GEOSS Platform Plus

D3.1 - Version 1.0

Enhanced GEOSS Platform with 1st set of applications

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Task:	T3.1	
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Abstract:

This document describes the evolved GEOSS Platform and the technical implementation, integrating the GEOSS Portal, Yellow Pages, GEO DAB and other middleware enhancements as resulting from GPP T3.4 (*GEOSS Platform Integration and Deployment*), as well as the first set of applications output of GPP T3.5 (*Application Design, Development and Deployment*) during the first project cycle. A technical note providing an overview of the identified applications and the developed evolutions will accompany this software release. In particular, the technical note will clarify which services/applications/functionalities are integrated and which data is made accessible.

Document Log

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Executive Summary

This document (*D3.1, Enhanced GEOSS Platform with 1st set of applications*), provides an architectural overview and describes the enhancements identified from the analyses of applications identified in the first cycle and recognised (and documented as requirements) in the context of WP2, *Use cases definition and user requirements specification ([RD-1]).* The identified Scenarios based on applications aim at demonstrating how communities can benefit from the use of the GEOSS Platform ecosystem and how they can contribute to the evolution of GEOSS, and in particular the wider GEOSS infrastructure and the GEOSS Platform and how to contribute with actionable information derived by the use of the applications.

Applications are the bridge between data available in GEOSS and the usage of them. The community driven approach adopted drives the new architecture proposal of the GEOSS infrastructure at large and in particular of the GEOSS Platform capabilities by identifying what are the main evolutions within the GEOSS Ecosystems.

For this reason The GEOSS Platform Plus project is focused on the application needs coming from the GEO Communities. The applications highlights what the Global Earth Observation System of Systems (GEOSS) should address and how the GEOSS Platform can evolve as mean of implementation of GEOSS and thus how it should evolve to fulfil communities needs and enforce data usage for generating actionable information. In this first cycle analysis some applications based on Use Cases (see [RD-1]) have been considered to identify a set of implementations that address both the GEOSS infrastructure, GEOSS Platform and middleware components.

The following developments have been implemented as GEOSS Platform enhancements and as middleware components enhancements to address the first cycle applications needs:

- AfriGEO Community Portal customisation
- SDG 15.3.1 for the Land Degradation
- Replicability, reproducibility and reusability support: VLAB

Table of Contents

1. Introduction

1.1 Purpose and Scope

This document (*D3.1 - Enhanced GEOSS Platform with 1st set of applications*) has been generated in the context of WP3 - GEOSS Evolution design, development, integration and deployment within the GPP (short for GEOSS Platform Plus) project, Grant Agreement no. 101039118.

The current document provides a technical description of the implemented enhancements in the first cycle of the GPP Project, in support of the applications requirements grouped within the high level scenarios described in Table 1.

Scenarios ID	Scenarios	Addressed in first cycle
S1	Resources discovery and access with linked information	Y
S2	Service Use	Y
S3	Resources Registration	Y
S4	Promotion and collaboration.	
S5	Data providers (registration)	
S6	Exploiting discovery and access capabilities	Y
S7	Discovering experiment results	Y
S8	Reproducing an experiment	Y
S9	Replicating an experiment	Y
S10	Reusing an experiment	

Table 1 Scenarios identified based on applications analysis

The scenarios were identified in the context of WP2 and documented in [RD-2], and they highlighted the need to better improve the usability of the GEOSS data. The use of data is a key driver for the future of GEOSS. To better identify how to use those data a user centric approach has been adopted in GPP by involving the GEO communities and identifying communities' driven applications to non-specialists in the domain of adaptation to extreme climatic events and to changes in climatic conditions. Another important aspect of the project is to enable the generation of actionable information and to fully exploit the GEOSS infrastructure and its components to the benefit of the users, to enable the connections with the data providers (including in-situ), which are relevant for the achievement of use cases, and to provide a user-friendly, up-to-date and therefore familiar environment, by making sure that the current trends in information technology are considered and exploited as necessary.[RD-2], and they highlighted the need to better improve the usability of the GEOSS data. The use of data is a key driver for the future of GEOSS. To better identify how to use those data a user centric approach has been adopted in GPP by involving the GEO communities and identifying communities' driven applications to non-specialists in the domain of adaptation to extreme climatic events and to changes in climatic conditions. Another important aspect of the project is to enable the generation of actionable information and to fully exploit the GEOSS infrastructure and its components to the benefit of the users, to enable the connections with the data providers (including in-situ), which are relevant for the achievement of use cases, and to provide a user-friendly, up-to-date and therefore familiar environment, by making sure that the current trends in information technology are considered and exploited as necessary.

