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D5.2 – Blue-Cloud VRE Operation Report

Work Package	WP5 | Blue-Cloud VRE platform evolution and integration with EOSC resources and services
Task	N.A.
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Glossary of terms

Item	Description
API	Application Programming Interface
CMS	Content Management System
CVS	Code Versioning System
DD&AS	Data Discovery & Access Service
D4Science	Data Infrastructure promoting Open Science (managed by CNR)
EOSC	European Open Science Cloud
EOVs	Essential Ocean Variables
GRSF	Global Record of Stocks and Fisheries
JSON	Javascript Object Notation
OGC	Open Geospatial Consortium
OIDC	OpenID Connect
UI	User Interface
VLab	Virtual Laboratory
VRE	Virtual Research Environment

Keywords

EOSC; Virtual Labs; Big Data; Virtual Research Environment; e-infrastructures

Disclaimer

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EXECUTIVE SUMMARY

The Horizon Europe Blue-Cloud initiative started in 2019 with the aim of creating a European Open Science Cloud for marine data. This involves federating data and e-infrastructures to provide data products and technologies as open science resources for the wider marine research community. Since 2023, the Blue-Cloud 2026 follow-up project has sought to further evolve this pilot ecosystem into a Federated European Ecosystem, offering FAIR and open data and analytical services crucial for advancing research on oceans, EU seas, and coastal and inland waters. Building on the pilot Blue-Cloud project, the current technical framework is designed to be extensible and open, continually evolving to meet the community's needs.

The Blue-Cloud platform architecture comprises two major components: (a) the Blue-Cloud Data Discovery and Access Service (DDAS) component, which facilitates federated discovery and access to 'blue data' infrastructures, and (b) the Blue-Cloud Virtual Research Environment (VRE) component, which provides a Blue-Cloud VRE as a federation of computing platforms and analytical services. The VLabs leverage both DDAS and VRE, co-created with leading marine researchers to demonstrate the power of the Blue-Cloud Open Science platform through real-life scientific cases.

This deliverable focuses on the VRE operation, specifically on how the VRE services have been utilised and managed to support the development of the Blue-Cloud VRE gateway (https://blue-cloud.d4science.org), its underlying infrastructure, and the VLabs on top of it, during the reporting period from January 2023 (M1) to June 2024 (M18).

A total of 13 VLabs were created and operated to meet the needs arising from the Blue-Cloud 2026 project. Additionally, 7 VLabs from the previous Blue-Cloud project are being maintained. These working environments serve more than 1,700 users from 34 countries. Between January 2023 and June 2024, users initiated more than 26,000 working sessions via the Blue-Cloud VRE, averaging 1,447 sessions per month.

Operating the VRE and VLabs involves managing support requests, issues, and incidents. A total of 143 tickets have been created and managed in the Blue-Cloud Project Issue Trackers (23 in the project consortium tracker and 120 in the support tracker), with 85% of these tickets closed. Additionally, 24 tickets related to Blue-Cloud have been created within the D4Science overall context, with an 88% closure rate.

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1. Introduction

The Horizon Europe Blue-Cloud initiative began in 2019 with the goal of creating a European Open Science Cloud for marine data. This involves federating data and e-infrastructures to make data products and technologies available as open science resources for the broader marine research community. Since 2023, the Blue-Cloud 2026 follow-up project has aimed to further develop this pilot ecosystem into a Federated European Ecosystem, delivering FAIR and Open data and analytical services essential for advancing research on oceans, EU seas, coastal, and inland waters. Building upon the pilot Blue-Cloud project, the current Blue-Cloud technical framework is designed to be extensible and open, evolving continually to meet the community's needs. It facilitates collaborative research and the adoption of Open Science principles through a distinguished set of services. Among those, the following are considered Blue-Cloud core services:

- The **Data Discovery and Access Service** (DD&AS) is an overarching service to facilitate federated discovery and access to a series of established repositories (Blue Data Infrastructures (BDIs)), and smart sharing of retrieved multi-disciplinary datasets with human and machine users.
- The Blue-Cloud **Virtual Research Environment (VRE)** orchestrates the computing and analytical services in specific integrated and managed applications exploiting federated Blue-Cloud data resources as well as external data resources**.**
- Five **dedicated Virtual Laboratories** (VLabs) and **EOV Workbenches** co-created with top-level marine researchers to showcase the power of the Blue-Cloud Open Science platform via real-life scientific cases [5].

This deliverable documents how the components of the Blue Cloud VRE have been exploited and operated to support the development of the Blue Cloud VLabs, these components also facilitate the co-creation of entire VLabs and encompass a variety of services, ranging from those promoting collaboration among users to those supporting the execution of analytical tasks within a distributed computing infrastructure. They also provide interfacing with the Data Discovery & Access Service (DDAS) and the exploitation of external services such as the EOSC AAI and the WEkEO DIAS of Copernicus Marine, enabling researchers to leverage external resources and data sources, expanding the capabilities and richness of their research endeavours. These functionalities contribute to the comprehensive and interconnected nature of the Blue Cloud ecosystem.

The procedures involved in the VRE and VLab lifecycle are detailed in Section 2, from initial planning to full-scale operation. Comprehensive statistics on VLabs usage are given in Section 3, showcasing the extent of engagement and productivity within the Blue-Cloud VRE. Detailed sections on each VLab provide insights into their unique functionalities and research outputs.

Additionally, the exploitation of the Blue Cloud VRE by other initiatives, such as FAIR-EASE and CLIMAREST, underscores the collaborative nature of the Blue-Cloud 2026 project within the broad European Open Science framework.

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This introduction sets the stage for a thorough exploration of how the Blue-Cloud VRE and VLabs are fostering innovation, enhancing data accessibility, and supporting the marine research community.

The Blue-Cloud VRE relies on the D4Science infrastructure [1][2] and the gCube [3] open-source technology. It is deployed within the Blue-Cloud gateway (accessible at https://blue-cloud.d4science.org) to provide access to these services and Virtual Laboratories.

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2. Blue-Cloud VRE and VLabs Planning and Procedures

The Blue-Cloud VRE is built on the D4Science infrastructure and the gCube open-source technology [1-3]. From the end-user point of view, it manifests in the EOSC Blue Cloud2026 gateway (accessible at https://blue-cloud.d4science.org), the access point to the services and Virtual Laboratories made available to the Blue-Cloud community.

The development of the Blue-Cloud VRE counts on the availability of new versions of the enabling technology that are made available by https://code-repo.d4science.org/gCubeCI/gCubeReleases. These versions are produced by taking into account the requirements (with relative priority) formulated by the Blue-Cloud community via the specification of the VLabs [5, 6] that might correspond to new facilities to be developed or requests for enhancements of existing facilities as well as requests for resolving malfunctions.

The technology supporting the development of the Blue-Cloud VRE for the reporting period (M1 to M18) was included in the following 13 gCube open-source software releases that have been deployed into the D4Science production infrastructure powering the VRE: 5.14.1 and 5.14.2 (Jan. 2023), 5.14.3 and 5.14.4 (Feb. 2023), 5.15 (Feb. 2023), 5.15.1 (Mar. 2023), 5.15.2. (Apr. 2023), 5.15.3 (May. 2023), 5.15.4 (Jun. 2023), 5.15.5 (Aug. 2023), 5.16 (Sep. 2023), 5.16.1 (Mar. 2024), 5.17.1 (May 2024).

All requests are modelled and managed through an issue tracker operated by D4Science, accessible at https://support.d4science.org. For the needs of the Blue-Cloud community, a dedicated Blue-Cloud 2026 project issue tracker was established and configured to handle ticket creation for tasks, support requests, incidents, VLab creations, and more, a screenshot of the current issues is depicted in Figure 1. Additionally, an extra issue tracker named Blue-Cloud Support is in operation. This tracker is open not only to project members but also to the broader Blue-Cloud 2026 community, including students, and any practitioners interested in Blue-Cloud 2026 technology.

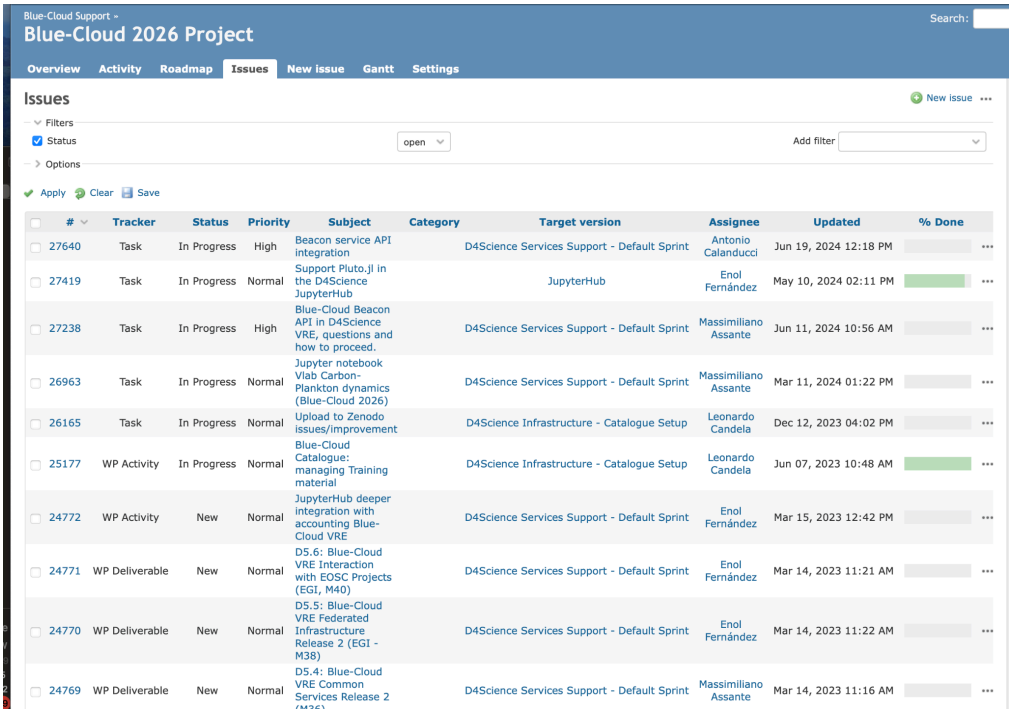

Figure 1. A screenshot of the Blue-Cloud2026 Support issue tracker

2.1 Procedures

Deploying and operating VLabs is a collaborative effort involving the WP5 team, responsible for deploying and configuring the technology, and Work Packages 3 and 4, tasked with developing and onboarding their technology. There is also interaction with WP2 in case of data access challenges. This joint effort aims to create the VLabs expected by the work package.

The procedure for VRE and VLab deployment is well-established, having been inherited from the D4Science infrastructure. Detailed steps can be found in the D4Science Wiki:

https://wiki.d4science.org/index.php?title=Virtual_Research_Environments_Deployment_and_Operation

For Blue-Cloud 2026 needs, it was decided to support this activity with the project activity tracker. A specific VRE tracker has been created to capture the entire process from specification to operation. The VRE/VLab designer/requester produces the specifications for the VRE/VLab, which must include the following details:

- VLab name and abstract;
- Membership policy, i.e., whether the VLab is open or restricted, who is allowed to invite members;
- VRE expected datasets;
- VLab expected functionalities;
- VLab due date;

The following statuses are supported:

- ***Planned***: the WP5 team is fine with the specification, i.e., the specification contains enough details to proceed with the creation, and acknowledges that the creation of the VLab is feasible by the due date initially requested (or liaise with the designer/requester to find a mutually suitable date);
- ***Available***: the VLab is up and running and ready to be validated by the user designer/requester;
- ***Released***: the VLab has been validated, and the target community can start using it;
- ***Removed***: the VLab has been disposed as per the request of its manager;
- ***Rejected***: the requested VLab cannot be created as the requirements outlined for it cannot be satisfied.

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3. Blue-Cloud VRE and VLabs Creation, Deployment, and Operation

This section provides a concise overview of the resources utilised by VLab creators for deploying VLabs, includes a comprehensive list of all deployed and operational VLabs, and offers detailed descriptions of each.

The process of defining and deploying a new VLab is facilitated by a wizard (see Figure 2) that assists authorised users in converting open requests, as detailed in Section 2, into formal specifications and, subsequently, into fully operational VLabs accessible through the Blue-Cloud gateway at https://blue-cloud.d4science.org/. During this process, users are prompted by the wizard to input: (i) descriptive details that define the intended VLab (such as name, description, and duration), and (ii) the specific functionalities and datasets to be included in the VLab by choosing from those available. The list of functionalities provided is based on what is achievable with the software versions and services supported by the underlying infrastructure.

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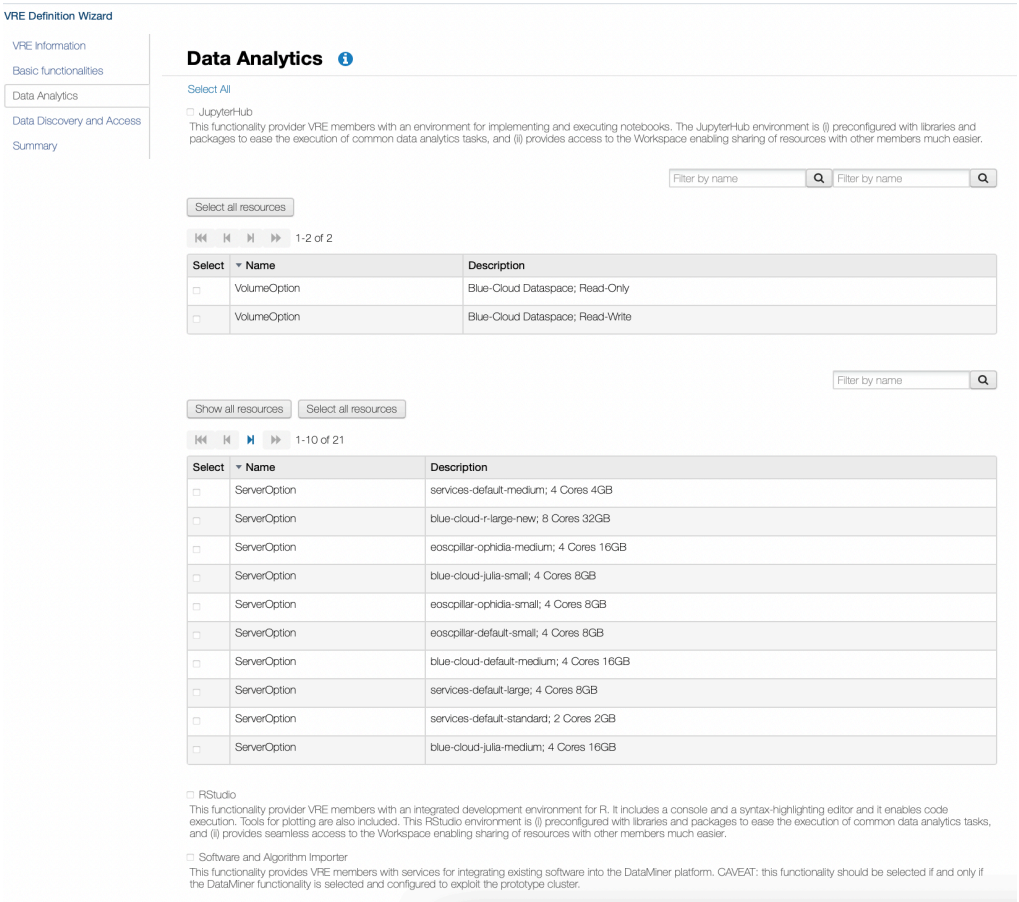

Figure 2. VLab Creation Wizard Screenshots for JupyterHub Server Options selection

A total of 13 VLabs were created and/or operated to serve the needs arising in the context of the Blue-Cloud 2026 project. In addition to these 13 VLabs, a number of VLabs stemming from the previous Blue-Cloud Project have been maintained in operation, for a total of 20 VLabs; the complete list is in Table 1 .

