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FUSION DES DONNÉES BGC-ARGO ET SATELLITAIRES PAR L'IA: VERS UNE RECONSTRUCTION 4D DE PROPRIÉTÉS BIOGÉOCHIMIQUES OCÉANIQUES

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ATELIER IA ODATIS
27 JANVIER 2026, MARSEILLE, FRANCE

LOV LABORATOIRE D'OCÉANOGRAPHIE DE VILLEFRANCHE
IMEV INSTITUT DE LA MER DE VILLEFRANCHE

The **4D-BGC products** presented here, developed using the **SOCA method**, aim to:

📈 Leverage the growing **BGC-Argo dataset** and the power of **machine learning techniques** in marine sciences

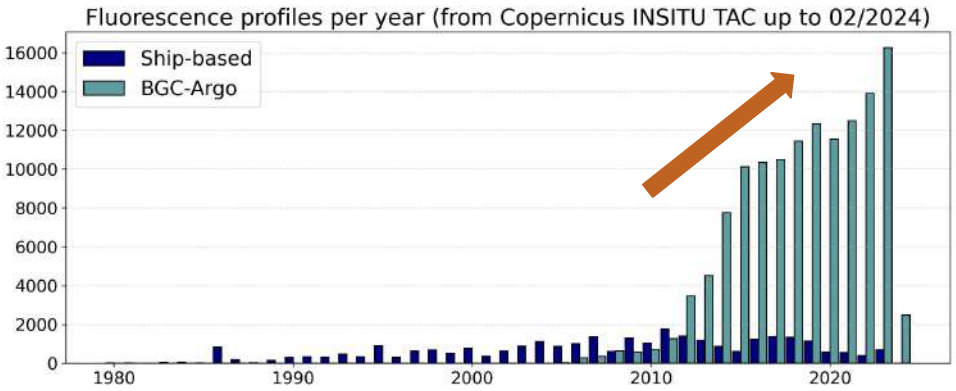
🌍 Foster synergies with **satellite ocean color** by combining:

→ synoptic surface views (from satellite)

→ with vertical in situ profiles (from BGC-Argo)

🎯 Deliver accessible and user-friendly **4D-BGC products**

→ for both the scientific community and operational users



biogeochemical Argo

Claustre et al., 2020

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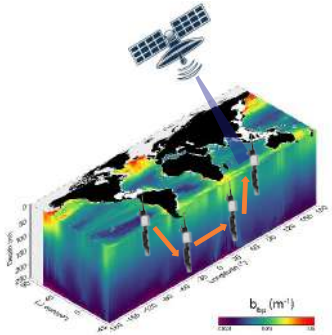


3 PRINCIPAL COMPONENTS

Sattelite-derived inputs:

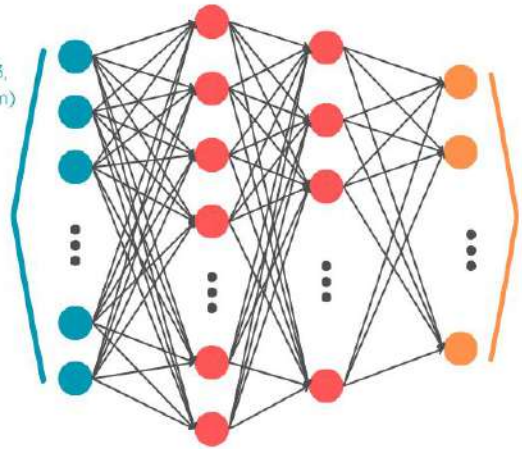
- **Ocean color:**
  - Reflectances (median of matchups for five wavelenghts: 412, 443, 490, 555 and 670 nm + standard deviation of matchup for 412 nm)
  - Photosynthetically Available Radiation (PAR)
- **Altimetry:**
  - Sea Level Anomaly (SLA)
  - Absolute Dynamic Topography (ADT)

Argo depth-resolved inputs:

- Principal components of PCA applied to temperature and salinity profiles
- Mixed Layer Depth (MLD)

Geolocation:

- Cartesian transformation of longitude and latitude (x, y, z)
- sine and cosine of the day of the year (transformed into radians)



SOCA2024-BBP:
Particulate backscattering for 36 vertical levels from the surface to 1,000 m depth

SOCA2024-CHL:
Chlorophyll-a concentration for 50 vertical levels from the surface to 1.5 Znorm depth (max between MLD and 2xZe)

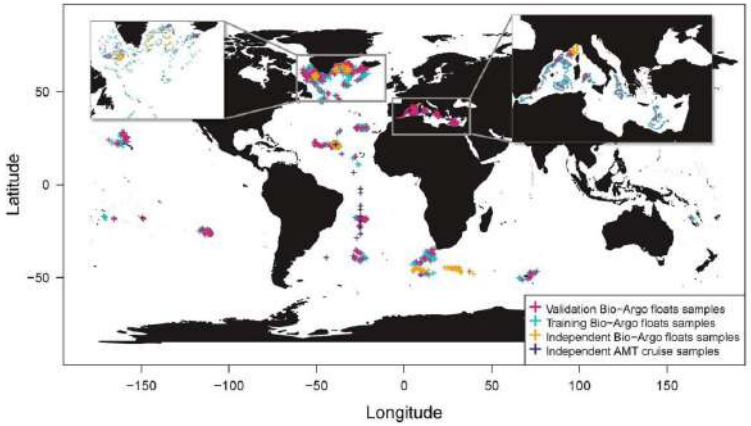
SOCA2025-LIGHT:
PAR and ED(380, 412, 490) for 51 vertical levels from the surface to 250 m (every 5 m depth)

Sauzède et al., 2016; Renosh et al., 2023; Sauzède et al., in prep.