In the first implementation cycle the SDG 15.3.1 enhancements, the AfriGEO community portal implementation and an enhancement of VLAB as middleware component have been included, and a variety of new data sources have been registered, harvested and made available via the GEOSS Platform, such as the interface with the Digital Earth Africa data cube catalogue.

1.2 Document Organisation

The document is organised as it follows:

- Section 1: Introduction. It describes the purpose and scope of the document and its organization.
- Section 2: Rationale and Context. It contextualizes the content of this document by providing background information and details on the operational landscape encompassing the GEOSS Platform.
- Section 3: Architecture. It describes the general architecture of the system.
- Section 4: The Enhancements. It is the hearth of the document where all the enhancements are described divided by the Project strategic lines.
- Section 5: Requirements traceability. It Traces the WP2 User Requirements (functional and non-functional) to the implementations tasks.
- Annex A. References. List the references used in the document.
- Annex B. Figures and Tables. It provides links to figures and tables in the document.
- Annexes C: The GEO DAB Standards
- Annex D: Terminology. It explains the meaning of the acronyms and definitions used in the document.

2. Rationale and Context

2.1 Background and operational context

A central part of GEO's Mission is to build the Global Earth Observation System of Systems (GEOSS). GEOSS is a social and software ecosystem sharing independent and open Earth observation (EO) information and processing services. It connects and coordinates a large array of observing systems, data systems and processing services to strengthen monitoring of the state of the Earth. It facilitates the sharing of environmental data and information collected by countries and organizations within GEO. GEOSS ensures that these data are accessible, of identified quality and provenance, and interoperable to support the development of tools and the delivery of information services. Thus, GEOSS increases our understanding of Earth processes and enhances predictive capabilities that underpin sound decision-making: it provides access to data, information and knowledge to a wide variety of users.

The GEOSS Platform has been created to provide the technological tool to implement GEOSS. The story of the Platform began in 2008, as Clearinghouse catalogue; in 2012 the platform evolved into a Brokering infrastructure with the inclusion of the GEO Discovery and Access Broker (GEO DAB). The first user interface, the GEOSS Portal was initially created in 2010 and in 2016 has seen great enhancements in terms of user experience and enhanced discovery, access and visualization functionalities. In 2017 the platform has evolved into the currently known GEOSS Platform (see Figure 1).

