Hyperspectral Bio-Optical Observations Sailing on Tara (HyperBOOST)

D5.6 HyperBOOST Final Report

Tender document
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Proposal led by

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1.0	06/02/2026	Victor Martinez-Vicente, Elin Meek	Document Version 1, all sections complete.
1.5	17/03/2026	Marie-Helene Rio, Javier Concha	Comments
2.0	24/06/2026	Victor Martinez-Vicente, Elin Meek	Comments addressed, all sections updated

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List of acronyms

Ap	Hyperspectral particulate absorption
BGC	Biogeochemical
CDOM	Colour Dissolved Organic Matter
CHL	Chlorophyll
CMEMS	Copernicus Marine Service
cp	Hyperspectral particulate attenuation
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
EEMs	Excitation Emission Matrixes
EO	Earth Observation
FDOM	Fluorescent Dissolved Organic Matter
Hyper-bb	Hyperspectral particulate backscattering, collected with a Sequoia Sci
IOP	Inherent Optical Properties
MDB	Match-up Database
OC	Ocean Colour
OCDB	Copernicus Ocean Colour Database
PA	Particulate light Absorption coefficient
PIF	Particulate Inorganic Fractions
PM or SPM	Suspended Particulate Matter (total load)
POC	Particulate Organic Carbon
POF	particulate organic fraction
POM	Particulate Organic Matter
QC	Quality Control
Rrs	above-water Remote-sensing reflectance data
So-Rad	Solar tracking radiometry platform system
SPM	Total Suspended Matter
TOC	Total Organic Carbon
TREC	Traversing European Coastlines
TU	Water turbidity
WP	Work Package

EXECUTIVE SUMMARY

HyperBOOST had significant **scientific, operational and programme-level impact**. Scientifically, it has delivered one of the most comprehensive and complete hyperspectral in situ optical datasets for European coastal waters to date, serving as the basis for algorithm development studies, and its results have been presented in high impact publications and scientific conferences. Operationally, it provided satellite product validation results for operational products, such as CMEMS and OC-CCI, supporting regionalisation of ocean colour data. At a programme level, HyperBOOST acts as a model project demonstrating effective collaboration with EC projects. In a forward-looking perspective, the project also strengthens Europe's readiness for hyperspectral missions by providing early validation for NASA-PACE and methodological foundations for ESA-CHIME.

Key outputs of HyperBOOST included:

- A publicly available fully quality-controlled, harmonised hyperspectral in situ dataset.
- Advanced bio-optical research, disseminated through peer-reviewed publications and conferences
- Product validation to support future ESA and EC projects on biodiversity and carbon related algorithms, and preparatory activities for CHIME.
- Increased awareness of EO applications for marine ecosystems through communication and educational materials.

The immediate and long-term outputs and impact of the HyperBOOST project is summarised in Figure 1.