Thanks to the overall success of the **BGC-Argo program** and the **exponential increase in data**, the number of usable profiles for generating 3D products has increased **twelvefold** in less than ten years!

→ BGC-Argo covers previously unsampled or undersampled regions, **significantly improving the global representativeness of the products**.

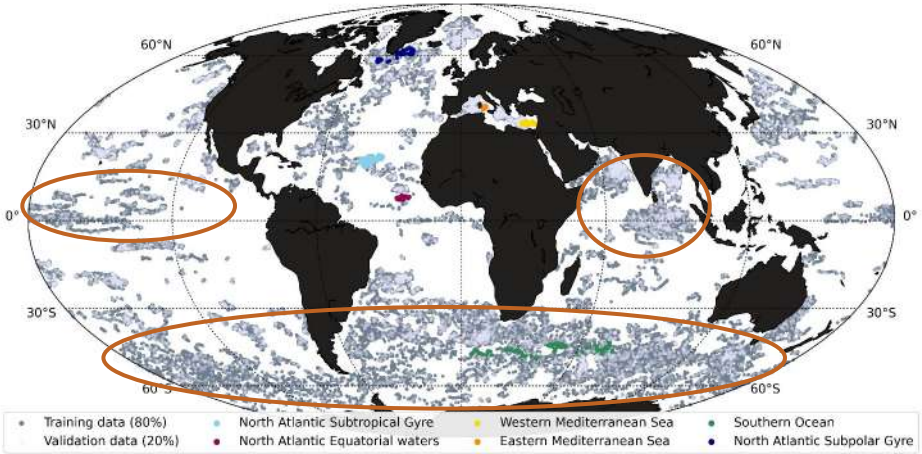
2016



Sauzède et al., 2016

~4,500 satellite/BGC-Argo matchups

2024



Sauzède et al., in prep.

~60,000 satellite/BGC-Argo matchups

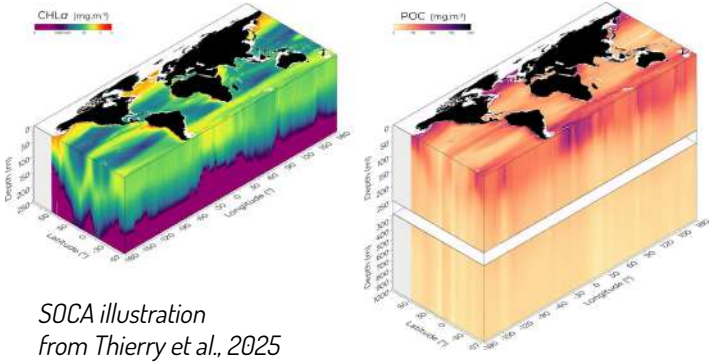
Global 3D gridded POC (+b_{bp}), Chla and light (NEW!) from Copernicus Marine Service :

- **Horizontal resolution:** 0.25°x0.25°
- **Vertical resolution:** 36 depth levels from surface to 1000 m depth
- **Temporal resolution:** weekly fields from 1998 to 2023 + monthly climatological fields
- **~ yearly update**