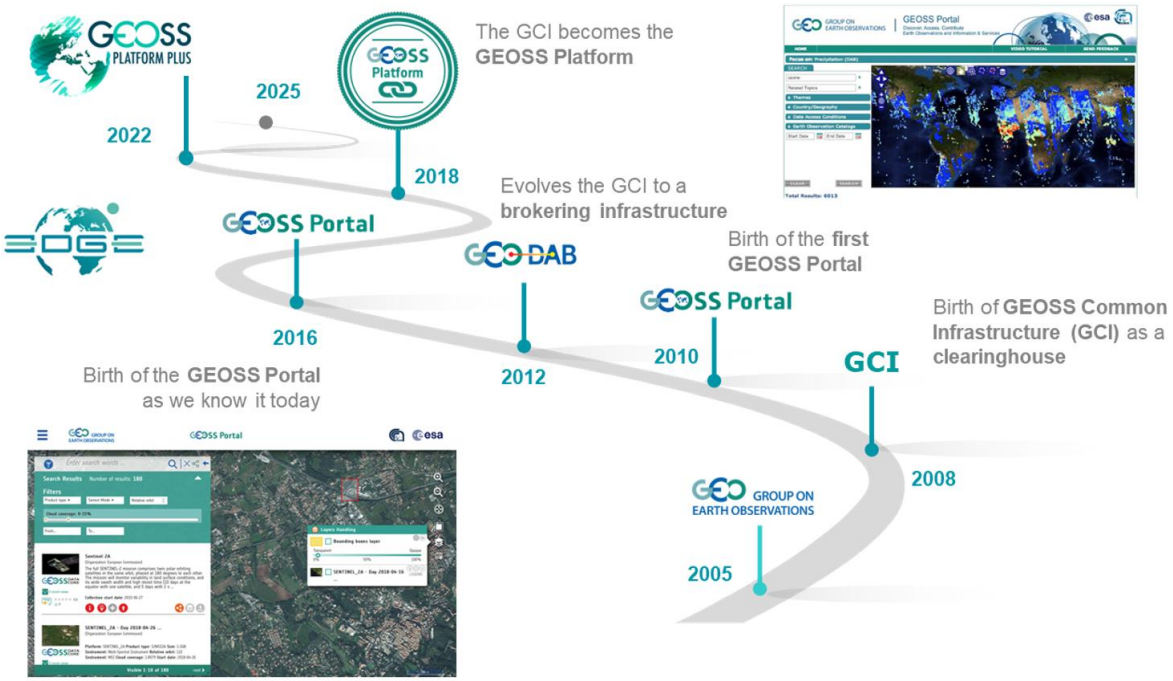


Figure 1 - The GEOSS Platform Journey

A first effort in demonstrating several proofs of concepts experimenting service execution with selection of public cloud-based analytical platforms (e.g. DIASs, AWS), navigation through linked

(context) information and dedicated customisation of community portals features have been implemented and experimented within a development platform in the framework of the EDGE (European Direction in GCI Enhancements) Project (for more details see [WR-1]).

Another EU effort in contributing to GEO is the GEOSS Platform Plus (GPP) Project with the aim to respond to the new challenges focused on the European Green Deal, implementation of the EU Strategy on adaptation to climate change and the outcomes of the Mid Term Review frameworks (see Figure 3) by developing new tools and functionalities to better address the user needs adopting an user centric approach by engaging User communities, GWP activities, initiatives and flagships and including European efforts in the Climate Change and green deal frameworks (see Figure 2 and Figure 3).

