

# HyperBOOST

Hyperspectral Bio-Optical  
Observations Sailing on *Tara*



PROGRAMME OF THE  
EUROPEAN UNION



co-funded with



## 6<sup>th</sup> Sentinel-2 Validation Team Meeting

12 – 14 September 2023 | ESA – ESRIN | Frascati (RM), Italy

V E. Brando, F. Falcini , C. Marchese, V. Martinez Vicente, S. Simis, T. Jordan, D. Doxaran, A. Poteau, C. Santinelli, G. Bachi, E. Boss, M. H. Rio , J.A. Concha

Project partners

**PML** | Plymouth Marine  
Laboratory

**LOV** | LABORATOIRE  
D'Océanographie  
DE VILLEFRANCHE

**1865** THE UNIVERSITY OF  
**MAINE**

**CNR ISMAR**  
ISTITUTO  
DI SCIENZE  
MARINE

Collaborating with

**EMBL**



The HyperBOOST project is funded by the European Space Agency (ESA)

[www.hyperboost.info](http://www.hyperboost.info)





## TREC: Traversing European Coastlines

A scientific expedition to understand biodiversity and ecosystems along Europe's coastlines



Giving the scale and urgency of human and planetary health challenges

EMBL is leading this large pan European, highly collaborative and cross disciplinary effort: combining ecology, evolution, geosciences with molecular and cellular disciplines

### Challenge

### TREC relevance

### TREC contribution

<p><b>Climate change</b></p> <p>Accumulation of greenhouse gases (Carbon Dioxide, CO<sub>2</sub>) into the atmosphere</p>	<p>Leading to global warming and ocean acidification</p>	<ol style="list-style-type: none"> <li>1. Map and quantify known carbon fixation processes and discover new ones</li> <li>2. Assessing the impact on environmental gradients (Temp &amp; pH) on species, communities &amp; organismal interactions</li> </ol>
<p><b>Chemical pollution</b></p> <p>Industrial waste, agriculture, pharmaceuticals, etc</p>	<p>Pollutants accumulate into the environment and degrade ecosystems</p>	<ol style="list-style-type: none"> <li>1. Develop a mechanistic understanding of pollutant-organisms interaction</li> <li>2. Reveal organisms and functional traits of biotechnological relevance</li> </ol>
<p><b>Antibiotic resistant spread</b></p>	<p>Overuse of antibiotics impacts human and planetary health in various ways</p>	<p>Quantifying gene fluxes across fundamentally different ecosystems</p>





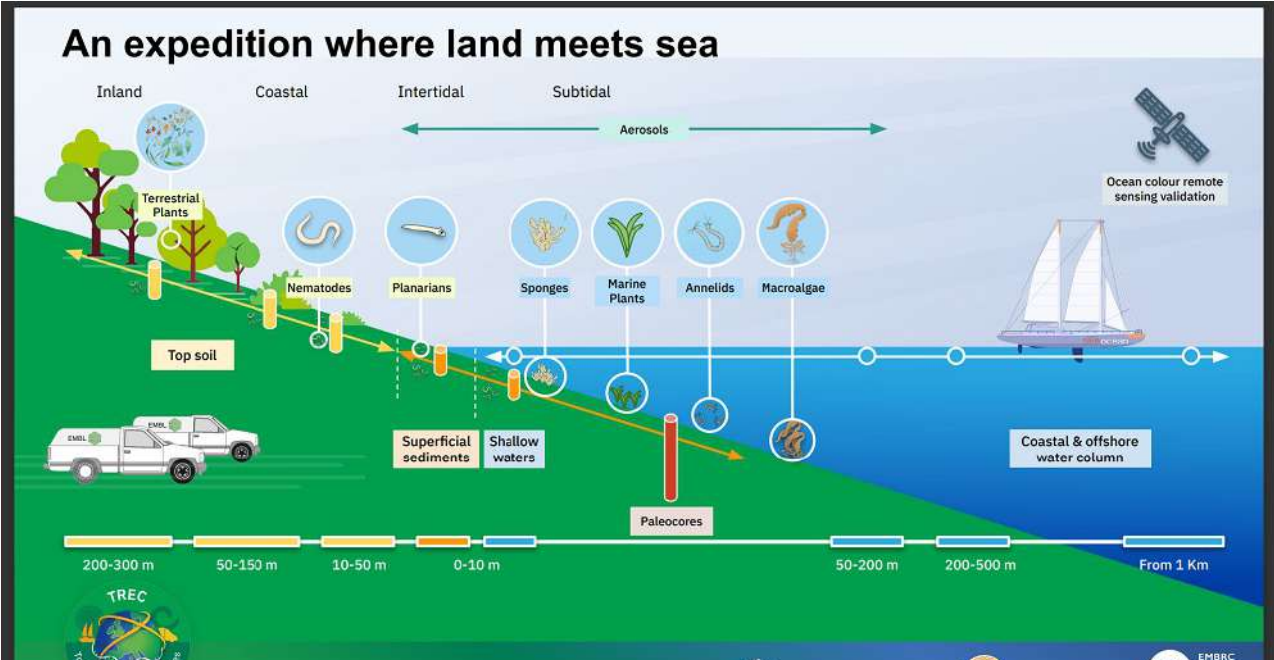
## TREC: Sampling 120 Coastal Sites

- Pristine nature
- Agriculture
- Cities and Ports
- River outputs



**Processing Lab and Sampling Vehicles**  
Topsoil, shallow sediments, and waters, aerosols, selected species & meta/contextual data

**Tara Schooner**  
Coastal and offshore water column (1-3 stations per sampling site) aerosols & meta/contextual data





# HyperBOOST - Hyperspectral Bio-Optical Observations Sailing on *Tara*

## YEAR 2023 :

**Roscoff** 09/04 - 12/04

**Amsterdam** 28/04 - 02/05

Bremerhaven 06/05 - 09/05

**Aarhus\*** 01/06 - 06/06

Sopot 17/06 - 19/06

**Tallin** 26/06 - 03/07

**Stockholm** 15/07 - 19/07

**Kristineberg\*** 02/08 - 04/08

Bergen 11/08 - 14/08

**Galway** 09/09 - 15/09

**Lorient** 23/09 - 25/09

**La Rochelle** 28/09 - 01/10

**Bilbao** 11/10 - 18/10

**Porto** 27/10 - 30/10

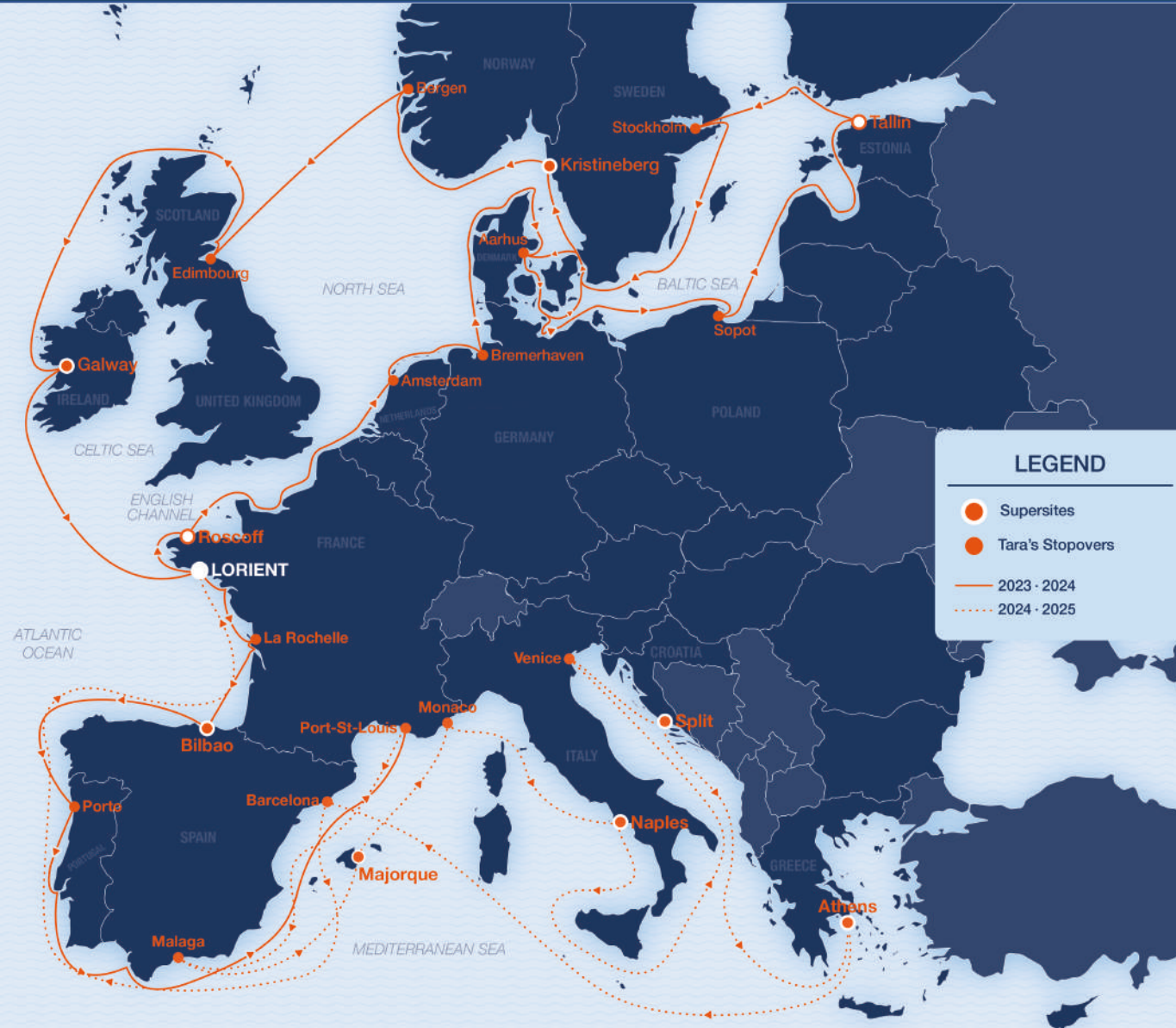
**Cadix\*** 12/11 - 14/11

*supersites / outreach events / \*shipping*



## Three types of sites:

- Coastline (1 station)
- Estuary (2-3 stations)
- Supersites (3-4 stations)