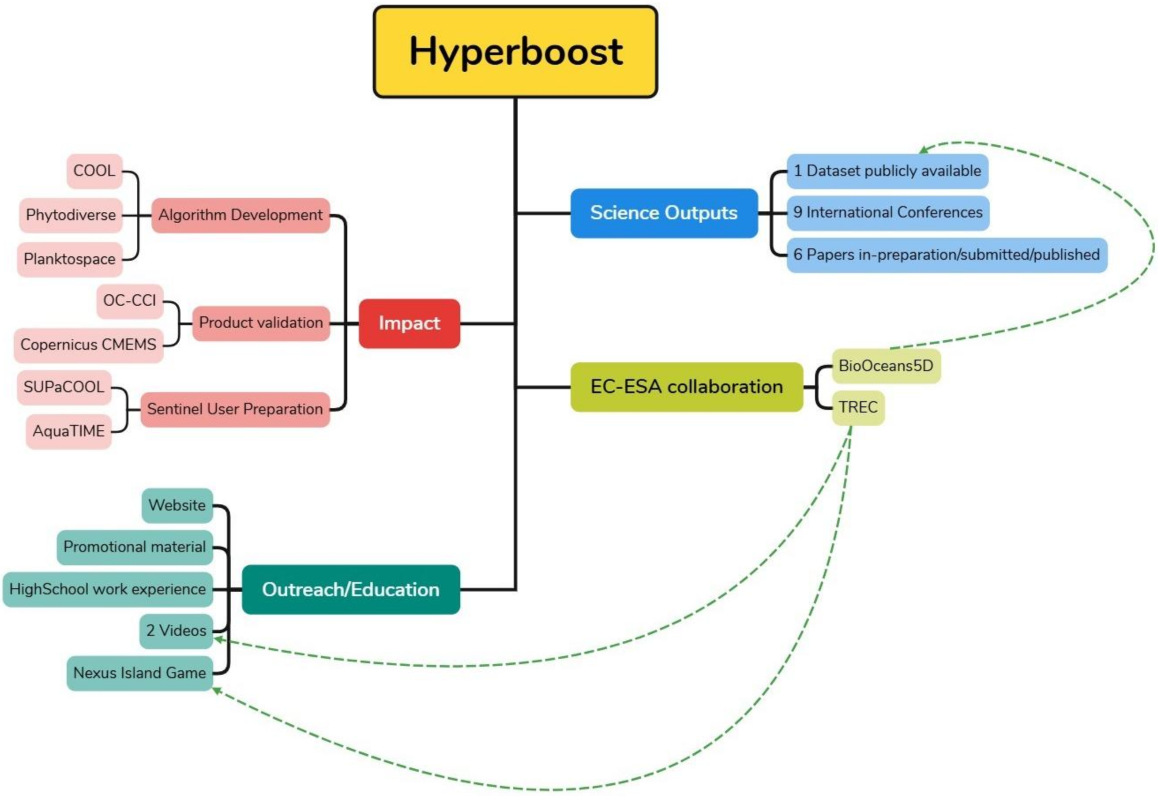

Figure 1: Summary of outputs for HyperBOOST

1. SCOPE OF THE DOCUMENT

This is the final report of Hyperspectral Bio-Optical Observations Sailing on Tara (HyperBOOST) project; it provides a succinct summary of the work carried undertaken in the project. Rather than repeat material contained in reports submitted previously, the final report has selected key outcomes to highlight. The following sections are included, a brief introduction to the project, the scientific background, scientific impact, broader impact, and concludes with a forward look and provides a few concluding remarks.

2. INTRODUCTION TO THE HYPERBOOST PROJECT

In situ bio-optical datasets are essential for the assessment of the uncertainties of satellite ocean colour measurements and derived products. This is especially critical in coastal waters (between 200 m and 5 km distance from the coastline), where land adjacency effects, complex atmospheric aerosol mixtures, optically active components (chromophoric dissolved organic matter) and bottom reflectance, contaminate the signal that reaches the satellite. Extensive campaigns and analysis covering these optical complex environmental conditions are rare in the literature.

To the best of our knowledge, the most recent concerted effort on collecting a complete dataset was undertaken about 20 years ago (Babin et al., 2003). With the advent of the hyperspectral missions in the near future (i.e. NASA PACE) and in preparation for the next high spatial resolution ones (i.e. ESA CHIME), it is very timely to dedicate effort to collect new in situ data relevant to those sensors and to update previous knowledge on optical properties variability. If this new in situ dataset is matched with current satellite colour measurements and derived products, then their value increases as they can be used for estimating uncertainties in coastal waters.

Overall, increasing knowledge on the satellite product uncertainty will enhance their reliability, which in turn will support their use for Essential Biodiversity Variables (EBV) and Essential Ocean Variables (EOV)(Martín Míguez et al., 2026). This also represented a unique opportunity to validate the algorithms for CDOM retrieval in coastal waters that is crucial for estimation of the role of river estuaries in the global carbon cycle.

The Tara expedition (https://fondationtaraocean.org/en/home/) within the frame of the Traversing European Coastlines EC projects (https://www.embl.org/about/info/trec/expedition/) and BIOOCEANS5D (https://biocean5d.org/), offered in 2023-2024 the unique opportunity to use the same set of protocols, instruments, and sample analysis, to collocate a rich biological dataset describing the microbiologic diversity (Pesant et al., 2015).

Thanks to the agility from ESA to mobilise resources, the HyperBOOST project was able to add on optical in situ observations to the Tara expedition, which enhanced the value of the biological samples collected

3. SCIENTIFIC IMPACT

The main HyperBOOST scientific output is the collection of a harmonised and standardised bio-optical dataset, which is available at this link (**https://doi.org/10.5281/zenodo.18801353**) and is the subject of a scientific publication under review. The dataset included a variety of optical and optically relevant measurements which were specifically collected as a result of ESA's support (Figure 1).

