Biogeochemical-Argo, Exploring Global Ocean Chemistry and Biology in Real-time with Robots and Sensors

Informing scientists, ocean managers, and the public

Kenneth S. Johnson
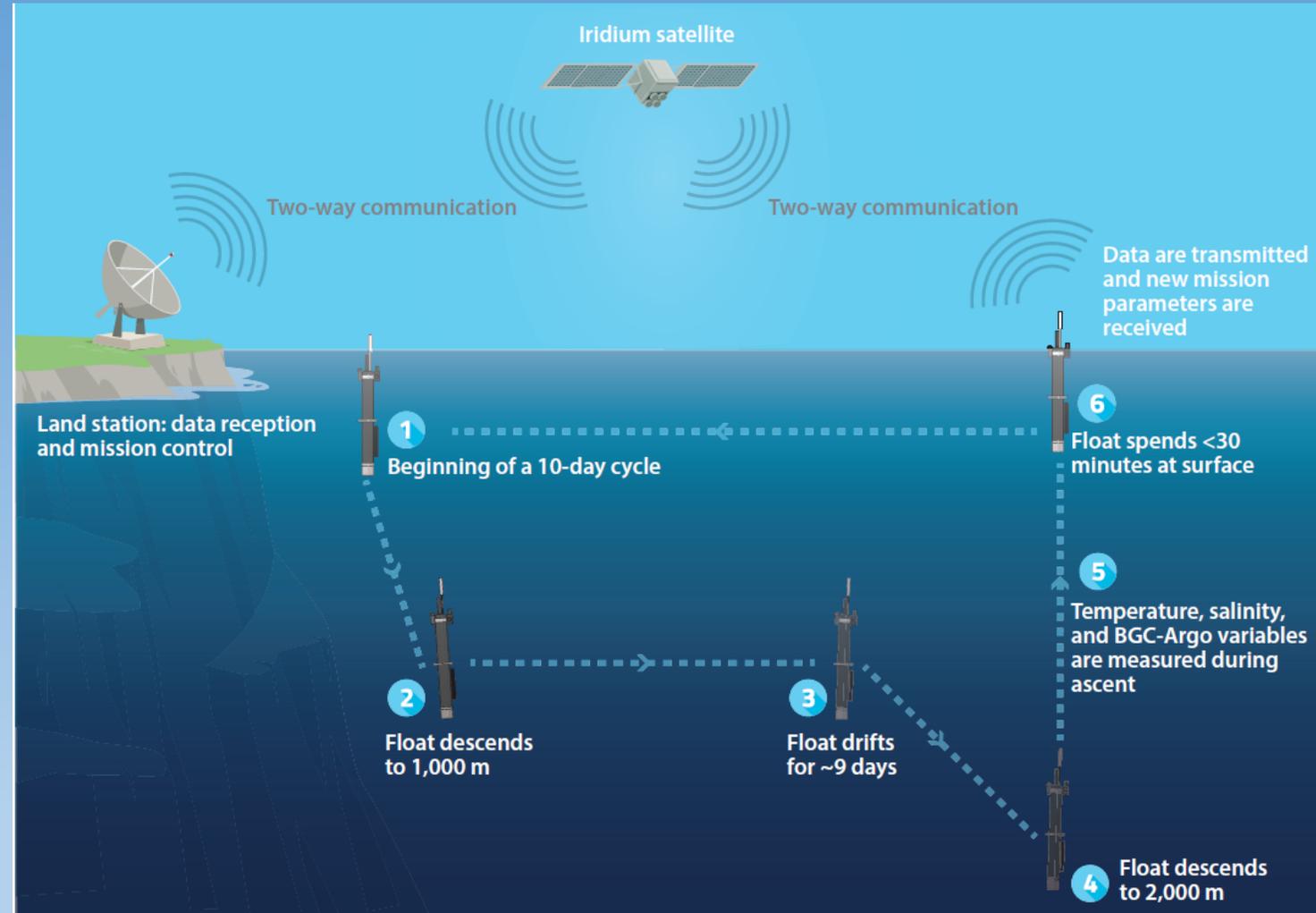Monterey Bay Aquarium Research Institute
johnson@mbari.org

Symposium on the Advancement of Marine Biological Big Data Utilization Technologies

NSF

UNITED STATES ANTARCTIC PROGRAM · NATIONAL SCIENCE FOUNDATION

NOPP

NOAA · NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · U.S. DEPARTMENT OF COMMERCE

NASA

GO-BGC
Global Ocean Biogeochemistry Array

SOCCOM | Unlocking the mysteries of the Southern Ocean

What is Biogeochemical-Argo?

- A global array of robotic chemical and biological sensors, operating as part of the One Argo system.

- It supplies essential data for ocean health, carbon budgets, effects of marine CO_2 removal (mCDR).

- *All data is freely available within 24 hours.*

Iridium satellite

Two-way communication   Two-way communication

Data are transmitted and new mission parameters are received

Land station: data reception and mission control

1 Beginning of a 10-day cycle

6 Float spends <30 minutes at surface

5 Temperature, salinity, and BGC-Argo variables are measured during ascent

2 Float descends to 1,000 m

3 Float drifts for ~9 days
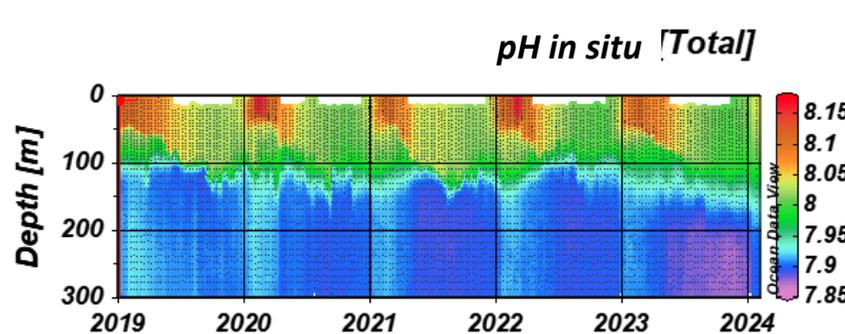
4 Float descends to 2,000 m
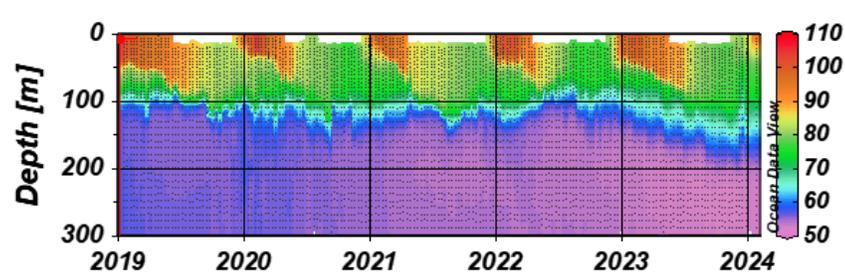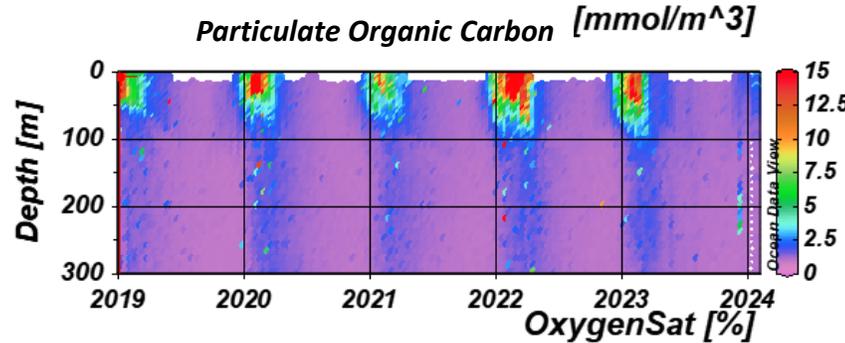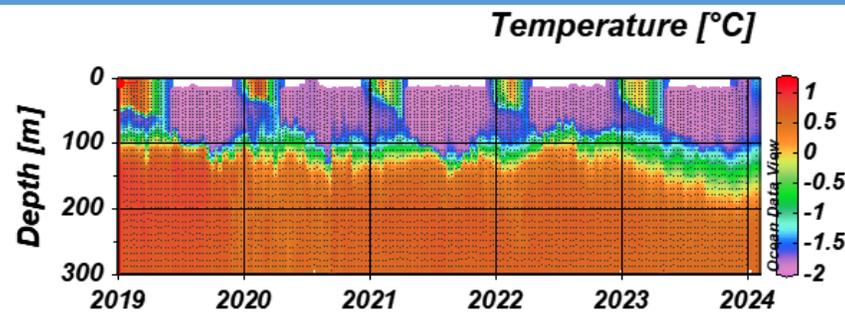
GO-BGC Global Ocean Biogeochemistry Array

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BGC-floats measure oxygen, nitrate, pH, bio-optics.