VLab name	Start date	Membership	#Users
Blue-Cloud Training Lab	May 2024	Private	50
Coastal Water Dynamics VLab	Mar 2024	Private	10
Marine Omics Observations VLab	Mar 2024	Private	9
Eutrophication-Workbench VLab (WB #2)	Feb 2024	Private	12

Physics-Workbench VLab (WB #1)	Jan 2024	Private	17
Ecosystem-Workbench VLab (WB #3)	Jul 2023	Private	12
Ecological Restoration Lab VLab	Jul 2023	Restricted	23
Blue-Cloud 2026 Training Academy Vlab	May 2023	Restricted	11
Integration Coastal Ocean Observations along Europe (VLab #1)	Mar 2023	Private	19
Coastal Currents from Observations (VLab #2)	Mar 2023	Private	12
Carbon Plankton Dynamics (VLab #3)	Mar 2023	Private	11
Global Fisheries Atlas (VLab #5)	Mar 2023	Private	15
Blue-Cloud 2026 Project VLab	Jan 2023	Restricted	145
JERICO-CORE	Dec 2021	Private	36
Fisheries Atlas	Dec 2020	Open	84
Zoo and Phytoplankton EOV	Jul 2020	Restricted	198
GRSF_Pre	Jun 2020	Restricted	15
Marine Environmental Indicators (VLab #4)	Apr 2020	Open	278
Plankton Genomics	Apr 2020	Open	88
Blue-Cloud Lab	Oct 2019	Open	334

Table 1. List of Blue-Cloud VLabs

Table 1 reports the complete list of VLabs created and/or operated during the reporting periods: 13 Vlabs from January 2023 to June 2024, in shaded background instead, the VLabs stemming from the previous Blue-Cloud H2020 project that have been maintained in operation.

The following VLabs were specifically conceived to support the developments of the Blue-Cloud 2026 thematic VLabs and WorkBenches:

- Integration Coastal Ocean Observations along Europe (ICOOE) VLab is developed in the context of the VLab #1 (cf. Sec. 3.1);
- The Coastal Currents from Observations VLab is developed in the context of VLab #1 (cf. Sec. 3.2);
- The Carbon Plankton Dynamics VLab is developed in the context of VLab #3 (cf. Sec. 3.3);

- The Marine Environmental Indicators VLab is developed in the context of VLab #4 (cf. Sec. 3.4), this VLab was also present in the previous Blue-Cloud project.
- The Global Fisheries Atlas (VLab #5) is developed in the context of VLab #5 (cf. Sec. 3.5);
- The Physics-Workbench VLab is developed in the context of WorkBench #1 (cf. Sec. 3.6);
- The Eutrophication-Workbench VLab is developed in the context of WorkBench #2 (cf. Sec. 3.7);
- The Ecosystem-Workbench VLab is developed in the context of WorkBench #3 (cf. Sec. 3.8);

The following VLabs were conceived to support project activities and/or to provide their users with development and demonstrative environments:

- The Blue-Cloud **Lab** VLab was developed to give the Blue-Cloud community an open working environment to exploit and experiment with Blue-Cloud facilities (cf. Sec. 3.9);
- The Blue-Cloud **Training** VLab was devised to support Blue-Cloud 2026 internal VRE training events (cf. Sec. 3.10)
- The Blue-Cloud 2026 **Project** VLab was devised to support Blue-Cloud 2026 project activities and discussions (cf. Sec. 3.11)
- The BlueCloud **Training Academy** VLab is developed to support the Blue-Cloud 2026 training Academy program (cf. Sec. 3.20).

The following VLabs were developed in the context of Blue-Cloud (H2020) project and maintained and operated by Blue-Cloud 2026 because the services they provide access to are currently exploited by the community:

- The Fisheries Atlas VLab was developed to support Demonstrator #4 - Fish, a matter of scales (cf. Sec. 3.12);
- The GRSF_Pre VLab was developed to support Demonstrator #4 - Fish, a matter of scales (cf. Sec. 3.13);
- The Plankton Genomics VLab was developed to support Demonstrator #2 - (cf. Sec. 3.14);
- The Zoo and Phytoplankton EOV VLab was developed to support Demonstrator #1 - Zoo- and Phytoplankton EOV products (cf. Sec. 3.15);

The following VLabs were developed to support the Blue-Cloud synergy program through which the Blue-Cloud VRE is exploited by other projects and communities:

- The Coastal Water Dynamics VLab was developed in the context of FAIR-EASE Project (cf. Sec. 3.16);

- The Marine Omics Observations VLab was developed in the context of FAIR-EASE Project (cf. Sec. 3.17);
- The Ecological Restoration VLab is developed in the context of CLIMAREST Project (cf. Sec. 3.18);
- The JERICO CORE VLab has been developed as a pilot supporting the JERICO Coastal Oceans Resource Environment (JERICO CORE) (cf. Sec. 3.19);

Overall Statistics related to the VLab usage

In Figure 3, the number of VLabs operated per month during the reporting period, from January 2023 to June 2024 is reported. During the reporting period 13 VLabs have been created.

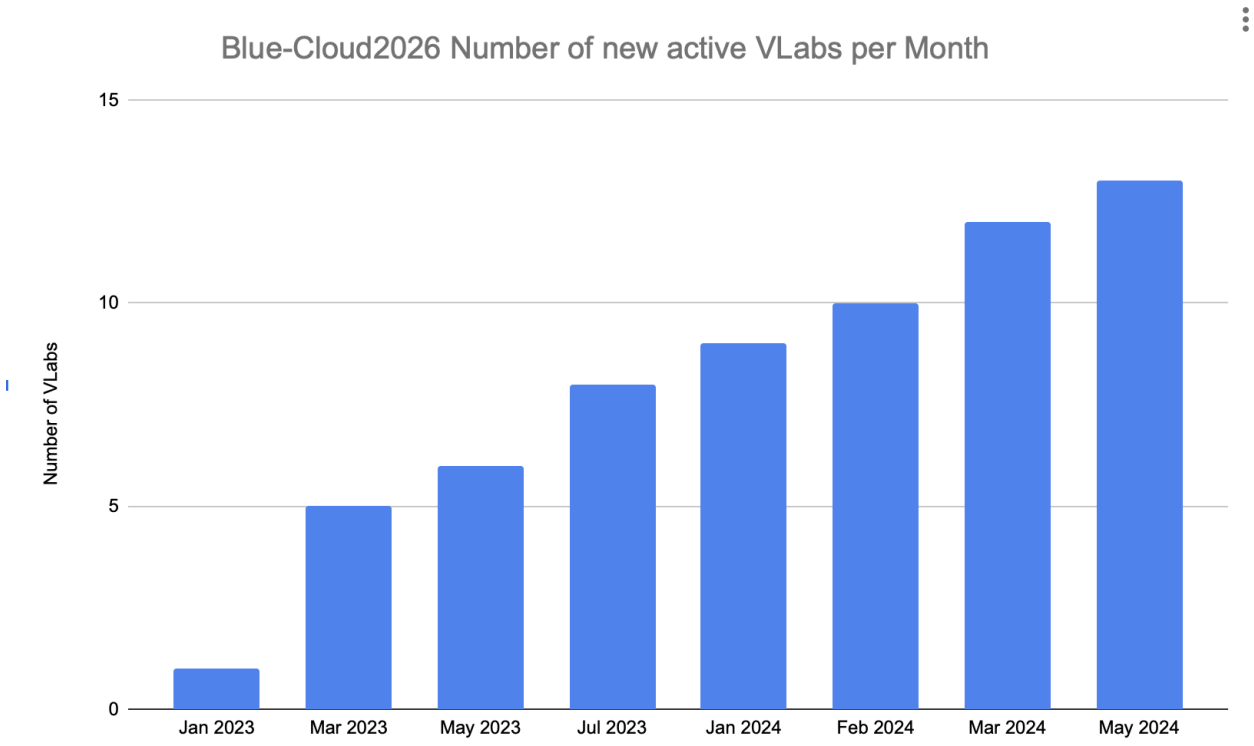

Figure 3. Number of VLabs operated per month (January. '23 -June. '24)

In Figure 4, the overall number of users benefitting from the facilities offered by the existing VLabs is reported. In January ’23, the previous Project existing VLabs served more than 1.000 users; at M18 more than 1.700 users are registered as active users.

Detailed figures per VLab are reported in the VLab-dedicated sections of this document.

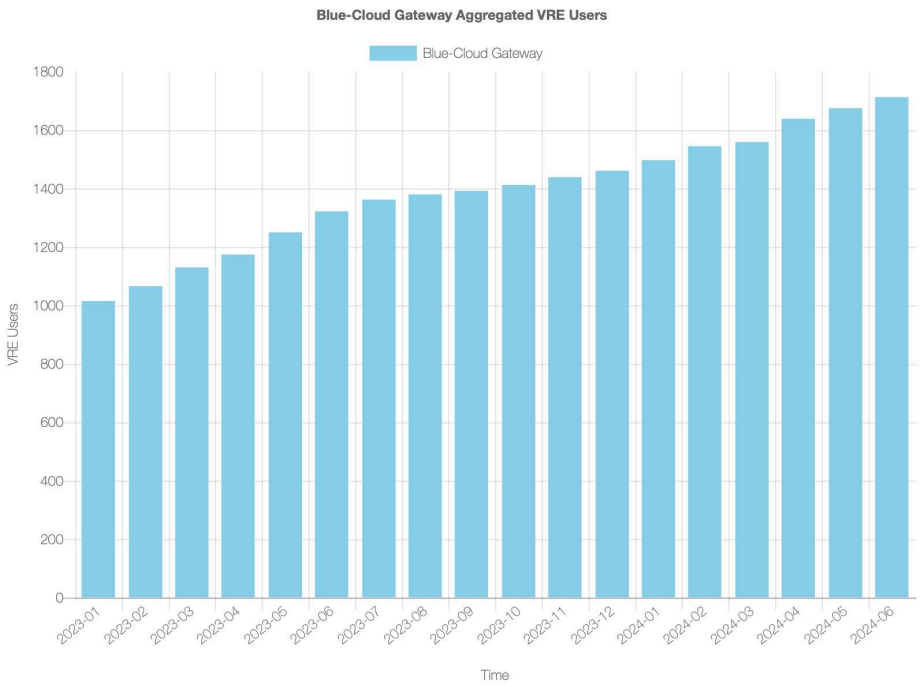

Figure 4. Number of users served by the Blue-Cloud VRE

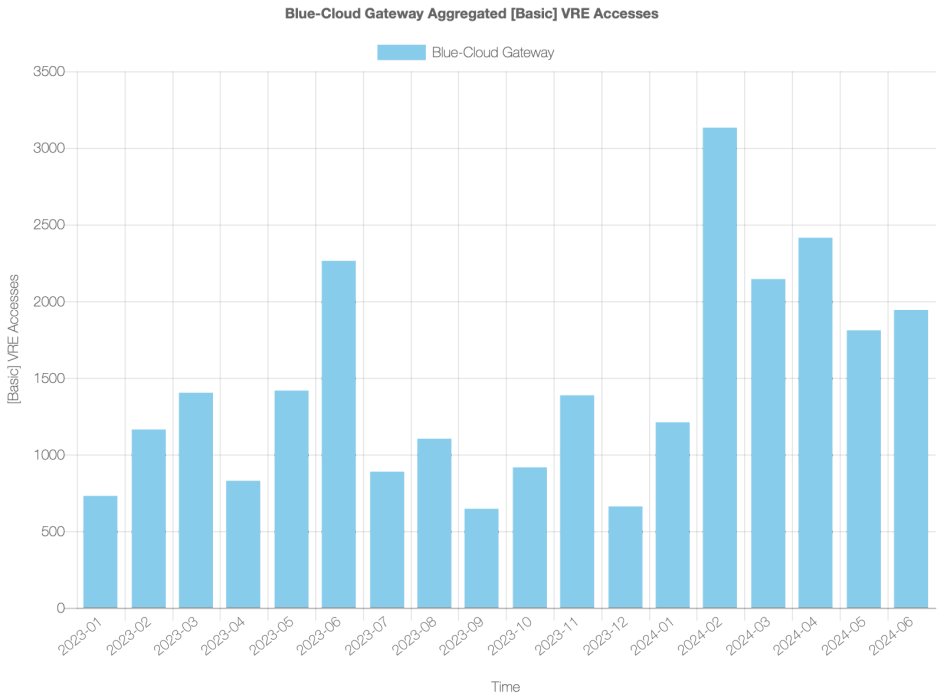

Figure 5. VLab Accesses (sessions) per month

Figure 5 reports the monthly working sessions initiated via the Blue-Cloud VRE. Up to June 2024, the users have executed more than 26.000 working sessions, with an average of 1.447 sessions per month.

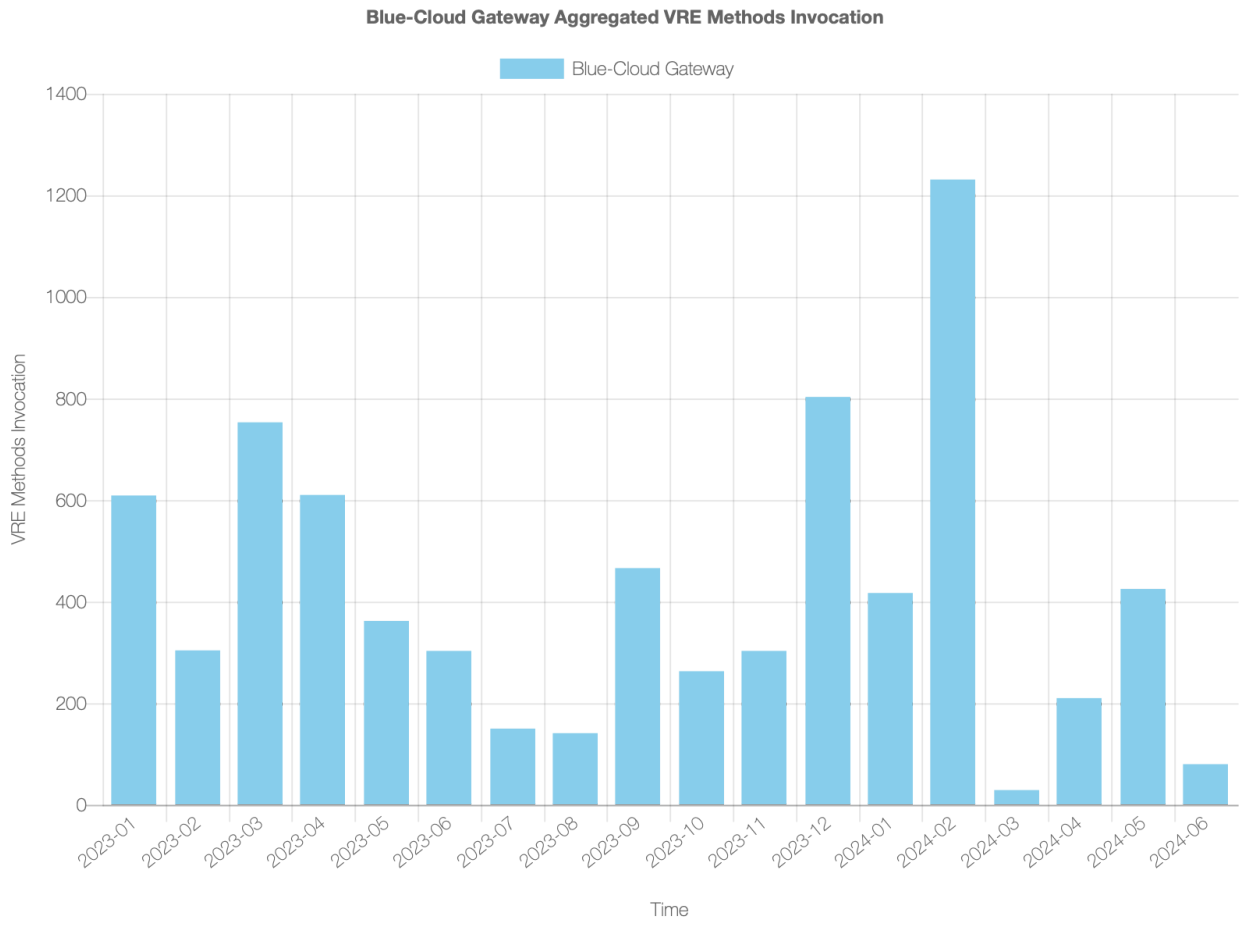

Figure 6. VLabs methods execution per month

Figure 6 reports the overall number of methods/jobs submitted per month via the Blue-Cloud VRE. The high variance in exploiting the high throughput computing platform was well-managed by the Blue-Cloud VRE, which automatically scaled up to manage peaks in exploiting the VLab services.