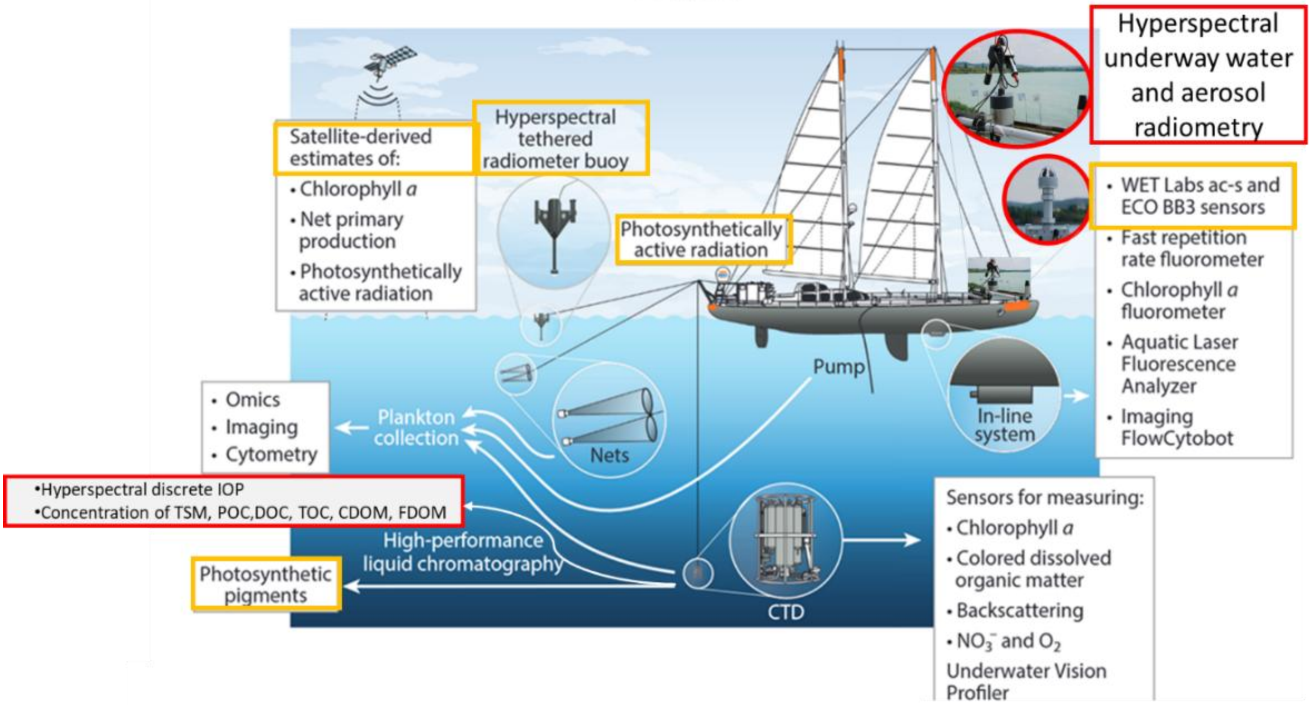

Figure 3. Measurements carried out aboard TARA related to phytoplankton and optics .Yellow Existing observations to which HyperBOOST contributes to. Red New observations to be collected for the first time in TARA, with support from ESA to HyperBOOST.

This uniquely comprehensive hyperspectral **in situ dataset**, with particular added value from the dedicated HyperBOOST leg targeting open-ocean in the Mediterranean Sea comprised a total of over 200 stations (Table 2.1 and Figure 2) and thousands of under-way continuous data.

Table 3.1 Discrete samples

Year	Discrete Data
2023	99 stations (3 replicates) 297 samples
2024	89 stations, 3 replicates (0 m + Deep Chlorophyll Maximum) 295 samples
2024- HyperBOOST leg	14 stations x 2 depths (3 replicates) 72 samples