Figure 2 - GEOSS Platform Components

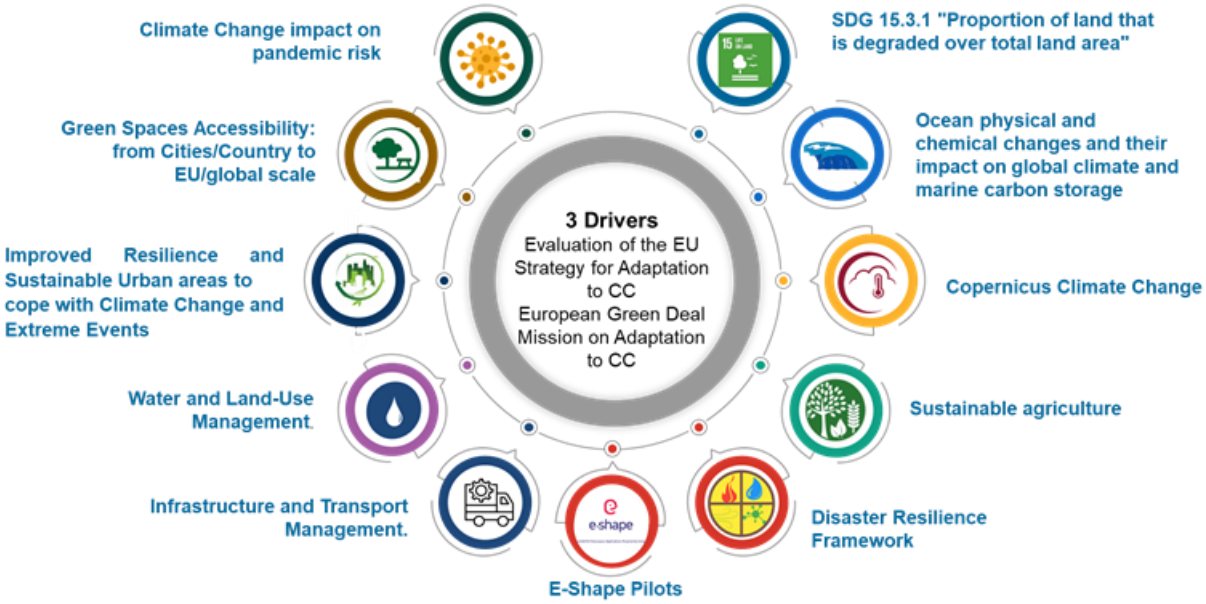


Figure 3 - The GPP Drivers and focus domains

Another objective of the GPP Project is to make the GEOSS Platform usable for a wide variety of users within the GEO communities and beyond it, that covers users coming from scientific communities to non-experts and decision makers. Figure 4 provides a representation of the type of users involved and the functionalities they are interested in when using the GEOSS Platform.

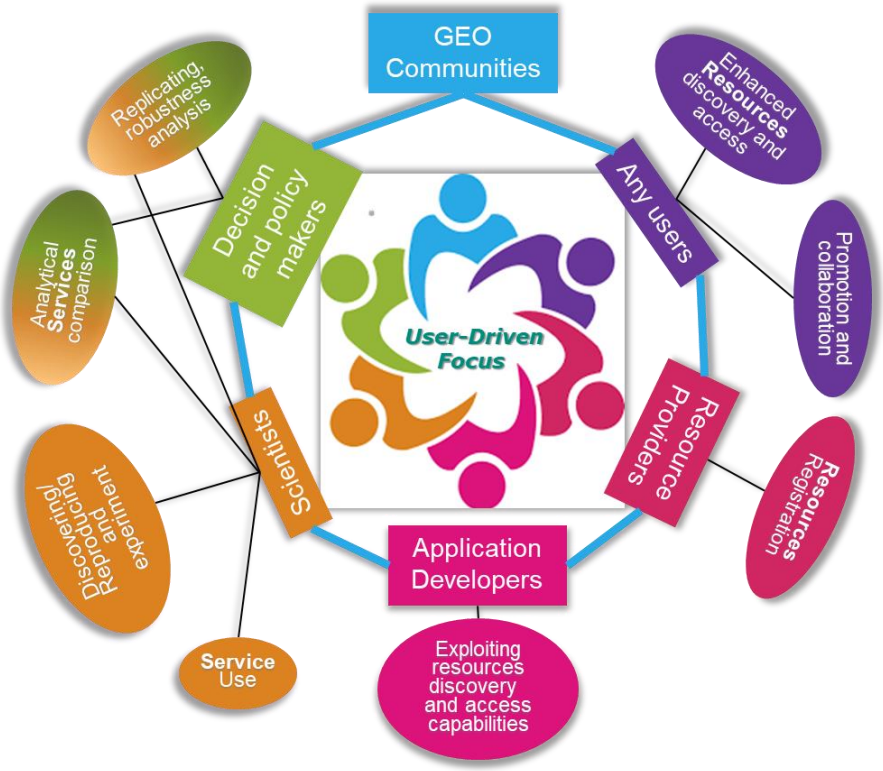


Figure 4 GPP User types and functionalities

2.2 Links with other project activities

GPP identifies five work packages as follows:

- WP1: Project management
- WP2: Use cases definition and user requirements specification
- WP3: GEOSS Evolution design, development, integration and deployment
- WP4: User validation and assessment
- WP5: Dissemination, training, exploitation and GEOSS Contribution