They operate for years in the harshest environments.
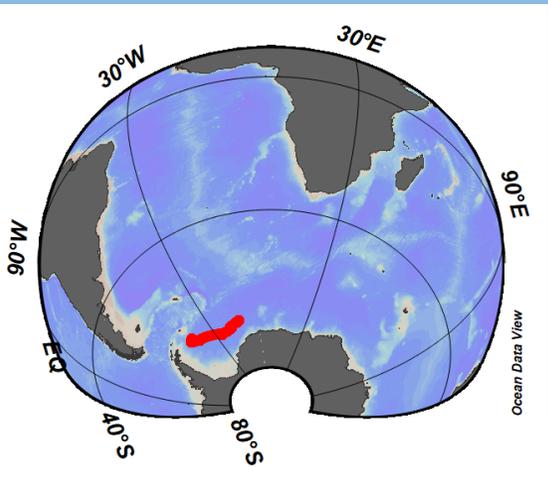
Float 11090/WMO 5905995 in the seasonal ice zone of the Weddell Sea
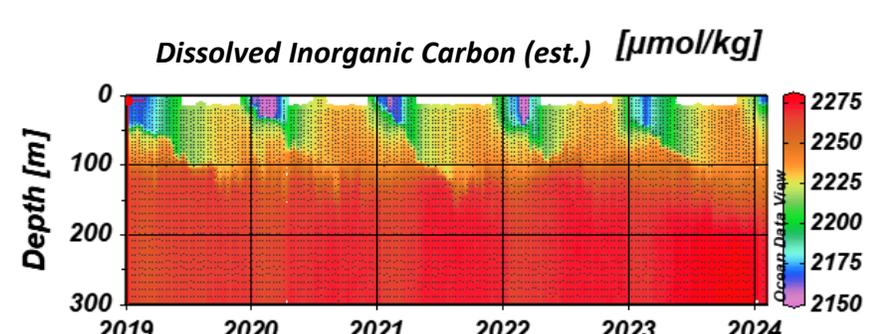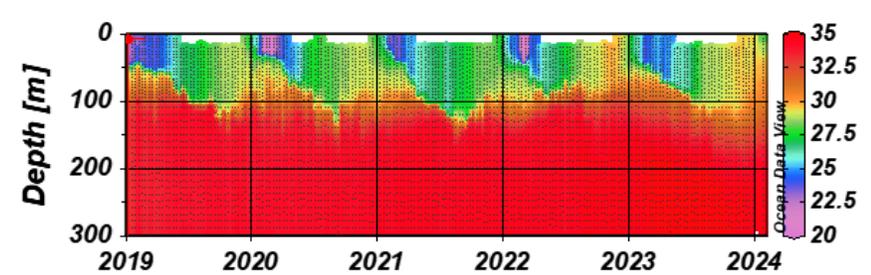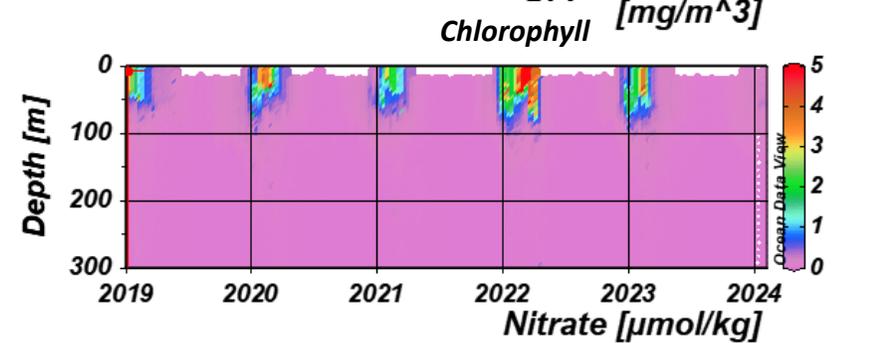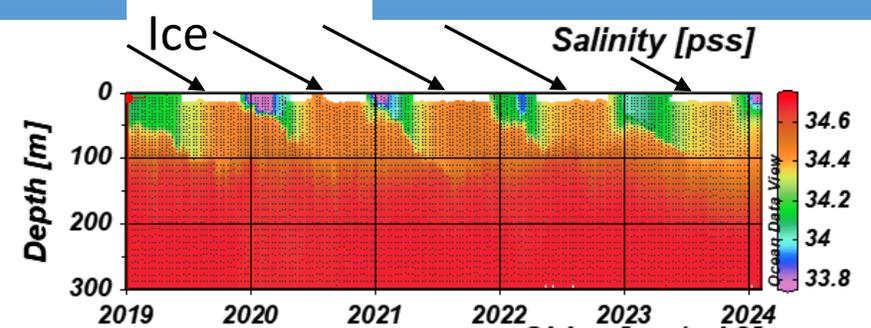
BGC-Argo (& GO-BGC) are components of the One-Argo system, working in synergy to observe the global ocean
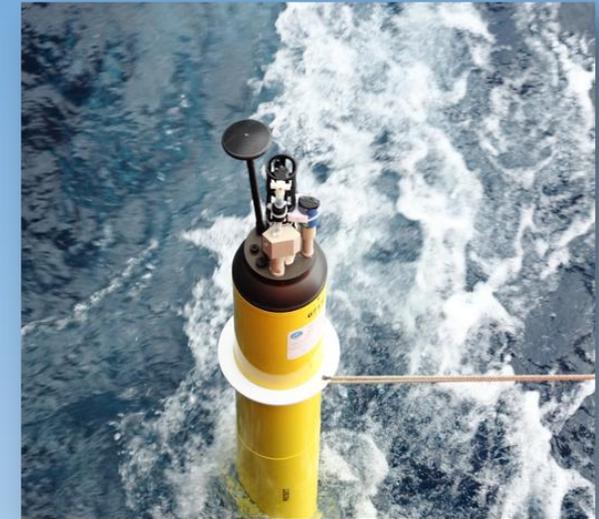

Deep-Argo

Temp./Salinity to 6000 m

Core-Argo

Temp./Salinity to 2000 m

Biogeochemical-Argo

T/S/Chem./Biol. to 2000 m

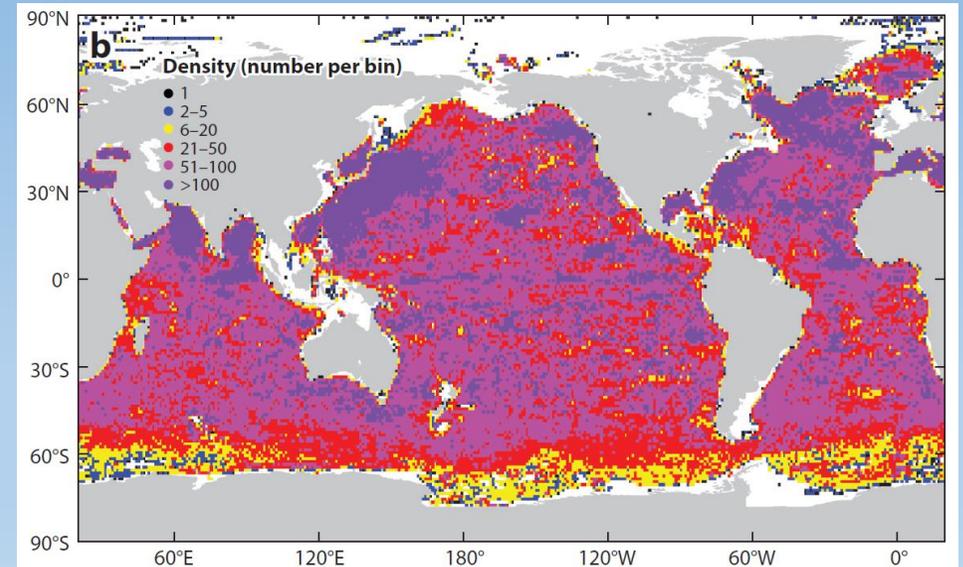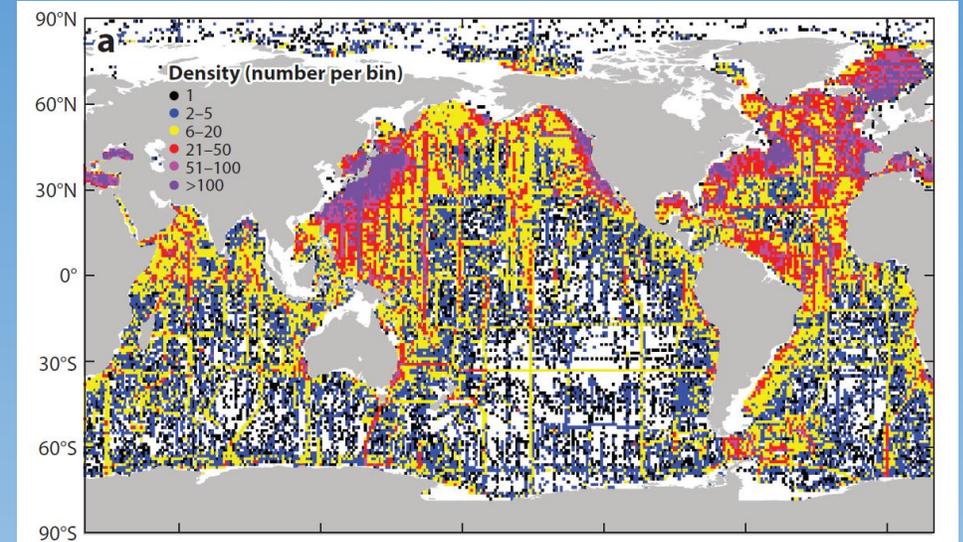Freely drifting, deep ocean robotic instruments that profile to the sea surface

Robotic Argo observations of temperature and salinity have transformed ocean physics

Ships, past 100 years

Argo floats, past 21 years

Number of temperature profiles per 1° x1° bin

Legend (Number of temperature profiles per 1° x1° bin):
- 1
- 2–5
- 6–20
- 21–50
- 51–100
- >100

GO-BGC Global Ocean Biogeochemistry Array

SOCCOM — Unlocking the mysteries of the Southern Ocean

# BGC-Argo is delivering the same revolution for carbon, nitrate, oxygen

BGC-Argo Science & Implementation Plan

- International (18 nations deploy BGC floats)

- Plan calls for a sustained array of **1000 profiling floats**, based on observing system simulation experiments

- Each float carries O_2, pH, NO_3^-, bio-optical sensors

- Well defined science mission

  - Carbon cycle, acidification, deoxygenation, productivity, fisheries management, biomass, carbon sequestration