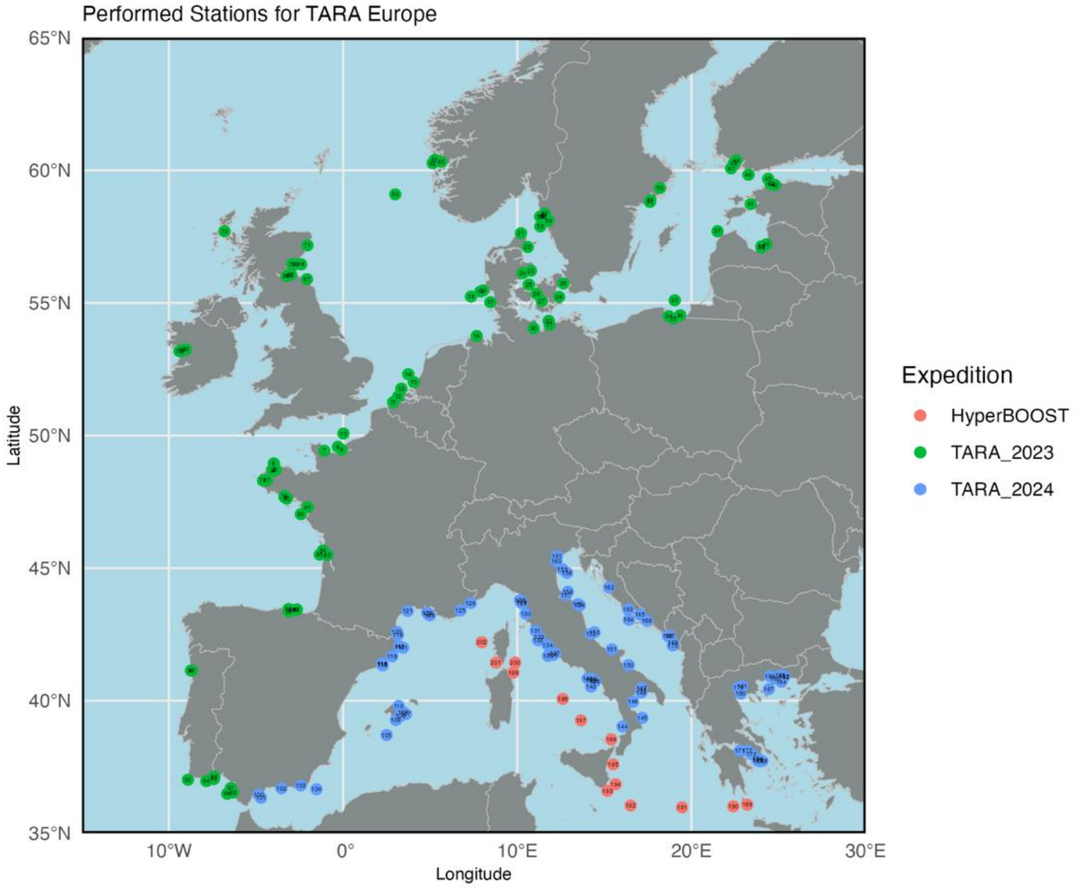

Figure 3 The 202 stations (dots) sampled by TARA in 2023 (green dots) and 2024 (blue dots) along European coastline, as part of the TREC expedition and the HyperBOOST leg (red dots).

Key scientific findings include strong correlations between Colour Dissolved Organic Matter (CDOM), Fluorescent Dissolved Organic Matter (FDOM) and Dissolved Organic Carbon (DOC) in coastal regions, confirmation of highest DOC values in the Baltic and river-influenced areas, and the successful development of new portable sampling solutions (e.g. a hand-built peristaltic pump), as well as the demonstration of the validity of hyperspectral autonomous radiometry (Sorad) collected from a sailing vessel (a first to our knowledge).

HyperBOOST publications:

Jordan, TM, Simis, SGH, Selmes, N, Sent, G, Ienna, F and Martinez-Vicente, V. 2023. Spatial structure of *in situ* reflectance in coastal and inland waters: implications for satellite validation. Frontiers in Remote Sensing, 4. **https://doi.org/10.3389/frsen.2023.1249521**

Marchese, C., E. Boss, F. Falcini, D. Doxaran, C. de Vargas, G. Pfister, and V.E. Brando. 2024. Satellite data sharing for scientific inter-group cooperation using the leaflet R package. Oceanography 37(3):70–74, **https://doi.org/10.5670/oceanog.2024.513.**

Margherita Costanzo, Vittorio E. Brando, Emmanuel Boss, Ali Chase, David Doxaran. A Novel Approach for Estimating Non-Algal Particle Absorption from Seabird’s AC-S and Its Application to Improve the Retrieval of Pigment Concentrations Along European Coastlines . Submitted to Limnology and Oceanography.