MyOcean Pro Viewer

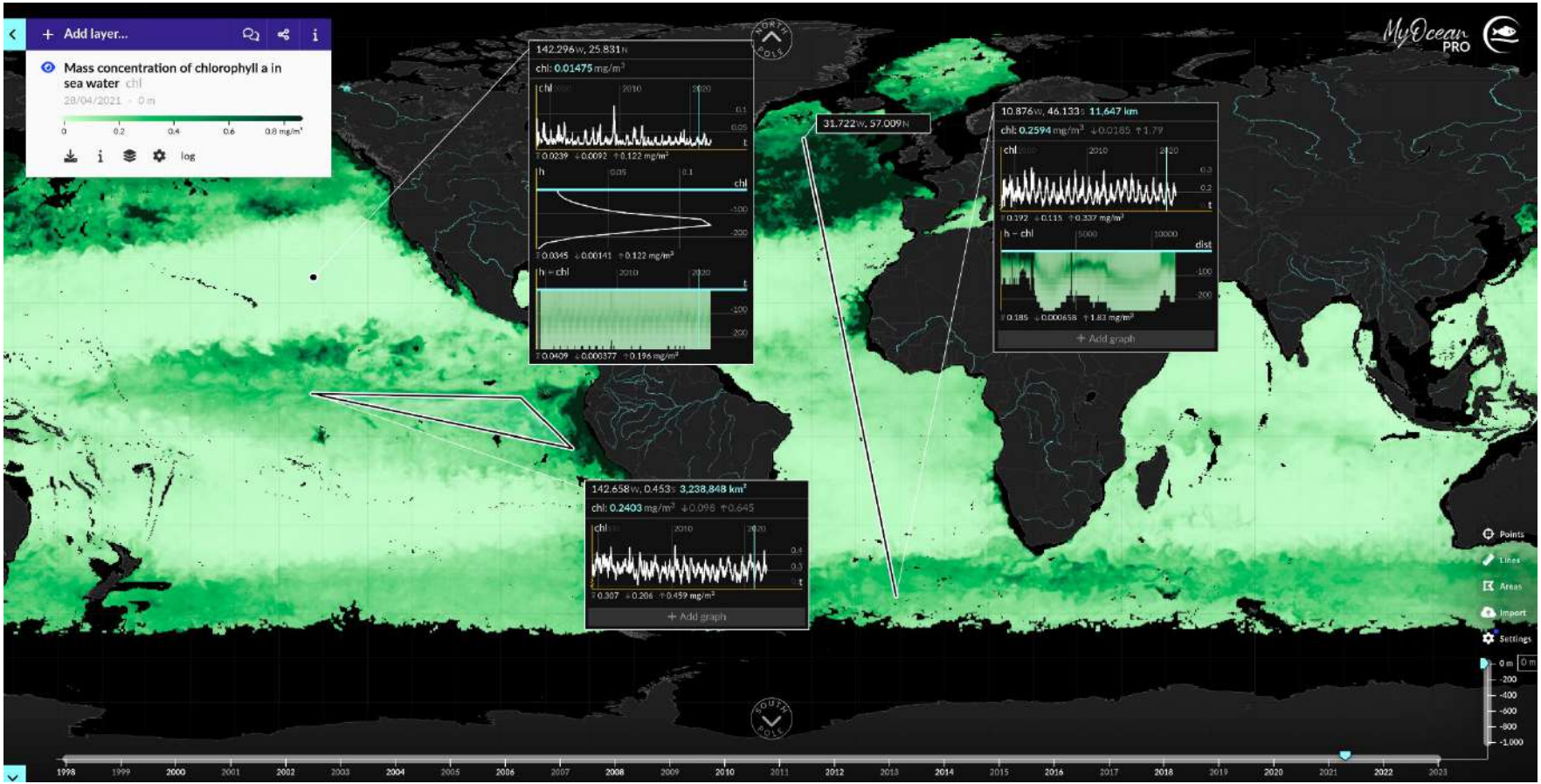
SCAN ME

Copernicus ID:
MULTIOBS_GLO_BIO_BGC_3D_REP_015_010



SOCA illustration from Thierry et al., 2025

SOCA 4D-BGC OPERATIONAL PRODUCTS IN COPERNICUS MARINE SERVICE



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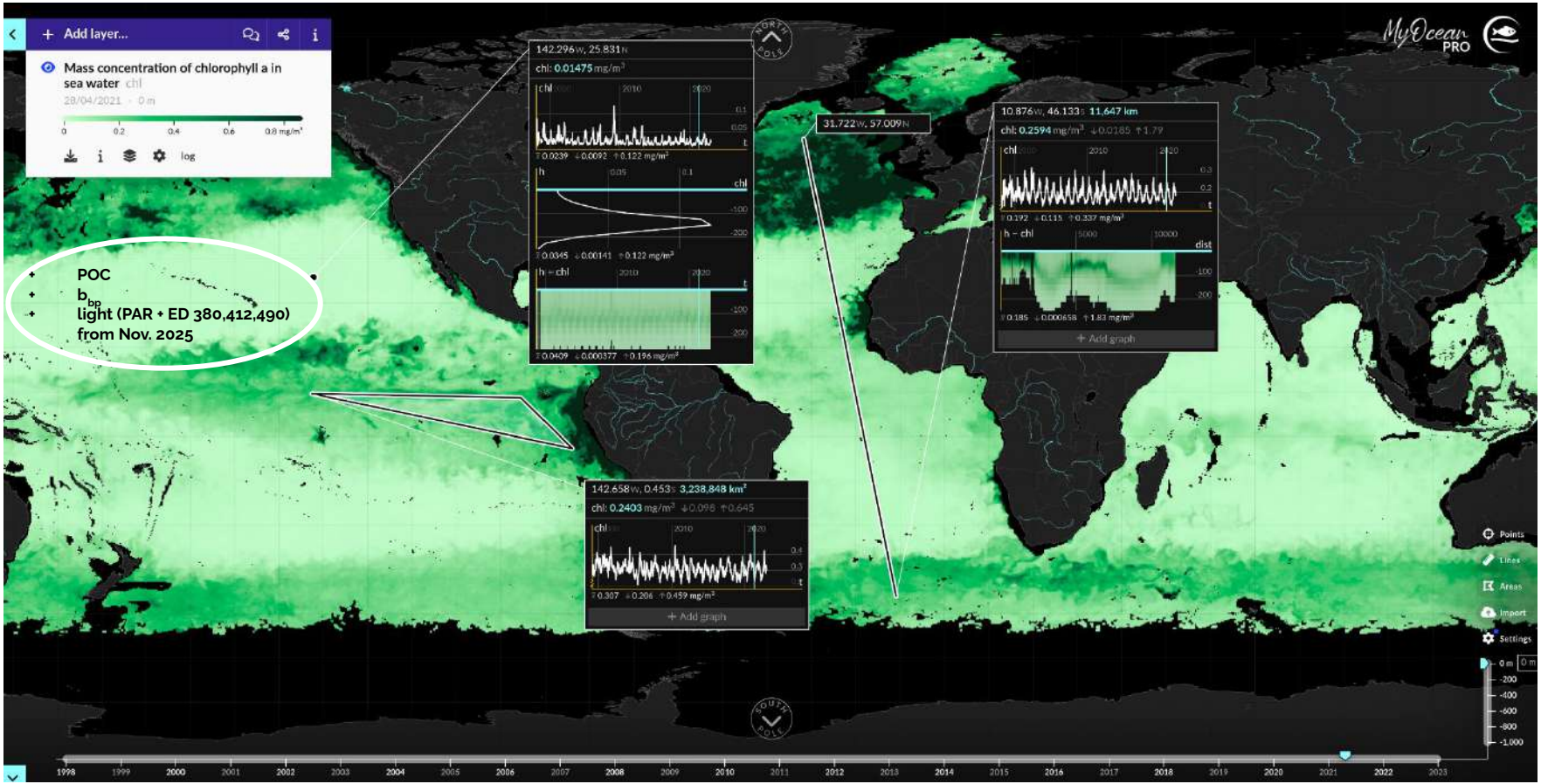
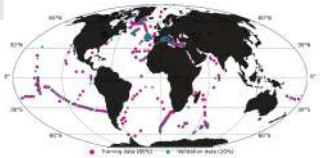


SOCA-PFT: IMPLEMENTATION OF A 2-STEP APPROACH

→ will be integrated to the Copernicus SOCA MULTIOBS product in **Nov. 2026** !