- Data freely available in real-time (< 24 hours)

http://biogeochemical-argo.org

Biogeochemical-Argo
Science & Implementation Plan

The Biogeochemical-Argo Planning Group

biogeochemical Argo

ISA ROSSO
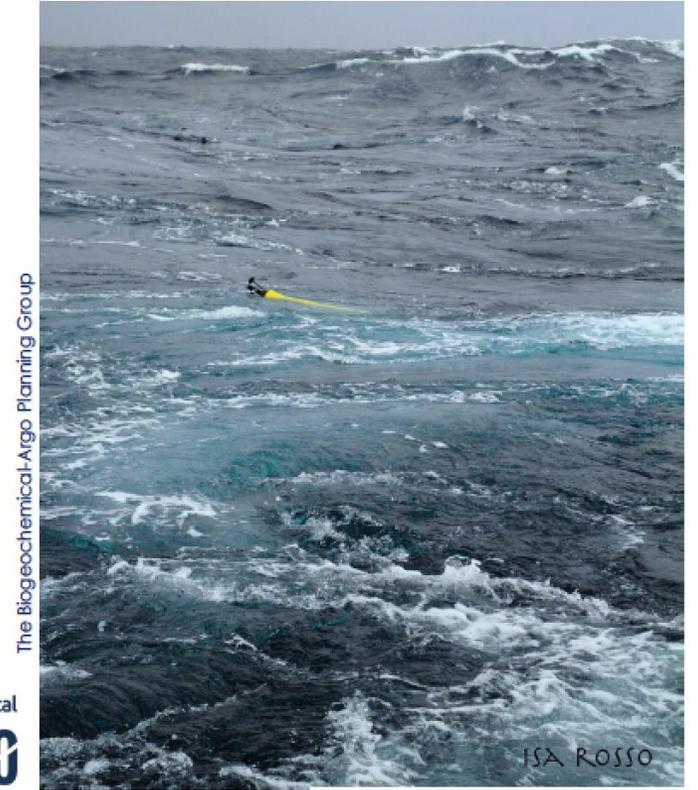
Edited by Ken Johnson & Hervé Claustre

biogeochemical Argo

BGC-Argo floats with oxygen, nitrate, pH, bio-optical sensors

504 floats

Legend: USA, UK, France/EU, China, Australia, India

Floats shown have reported at least 1 cycle in the past 1 year(s)   [16-Oct-2025]

BGC-Argo now has about ½ of the desired 1000 multi-sensor floats.
82% are US floats.
Many more with oxygen only.

BGC-Argo floats with oxygen sensors

971 floats
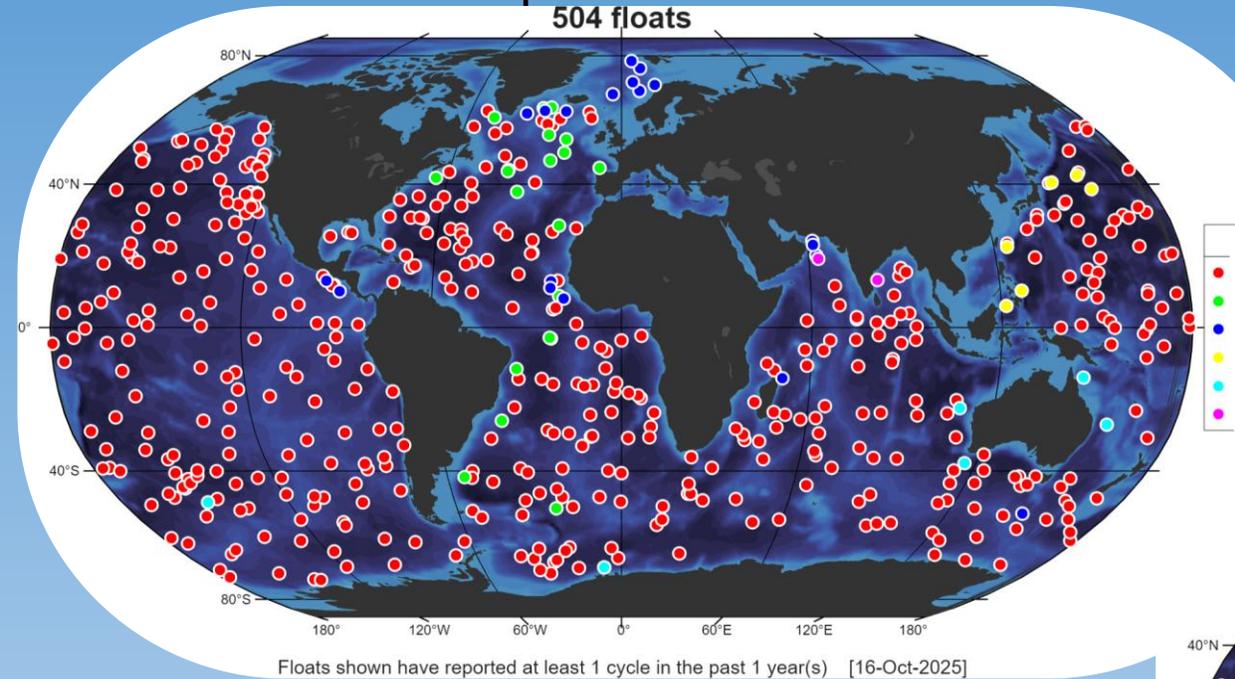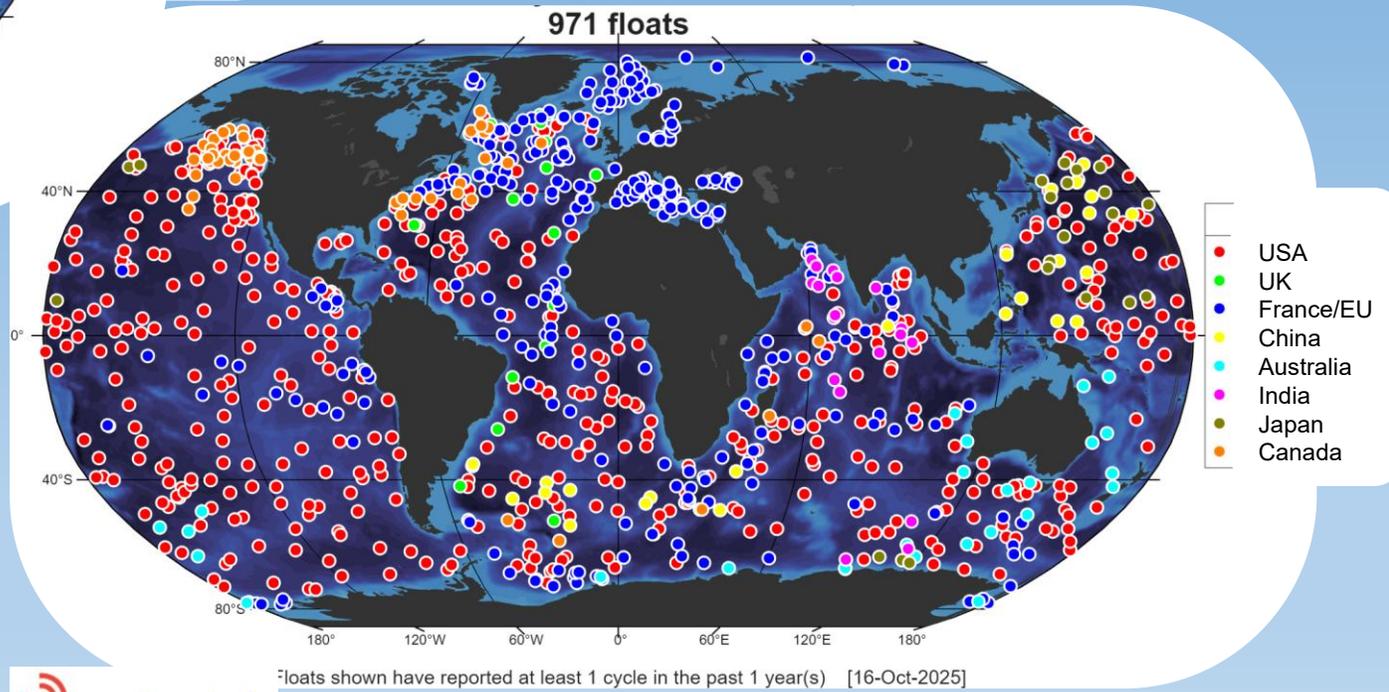
Legend: USA, UK, France/EU, China, Australia, India, Japan, Canada

Floats shown have reported at least 1 cycle in the past 1 year(s)   [16-Oct-2025]

AUSTRALIA (21)	CHINA (19)	FINLAND (2)
BULGARIA (8)	DENMARK (2)	FRANCE (96)
CANADA (78)	EUROPE (13)	GERMANY (45)
INDIA (15)	NEW ZEALAND (2)	SPAIN (2)
ITALY (42)	NORWAY (12)	UK (21)
JAPAN (14)	POLAND (10)	USA (423)

GO-BGC Global Ocean Biogeochemistry Array
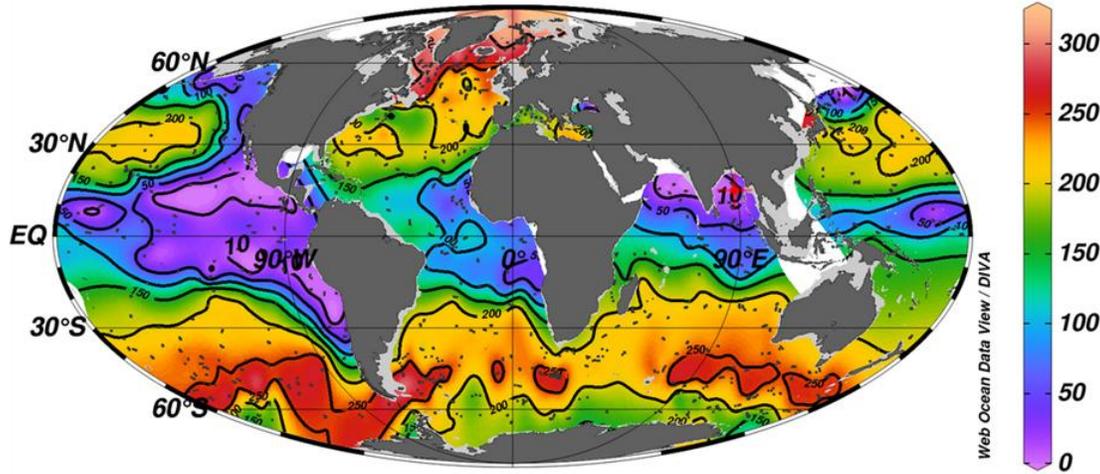
biogeochemical Argo