Robert W. Schlegel, Denis Pailler, Thomas M. Jordan, Vittorio E. Brando, Stefan Simis, Victor Martinez-Vicente, Paco Stil, Emanuel Boss, David Doxaran. Hyperspectral field and satellite radiometric matchups in oligotrophic waters. Submitted to Optics Express.

Margherita Costanzo,Vittorio Brando, Federico Falcini, Christian Marchese, Luis Gonzalez Vilas, Emmanuel Boss, David Doxaran, Paola Potin, Stefan Simis, Tom Jordan John Wood, Chiara Santinelli, Giancarlo Bachi, Giovanni Checcucci, Claudia Tropea, Marco Carloni, Mirco Guerrazzi, Silvia Valsecchi, Valtere Evangelista, Marie-Helene Rio, Javier A. Concha, Colomban de Vargas, Victor Martinez-Vicente. The Hyperspectral Bio-Optical Observations Sailing on Tara (HyperBOOST) dataset. Submitted to Earth System Science Data.

Paola Potin, Isabella Mayot, Chiara Santinelli, Vittorio E. Brando, Margherita Costanzo, Emmanuel Boss, Victor Martinez-Vicente and David Doxaran. Variability in the Light Absorption Coefficients of Phytoplankton, NAP and CDOM in European Coastal Waters over the last 30 years. To be submitted to Biogeosciences

Santinelli C., Schiller J., Bachi G., Berthelot H., Bertucci P., Boork P., Boss E., Brando V., Carloni M., Checcucci G., Couet D., de Vargas C., Doxaran D., Evangelista V., Guerrazzi M., Guillam M., Jordan T., Lago S, Martinez-Vicente V., Tropea C., Valsecchi S., Vincent F., DOM dynamics along the European coasts, new insights from the TRaversing European Coastlines (TREC) expedition. In preparation.

Santinelli C., Boss E., Brando V., Schiller J., Bachi G., Bertucci P., Boork P., Carloni M., Checcucci G., Couet D., de Vargas C., Doxaran D., Evangelista V., Guerrazzi M., Guillam M., Jordan T., Martinez-Vicente V., Tropea C., Valsecchi S., Capturing DOM dynamics in coastal areas using satellite observations. In preparation

Martinez-Vicente V, E. Boss, D. Doxaran, M.Costanzo, V. Brando, P. Potin, I. Mayot, Hyperspectral light scattering properties in European coastal waters and their relation to particle composition. In preparation.

HyperBOOST Conference Attendance:

- LOV Annual Seminar – 2023
- 6th Sentinel 2 validation Meeting- 2023
- Ocean Optics - 2024
- BIOSPACE25
- One Ocean Science Congress – 2025
- ESA Living Planet – 2025
- 2nd Ocean Carbon from Space Workshop- 2025
- IOCS- 2025
- AGU Ocean Sciences – 2026
- Ocean Optics - 2026

Finally, the HyperBOOST deliverables have been archived in Zenodo for future reference (Appendix I).

4. BROADER IMPACT

All of the data was acquired consistently using the same instrumentation and harmonised protocols throughout the campaign, enabled by the Tara sampling framework. This consistency across regions and seasons is a major strength of the dataset, ensuring comparability across stations and supporting robust scientific analysis. This has allowed for the application of the dataset beyond the project activities, applied to other ESA and European Earth Observation activities (i.e. Copernicus). During the project, validation of satellite ocean-colour products was undertaking using the HyperBOOST in-situ datasets, remote-sensing reflectance (Rrs), chlorophyll-a (Chl), suspended particulate matter (SPM), and inherent optical properties (IOPs). Validation was conducted across multiple sensors, spatial resolutions, and product types, including Level-2 and Level-3 products from Sentinel-3 OLCI, Sentinel-2 MSI, CMEMS, OC-CCI, and early hyperspectral data from NASA's PACE OCI mission. See **D4.1 Product Validation Report** (Initial) **v1 and (Final) v2** and Schlegel et al.

Beyond the project, HyperBOOST data are already being used to support validation of current satellite missions, and the dataset provides a valuable testbed for simulation and preparation of future hyperspectral missions (CHIME), through ESA's SUPaCOOL and AquaTIME projects. Looking ahead, future work will focus on integrating HyperBOOST optical data with complementary Tara and TREC datasets, such as imaging and omics observations, to enable new ecological and biodiversity applications and to strengthen links between Earth observation, marine ecosystems, and biodiversity science (Planktospace and Phytodiverse). The Hyperboost dataset is also being used for developing and testing novel carbon products in coastal areas (in COOL).