**LEGEND**

- Supersites
- Tara's Stopovers
- 2023 · 2024
- - - 2024 · 2025

EMBL



tara  
EUROPA



# HyperBOOST - Hyperspectral Bio-Optical Observations Sailing on *Tara*



Funded by The European Space Agency

YEAR 2024 – still in progress

Malaga March

**Mallorca** March

Monaco April

**Naples** April

Venise May

**Split** June

**Athens** July

**Marseille** August

**Back to Lorient** Octobre

*\*supersites / outreach events / \*shipping*



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EMBL

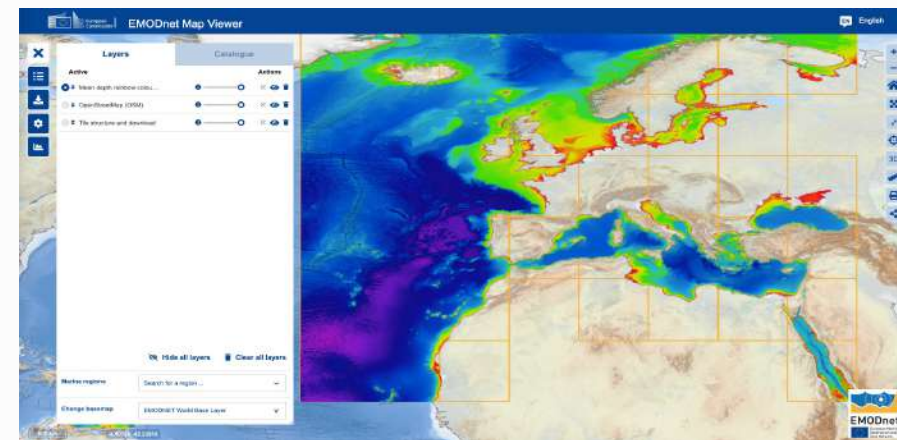
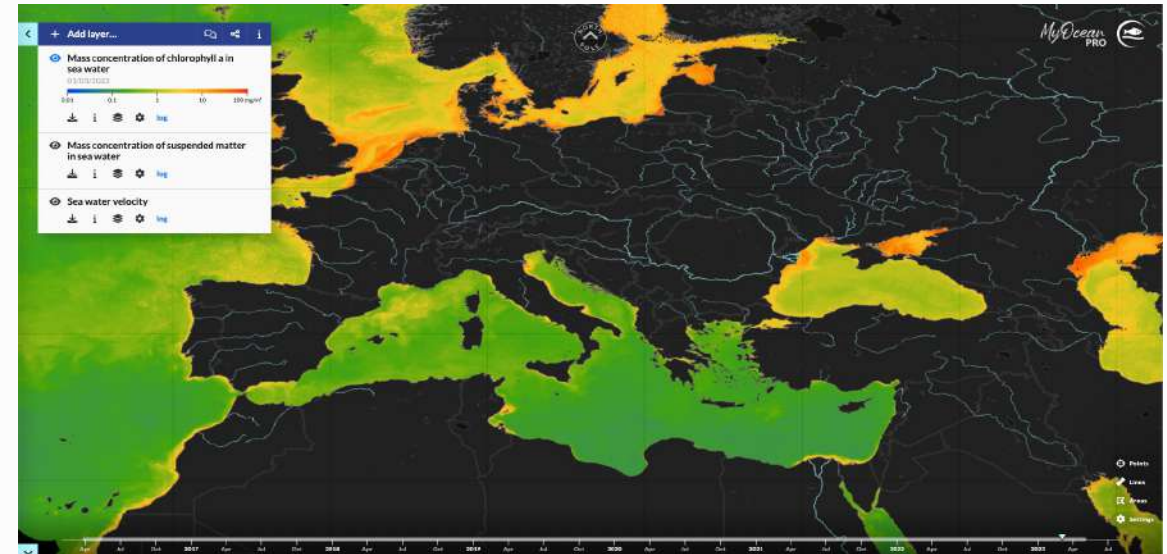


tara  
EUROPA



## Sampling Strategy: Satellite data to sample appropriate waters along the European coastlines

- Historical analysis to identify biogeochemical patterns along the European coastlines
  - Computation of monthly climatologies centered for each site on the week when TARA is planned to sample
  - Time series at ~300m spatial resolution from the OLCI operational products available from the Copernicus Marine Service
- Redefine, when possible (in case of cloud-free conditions), the exact location of the sampling stations
  - Use of real-time data from the Copernicus Marine Service operational products (OLCI and/or S2)





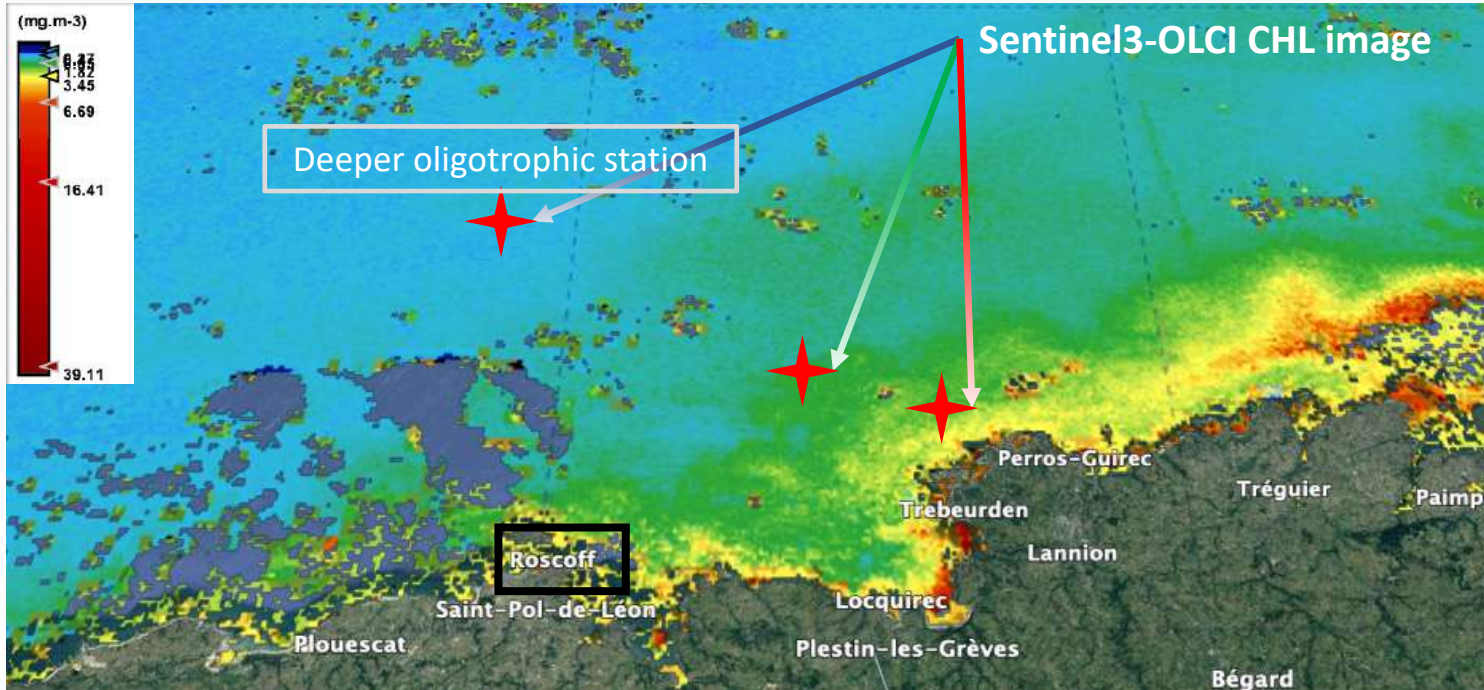
## Sampling Strategy: Satellite data to sample appropriate waters along the European coastlines

### Main objective:

- Sample within the diverse biogeochemical patterns (from the coastal/shallow biogeochemical zones to the most offshore waters)

### Three types of sites:

- Coastline (1 station)
- Estuary (2-3 stations)
- Supersites (3-4 stations)



Recognition of three climatological fronts/biogeochemical patterns

### Other data used for the placement of stations

- ✓ Total Suspended Matter (TSM)
- ✓ Bathymetry
- ✓ Ocean currents

## STEPS →

Download of Sentinel-3 OLCI regional CHL data

Production of CHL Monthly climatology

Visualization on an interactive and georeferenced maps



## Measurements carried out aboard TARA related to phytoplankton and optics

- Within HyperBOOST PML, CNR, and LOV are extending the variables collected during the TREC integrated sampling by **including bio-optical measurements** (hyperspectral radiometry, optical properties, biogeochemical and optically active components) relevant to present and future satellite ocean colour missions.

Existing observations to which HyperBOOST contributes to

New observations to be collected for the first time in TARA, with support from ESA to HyperBOOST