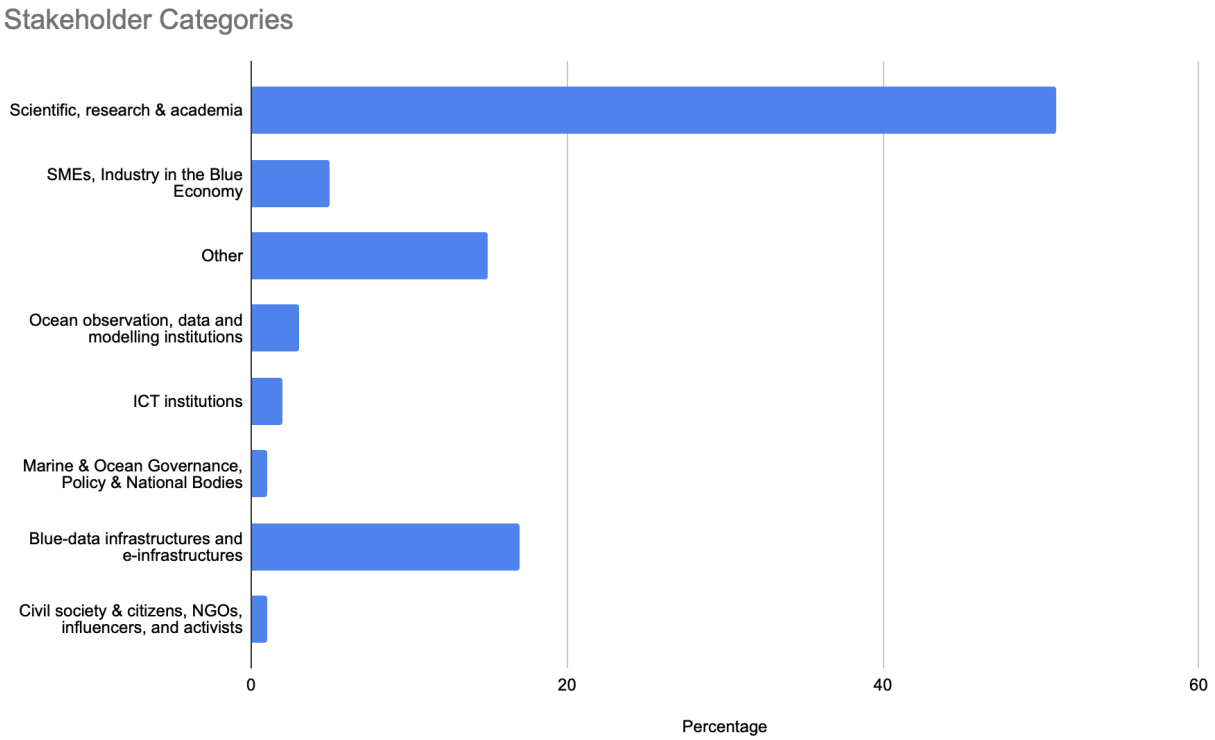

Figure 7. Type of Stakeholders served by Blue-Cloud VRE

Figure 7 reports the information collected about stakeholders. About 55% of VRE members are from the "Scientific, research & academia" group, followed by "Blue-data infrastructures and e-infrastructures" with about 20% and 4% from SMEs, Industry in the Blue Economy. Most of the contacts listed in the Blue-Cloud community database are based in Europe. Still, the project also brought users from other countries (e.g., the USA, Australia, Morocco, and Indonesia) on board.

This distribution highlights an expected predominant focus on scientific and academic stakeholders, with significant contributions from blue-data infrastructures and various other roles supporting a broad spectrum of activities within the Blue-Cloud2026 Project.

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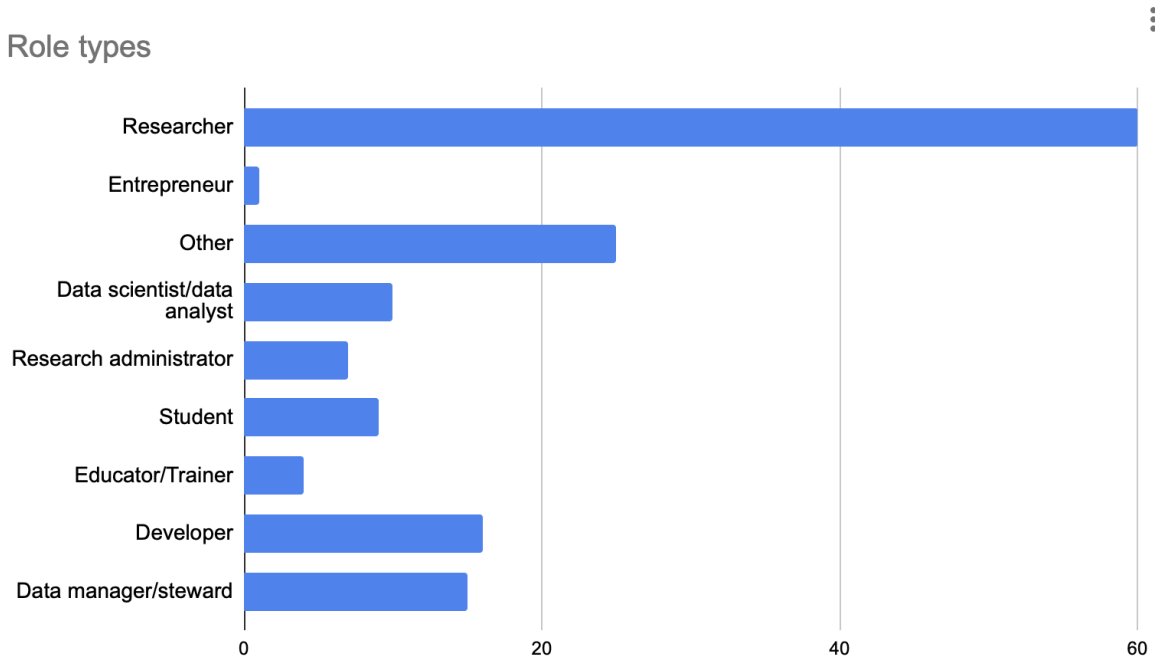

Figure 8. Type of Roles served by Blue-Cloud VRE

Figure 8 reports the information collected about user role types; the distribution of roles is as follows: Researchers comprise the largest group, comprising about 39% of the total; Developers are the second largest group, accounting for about 13%; Data scientists/data analysts and Data managers/stewards represent about 11% each.

This breakdown highlights an expected predominant focus on research-related roles, with significant contributions from the development and data management/analysis sectors.

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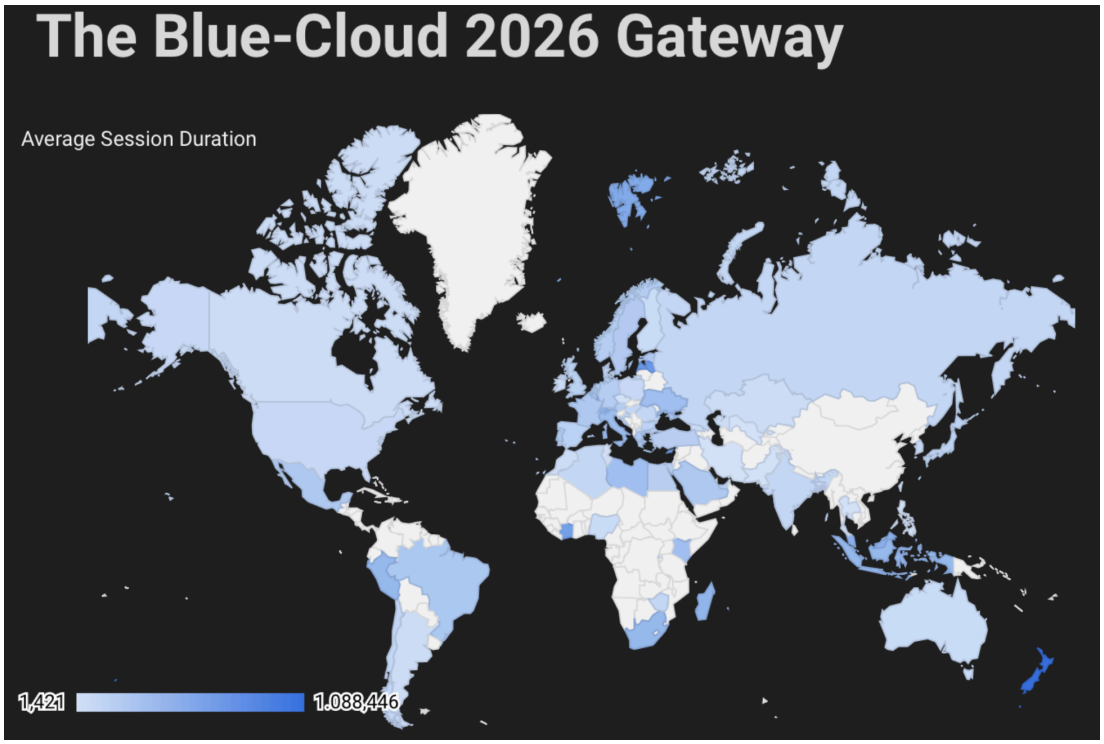

Figure 9. Geographical distribution of the sessions in the second reporting period

Figure 9 illustrates the overall geographical distribution of sessions registered during the second reporting period, highlighting the standard deviation of average session durations. Darker countries indicate session durations longer than the average.

The operation of the VRE and the VLabs requires the management of requests for support, issues, and malfunctions. A total of 143 tickets have been created and managed in the Blue-Cloud Project Issue Trackers (23 in the project consortium tracker and 120 in the support tracker), with 85% of these tickets closed. Additionally, 24 tickets related to Blue-Cloud have been created within the D4Science overall context, with an 88% closure rate.

Ticket type	***Total number***	***Open / in progress***	***Closed***
Incident	10	1	9
Support	39	5	34
Task	77	14	63

VLab	13	0	13
Other	4	1	3

Table 2. Tickets created in the 2 Blue-Cloud Issue Trackers

A brief description of each available VLab, including the ones created in the previous reporting period, is reported in the following sections.

All the VLabs are equipped with:

- A ***shared workspace*** to enable every user to store and organise the information objects he/she is interested in working with. In addition to that, the user is allowed to collaborate with other users by sharing objects and messages;
- A ***user management facility*** to enable authorised users (i.e., VLab Managers) to manage other users using or wanting to access the VLab. VLab Managers can (i) authorise users for access to the VLab, (ii) assign or withdraw roles to users, (iii) remove users, and (iv) send communications to the current users;
- A ***social networking facility*** to enable users to use the common facilities typical of social networks – e.g., posting news, commenting on posted news – yet adapted to the settings of working environments like those characterising Blue-Cloud. Users can post news as well as applications;
- A ***notification facility*** to alert users on relevant activities as they happen. These notifications offer a sense of anticipation and create a productivity boost. Users receive an alert (through a priori selected channels, e.g., email, web portal, Twitter) notifying them when something of interest has happened in their VLab(s);
- A ***members facility*** to provide users with a list of VLab co-workers, i.e., the list of members partaking in the VRE and contributing to it;
- A ***messaging facility*** to provide users with a cloud-based common email environment. The distinguishing feature is represented by its integration with the rest, e.g., it is possible to send any information object residing in the workspace (regardless of how “big” and “complex” it may be) as an attachment without consuming bandwidth.

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3.1 Integration Coastal Ocean Observations along Europe (VLab #1)

This VLab provides an **environment to access, integrate and exploit observations collected along the European coastal ocean areas**.

It brings together observations collected by partners of the Joint European Research Infrastructure for Coastal Observatories (JERICO-RI) with other available observation and complementary information, implementing advanced processing and post-processing facilities, analytical tools and interactive state-of-the-art visualisations that provide an unprecedented insight on key processes affecting European coastal ocean environments.

It focuses on three thematic services based on key scientific and societal questions:

- TS#1:Transboundary processes and connectivity;
- TS#2: Extreme Events;
- TS#3: Ocean Glider; supporting researchers, Blue Economy actors, environmental and crisis response managers.

Data used:

- CMEMS
- EMODnet Physics, Bathymetry, Human Activities and Biology
- SOCIB Data Repository;
- PLOCAN;
- Instituto Hidrografico;
- Puertos del Estado.

Target users:

- **Primary users/early adopters:** Blue Cloud Hackathon participants, Blue Cloud Training Academy, Webinars Blue Cloud Task Forces: i.e. EU DTO (Digital Twin for the Ocean);

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- **Secondary users:** Researchers: Coastal modellers from JERICO, Puertos del Estado and PLOCAN. Data products catalogues: CMEMS, EU HF Radar node, EMODnet Physics (Data products), European Space Agency (ESA);
- **Tertiary users:** Policy makers/EU initiatives: Several physics variables- EOVs- GOOS, The EU Marine Strategy Framework Directive (MSFD) Descriptors; Descriptor 7: Hydrographical conditions.

Figure 10. A screenshot of the ICOOE (Integration Coastal Ocean Observations along Europe) VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics engine*** enabling users to benefit from the offerings of the **Cloud Computing Platform (CCP)** and interactively execute an extensive array of data analytics tasks on datasets;
- **RStudio** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;

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- ***JupyterLab*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case.