BGC-ARGO T/S AND FLUORESCENCE PROFILES

FLAVOR-TS
Sauzède et al., 2015

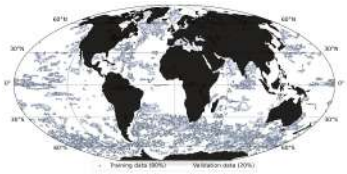


HPLC database

CHLA + PICO-, NANO- AND MICRO-CHLA PROFILES FROM BGC-ARGO FLOATS

CONCOMITANT SURFACE SATELLITE OCEAN COLOR AND ALTIMETRY

~60,000 matchup stations with satellite and BGC-Argo with PFT information



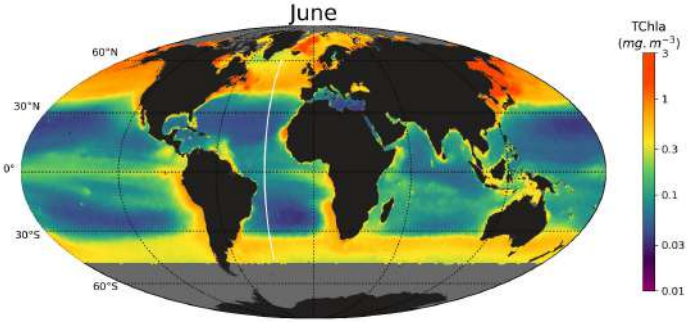
Augmented database

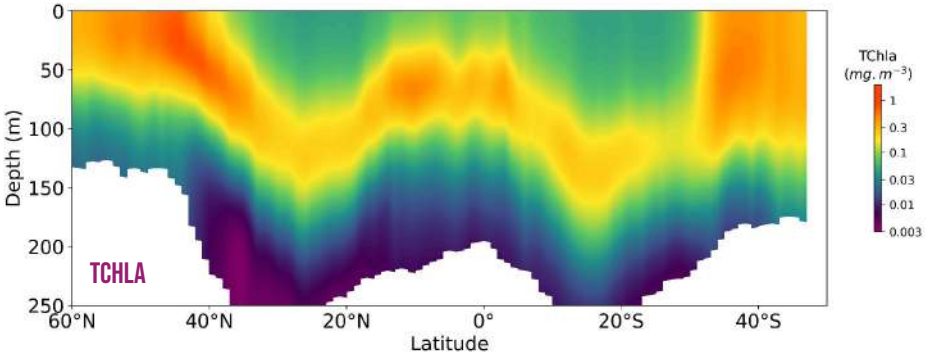
SOCA-PFT

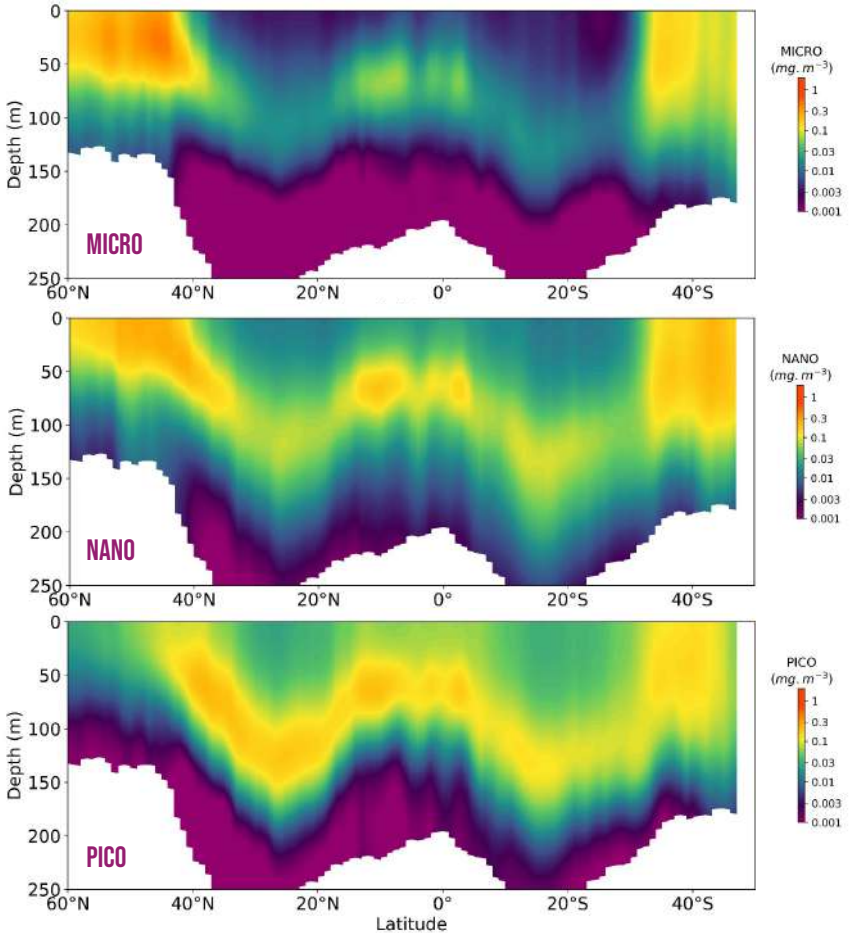
CHLA + MICRO-, NANO- AND PICO-CHLA PROFILES