Importantly, HyperBOOST can be viewed as a **case study of a successful EC–ESA joint action**, underlining its programme-level impact beyond the project itself. This was highlighted in an Agora session during ESA Living Planet Symposium 2025 and is a model of collaboration between ESA and EC projects.

5. COMMUNICATION AND EDUCATION

WP5.1 ensured effective dissemination, and legacy planning. The project website (project website D5.4 **About - HyperBOOST**), will remain live for at least five years, with continued updates to data links and publications. The HyperBOOST project attended and presented at nine conferences/meetings. Educational activities strengthened links between EO science, biodiversity, and students, inspiring the new generations of ocean remote sensing scientists.

Educational materials

1) Hosting high school students for a work experience (17-year-old) in person at the Plymouth Marine Laboratory
2) Co-developing educational material with ESA and EMBL to extend the educational Nexus Island Game
3) Developing an specific educational activity for linking satellite EO to biodiversity.

The work experience at Plymouth Marine Laboratory (PML) was organised during the first week of July 2023 and attracted 10 students from local high schools. The students gained a range of experience in biodiversity, biogeochemistry, modelling, remote sensing, digital technology, lab work, and research vessel activities.

During the HyperBOOST project there was engagement with EMBL to extend the game Nexus Island to include EO elements. Nexus Island was used as an educational activity running alongside the TARA-TREC campaign. Nexus Island (**https://www.embl.org/ells/teachingbase/nexus-island/**) is a 50-minute, game-based workshop designed to engage participants with concepts of planetary health.

The ESA cards extension is now available **ESA - Nexus Island ESA Extension in the classroom**. The cards were translated into 5 languages, relevant to the countries TARA visited during 2024. The Nexus Island game was also tested during the work experience at PML.

Promotional videos

The project generated two promotional videos, the first one advertised the aims and objectives of the project, the second promoted the results and outcomes.

First promotional video D5.1: **https://youtu.be/hg5vLJ65xbA** (467 views)

Second promotional video D5.2: This will be available on the **website**



6. CONCLUSIONS AND FUTURE AVENUES

The HyperBOOST project has successfully demonstrated:

- Programmatic collaboration between ESA and EC projects allow for synergies that produce results greater than the sum of the individual parts
- A sailing platform is able to deploy autonomous radiometry capable of being used for satellite validation
- The combination of hyperspectral bio-optical and reflectance data allowed development of novel algorithms and new knowledge, not only for biodiversity but also carbon pools.
- The harmonisation of sample collection, analysis and processing is key to the usability of datasets for large scale analysis

Future developments to take advantage of the lessons learnt in HyperBOOST are:

- **ESA to enhance field campaigns, where** biological/biogeochemical data collection is planned (already supported by EC projects), with bio-optical and radiometric **harmonised** measurements. This addresses the need to create datasets allowing development of new algorithms and satellite product validations.
- Support the deployment of **autonomous optical instrumentation on different types of platforms** (sailing vessels, commercial vessels/ferries)
- Acknowledge the data latency for biological datasets (e.g. imaging) and **promote a faster open access to biological data**
- **Extend in situ sampling** with complementary datasets to HyperBOOST to cover the **temporal variations** of optical properties and the related biological/biogeochemical

APPENDIX I: **Links to the HyperBOOST Deliverables on Zenodo**

Name	Link
D1.1 Protocols, Mission plan, TARA checklist (PMPC)	https://doi.org/10.5281/zenodo.18468968
D1.2 Dataset design model (DDM)	https://doi.org/10.5281/zenodo.18469092
D2.1 *In situ* dataset (IID) and Dataset description (internal)	https://doi.org/10.5281/zenodo.17093990
D3.1 Collocated *in situ*/satellite dataset (CID) and collocated *in situ*/satellite dataset description (2023 cruise)	https://doi.org/10.5281/zenodo.18469185
D3.2 Product validation plan (PVP)	https://doi.org/10.5281/zenodo.18469224
D4.1 Product Validation Report	https://doi.org/10.5281/zenodo.18468613
D5.1 Initial promotional video	https://youtu.be/hg5vLJ65xbA
D5.2 Final promotional video	Index - HyperBOOST
D5.3 Education Material on EO for biodiversity	Index - HyperBOOST
D5.4 Website	Index - HyperBOOST

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