3.2 Coastal Currents from Observations (VLab #2)

This VLab provides a service to **generate integrated ocean surface current maps** from direct and indirect current measurements derived from different sources, High Frequency (HF) radar, drifter data, and geostrophic currents from altimetry data, using the **DIVAnd (Data Interpolating Variational Analysis in n dimensions) method**. The merging and analysis of these datasets are performed using various constraints, in particular, the presence of the coastline, constraints on horizontal divergence, and a momentum balance (between acceleration, Coriolis force, and surface pressure gradient).

Blue Cloud added value:

The main output of this VLab is a service in the form of easily customisable Jupyter notebooks that allow users to generate surface currents maps for a user-chosen coastal region (when data is available and in particular the availability of HF radar data which extents depending on the configuration about 50 km - 200 km offshore). The user could also make Lagrangian simulations based on these current maps to visualise the movements of artificial drifters released at a user-chosen location (assuming suitable data coverage). The outputs generated consist of gridded surface current maps provided in NetCDF files. These will be used to run the MEDSLIK-II oil spill model to simulate the dispersion of an oil spill accident. The operational chain of the MEDSLIK-II model is going to be adapted and deployed in a Docker container.

Data used:

- **CMEMS;**
- **GEBCO;**
- **EMODnet Bathymetry;**
- **NOAA;**
- **Open Street Map;**

- **ECMWF.**

Target users:

- **Primary users/early adopters:** Blue Cloud Hackathon participants and Blue Cloud Training Academy: Webinars;
- **Secondary users:** students at ULiege, coastal modellers;
- **Data products catalogues:** CMEMS, EU HF Radar node, EMODnet Physics (Data products), European Space Agency (ESA);
- **Tertiary users:** Policy makers/EU initiatives: Several physics variables- EOVs- GOOS, The EU Marine Strategy Framework Directive (MSFD) Descriptors; Descriptor 7: Hydrographical conditions.

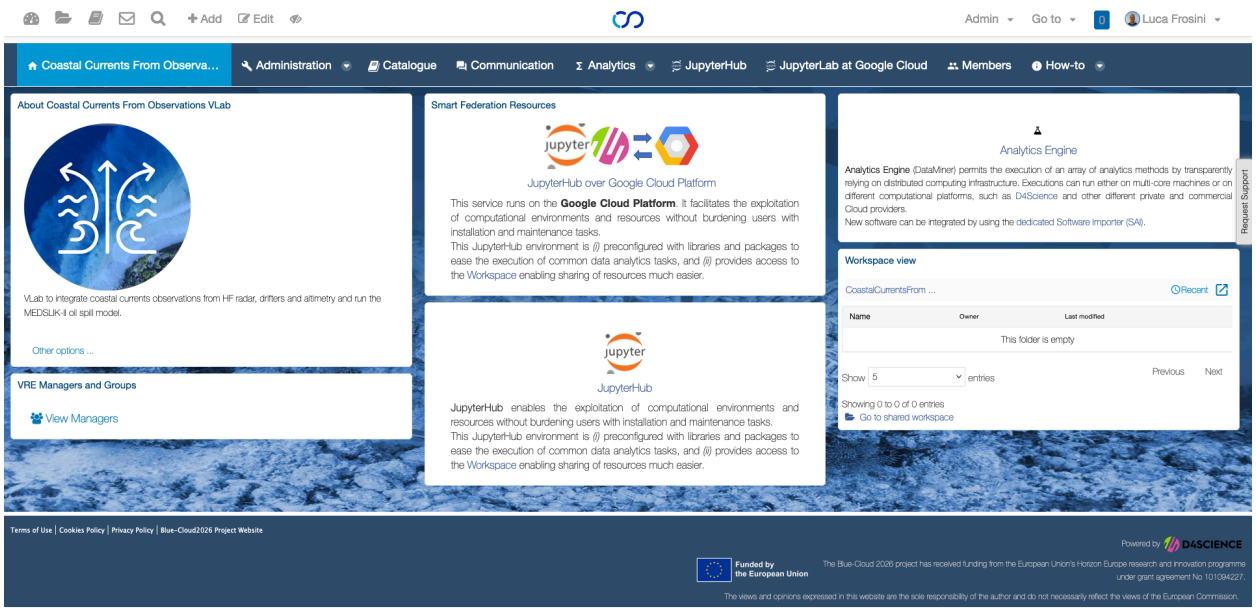


Figure 11. A screenshot of the Coastal Currents from Observations VLab

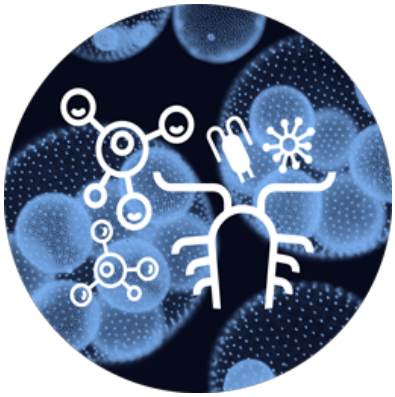
In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics facility*** enabling users to benefit from the offerings of the Data Miner service [1,3] and interactively execute an extensive array of data analytics tasks on datasets. As of

January '21, the facility offers ***66 ready-to-use method implementations*** ranging from Bayesian methods to maps comparison and data clustering;

- ***JupyterLab* on D4Science premise**: enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- ***JupyterLab* on Google Cloud Platform**: it facilitates the exploitation of computational environments and resources without burdening users with installation and maintenance tasks. This JupyterHub environment is (i) preconfigured with libraries and packages to ease the execution of everyday data analytics tasks and (ii) provides access to the Workspace, enabling the sharing of resources much more effortless;
- ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case.

3.3 Carbon Plankton Dynamics (VLab #3)



This VLab provides a **service to analyse** the relative contribution of the **drivers in phytoplankton dynamics** in the Belgium part of the **North Sea** and the **northern Adriatic Sea**. The Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) model is built using data containing phytoplankton and zooplankton abundances, nutrients (nitrogen, silica and phosphor), and carbon data (dissolved inorganic carbon, air-sea carbon flux). This model helps to understand plankton dynamics' spatio-temporal variations and determine whether they act as a carbon sink or source.

This VLab is available at https://blue-cloud.d4science.org/web/carbonplanktondynamics

Blue Cloud added value:

The collaborative and open science tools used in the Blue Cloud VRE platform allow their re-use by other researchers, so it can be applied to fit their own research and/or to respond to different research questions, such as **"How do marine ecosystem respond to changing environmental conditions, such as ocean acidification and warming?"** or **"What is the role of biogenic reefs in carbon sequestration and its implications for climate change mitigation?**

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Data used:

- **EMODnet Biology/EurOBIS**
- **EMODnet Chemistry;**
- **SOCAT;**
- **ICOS-Carbon portal.**

Target users:

- **Primary users/early adopters:** Blue Cloud Hackathon participants, Blue Cloud Training Academy, Webinars Blue Cloud Task Forces: i.e. EU DTO (Digital Twin for the Ocean).
- **Secondary users:** Researchers such as Ecological modellers. DTO via EDITO Infra.
- **Tertiary users:** Policy makers/EU initiatives: Zoo and Phyto-plankton biomass and diversity EOVs-GOOS, The EU Marine Strategy Framework Directive (MSFD) Descriptors: Descriptor 1: Biological diversity and Descriptor 4: Elements of marine food webs, Blue Carbon Initiatives.

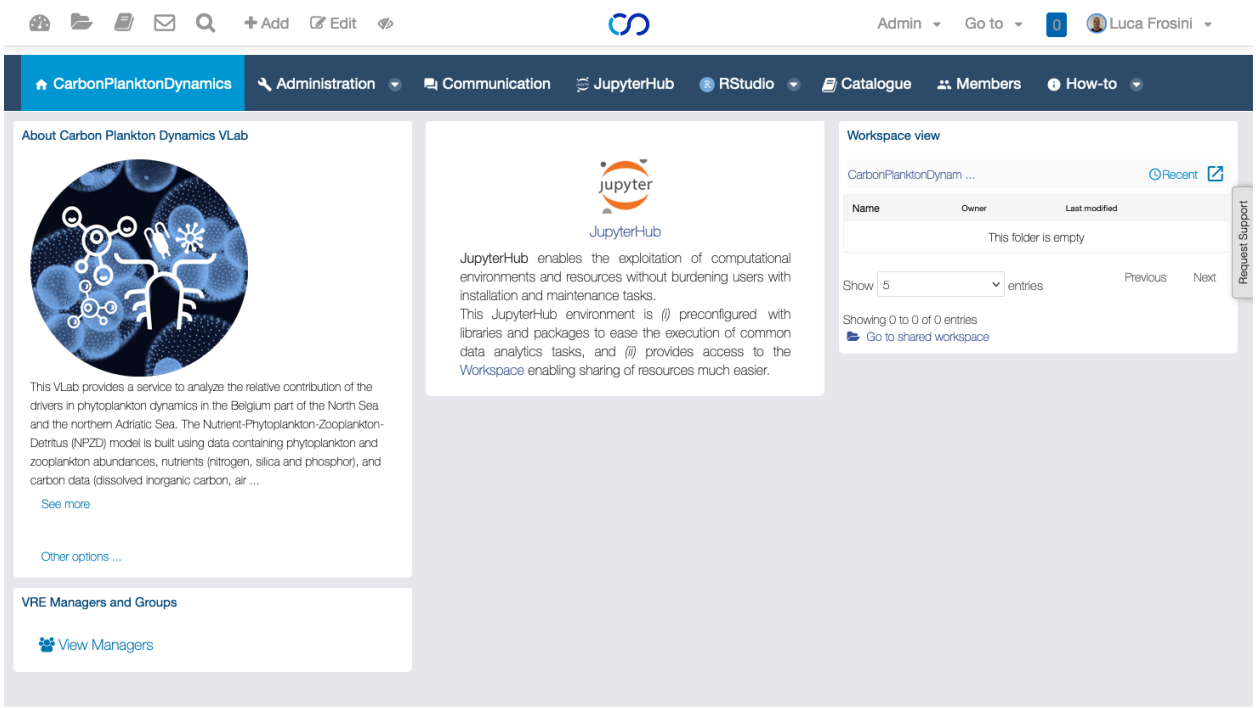


Figure 12. A screenshot of the Carbon Plankton Dynamics VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- the **RStudio** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- the ***JupyterHub*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- the ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case.

3.4 Marine Environmental Indicators (VLab #4)

The Marine Environmental Indicators VLab is developed as the follow up of Demonstrator #3 - Marine Environmental Indicators [4]. It is conceived to provide its users with facilities to (i) identify environmental quality indicators in selected marine regions/areas; (ii) obtain new added-value data by applying big data analysis and machine learning methods on the multi-source data sets, and (iii) to perform online and on the fly operations such as selecting a portion of a dataset, to perform statistical analysis or display the data.

This VLab is available at https://blue-cloud.d4science.org/web/marineenvironmentalindicators

This VLab has been in operational status since April 2020. It is currently serving 278 users.

A screenshot of the VLab is available in Figure 13. It shows the MEI Generator app specifically developed for this community and the menu items for accessing the VLab facilities.

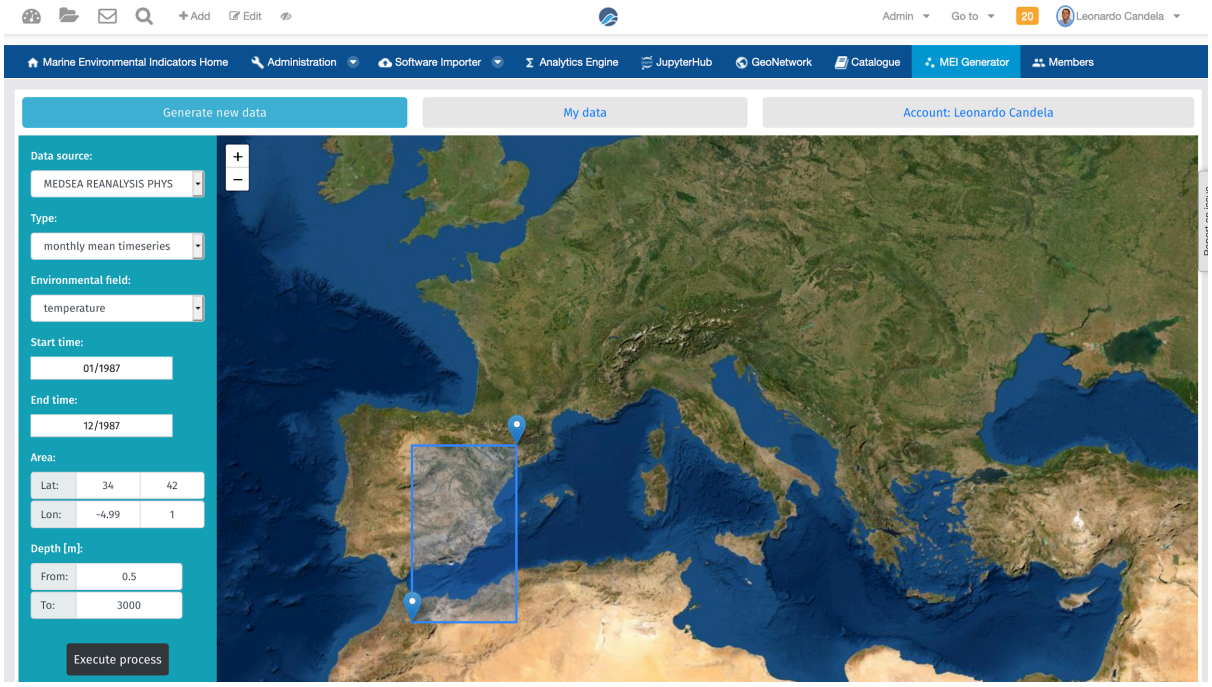


Figure 13. A screenshot of the Marine Environmental Indicators VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***software importer facility*** enabling users to onboard existing software and algorithm implementations into the Data Miner platform [1,3];
- a ***data analytics facility*** enabling users to benefit from the offerings of the Data Miner service [1,3] and interactively execute a large array of data analytics tasks on datasets. As of January '21, the facility offers ***19 ready-to-use method implementations,*** including preliminary versions of algorithms for computing the Storm Severity Index (dataset providing users insights on atmospheric wind/storm circumstances that impact the circulation of seas such as the Mediterranean Sea) and the seastat algorithm (i.e., the analytics process behind the MEI Generator app described below);
- the ***JupyterLab*** facility enabling users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace. Two specific notebooks have been developed and shared: a ***Model Development notebook*** to design, optimise and train a model; and a ***Prediction notebook*** to use a trained model and classify the profiles of a dataset into different classes.

- the ***geospatial data catalogue*** facility enables users to search and access geospatial products of interest to the community. At the time of writing this deliverable, the catalogue has not been populated yet with products of interest;
- the ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case;
- the ***MEI Generator app*** facility, i.e., a specific web application aiming at providing its users with a user interface facilitating the steps of generating new data starting from the existing ones and accessing and visualising the data previously calculated by the user.

One important feature of this VLab is that the environment was configured to serve two main classes of users: "VLab developers" and "VLab users". The former class of users has full access to all the facilities discussed above. The latter class of users has access only to the JupyterHub and MEI Generator app.

3.5 Global Fisheries Atlas (VLab #5)

The primary purpose of **Global Fisheries Atlas** is to provide an online environment with tools for end-users to discover and access data and knowledge about global fisheries, as well as tools for developers to update these related data and knowledge bases. This Vlab is built upon the two existing Vlabs, GRSF and Fisheries Atlas and will provide: GRSF Catalog: a search and browse facility enabling users to access GRSF stocks and fisheries records Fisheries Atlas datasets: provides services to discover available fisheries datasets and extract them in several formats widely used by the scientific community (e.g. CSV, shape files, NetCDF) Interactive web viewers to explore and thus get a better understanding of fisheries data with a set of indicators and maps (e.g. shiny apps). This will be used to visualise georeferenced tuna.