For each matchup, 50 points distributed in the productive layer are retrieved

EXAMPLE OF A CROSS SECTION IN THE ATLANTIC FOR JUNE

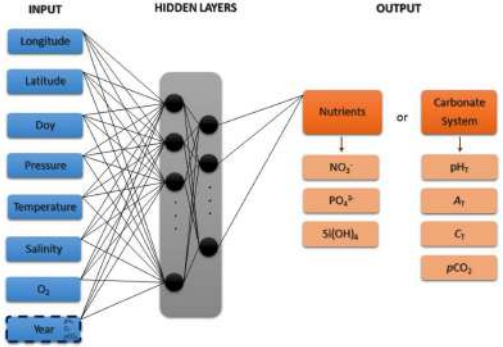






SOCA-CARBON: IMPLEMENTATION OF A 2-STEP APPROACH

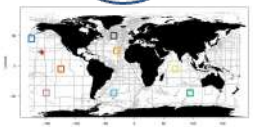
→ work in development by Louise Delaigue et al. (LOV)



Sauzède et al., 2017; Bittig et al., 2018

BGC-ARGO T/S AND DOXY PROFILES

CANYON-B /CONTENT



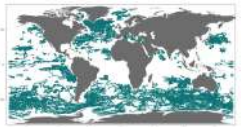
GLODAP database

CARBONATE SYSTEM PARAMETERS FROM BGC-ARGO FLOATS

CONCOMITANT SURFACE SATELLITE OCEAN COLOR AND ALTIMETRY

~60,000 matchup stations with satellite and BGC-Argo with PFT information

SOCA-CARBON



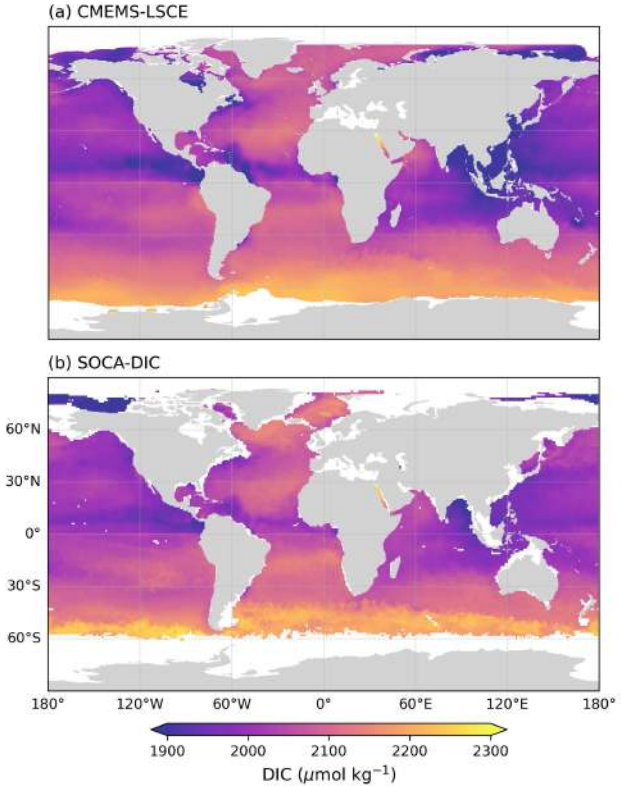
Augmented database

CARBON PROFILES

For each matchup, 36 depth levels from the surface to 1,000 m depth

SOCA-CARBON: IMPLEMENTATION OF A 2-STEP APPROACH

→ work in development by Louise Delaigue (LOV)



EXAMPLE FOR AUGUST 2022

SOCA-CARBON: IMPLEMENTATION OF A 2-STEP APPROACH

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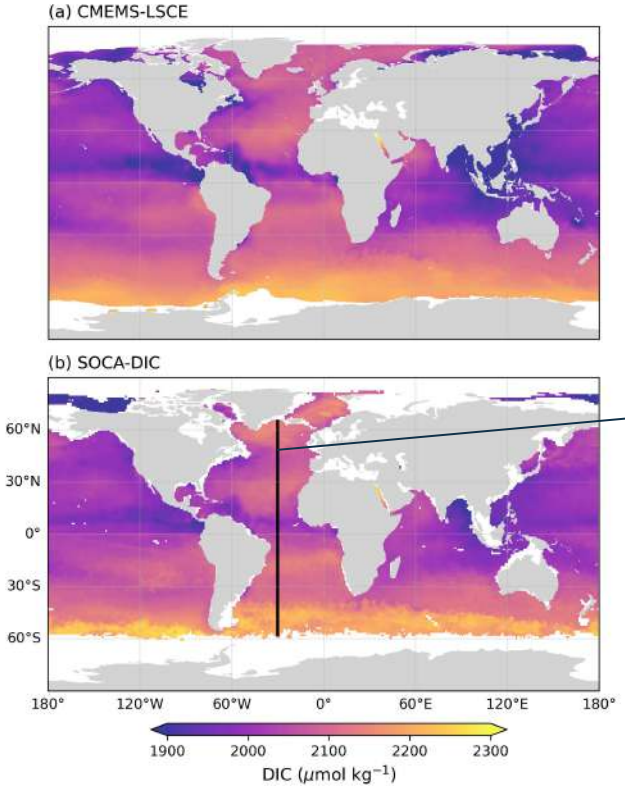
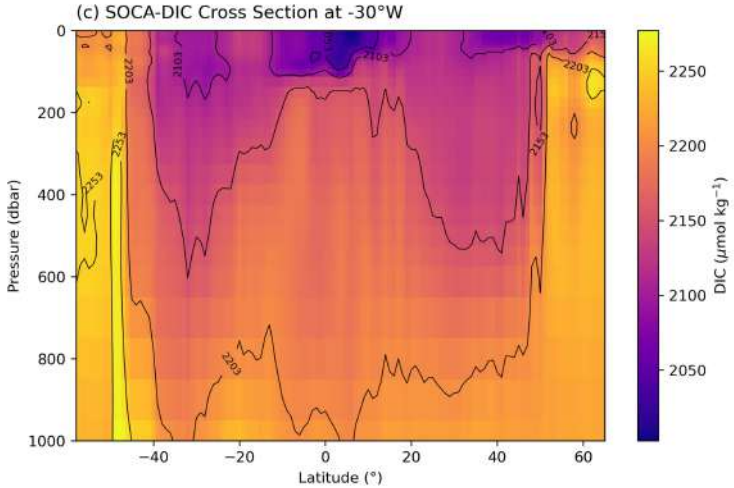