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Ship-based profiles are declining precipitously.
BGC-Argo is now the dominant source of biogeochemical data for the ocean interior.
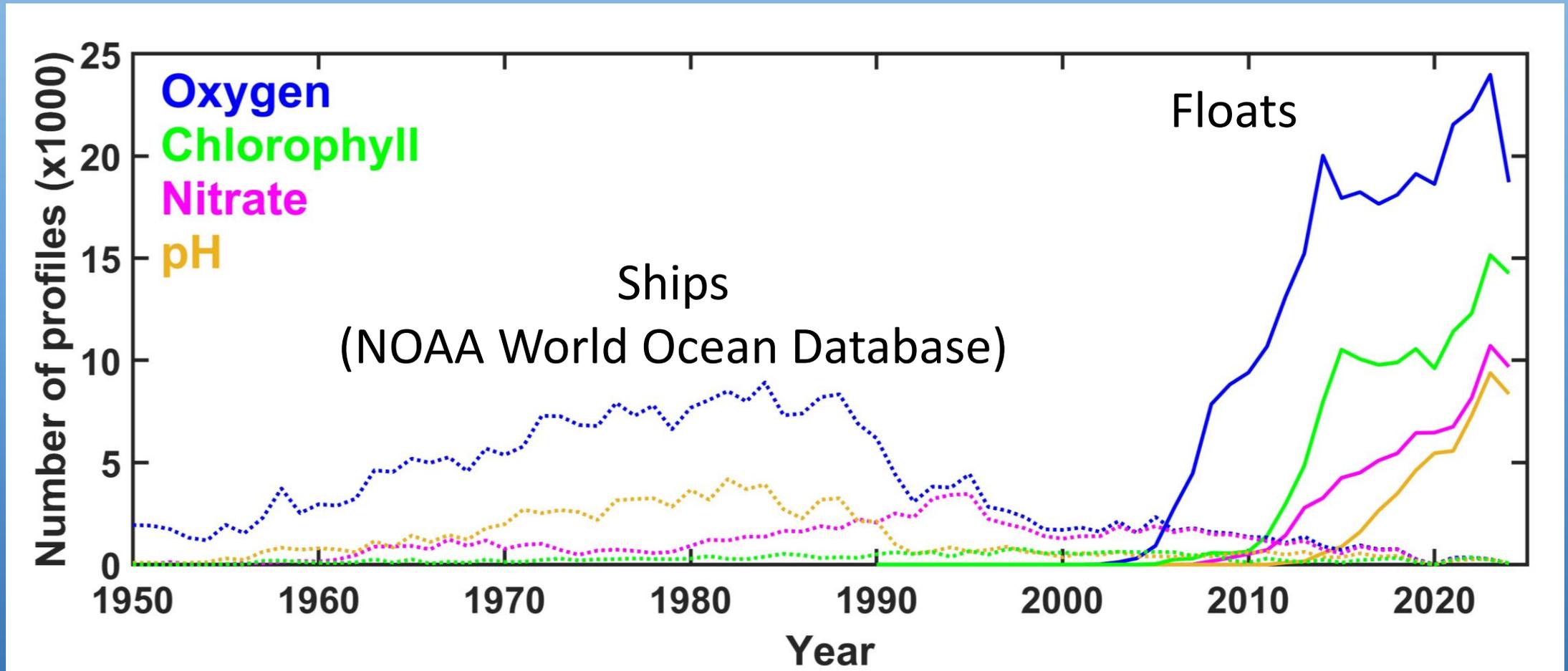
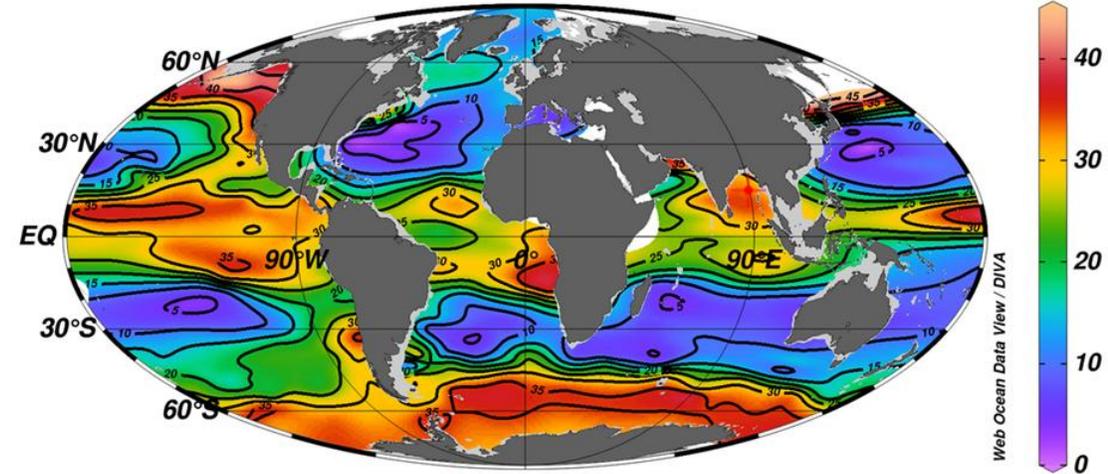# BGC-Argo provides monthly resolution of processes that took decades to observe from ships.
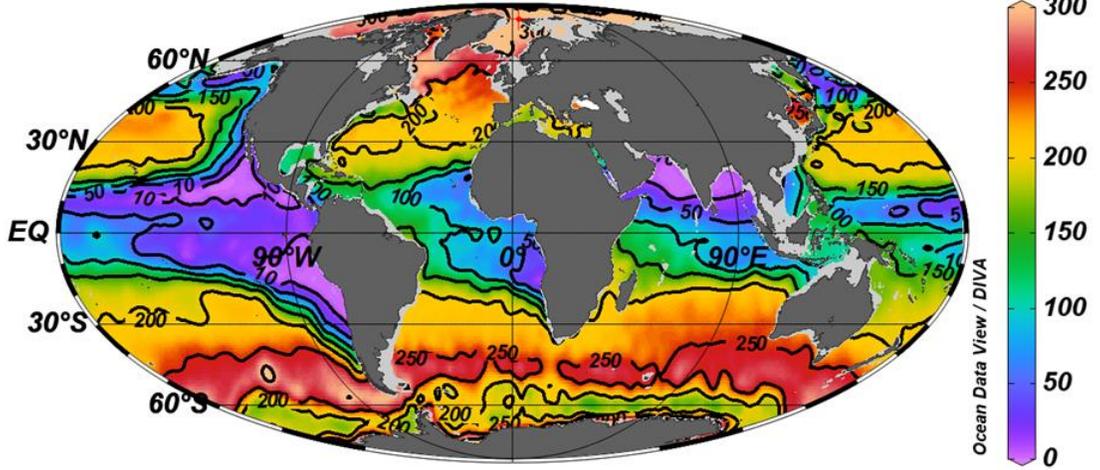

BGC-Argo Oxygen (µmol/kg) @ 300 m, May 2025

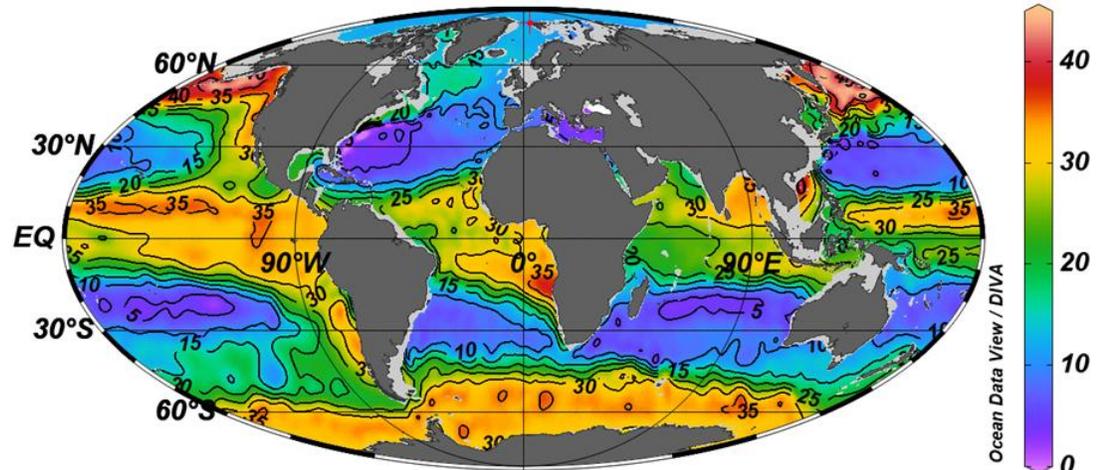BGC-Argo Nitrate (µmol/kg) @ 300 m, May 2025

GLODAP Oxygen at 300 m (µmol kg^{-1})

GLODAP Nitrate at 300 m (µmol kg^{-1})

webODV   Argo > Ocean > Biogeochemistry > BGC-Argo_Global_Profiles

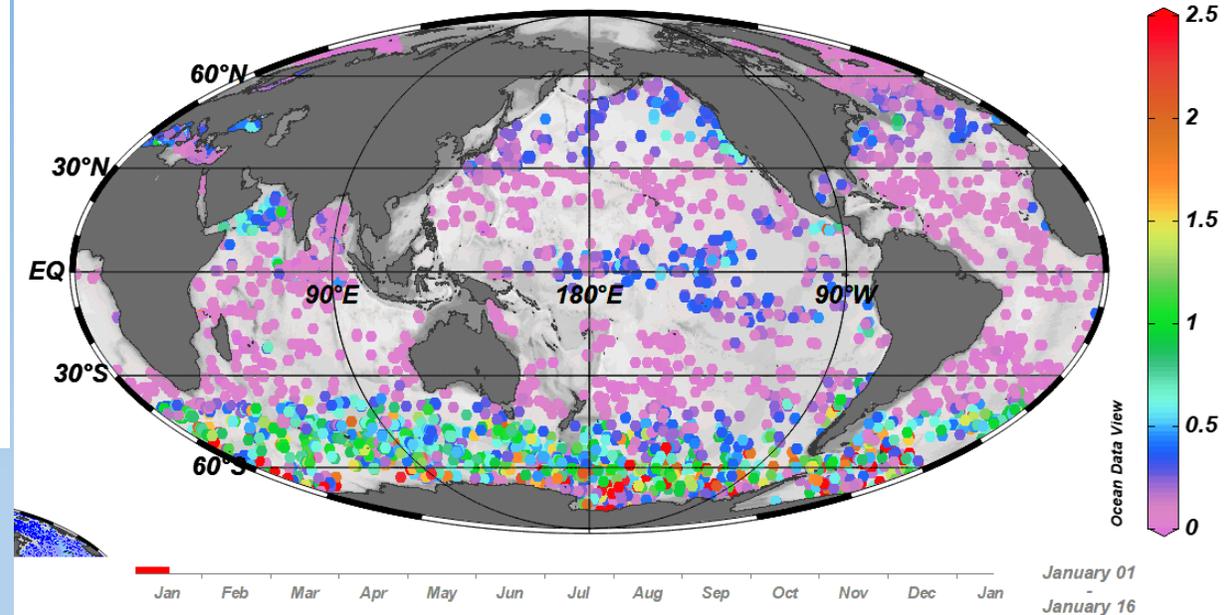GLODAPv2:2023, 1973-2024, a global set of high-quality, ship-based observations