The main pillars of the VLab are (a) the Fisheries Atlas and (b) the Global Record of Stocks and Fisheries.

- Fisheries Atlas is a standardised spatial data infrastructure storing and disseminating fisheries data by complying with OGC spatial data standards and assigning DOIs (on Zenodo). The main demonstrator is the Global Tuna Atlas, which is driven by a close partnership with FIRMS (FAO and tuna RFMOs).
- The Global Record of Stocks and Fisheries (GRSF) provides the knowledge base of stocks and fisheries inventoried at a global level, with standard unique identifiers. It enables a harmonised view of stocks and fisheries from 4 different data sources, namely, FIRMS (FAO), FishSource (Sustainable Fisheries Partnership), RAM (RAM Legacy Stock Assessment), and FAO SDG14.4.1 Questionnaire.

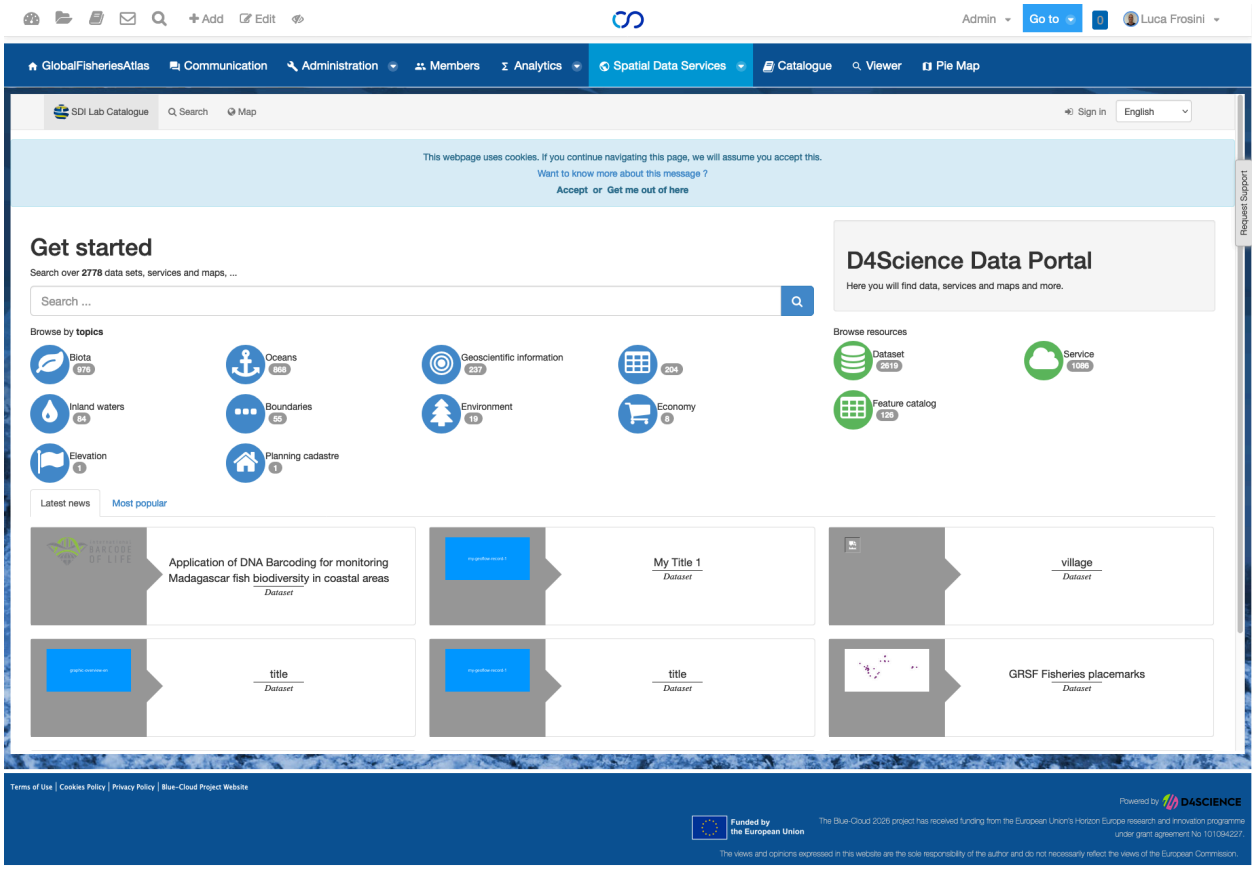
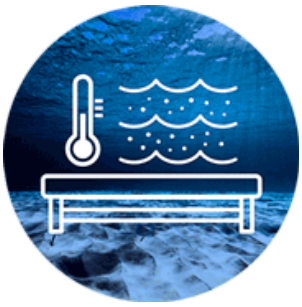


Figure 14. A screenshot of the Global Fisheries Atlas VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following services:

- Resources catalogue, enabling the retrieval, grouping, and visualisation of datasets and records (e.g. fisheries records);
- Triplestore, enabling access over the contents of semantic web knowledge bases (i.e. GRSF knowledge base) using W3C standards (i.e. through a SPARQL endpoint);
- MapViewer, supporting the visualisation of information on a map using multiple layers.

3.6 Physics-Workbench VLab (WB #1)



This Workbench is expected to implement a cloud-based workflow to generate harmonised, validated and customisable EOV data collections for temperature and salinity, integrating datasets released from different EU and non-EU data infrastructures for the test region of the Mediterranean Sea. It will combine data from different sources like Copernicus Marine Service, SeaDataNet, and NOAA. This requires making sure the data fits together and is accurate. We are then going to use this combined data to create improved climate information. Starting in the Mediterranean Sea. The goal is to expand globally by year 3 of Blue-Cloud 2026.

The optimised workflow will allow to rapidly/systematically derive and upgrade integrated data collections and generate different datasets as e.g. gridded climatologies. The Workbench will deliver the harmonised datasets and the cloud-based workflow in Open Access to users and big data infrastructures for uptake.

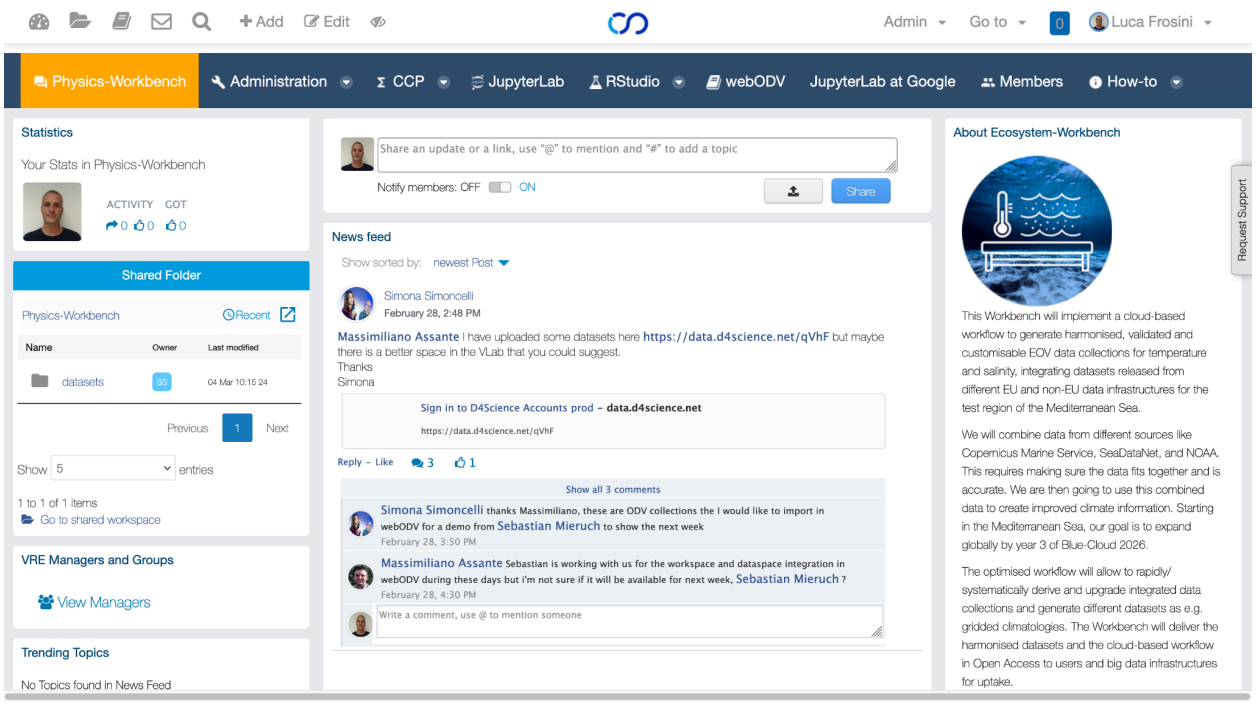


Figure 15. A screenshot of the Physics-Workbench VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics engine*** enabling users to benefit from the offerings of the **Cloud Computing Platform (CCP)** and interactively execute an extensive array of data analytics tasks on datasets;
- **RStudio** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- ***JupyterLab* on D4Science premise**: enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- ***JupyterLab* on Google Cloud Platform**: it facilitates the exploitation of computational environments and resources without burdening users with installation and maintenance tasks. This JupyterHub environment is (i) preconfigured with libraries and packages to ease the execution of everyday data analytics tasks and (ii) provides access to the Workspace, enabling the sharing of resources much more effortless;
- **webODV** provides online Ocean Data View (ODV, https://odv.awi.de) services, such as extraction, analysis, exploration, and visualisation of oceanographic and other environmental data.

At the time of writing, this WorkBench VLab is under development and is accessible to the WB Members only.

3.7 Eutrophication-Workbench VLab (WB #2)

This Workbench will implement a cloud-based workflow to generate harmonised, validated and customisable EOV data collections for Chlorophyll, nutrients and oxygen, integrating several datasets released from different EU and non-EU data infrastructures.

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics engine*** enabling users to benefit from the offerings of the **Cloud Computing Platform (CCP)** and interactively execute an extensive array of data analytics tasks on datasets;
- **RStudio** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;

- ***JupyterLab* on D4Science premise**: enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- ***JupyterLab* on Google Cloud Platform**: it facilitates the exploitation of computational environments and resources without burdening users with installation and maintenance tasks. This JupyterHub environment is (i) preconfigured with libraries and packages to ease the execution of everyday data analytics tasks and (ii) provides access to the Workspace, enabling the sharing of resources much more effortless;
- **webODV** provides online Ocean Data View (ODV, https://odv.awi.de) services, such as extraction, analysis, exploration, and visualisation of oceanographic and other environmental data.

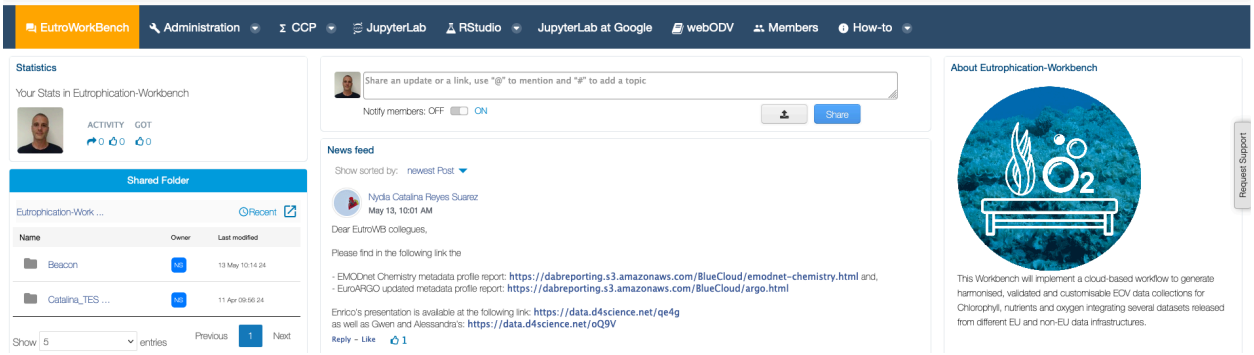


Figure 16. A screenshot of the Eutrophication-Workbench VLab

At the time of writing, this WorkBench VLab is under development and is accessible to the WB Members only.

3.8 Ecosystem-Workbench VLab (WB #3)

The primary purpose of the Ecosystem Workbench is to improve the availability, quality, and interoperability of extensive collections of plankton observations and extrapolated bio geographies. It provides a generic modelling workflow, dynamically accessing various data from traditional counts to quantitative imaging and genomic methods, available from the EMODnet/EurOBIS and ELIXIR data infrastructures. This habitat modelling workflow will generate high-quality

interpolated maps of these plankton entities at the global scale and produce ecosystem-level EOVs. Finally, this workflow provides the user with a clear QA/QC according to the latest and best practices in habitat modelling.

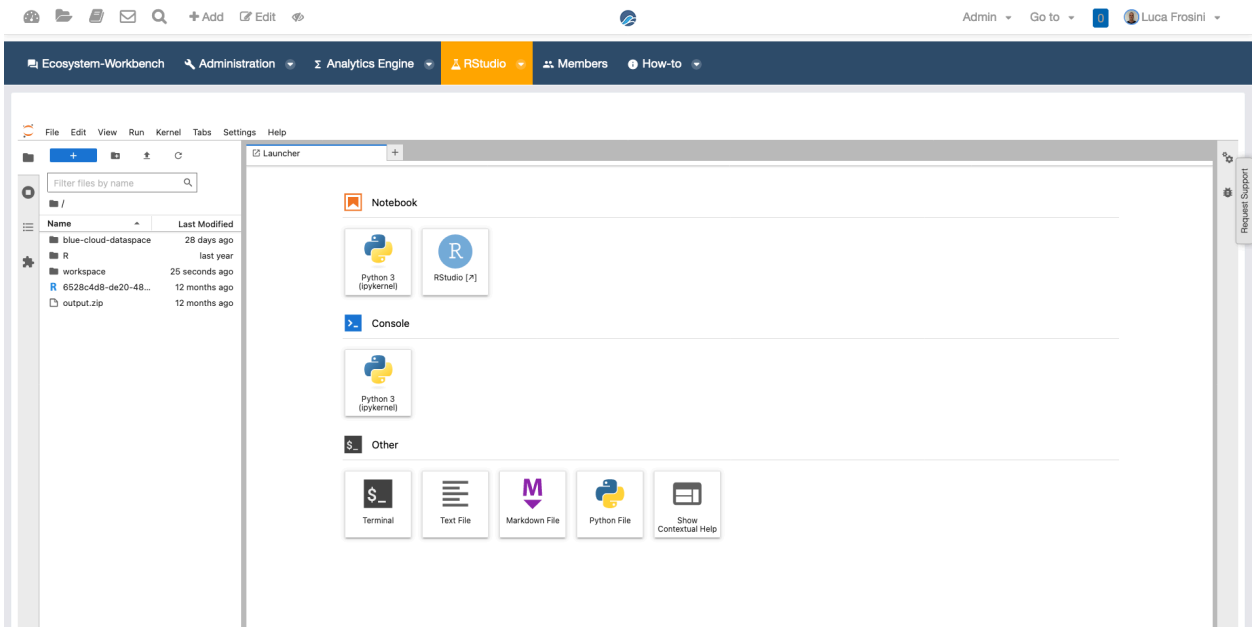


Figure 17. A screenshot of the Ecosystem-Workbench VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics engine*** enabling users to benefit from the offerings of the **Cloud Computing Platform (CCP)** and interactively execute an extensive array of data analytics tasks on datasets;
- the **RStudio** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace.