EXAMPLE FOR AUGUST 2022



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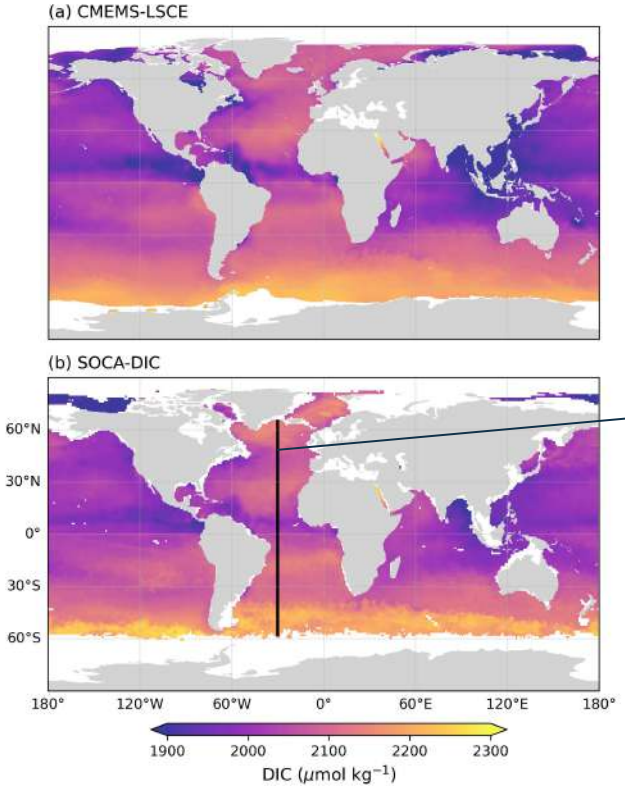

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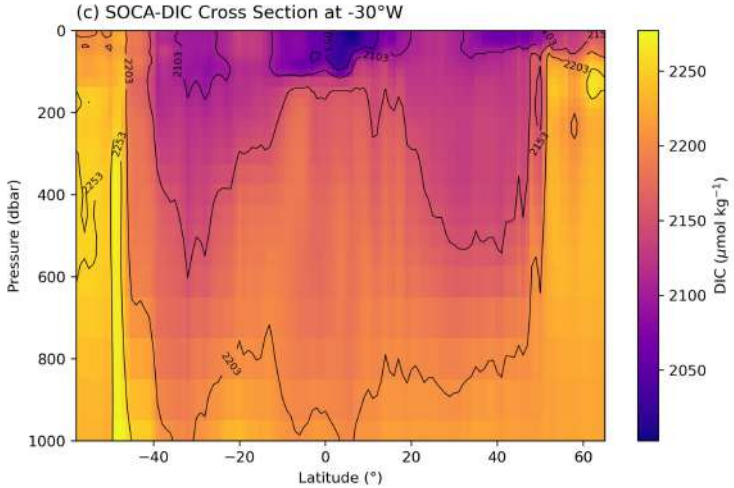
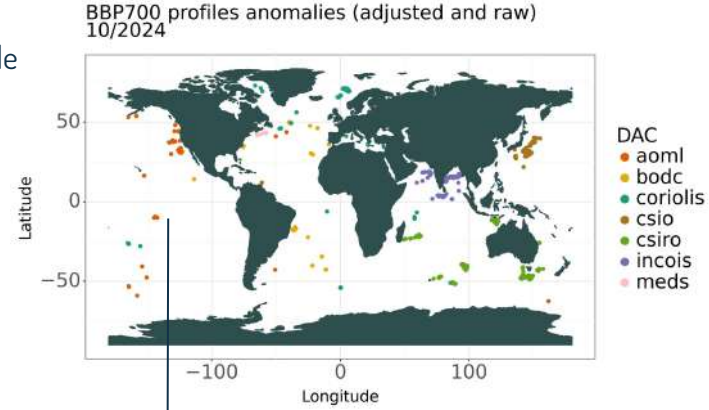