65,000,000 Argo oxygen measurements available
Surface oxygen percent saturation (100% = Equilibrium with the atmosphere)

Oxygen % Saturation
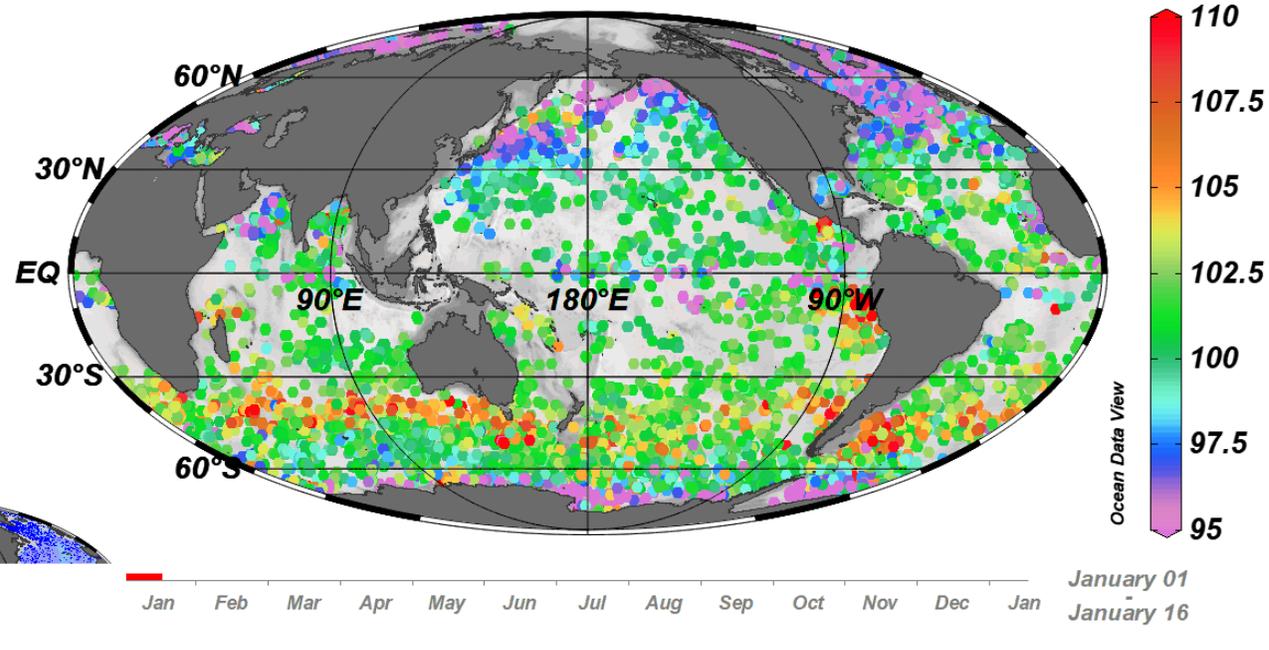
56,000,000 Argo chlorophyll measurements available

Chlorophyll (mg m^{-3})

GO-BGC Global Ocean Biogeochemistry Array

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Merging ship (1.2 million) and float (65 million) oxygen observations to determine ocean biological productivity

Calculate all of the physical fluxes

JAMSTEC & JMA

The sum is the biological signal of net ocean productivity

Annual upper ocean dissolved O_2 balance

Global balance :
$F_{A-S} + F_{vDIFF} + F_{hDIFF} + F_{ADV} = -NBP_{O_2}$
-206 ± 246 -248 ± 33 -120 ± 49 -316 ± 38 -889 ± 256

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The translation of scattered observations to regular maps with Machine Learning promotes widespread use of observational datasets
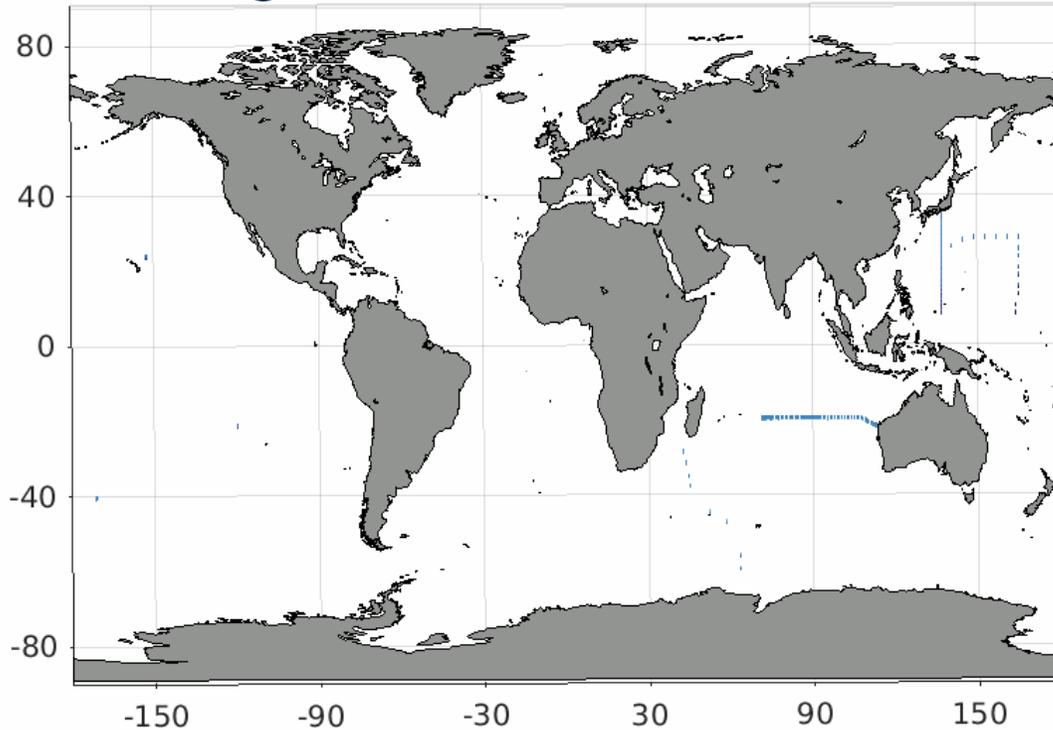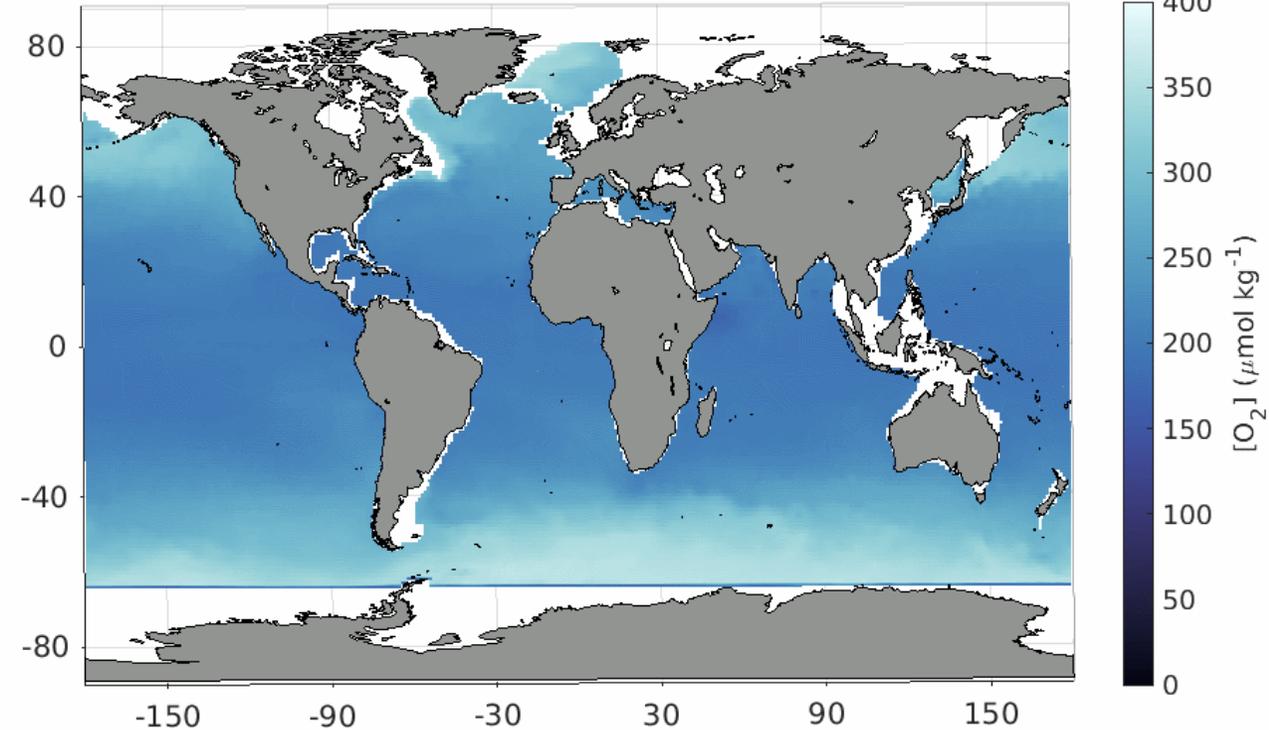

