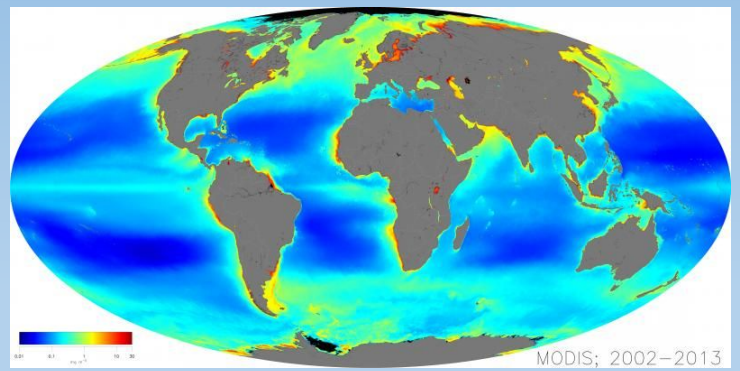
GO - SHIP

TOWARDS A SUSTAINED GLOBAL SURVEY OF THE OCEAN INTERIOR

GO-SHIP brings together scientists with interests in physical oceanography, the carbon cycle, marine biogeochemistry and ecosystems, and other users and collectors of hydrographic data to develop a globally coordinated network of sustained hydrographic sections as part of the global ocean/climate observing system.

GO-SHIP is a major contributor to WCRP's Climate Variability and Predictability Experiment (CLIVAR) and International Ocean Carbon Coordination Project. GO-SHIP is part of the Global Climate Observing System / Global Ocean Observing System (GCOS / GOOS).

Ocean color, SST, Altimetry, LIDAR



SOCAT
SURFACE OCEAN CO2 ATLAS