At the time of writing, this WorkBench VLab is under development and is accessible to the WB Members only.

3.9 Blue-CloudLab VLab

The Blue-Cloud **Lab** VLab is developed to provide the Blue-Cloud community with a working environment to experiment with Blue-Cloud facilities.

This VLab is available at https://blue-cloud.d4science.org/web/blue-cloudlab

This VLab has been in operational status since the Blue-Cloud H2020 Project, October '19, i.e., when the Blue-Cloud gateway was released. At the time of writing, June 2024, it is currently serving 334 users.

A screenshot of the VLab is available in Figure 18. It shows the home page and the menu items for accessing the VLab facilities.

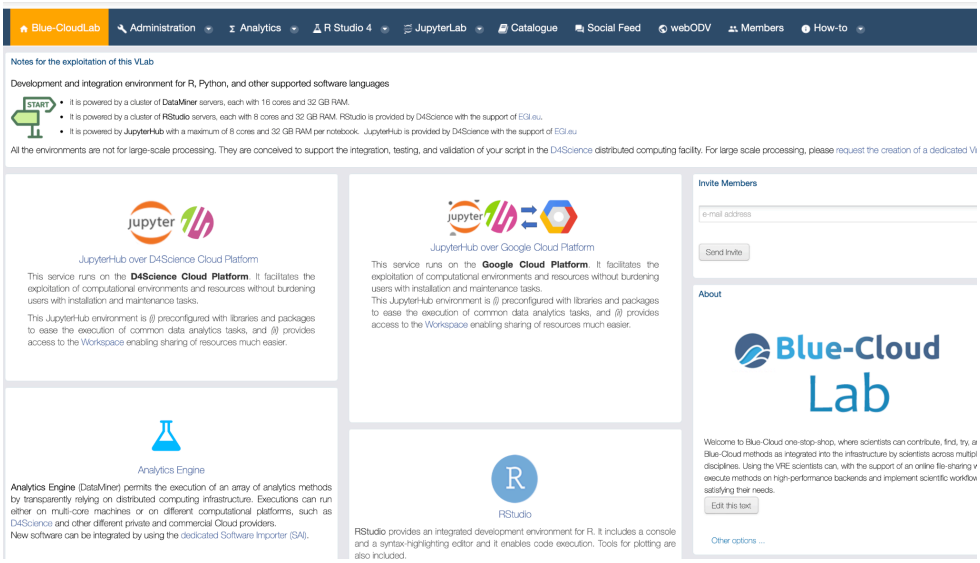


Figure 18. A screenshot of the Blue-Cloud Lab VLab at M18

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics facility*** enabling users to benefit from the offerings of the Data Miner service [1, 3] and interactively execute a large array of data analytics tasks on datasets. As of January '21 the facility offers ***39 ready to use method implementations*** ranging from Bayesian methods to maps comparison and data clustering;
- the ***RStudio*** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;

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- the ***JupyterLab*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- the ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case.

3.10 Blue-Cloud Training Lab

This VLab is specifically designed for training events related to the Blue-Cloud 2026 Project; it was used during the VRE All Hands training at M6. At the time of writing it is currently serving 50 users.

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***data analytics engine*** enabling users to benefit from the offerings of the **Cloud Computing Platform (CCP)** and interactively execute an extensive array of data analytics tasks on datasets;
- the **RStudio** facility enables users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- the ***JupyterLab*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- the **Darwin Core Viewer** can be used to explore the content of biodiversity / ecological data using Darwin Core data format.

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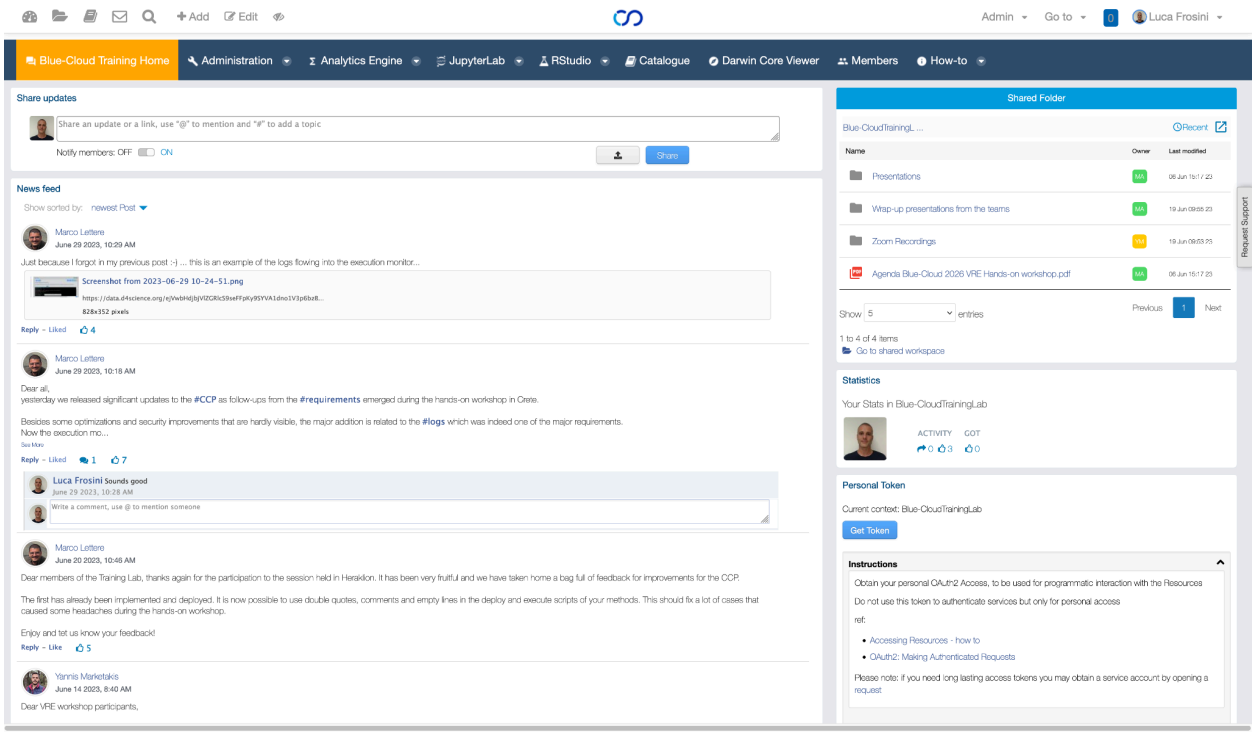

Figure 19. A screenshot of the Blue-Cloud Training Lab VLab

3.11 Blue-Cloud 2026 Project VLab

The Blue-Cloud 2026 **Project** VLab is devised to support Blue-Cloud2026 project activities and discussions. Only members of the Blue-Cloud2026 consortium have access to it.

The Blue-Cloud2026 Project VRE is available at https://blue-cloud.d4science.org/web/blue-cloud2026project

This VLab has been in operational status since January ’23 and it is currently serving 145 users, namely the Blue-Cloud206 Consortium members.

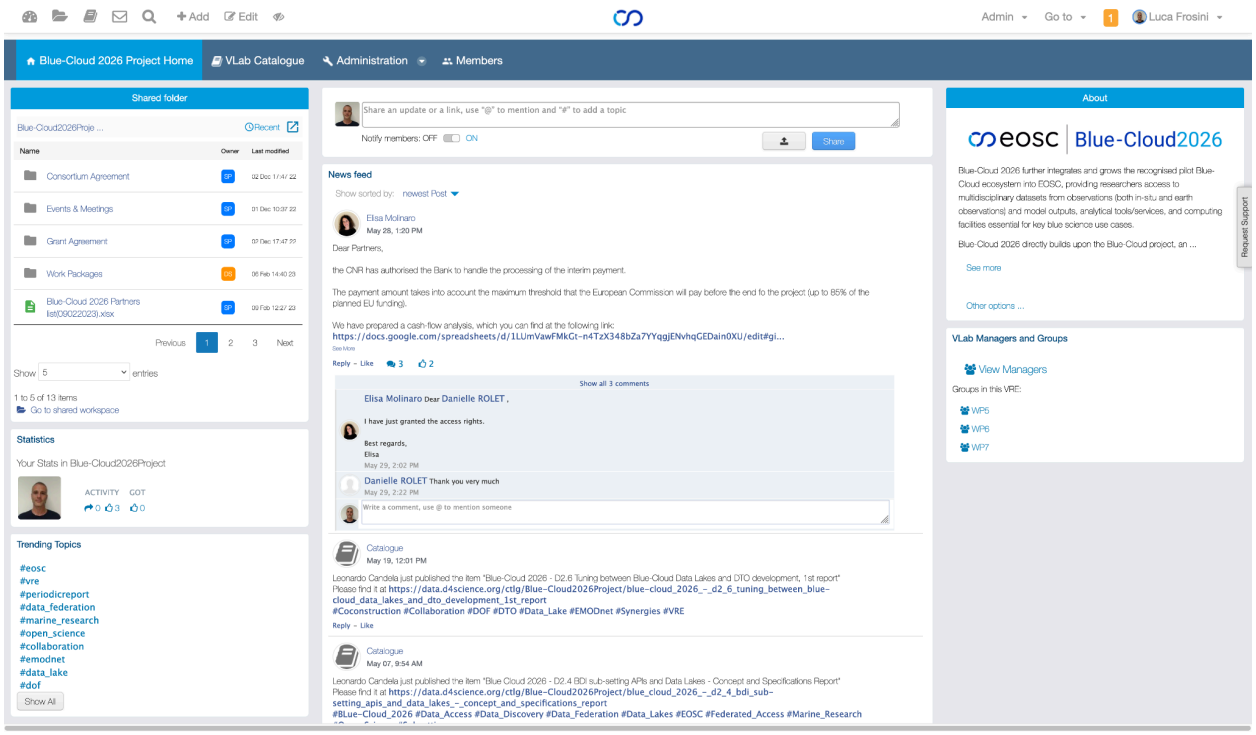

Figure 20. A screenshot of the Blue-Cloud 2026 Project VLab

In addition to the basic functionality, as a social networking area for supporting the discussions among members and a user management facility for managing membership, this VLab is specifically equipped with a ***Catalogue*** facility enabling users to publish, search and browse products of interest for the specific community. In particular, this catalogue is planned to be populated with ***project deliverables*** and ***service descriptions*** characterising the service portfolio developed by the project.

3.12 Fisheries Atlas Demonstrator

The Fisheries Atlas VLab is developed in the context of the Blue-Cloud (H2020) Demonstrator #4 - Fish, a matter of scales [2020d]. This environment is conceived to provide its users with facilities supporting the development of an online overview of harmonised time-series of catch and effort.

This VLab is available at https://blue-cloud.d4science.org/web/fisheriesatlas

This VLab has been in operational status since December 2020. It is currently serving 83 users.

A screenshot of the VLab is available in Figure 21. It shows one specific app of this VRE (the map viewer) and the menu items for accessing the VLab facilities.

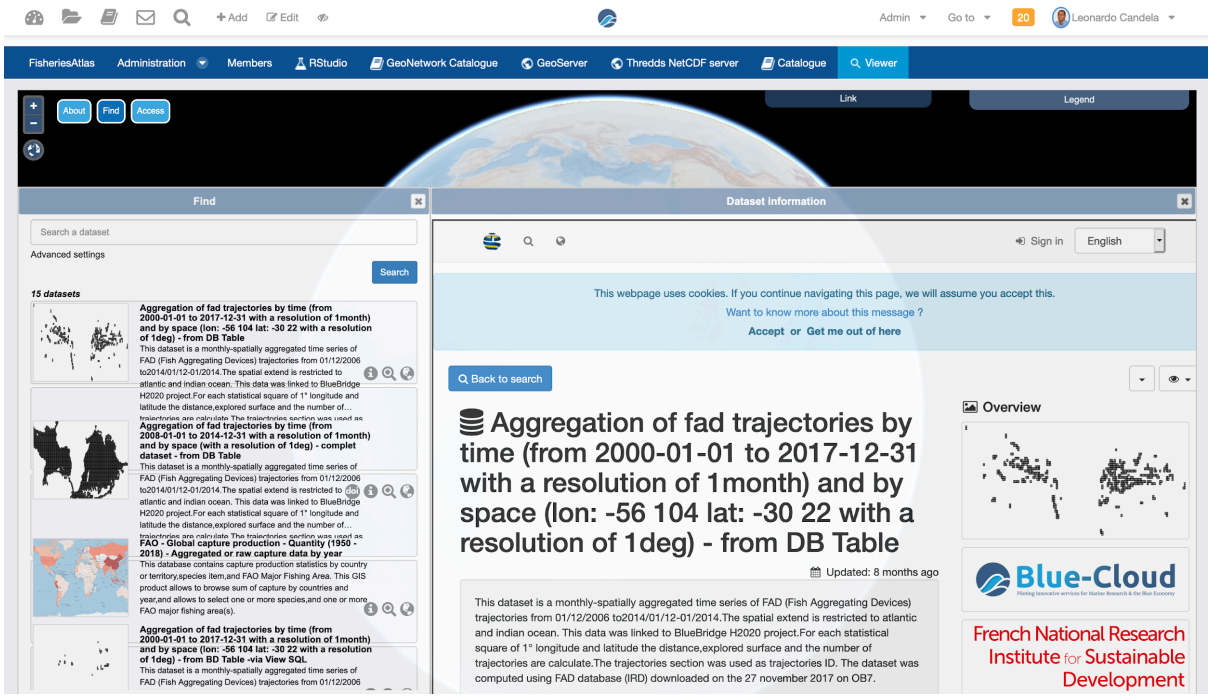

Figure 21. A screenshot of the Fisheries Atlas VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- the ***RStudio*** facility enabling users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- a ***geospatial data catalogue*** facility enabling users to search and access ***more than 3500 datasets, services and maps*** of interest for the community;
- two ***repositories for geospatial datasets***, one based on GeoServer technology and another one based on THREDDS Data Server.
- a ***map viewer*** providing users with seamless data discovery and visualisation of information including FAO and IRD produced Tuna Atlas layers; FAO Productions and trade national statistics; Selected Regional Fisheries Organizations data; Selected EMODNet layers; Selected CMEMS products; Selected species distribution maps; Selected FAO and VLIZ layers;

3.13 GRSF_Pre

The GRSF_Pre VLab is developed in the context of the Demonstrator #4 - Fish, a matter of scales [2019c, 2020d]. This environment is conceived to provide its users with a working environment to validate new content in the GRSF Knowledge Base [2019c], and thus it is not a public service. In 2020, the GRSF team used this environment to validate data harvests from 3 global GRSF sources that are now published into the GRSF Admin[1] and GRSF VREs[2].

This VLab is available at https://blue-cloud.d4science.org/web/grsf_pre

This VLab has been in operational status since June 2020. It is currently serving 12 users.

A screenshot of the VLab is available in Figure 22. It shows the catalogue facility displaying the available records.