GOBAI-O$_2$: temporally and spatially resolved fields of ocean interior dissolved oxygen over nearly 2 decades

Jonathan D. Sharp ✉, Andrea J. Fassbender, Brendan R. Carter, Gregory C. Johnson, Cristina Schultz, and John P. Dunne
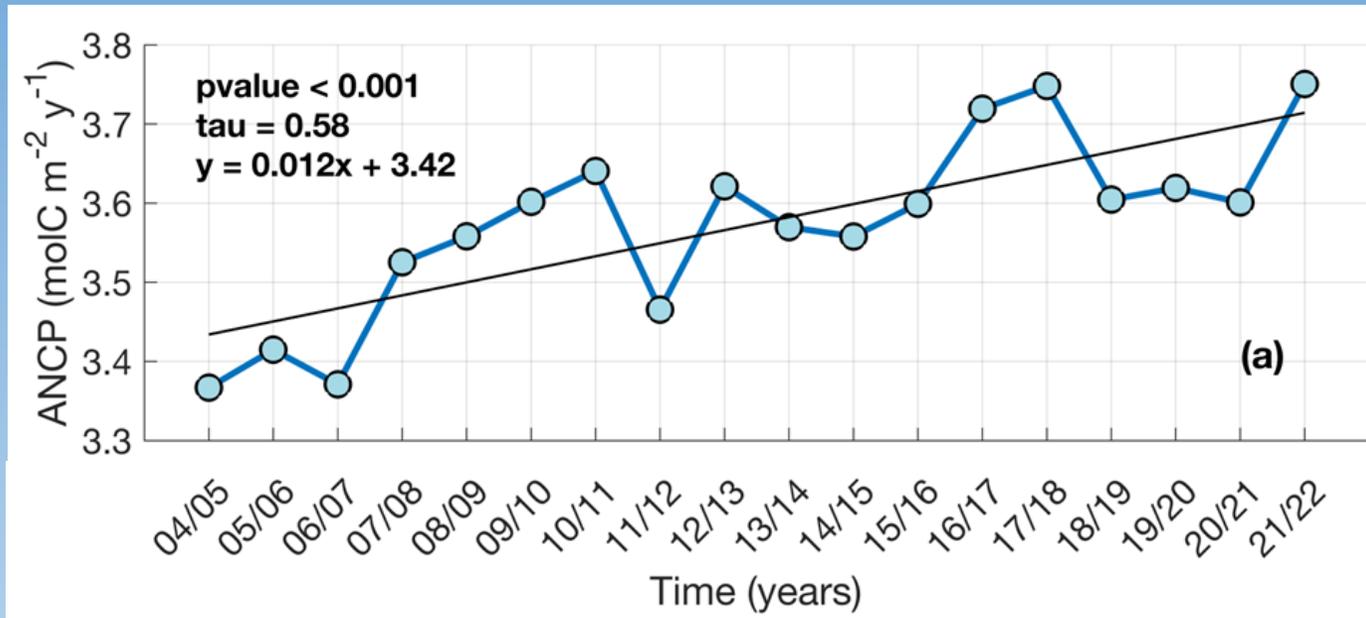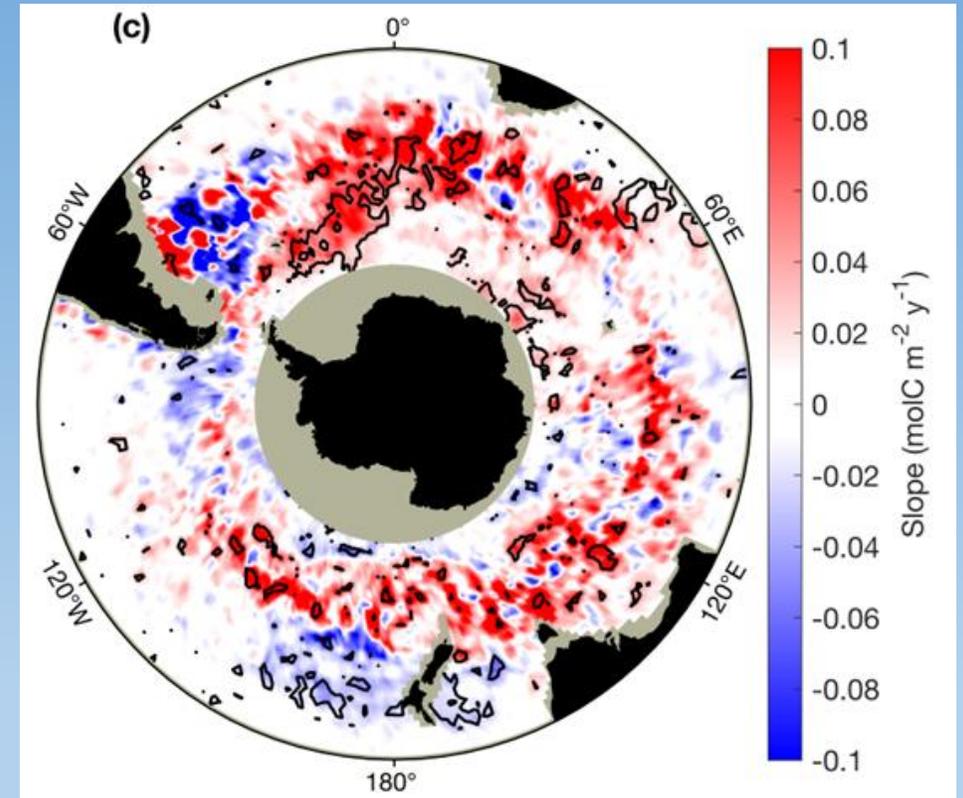
Two Decades of Increase in Southern Ocean Net Community Production Revealed by BGC-Argo Floats

Guillaume Liniger[1], Jonathan D. Sharp[2,3], Yuichiro Takeshita[1], and Kenneth S. Johnson[1]

Key Points:

Annual Net Community Productivity (ANCP) going up in Southern Ocean, likely due to warming.
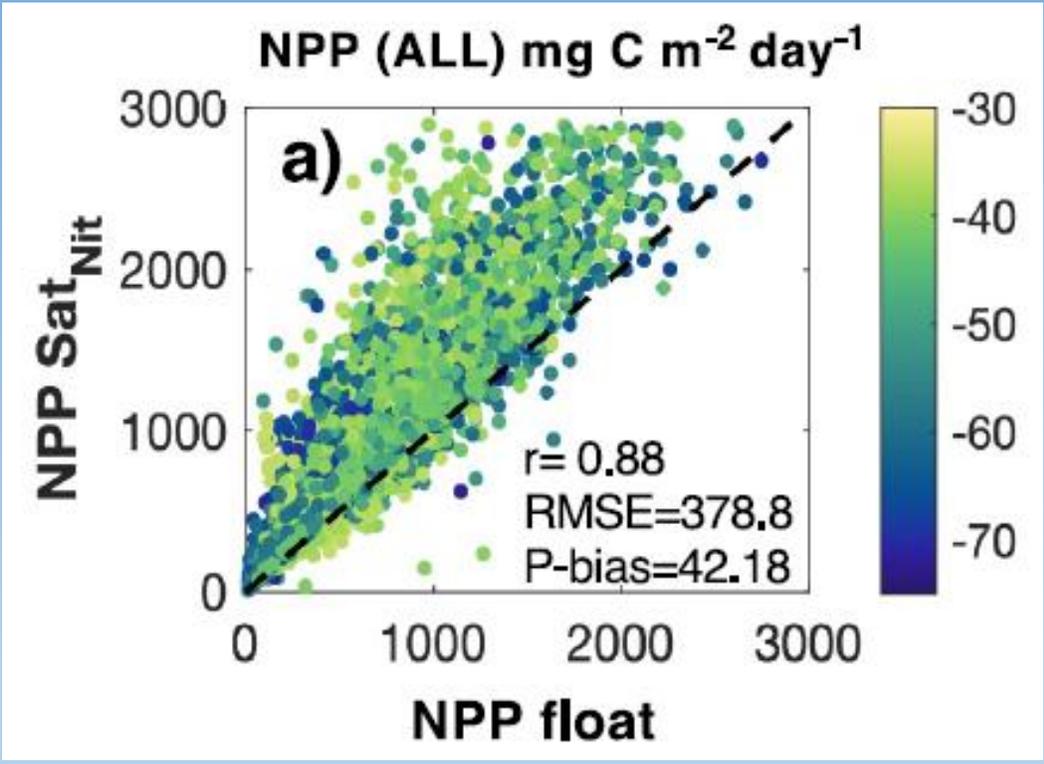
BGC-Argo float and satellite synergy

The Contribution of Deep Chlorophyll Maxima to Net
Primary Production in the Southern Ocean

Clara R. Vives[1,2,3], Christina Schallenberg[4,5], Peter G. Strutton[1,2,6], Jørgen Bendtsen[3]
Katherine Richardson[7], and Philip W. Boyd[1,5,6]

Key Points:
• Deep chlorophyll and biomass maxima
  are widespread south of 30°S in both