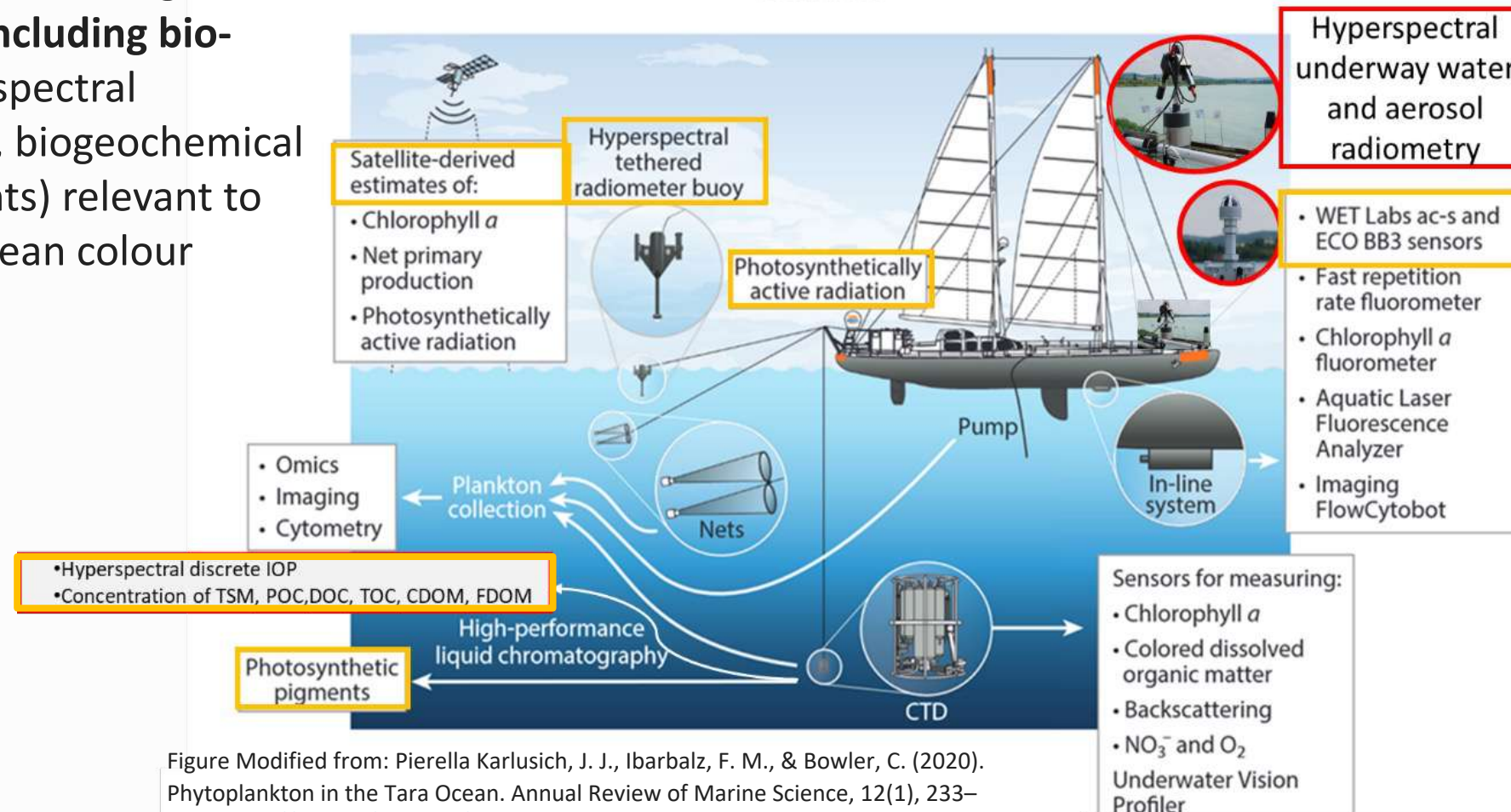


Figure Modified from: Pierella Karlusich, J. J., Ibarbalz, F. M., & Bowler, C. (2020). Phytoplankton in the Tara Ocean. Annual Review of Marine Science, 12(1), 233–265. <https://doi.org/10.1146/annurev-marine-010419-010706>





## Measurements carried out aboard TARA related to phytoplankton and optics

- Within HyperBOOST PML, CNR, and LOV are extending the variables collected during the TREC integrated sampling by **including bio-optical measurements** (hyperspectral radiometry, optical properties, biogeochemical and optically active components) relevant to present and future satellite ocean colour missions.
- This will enable to **provide validation data** in optically complex waters for **several missions, products, and datasets**.
- This presentation will **describe the bio-optical measurements** relevant to present and future satellite ocean colour mission that are being **carried out on Tara** and it will explore the **potential for the validation of Sentinel 2** radiometry and biogeochemical products.

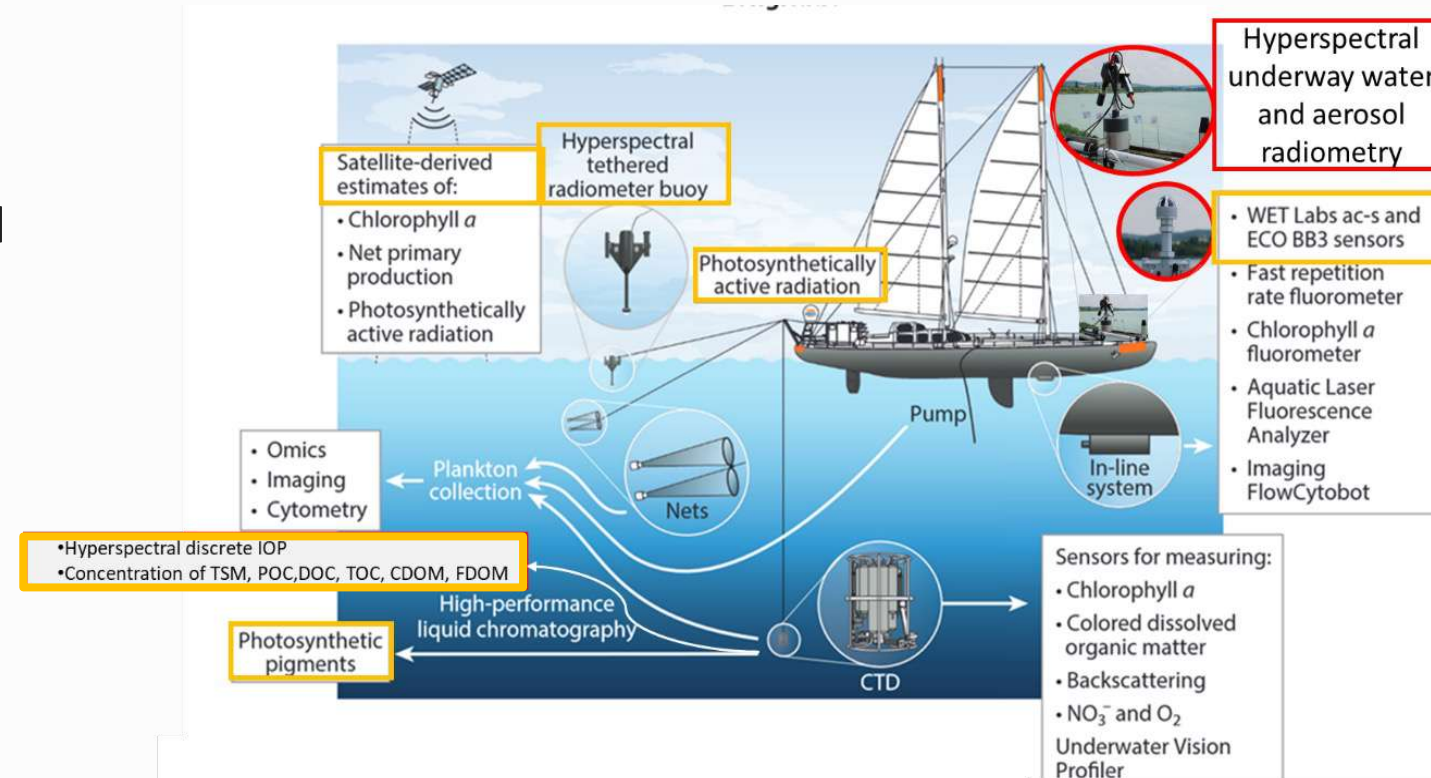


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## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: discrete samples

The HyperBOOST partners contributed to the Tara Europe protocol definition based on existing sampling protocols and their expertise:

- BioGeoChemistry – TOC – Concentrations of total organic carbon
- BioGeoChemistry – filtration with portable peristaltic pump – DOC/CDOM/FDOM/NUT-1 protocols
- BioGeoChemistry – DOC – Concentrations of dissolved organic carbon
- BioGeoChemistry – CDOM/FDOM – Chromophoric/Fluorescent Dissolved Organic Matter
- BioGeoChemistry – PM – Particulate Matter (PN/POC/d13C/d15N) & particulate light absorption (ap)
- Taxonomy – HP – pigments (HPLC)
- BioGeoChemistry – FOI – Fraction organic/inorganic )
- BioGeoChemistry – PA – Particulate absorption (ap)

The HyperBOOST partners will analyze all these samples as they become available



BioGeoChemistry – PM – Particulate Matter (PN/POC/d13C/d15N) & particulate light absorption (ap)

Contact: david.doxaran@imev-mer.fr

x3  
TRIPLICATE



**CAUTION** – This protocol is sensitive to carbon contamination

This proto



<!/ Regul

BioGeoChemistry – TOC – Concentrations of total organic carbon

Contact: Chiara Santinelli, CNR-IBF ([chiara.santinelli@ibf.cnr.it](mailto:chiara.santinelli@ibf.cnr.it))



x3

+



**CAUTION** – this protocol is extremely sensitive to contamination

- Do not smoke on deck during sampling
- Wear polyethylene gloves or nitril gloves without powder
- Wash the gloves with **MQW**



## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: discrete IOPs (CDOM, FDOM)

### Sampling and filtration

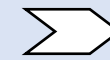
### Analysis and elaboration



Filtration with a portable pump attached to the niskin



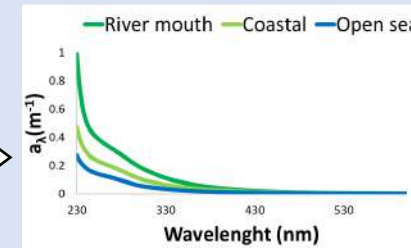
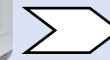
TOC analyzer



TOC/DOC  
(quantitative)



Spectrophotometer



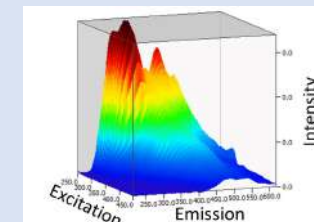
Absorption spectra



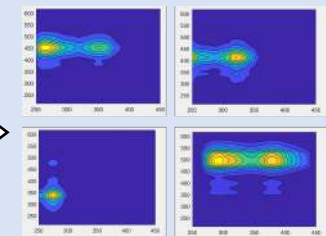
CDOM/FDOM  
(qualitative)