→ Possibility to develop it for pH, Alkalinity → pCO_2

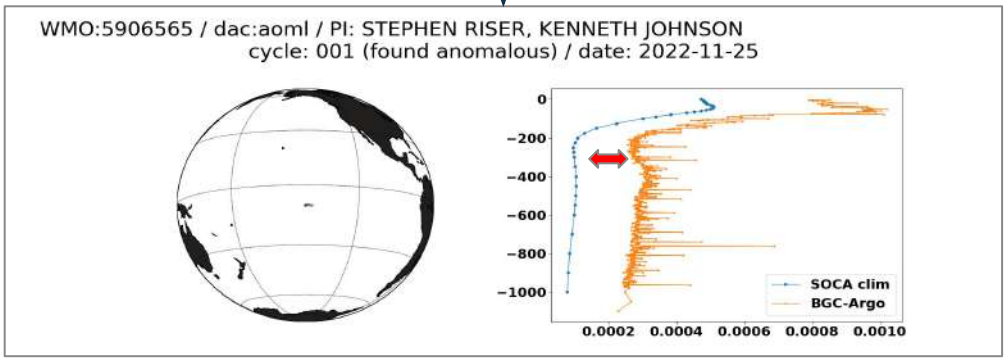
Audits interesting for operational users:

- **Comparison between observations vs. reference data**
- b_{bp} reference data: climatological fields from 4D-BGC SOCA BBP700 product available from the european Copernicus Marine Service
- Yearly released since June 2021 for b_{bp} (list of profiles and **plots** available from the BGC-Argo website)
- DOXY audits developed using WOA (list of profiles and **plots** available from the BGC-Argo website), will be updated using 4D-BGC GOBAI-O2 product (Sharp et al., 2023)

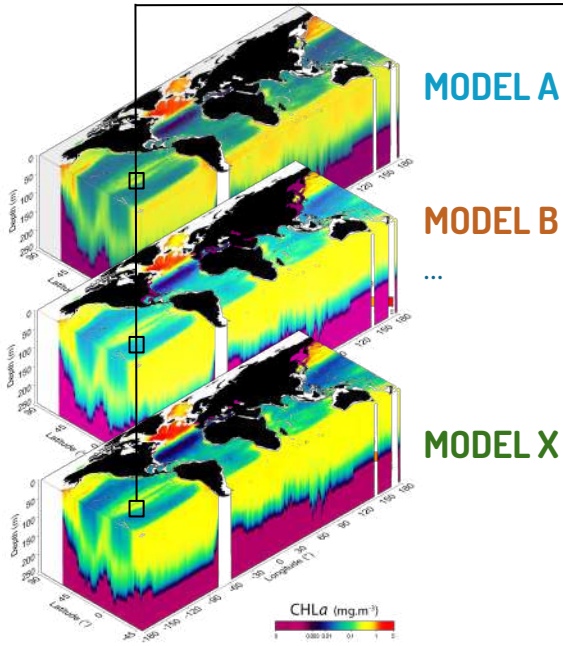


Perspectives as part of Copernicus BGC-OptiO and Euro-Argo One projects + international initiative (MBARI):

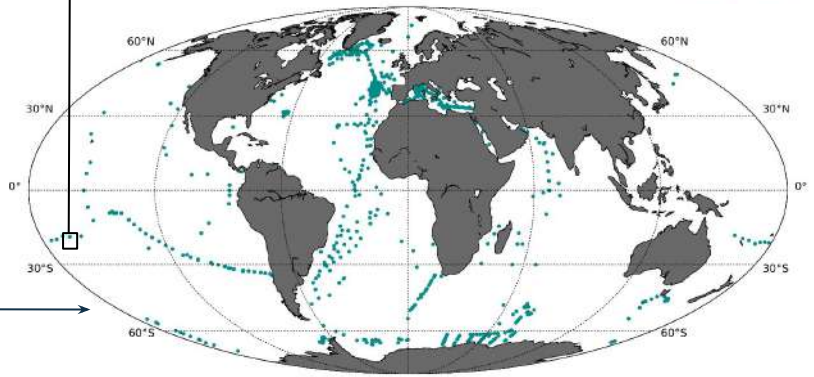
- Development for other parameters
- Improve statistics (e.g. use of **time series** or **specific layers of interest**)
- Future operational use in the InSitu TAC

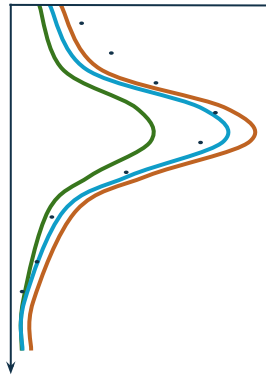


As trained on BGC-Argo data, SOCA can be used as a '**BGC-Argo emulator**', enabling a new **workflow for BGC-Argo validation** (e.g. evaluation of different corrections) against cruise **in situ HPLC reference measurements.**