Understanding the role of phytoplankton communities living beneath the depth seen by ocean color satellites to ocean Net Primary Production (NPP).
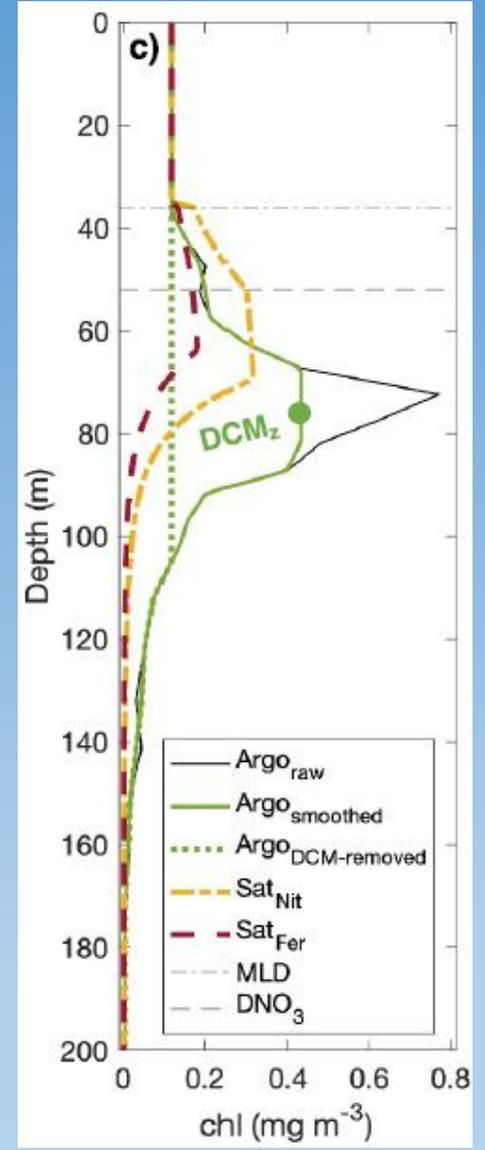
Differences in chlorophyll measured by floats and by satellites reflect variability in phytoplankton physiology

Seasonal biases in fluorescence-estimated chlorophyll-a derived from biogeochemical profiling floats

Jacqueline S. Long[1] ✉, Yuichiro Takeshita [1], Joshua N. Plant[1], Nina Buzby[2], Andrea J. Fassbender [1][3] & Ken S. Johnson [1]
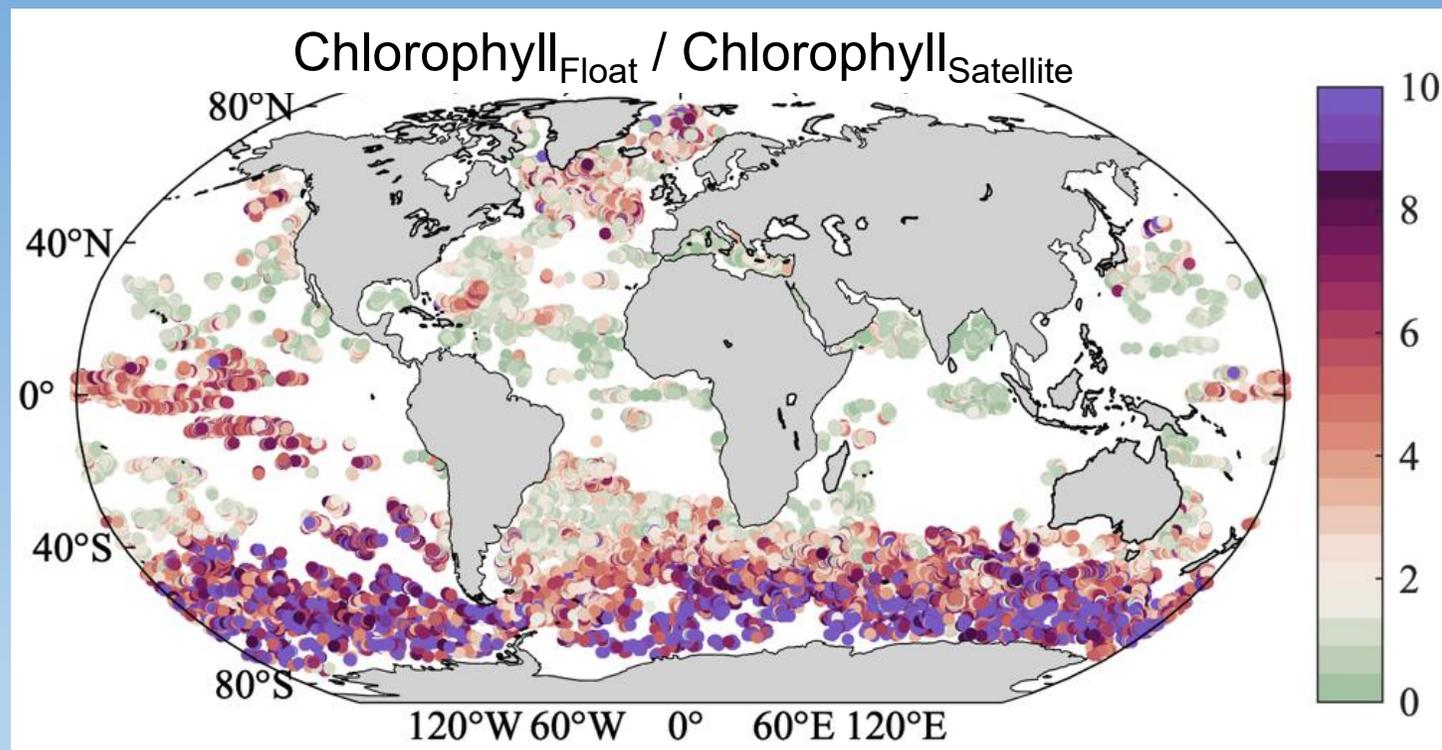
Chlorophyll$_{Float}$ / Chlorophyll$_{Satellite}$

What's next? Moving biological sensors from chlorophyll and backscatter to physiology and imaging.
Fast Repetition Rate Fluometery, Underwater Vision Profiler and Event-based Vision Sensors are good examples.

Tetsuichi Fujiki, Kanako Sato, Shigeki Hosoda (JAMSTEC)
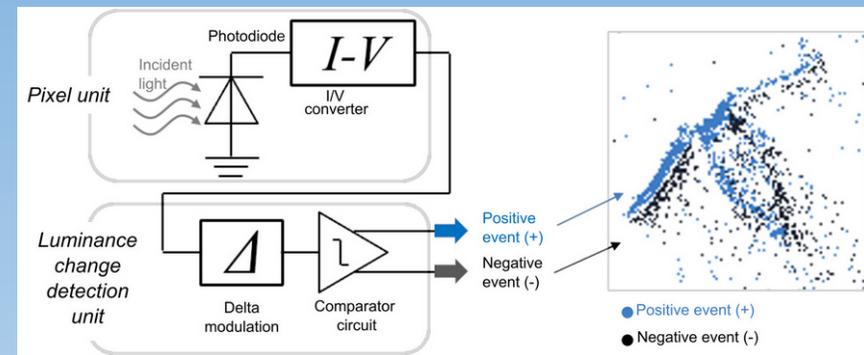
Tohoku University & JAMSTEC
Advanced Institute for Marine Ecosystem Change
(WPI-AIMEC)

…established in 2024 as **18th WPI Center** & **1st Multi-host WPI Center**

Mission:
Elucidate the response and adaptation mechanisms of marine ecosystems to Earth system changes

WPI-AIMEC's Primary Approach:
Uncovering the missing links between marine physics and ecology
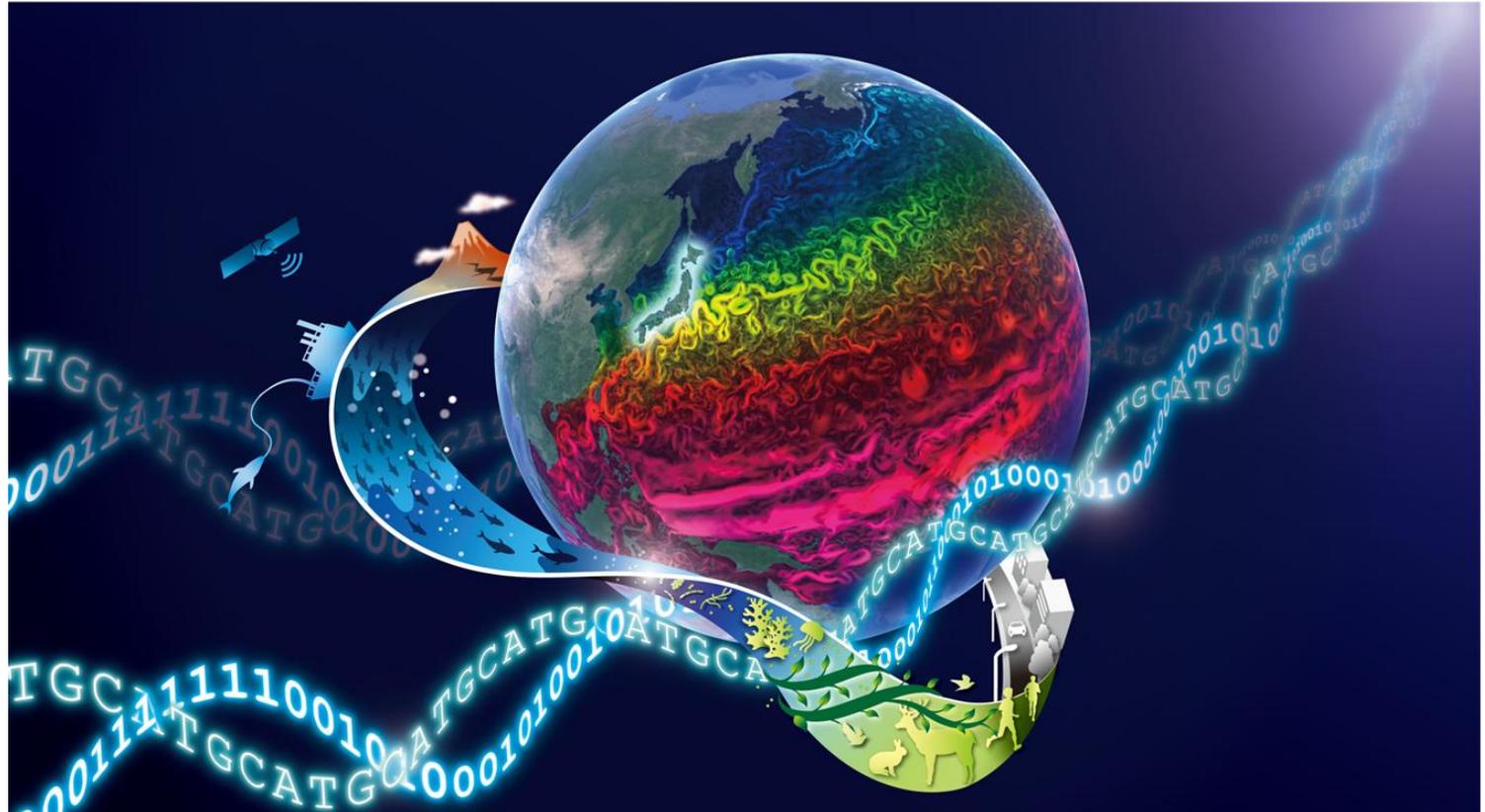### New developments in observational data acquisition with robotics