Fluorimeter



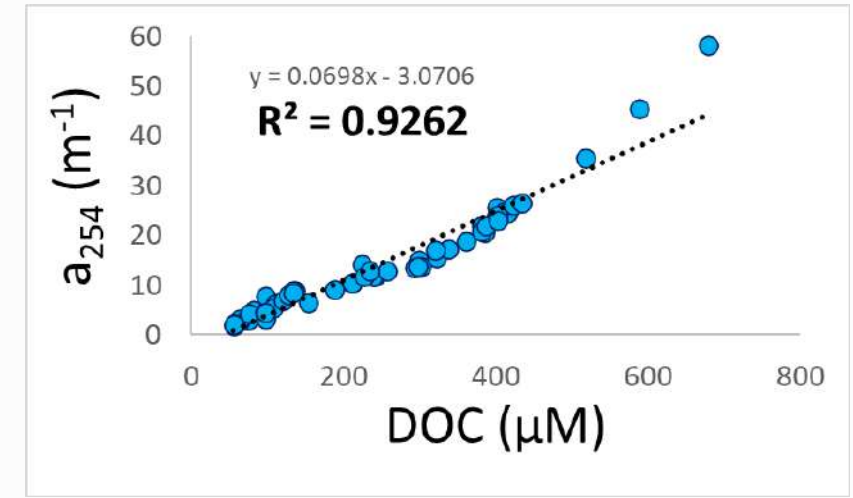
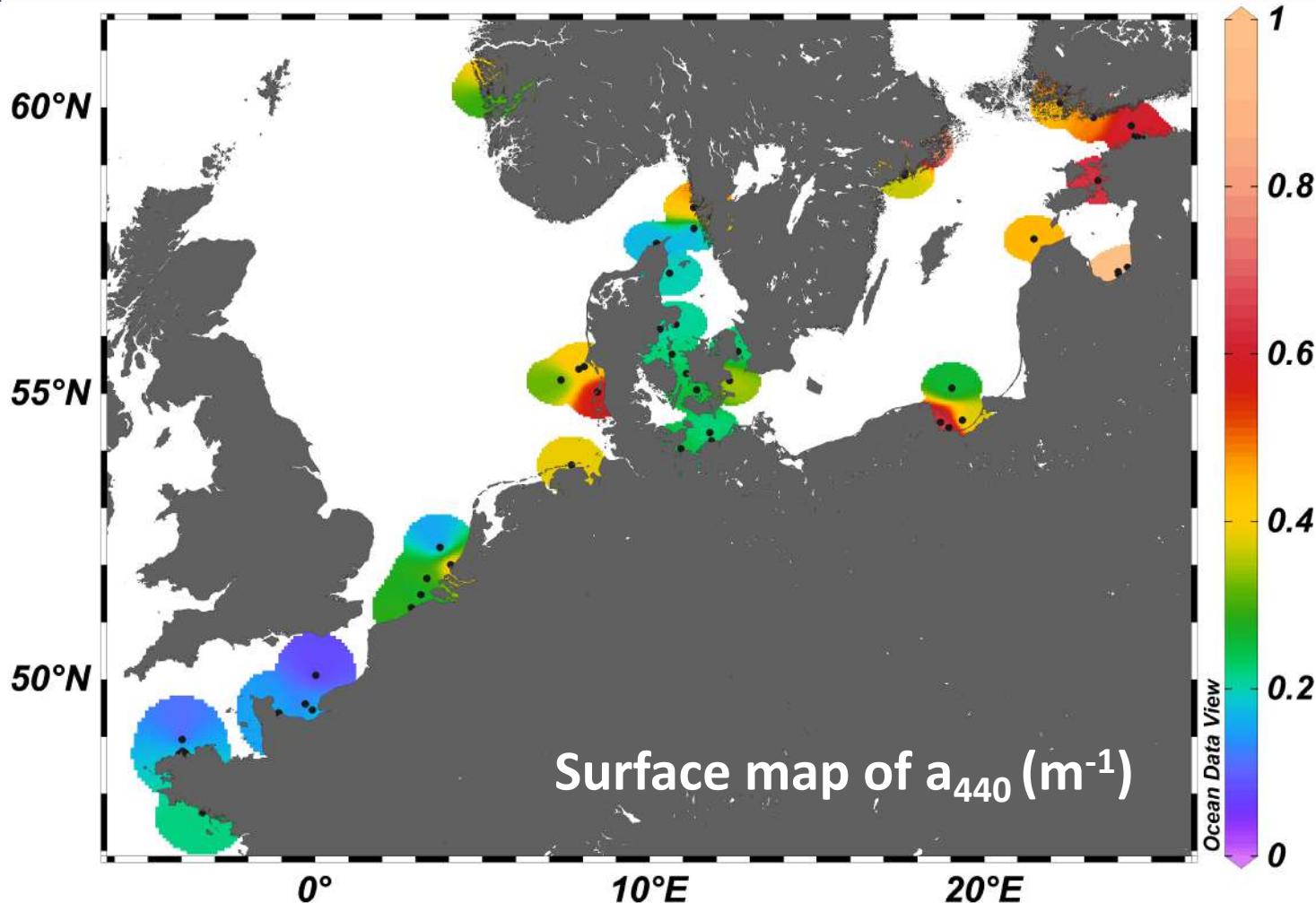
3D matrices



FDOM components



# Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: discrete IOPs (CDOM, FDOM)



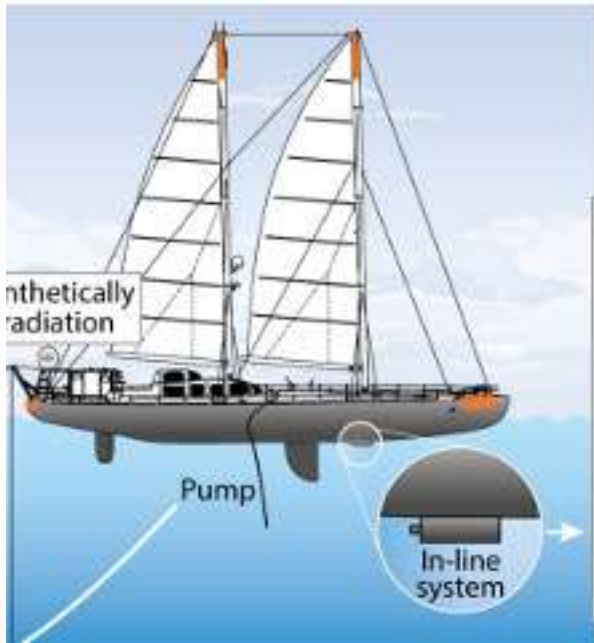
Correlation between DOC and  $a_{254}$

- 0.2  $\mu m$  filtration on board
- Samples shipped every 2 weeks to avoid long storage
- TARA 62 stations x 3 replicates  $\rightarrow$  186 samples
- TREC 41 stations x 3 replicates  $\rightarrow$  123 samples



## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: underway IOPs

Underway IOPs (with acs, bb3, LISST) have been acquired on Tara since the 2009 expedition.



- WET Labs ac-s and ECO BB3 sensors
- Fast repetition rate fluorometer
- Chlorophyll *a* fluorometer
- Aquatic Laser Fluorescence Analyzer
- Imaging FlowCytobot

### Forepeak overview

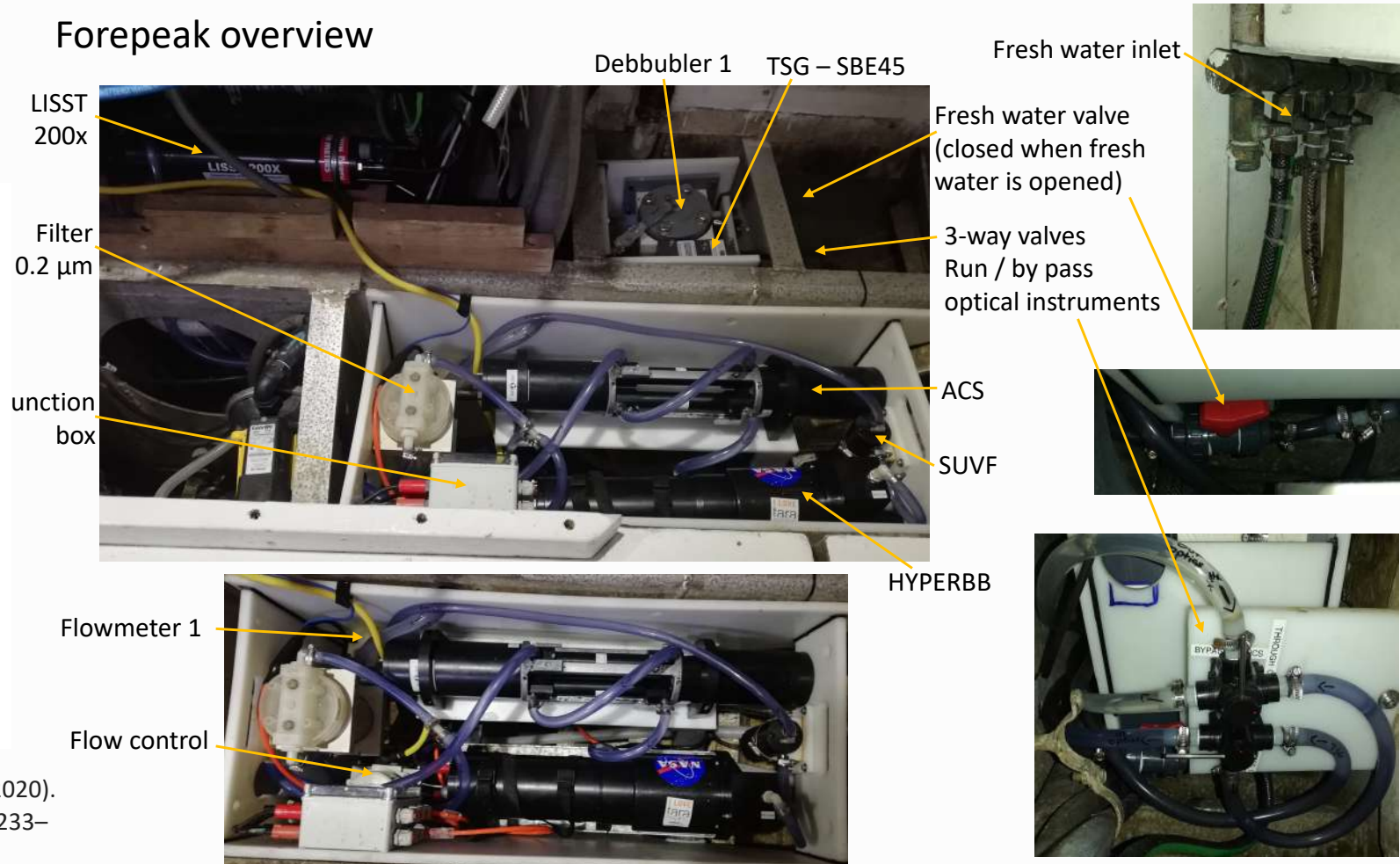


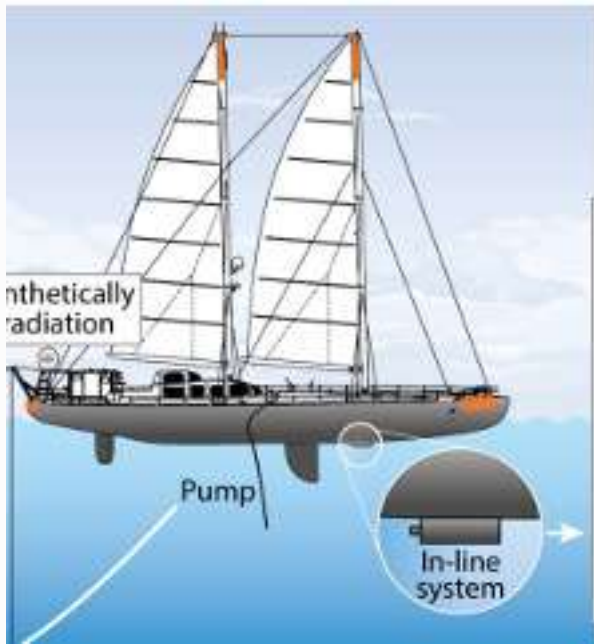
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Under corridor overview