[1] The GRSF Admin environment (https://i-marine.d4science.org/web/grsf_admin) provides authorized users with an environment and tools for building an integrated catalogue on stocks and fisheries information, i.e. for defining the authoritative version of the stocks and fisheries records made available by the GRSF official catalogue.
[2] The GRSF environment https://i-marine.d4science.org/web/grsf implements the "Global Record of Stocks and Fisheries" by providing users with an environment and tools for accessing stocks and fisheries information collated from three database sources: (i) Fisheries and Resources Monitoring System (FIRMS): http://firms.fao.org, (ii) RAM Legacy Stock Assessment Database: http://ramlegacy.org, and (iii) FishSource: http://www.fishsource.com

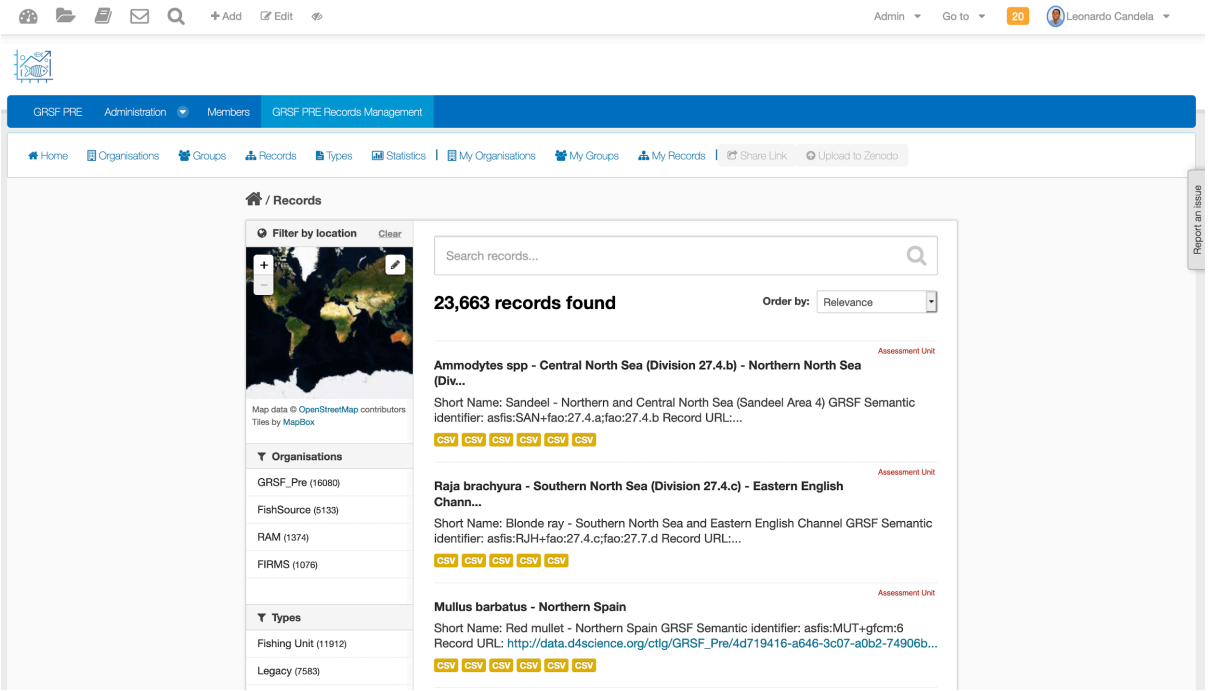

Figure 22. A screenshot of the GRSF_Pre VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***catalogue facility*** enabling users to visualise the GRSF candidate records stemming from the integration facility and manage their approval. This catalogue has been populated with ***more than 23,500 records,*** including Fishing Unit, Assessment Unit, and Marine Resource.

3.14 Plankton Genomics

The Plankton Genomics VLab was developed in the context of the Demonstrator #2- Zoo- and Phytoplankton EOV products [2022a]. This environment focused on plankton involving genomics analysis in its methodology. It showcases a deep assessment of plankton distributions, dynamics and fine-grained diversity to molecular resolution, focusing on two areas:

1. Species and functions discovery: discovery of as yet undescribed biodiversity from genetic and morphological signals from the characterisation of their geographical distributions, co-occurrences/exclusions and correlation with environmental contexts.

2. Biodiversity and ecology: exploring genetic and morphological markers of plankton diversity and abundance, particularly the new ones discovered above, to predict their spatiotemporal distribution and serve as high-resolution EOVs for biological processes.

This VLab is available at https://blue-cloud.d4science.org/web/planktongenomics

This VLab has been in operational status since February 2021. It is currently serving more than 88 users.

A screenshot of the VLab is available in Figure 23. It shows the Jupyter Notebook 1 developed in the JupyterHub VLab facility.

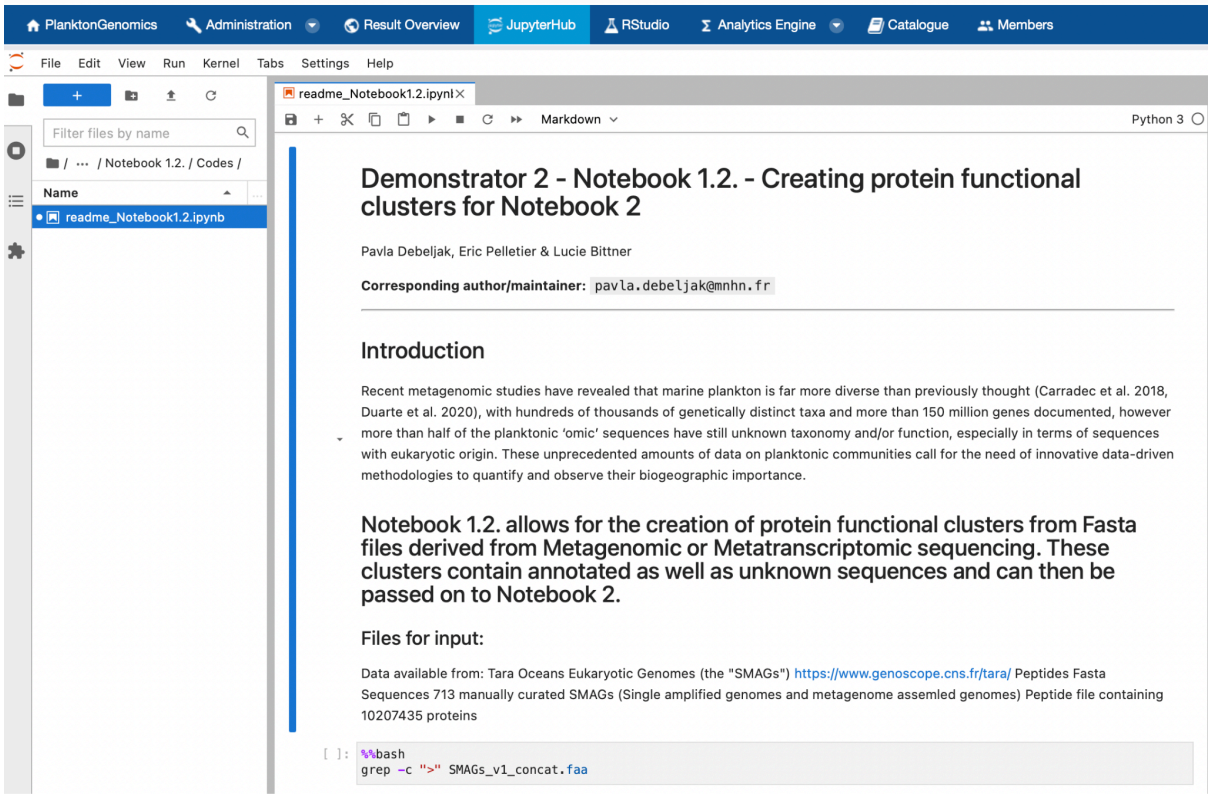

Figure 23. A screenshot of the Plankton Genomics VLab

3.15 Zoo and Phytoplankton EOV VLab

The Zoo and Phytoplankton EOV VLab was developed in the context of the Blue-Cloud (H2020) Demonstrator #1 - Zoo- and Phytoplankton EOV products [2020d, 2021b]. This environment is conceived to support a methodology to generate: (i) zooplankton products based on in situ observations of abundance of different zooplankton species in a region encompassing the North-East Atlantic; (ii) global ocean three-dimensional (3D) products of chlorophyll-a (Chla) concentration, that is a proxy for total phytoplankton biomass, based on Argo vertical profiles matched up with satellite imagery; (iii) a mechanistic model using near real-time data to quantify the relative contributions of the bottom-up and top-down drivers in phytoplankton dynamics.

This VLab is available at https://blue-cloud.d4science.org/web/zoo-phytoplankton_eov

This VLab has been in operational status since July 2020. It is currently serving 198 users.

A screenshot of the VLab is available in Figure 24. It shows the Data Miner GUI and the menu items for accessing the VLab facilities.

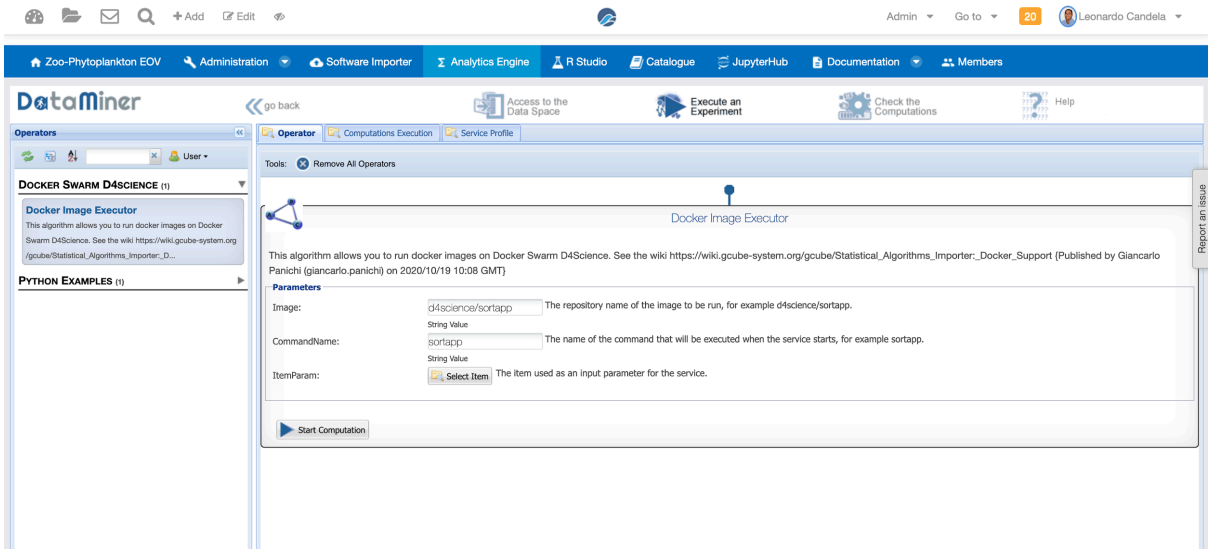

Figure 24. A screenshot of the Zoo and Phytoplankton EOV VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- a ***software importer facility*** enabling users to onboard existing software and algorithm implementations into the Data Miner platform [2019a, 2019b];

- a ***data analytics facility*** enabling users to benefit from the offerings of the Data Miner service [1, 3] and interactively execute a large array of data analytics tasks on datasets. As of January '21, the facility offers two ready-to-use method implementations. In particular, the ***Docker Image Executor*** algorithm that was specifically conceived to enable users to execute any algorithm packaged as a Docker image. This algorithm is exploited to support the execution of the ***DIVAnd algorithm*** (Data-Interpolating Variational Analysis in n dimensions)[3];
- the ***RStudio*** facility enabling users to use a fully-fledged RStudio® working environment directly from the VRE. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;
- the ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case;
- the ***JupyterLab*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace. Specific notebooks have been developed and shared: a notebook to create monthly fields of the vertical distribution of SOCA-Chl and a notebook to produce plots.

3.16 Coastal Water Dynamics VLab (FAIR-EASE Synergy)

This VLab is part of the Blue-Cloud2026 Synergy program with the FAIR-EASE Horizon Europe project. It provides users with online services including gridding, model/data intercomparison and data analysis and visualisation using the DIVAnd, SOURCE and ODV/webODV tools.

[3] https://github.com/gher-ulg/DIVAnd.jl

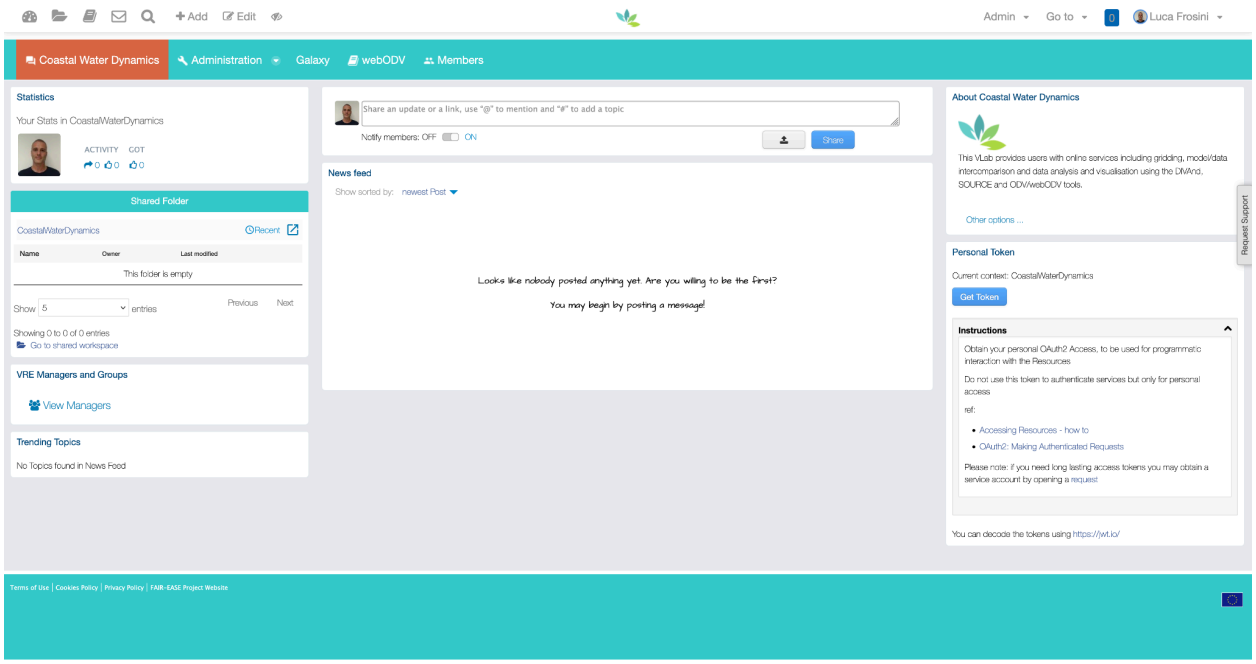

Figure 25. A screenshot of the Coastal Water Dynamics VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- The **Galaxy** Workflows tool is currently under integration.
- the **webODV** provides online Ocean Data View (ODV, https://odv.awi.de) services, such as extraction, analysis, exploration, and visualisation of oceanographic and other environmental data.