OneArgo

Core Argo
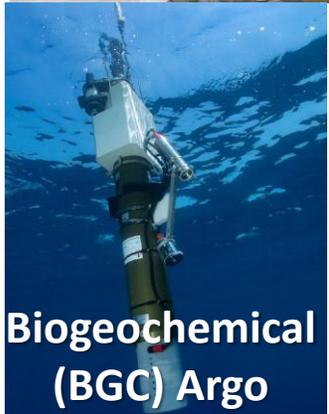
Biogeochemical (BGC) Argo
+
Deep Argo

Suga, T., Inagaki, F., Ando, K., and Kotani, M. (2024) UN STI Forum Science-Policy Brief.
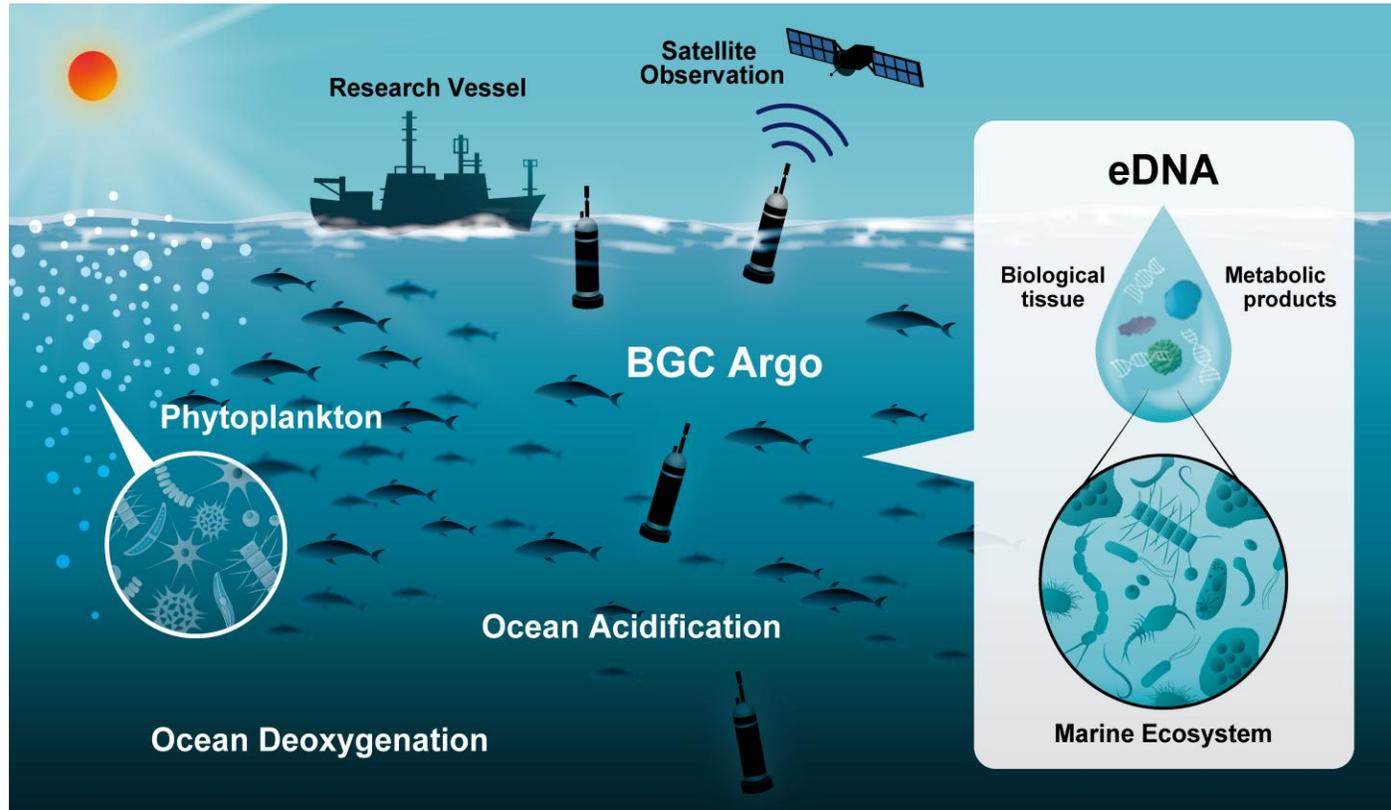
WPI-AIMEC is collaborating with the global marine science community to realize the Japan OneArgo initiative, adopted in the MEXT's "Roadmap 2023."

Big data from Argo (physical and biogeochemical observations) and eDNA will be analyzed in an integrated manner.
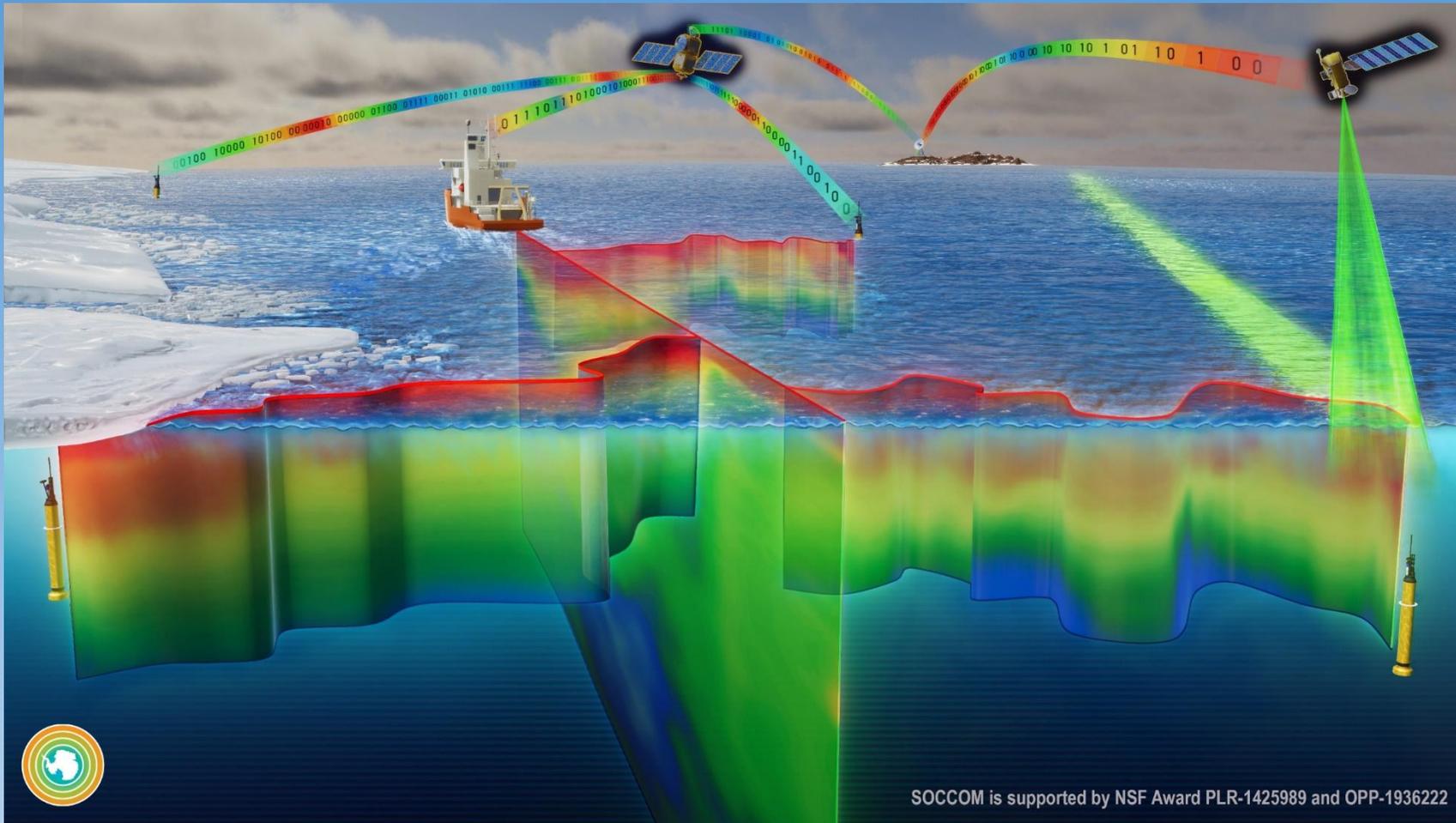
BGC-Argo unifies and strengthens ocean observing.

It does not replace ships and satellites, it makes the merged data more powerful!

Satellite data are extended to depth.

Ship data are extended in time.

SOCCOM is supported by NSF Award PLR-1425989 and OPP-1936222

biogeochemical
Argo

GO-BGC Global Ocean Biogeochemistry Array

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- >80% of the multi-sensor floats that enable the global array are US.

- 2026 is the last year of US funding.

- Given uncertainty in US science budgets, this may be the end of the project.

- International efforts to sustain BGC-Argo will be essential.

US floats in red.

Global array of floats with: NITRATE, PH_IN_SITU_TOTAL, CHL, BBP, DOXY, 503 floats

DAC
- aoml
- bodc
- coriolis
- csio
- csiro
- incois

Floats shown have reported at least 1 cycle in the past 1 year(s)   [10-Oct-2025]

GO-BGC Global Ocean Biogeochemistry Array

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