- WET Labs ac-s and ECO BB3 sensors
- Fast repetition rate fluorometer
- Chlorophyll *a* fluorometer
- Aquatic Laser Fluorescence Analyzer
- Imaging FlowCytobot

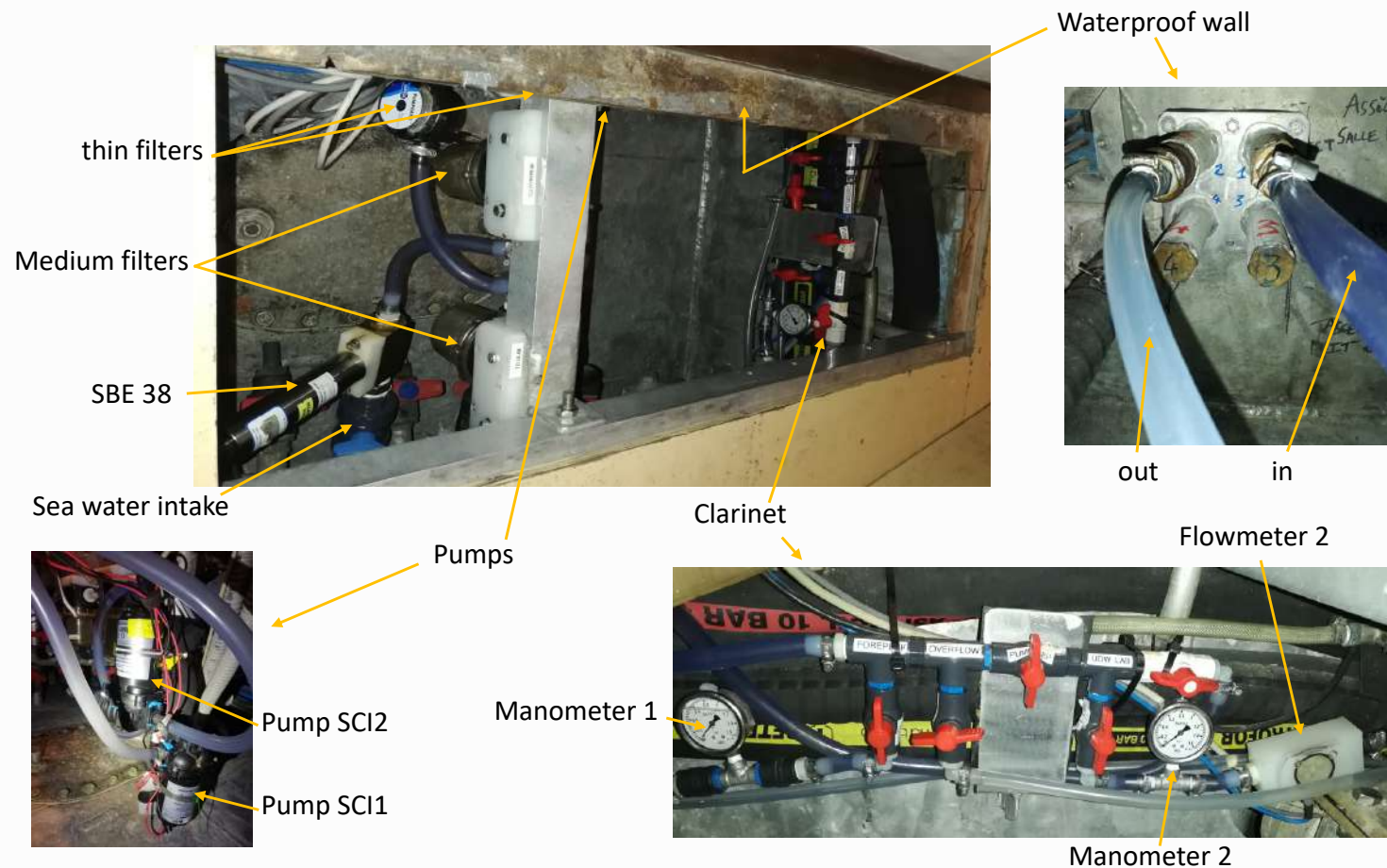


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Underway IOPs (with acs, bb3, LISST) have been acquired on Tara since the 2009 expedition.

Underway lab overview

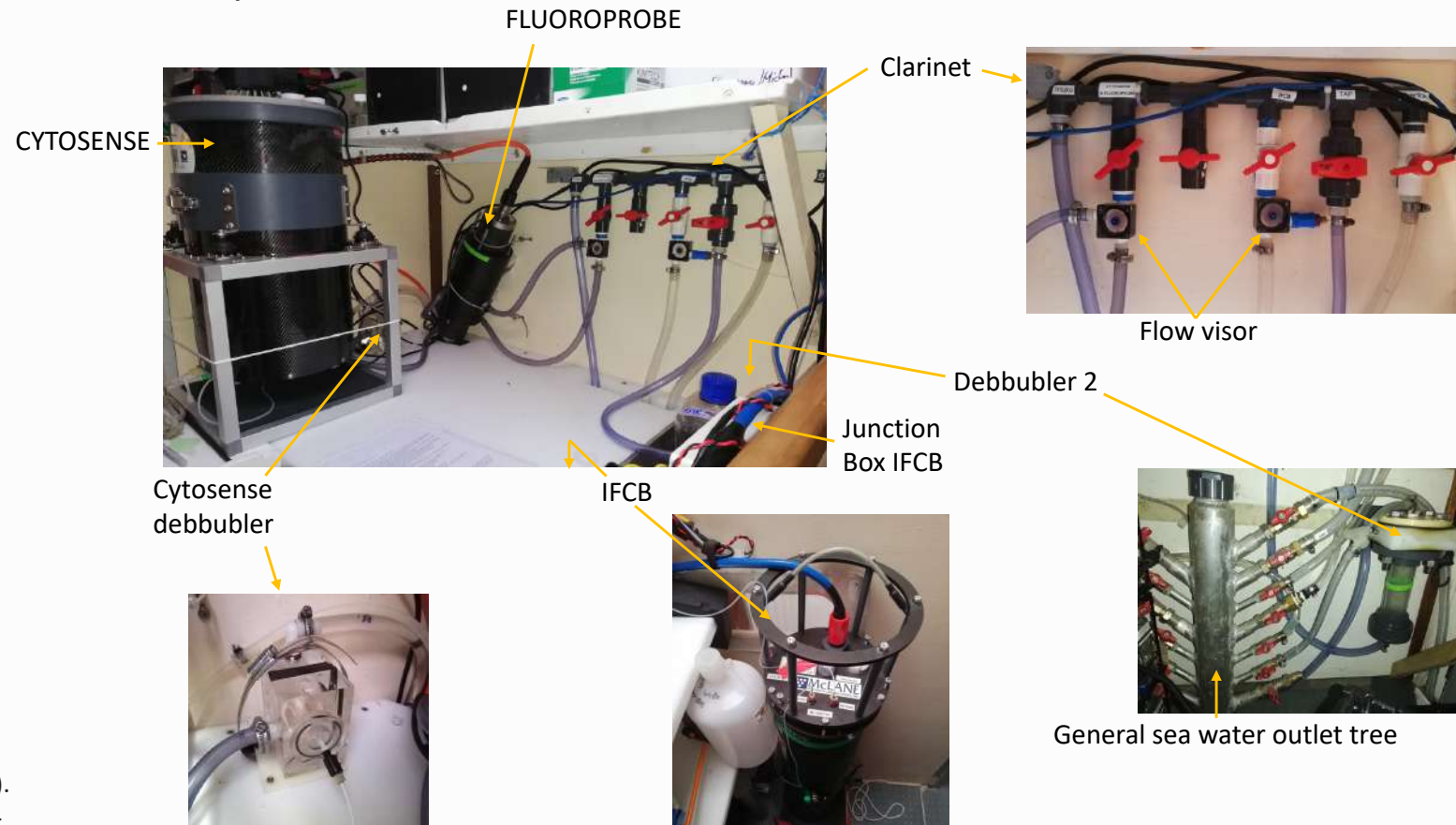
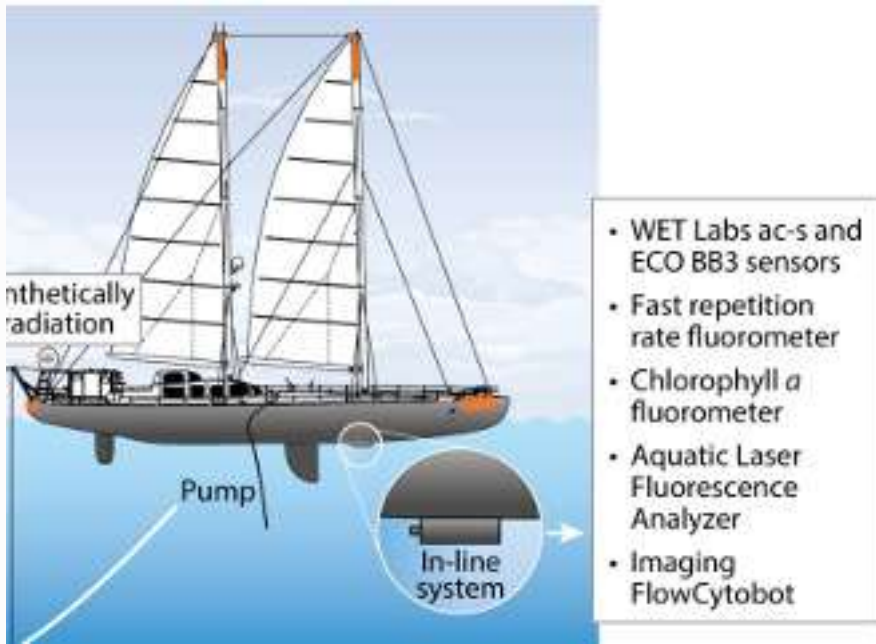


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## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: underway IOPs (acs,bb3, LISST)

Underway IOPs (with acs, bb3, LISST) have been acquired on Tara since the 2009 expedition.