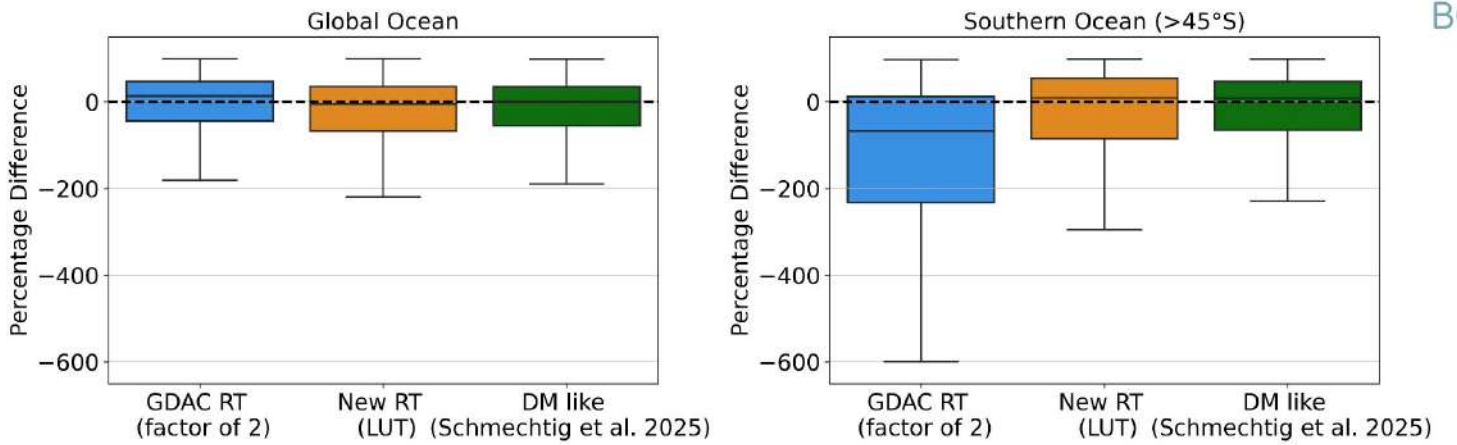
Global database of **HPLC reference measurements of Chl-a**





Global (or regional) **evaluation**:
→ **Best statistics** = Chla from BGC-Argo with the correction the more **representative of HPLC** reference measurements
= Best correction

→ SOCA workflow for the evaluation of several BGC-Argo Chla dataset depending on their correction methods



By developing **adapted statistical metrics**, this workflow will be used to identify and analyze potential biases at **regional and vertical scales**. It will also allow us to **deconvolute the effects of different corrections**, such as the NPQ (Non-Photochemical Quenching) and the physiological ratio between FChla and [Chla] corrections, both in Real-Time and Delayed-Mode.

SOCA 4D-BGC gap-filled products are a valuable source of data, useful for:

- ➔ **Scientific studies** (e.g. Bellacicco et al., 2025; Mayot et al., in review)
- ➔ **Operational uses:** data assimilation, initialization/validation of biogeochemical models

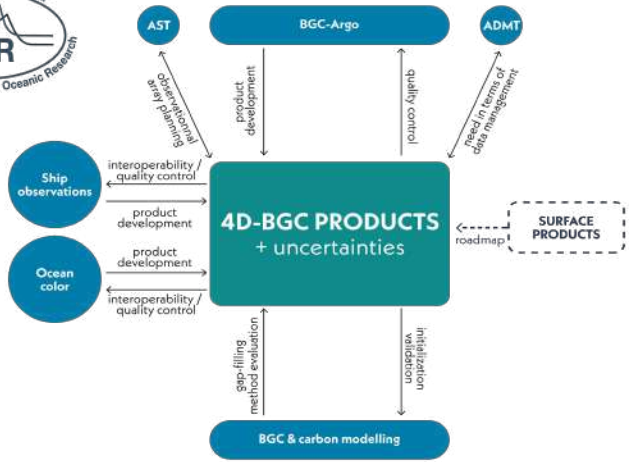
But not only:
Considerable advancements have been made over the last 5 years in **BGC-Argo data management**, including:

- ➔ **Quality control** of BGC-Argo float observations (e.g., bbp flagging of anomalous data)
- ➔ **Improvement** of fluorescence-based Chlorophyll-a concentration (Chla) estimates in **both Real-Time and Delayed-Mode,** notably thanks to SOCA-light
- ➔ **Evaluation of relationships between bio-optical properties and their biogeochemical counterparts** (e.g., b_{bp}/POC and fluorescence/Chla)

The prospect of developing **SOCA-PFTs** and **SOCA-CARBON** opens new avenues for biogeochemical models and PFT- and carbon-related studies.

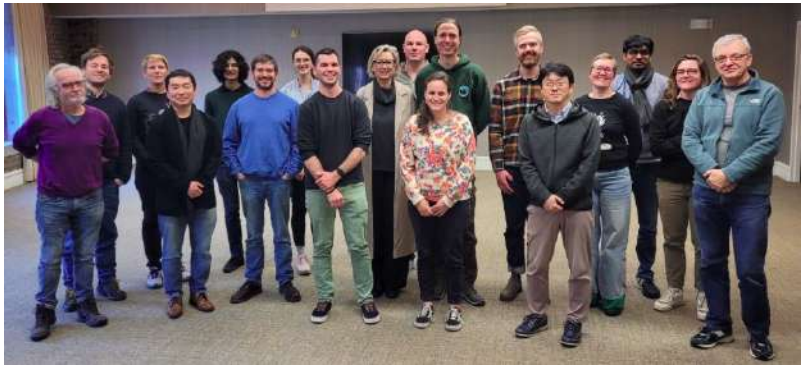
SCOR WG #168 4D-BGC: Coordinating the Development of Gridded Four-Dimensional Data Products from Biogeochemical Argo Observations

Co-chairs: *R. Sauzède (CNRS, France) & J. Sharp (NOAA, UW CICOES, US)*



- Facilitates collaboration on 4D-BGC data products to **enhance access** and utility of **BGC-Argo observations**
- Hosts a **webinar series** showcasing new 4D-BGC data products, their development, and applications in science, modeling, and policy
  Past sessions available on 4D-BGC YouTube channel
  Upcoming schedule: 4D-BGC website

- Maintains a BGC-Argo data products webpage (available from the BGC-Argo official website)
- Join the **mailing list** to stay updated on webinars and activities: Sign up (link available from the 4D-BGC website)



Merci!

Des questions?

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