3.17 Marine Omics Observations VLab (FAIR-EASE Synergy)

This VLab is part of the Blue-Cloud2026 Synergy program with the FAIR-EASE Horizon Europe project. Starting from an ongoing effort undertaken by the EMBRC infrastructure, with the establishment of the European Marine Omics Biodiversity Observation Network (EMO-BON), this pilot focuses on the challenge to set up a web-based VRE to provide products and services orientated to non-specialist researchers interested in omics approaches to study marine biodiversity. Today, EMO-BON includes

several marine stations that will sample for genomic microbial marine biodiversity, essential ocean variables (EOVs), and essential biological variables (EBVs).

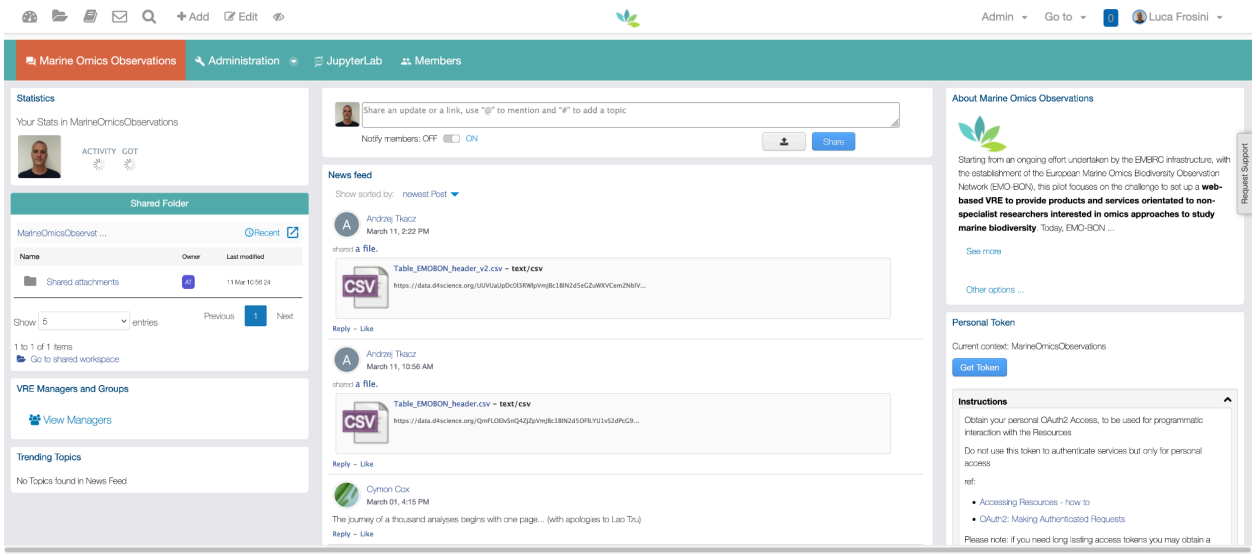

Figure 26. A screenshot of the Marine Omics Observations VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- the ***JupyterLab*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace.

3.18 Ecological Restoration Lab VLab (CLIMAREST Synergy)

CLIMAREST

This VLab is part of the Blue-Cloud2026 Synergy program with CLIMAREST, it will be using JupyterHub to host a series of notebooks that will include text (Markdown), interactive widgets to allow users to toggle through pre-created scenarios, and interactive figures (e.g., plotly). We are going to make a local version first to show project partners for feedback on whether this is a good solution before we decide on actual libraries/tooling (we are also considering R Shiny as a way to create something similar)

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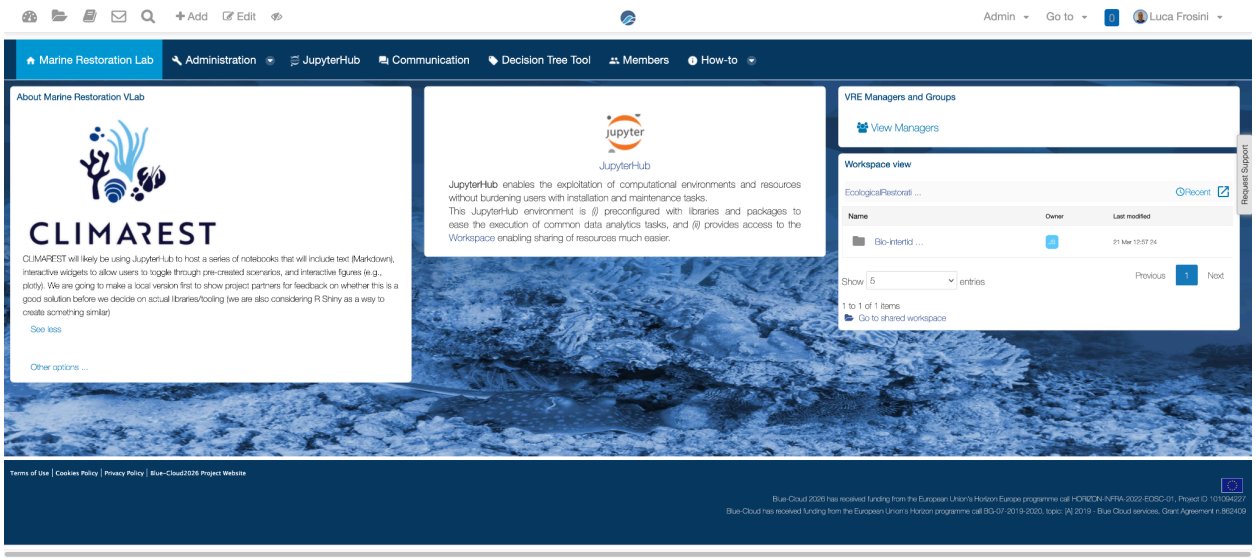

Figure 27. A screenshot of the Ecological Restoration Lab VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- the ***JupyterLab*** facility enables users to develop and execute Jupyter notebooks. This environment is integrated with the rest of VLab facilities, e.g., it is possible to use files from the workspace and to store new files within the workspace;

3.19 JERICO CORE VLab

The JERICO CORE Vlab was developed as a pilot supporting the collaboration between Blue-Cloud (H2020) and the JERICO Coastal Oceans Resource Environment (JERICO CORE). The VLab offers to any JERICO user a working environment for JERICO CORE tools and data to further their research and application needs (Access is restricted to project users only).

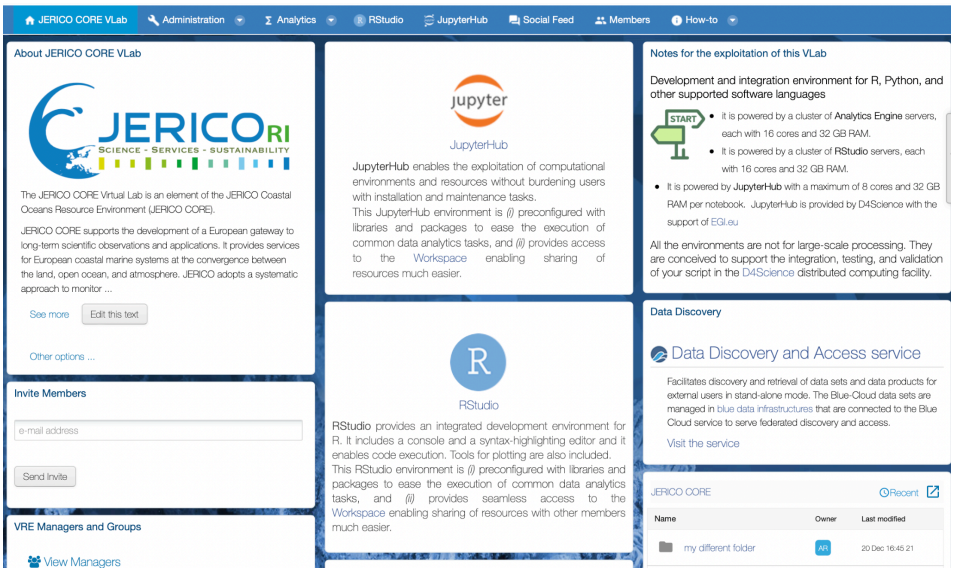

Figure 28. A screenshot of the JERICO-CORE VLab

This VLab has been in operational status since December 2021 and currently serving 36 users.

3.20 Blue-Cloud 2026 Training Academy VLab

This VLab supports the training activities organised by the Project

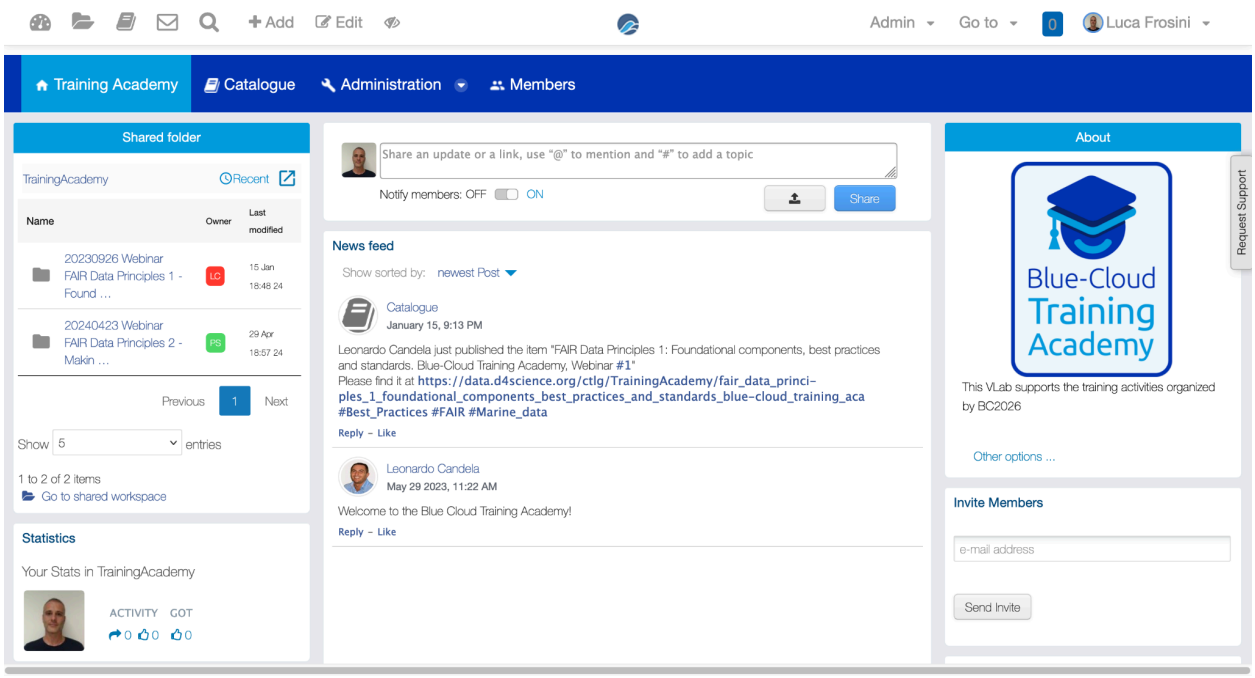

Figure 29. A screenshot of the Training Academy VLab

In addition to the basic functionality, e.g., a workspace for sharing objects of interest and a user management facility for managing membership, this VLab is specifically equipped with the following functionalities:

- the ***Catalogue*** facility enables users to publish, search and browse datasets and other products of interest for the specific use case. At the time of writing, more than 42 training materials have been produced to guide users on the usage of the Blue-Cloud 2026 core services and VLab services, which are being uploaded to the Training Academy Catalogue.

Funded by the European Union
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4. Concluding Remarks

This report detailed the meticulous planning, procedures, and operational strategies that underpin the Blue-Cloud VRE development and operation. By providing extensive statistics on VLab usage, we have highlighted the high level of engagement and productivity fostered within the Blue-Cloud ecosystem.

Each VLab, from coastal ocean observations and plankton dynamics to marine environmental indicators and fisheries atlas, has showcased its unique contributions to the broader marine science community. The synergy with other initiatives, such as FAIR-EASE and CLIMAREST, further emphasises the collaborative spirit and integrative approach of the Blue-Cloud 2026 project.

A total of 13 VLabs were created and operated to meet the needs arising from the Blue-Cloud 2026 project. Additionally, 7 VLabs from the previous Blue-Cloud project have been maintained. These working environments serve more than 1,700 users across over 20 countries. By June 2024, users had initiated more than 26,000 working sessions via the Blue-Cloud VRE, averaging 1,447 sessions per month. Operating the VRE and VLabs involves managing support requests, issues, and malfunctions. A total of 143 tickets have been created and managed in the Blue-Cloud Project Issue Trackers (23 in the project consortium tracker and 120 in the support tracker), with 85% of these tickets closed. Additionally, 24 tickets related to Blue-Cloud have been created within the D4Science overall context, with an 88% closure rate.

As we move forward, the Blue-Cloud platform continues to evolve, remaining open and extensible to meet the ever-changing needs of the marine research community as well as of the European Open Science Cloud, where the concept of the EOSC Node is taking shape as a fully operational enabling infrastructure for EOSC to which other thematic or regional Nodes can be integrated[4]. The ongoing development and enhancement of Blue-Cloud tools are pivotal in facilitating FAIR and open data practices, ultimately positioning Blue-Cloud as a driving e-infrastructure for deeper understanding in marine science.

[4] See https://digital-strategy.ec.europa.eu/en/news/commission-announces-winners-eosc-procurement and https://open-science-cloud.ec.europa.eu/about/eosc-eu-node

References

[1] M. Assante, L. Candela, D. Castelli, R. Cirillo, G. Coro, L. Frosini, L. Lelii, F. Mangiacrapa, P. Pagano, G. Panichi, F. Sinibaldi ***Enacting open science by D4Science***. (2019) Future Gener. Comput. Syst. 101: 555-563 10.1016/j.future.2019.05.063

[2] M. Assante, L. Candela, D. Castelli, R. Cirillo, G. Coro, A. Dell'Amico, L. Frosini, L. Lelii, F. Mangiacrapa, P. Pagano, G. Panichi, F. Sinibaldi (2023) ***Virtual research environments co-creation: The D4Science experience.*** Concurrency Computat Pract Exper. 2023; 35(18):e6925. doi:10.1002/cpe.6925

[3] M. Assante, L. Candela, D. Castelli, R. Cirillo, G. Coro, L. Frosini, L. Lelii, F. Mangiacrapa, V. Marioli, P. Pagano, G. Panichi, C. Perciante, F. Sinibaldi (2019) ***The gCube system: Delivering Virtual Research Environments as-a-Service***. Future Gener. Comput. Syst. 95: 445-453 10.1016/j.future.2018.10.035

[4] C. Nys, G. Maudire, J. Augot, J. Barde, E. Blondel, P. Cabrera, G. Cochrane, P. Debeljak, M. Drudi, A. Ellenbroek, A. Gentile, E. Lavergne, R. Lecci, Y. Marketakis, S. Pesant, L. Schepers, L. Tyberghein (2020) ***Blue Cloud Demonstrator Users Handbook V1***. D3.3 Blue-Cloud Deliverable, December 2020 10.5281/zenodo.6335525

[5] P. Martin-Cabrera (2023). **VLabs technical requirements.** Blue-Cloud 2026 Deliverable D4.1. December 2023 10.5281/zenodo.10412900

[6] M. Assante, P. Martin-Cabrera (2023). **VLabs Implementation Guidelines.** Blue-Cloud 2026 Deliverable D4.2. December 2023 10.5281/zenodo.10411081