Particulate absorption and attenuation from acs collected underway between Edinburgh and Dundee (22-26 of August 2023)

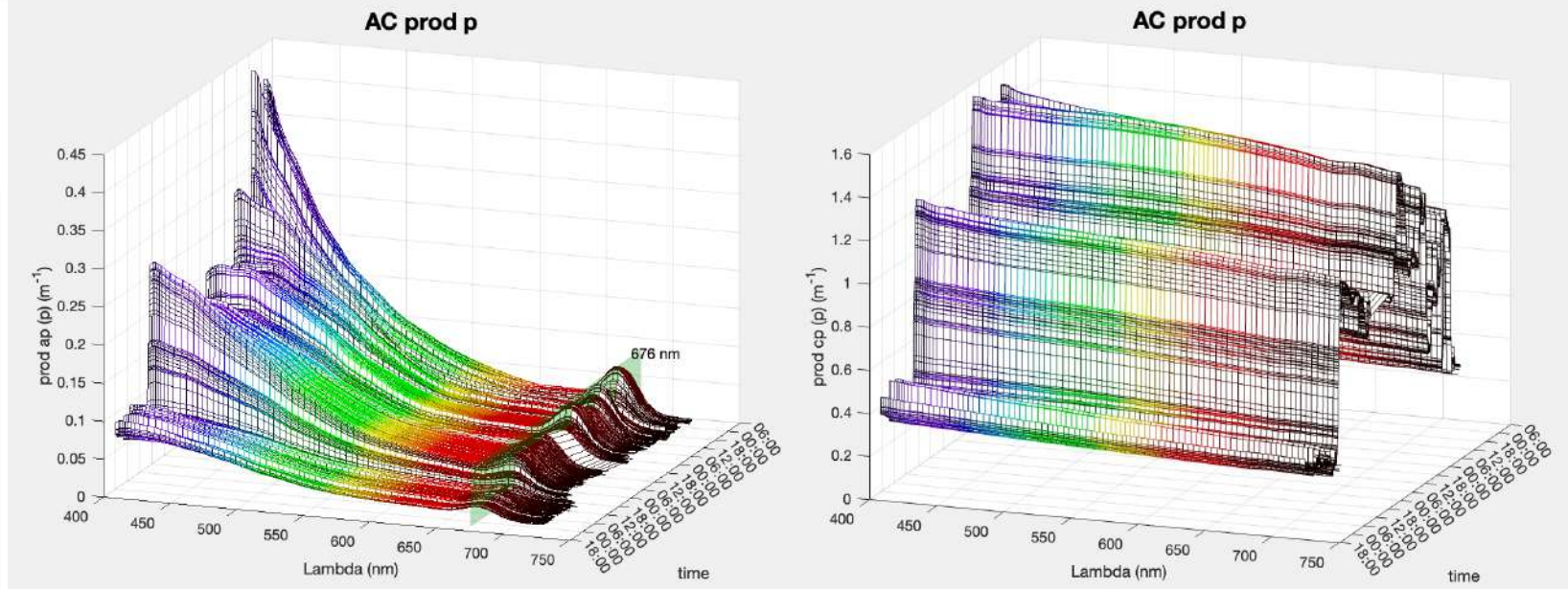
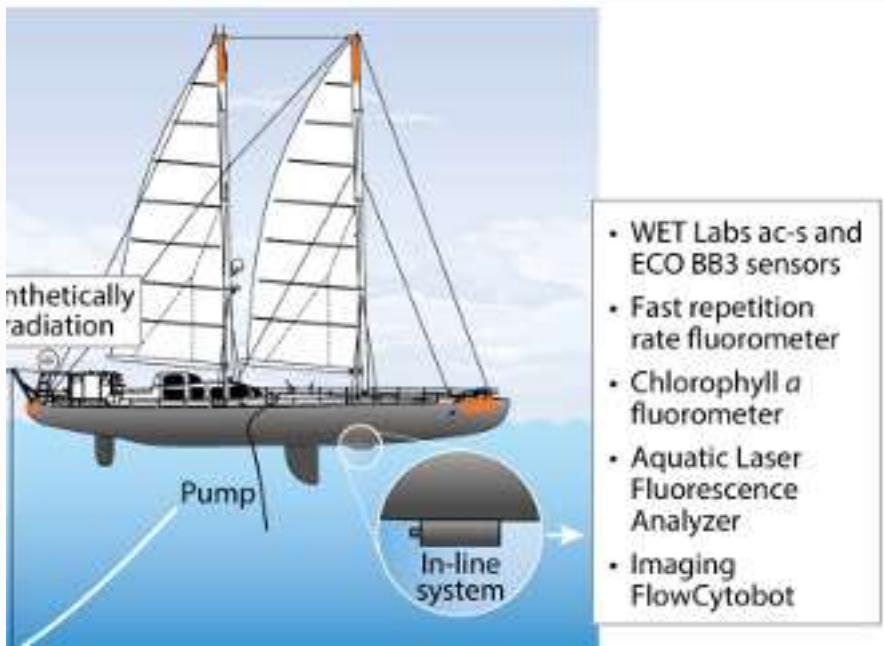


Figure Modified from: Pierella Karlusich, J. J., Ibarbalz, F. M., & Bowler, C. (2020). Phytoplankton in the Tara Ocean. *Annual Review of Marine Science*, 12(1), 233–265. <https://doi.org/10.1146/annurev-marine-010419-010706>

Processed ap and cp corrected for temperature and salinity, ap is scattering corrected using the method deemed best by Kostakis et al., 2022.

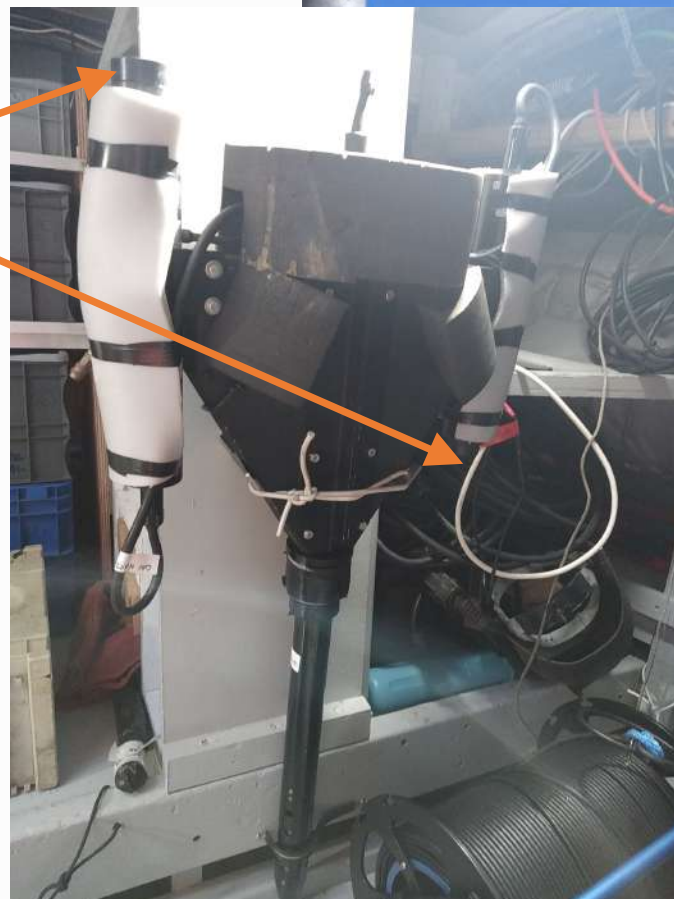




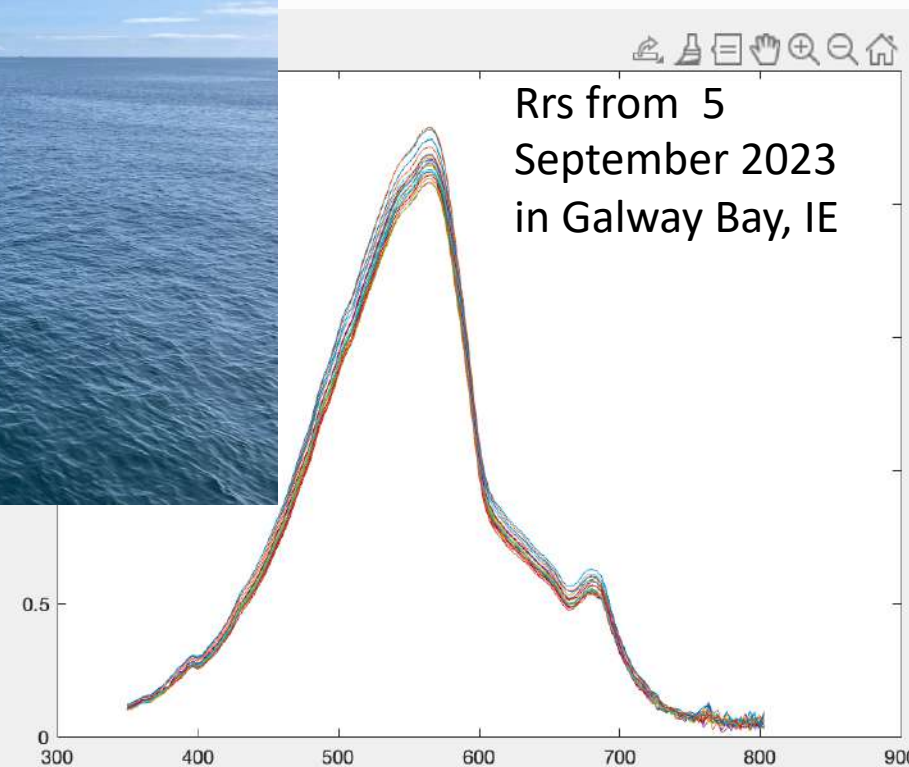
## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: discrete radiometry

Seabird Hyper-Pro II radiometer buoy floats at the surface and collects downwelling irradiance ( $E_d$ ) and upwelling radiance ( $L_u$ )

The hyper-Pro is deployed during **Tara's stations** only in **calm sea** and **cloud-free sky** conditions (15 times to date)



Hyper-Pro deployment on 25 August 2023 offshore from Dundee, UK





## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: underway above-water radiometry

One solar-tracking radiometry platform (So-Rad) and a **Hyperspectral Radiometer for Global & Diffuse Irradiance (HSP1)** were installed on Tara for TREC

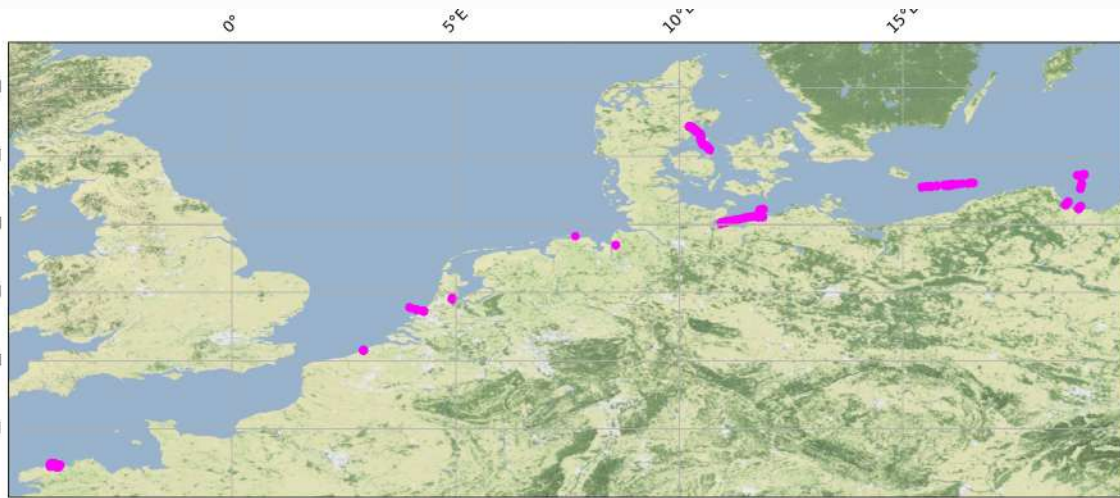
- The **So-Rad** is an **autonomous system** to obtain high-frequency above-water **hyperspectral reflectance** from non-stationary platforms such as ships and buoys as it **optimizes the measurement geometry**
- The **HSP1** measures **downwelling solar radiation**, partitioned between **Direct, Diffuse and Global Irradiance**.



*So-Rad (above-water reflectance)*



HSP-1 (direct-diffuse irradiance, AOT)



*So-Rad Reflectance data points passing initial QC (N ~ 5000) in April to early June*



## Measurements carried out aboard TARA related to phytoplankton and optics: Optics in-situ: underway above-water radiometry

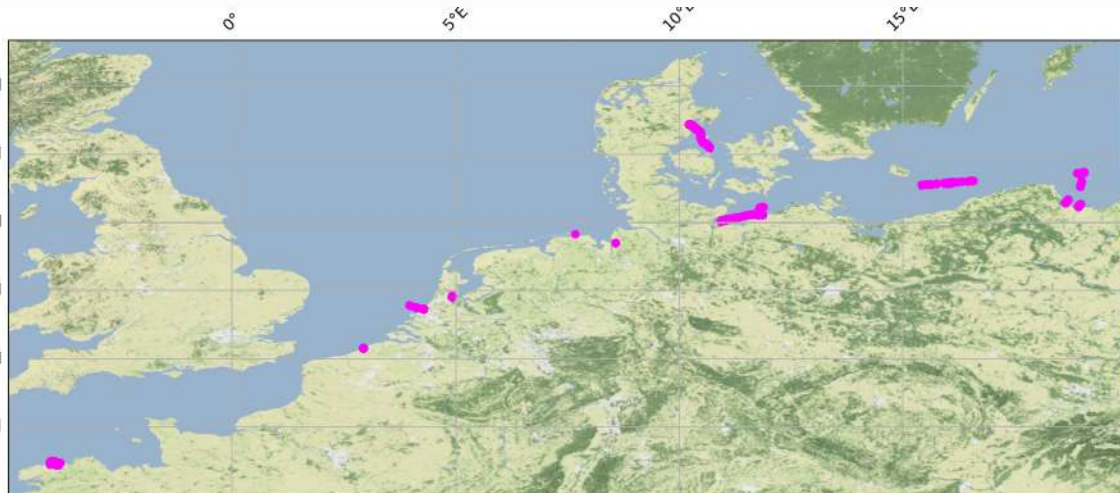
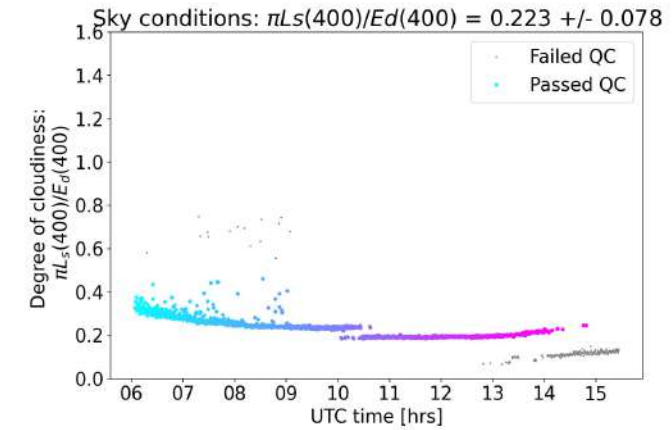
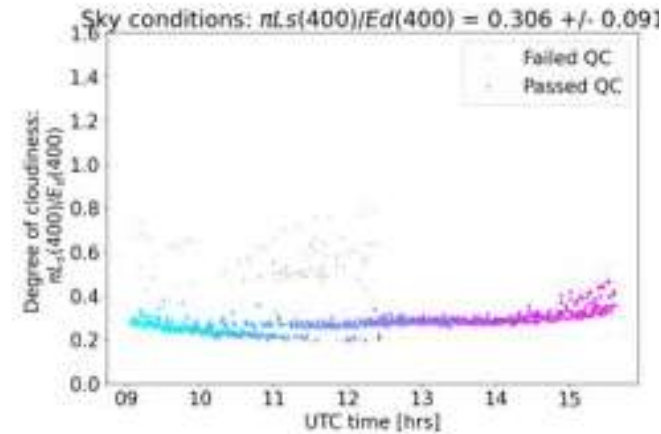
So-Rad reflectance data acquired on Tara

QC based on time series for sky conditions with a cloudiness proxy

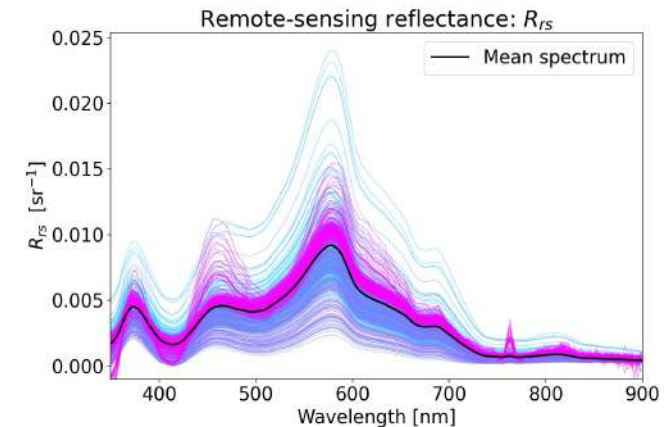
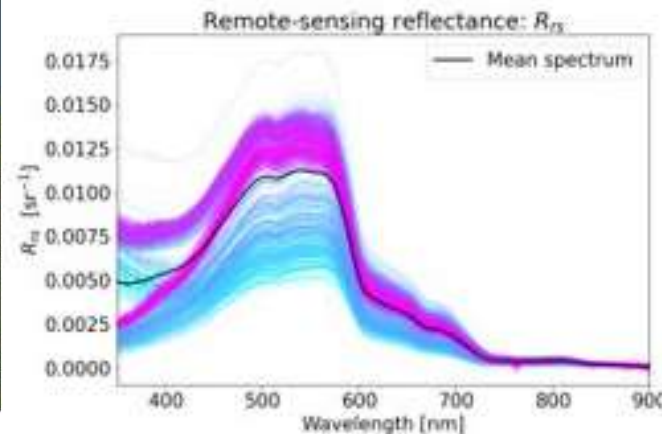
QC of effects of Tara's structure is still under development

Offshore from Roscoff: 03/04

Offshore from Gdansk: 11/06



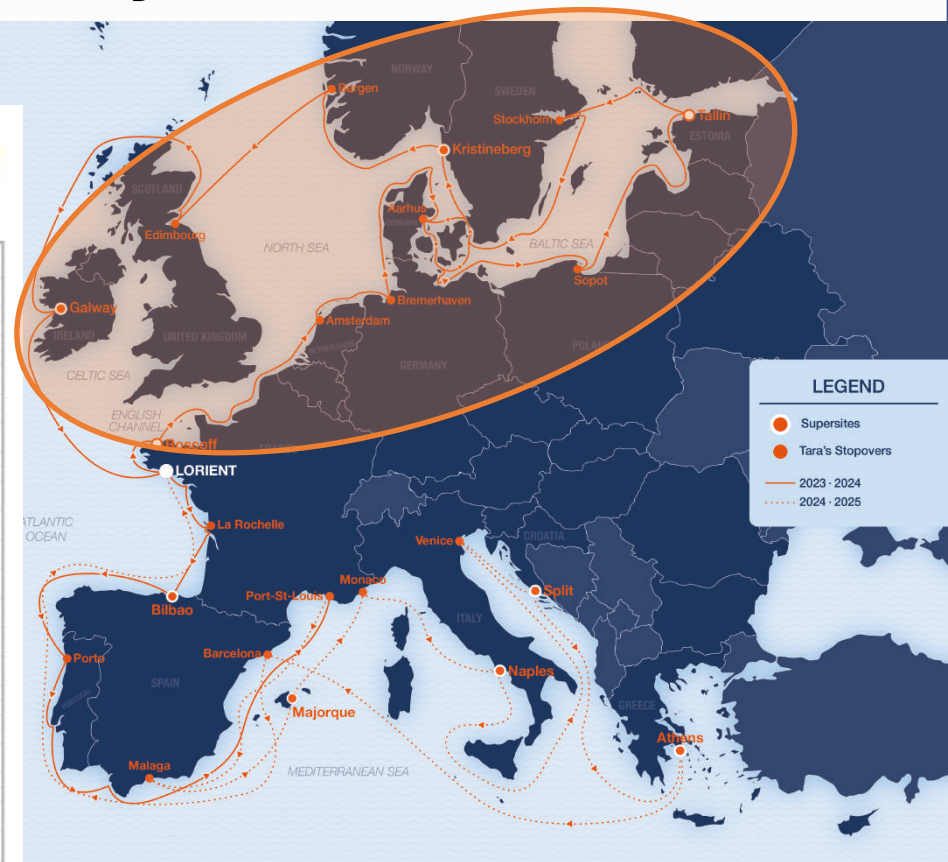
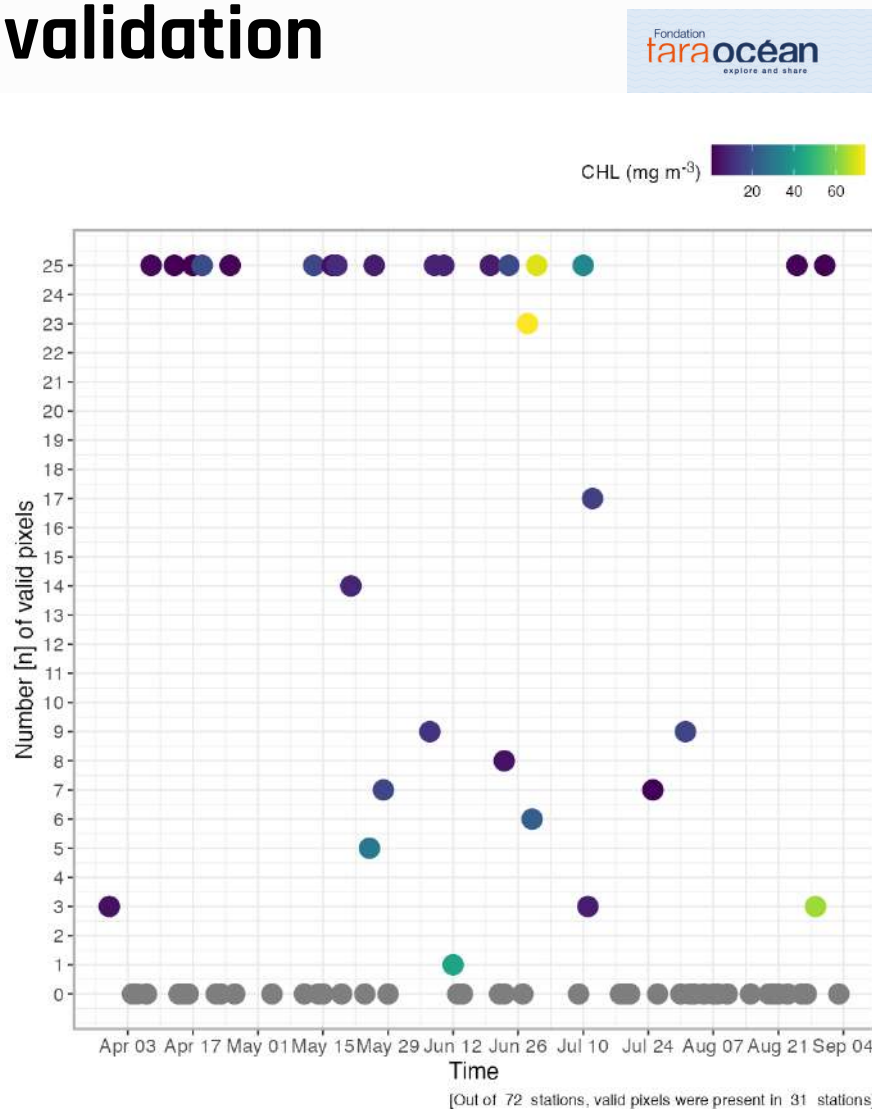
So-Rad Reflectance data points passing initial QC ( $N \sim 5000$  in April to early June)





## Measurements carried out aboard TARA related to phytoplankton and optics: Potential for satellite validation

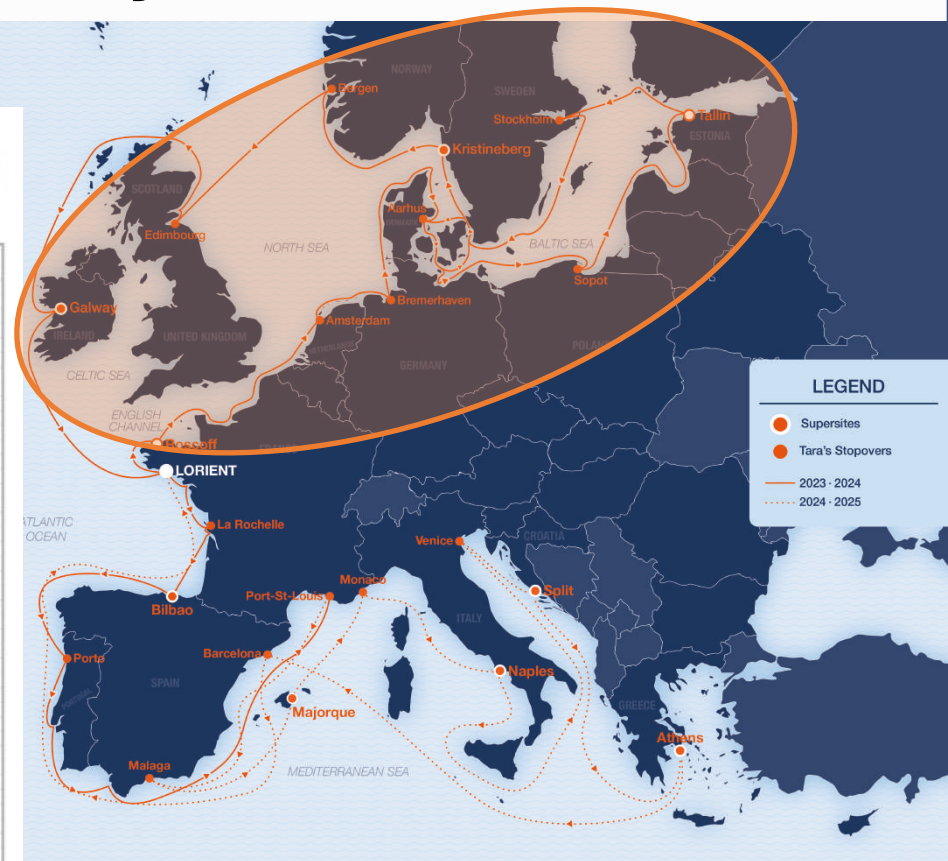
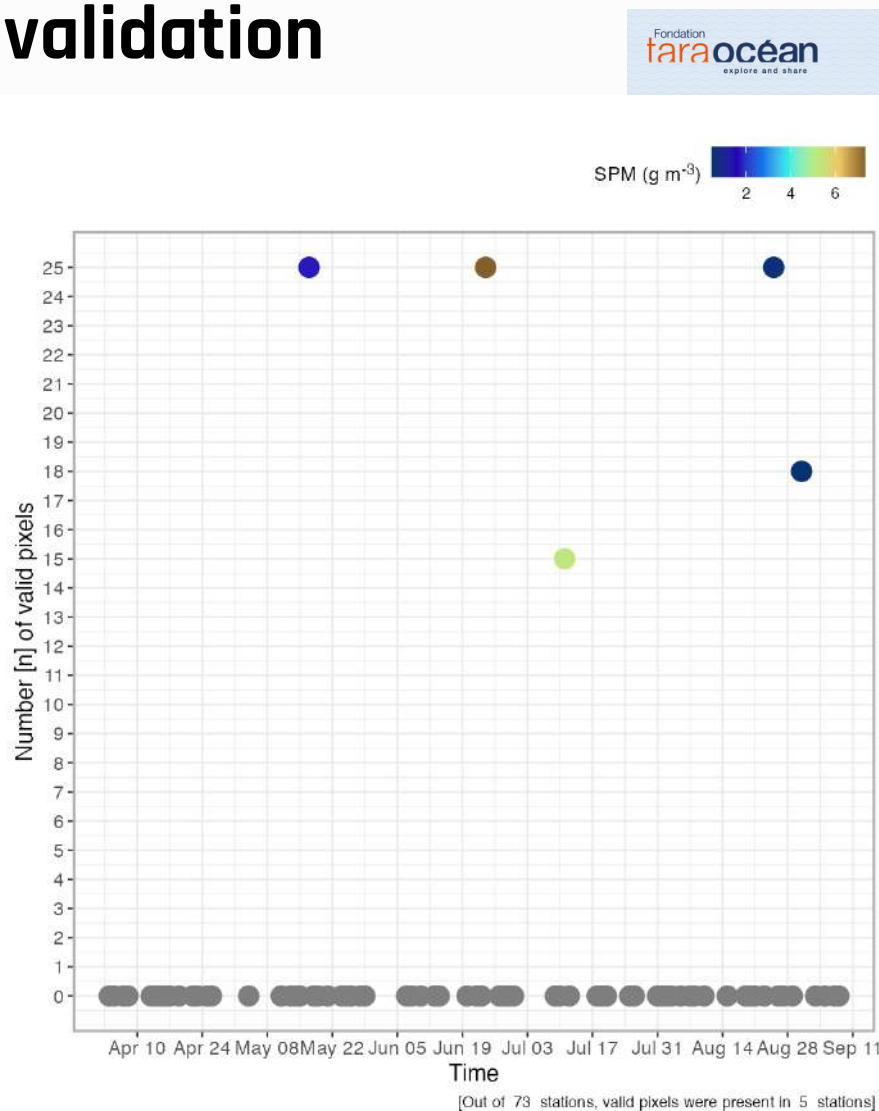
Number of potential matchups:  
**Sentinel-3 OLCI 300m**  
Preliminary analysis based on the GPS locations of the stations sampled by Tara to date and a **5x5 spatial window** on Sentinel-3 OLCI 300m **CMEMS regional products**.  
**Valid data for 31 of the 73 stations**





## Measurements carried out aboard TARA related to phytoplankton and optics: Potential for satellite validation

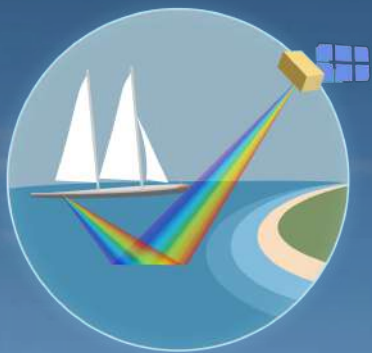
Number of potential matchups:  
**Sentinel-2 MSI 100m**  
Preliminary analysis based on the GPS locations of the stations sampled by Tara to date and a **5x5 spatial window** on Sentinel-2 MSI 100m **CMEMS regional products**.  
**Valid data for 5 of the 73 stations**





## Measurements carried out aboard TARA related to phytoplankton and optics: Future work

- **Process the in situ data**, run adequate **QC procedures**, provide **dataset description** for 2023 and 2024 stations.
- **Collocation of all discrete sample data and continuous data**:  
this will form the basis for **optical characterization of European coastal waters** including the mouth of 30 rivers using a **coherent set of instrumentation and protocols**, the first one after the Babin studies of the late nineties.
- Publication as **publicly available dataset** of all **discrete sample data and continuous data**
- **Matchup analyses** for the validation of **Reflectance, IOPs and BGC** parameters for the satellite data sources (**S2, S3, Landsat8/9, PRISMA, ENMAP, plus PACE only for 2024 stations**).
- Communication and outreach activities



# HyperBOOST

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# Thank you



Project partners

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**LOV** LABORATOIRE  
D'Océanographie  
DE VILLEFRANCHE

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**esa**

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[www.hyperboost.info](http://www.hyperboost.info)