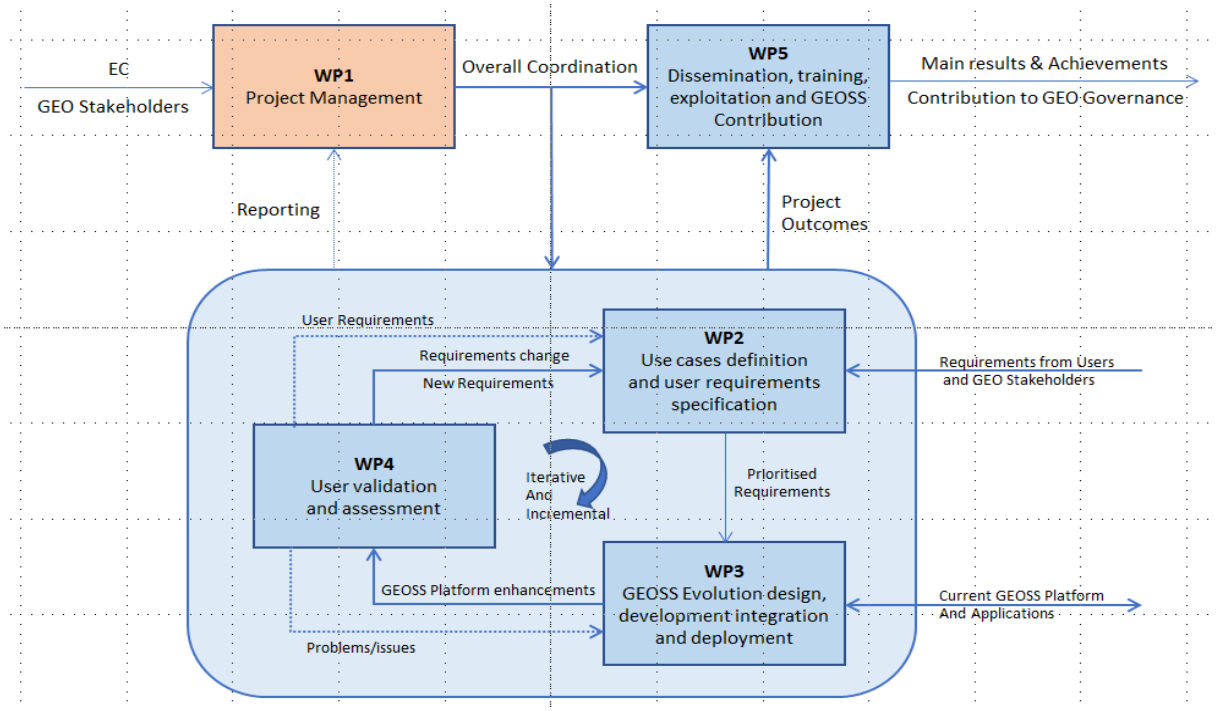


Figure 5 - GPP Workpackages and their relationships

Work-package 3 builds on prioritized GEOSS Platform requirements as input to the identification of enhancements, their implementation and definition of an integration and verification strategy. The output of WP3 is an enhanced GEOSS Platform. On top of the requirements resulting from WP2, current workpackage considers as well requirements and other inputs resulting from other (external activities).

3. Architecture

3.1 Architectural background and challenges for GEOSS

GEOSS has started evolving from a multi-functional system to a Web-based Ecosystem, where several (Web-based) components and technologies co-operate to deliver the services and products required by the GEO Community.

The GEOSS Platform is moving from a data to a knowledge platform providing users besides with the possibility to discover, inspect and access data as well with functionality to use data to derive actionable information and knowledge. Activities are on-going as well to discover, inspect, access and use information and knowledge via the Platform. Such developments are implemented via Platform Tools (or instruments), e.g. via specific Views and can be 'used' via APIs (directly interfacing on a Machine-to-Machine level with the GEO-DAB), via Widgets, or reuse components that are under development and can be integrated into community portals (GEOSS Like or external) in case of set-up for the relevant community(ies) and/or GEO Priority Area (e.g. for a specific SBA, Copernicus-service, ESA Thematic Exploitation Platform community, Sustainable Development Goal (SDG), Paris Agreement Targets, Sendai Framework, etc.).

Along this line, the next evolution should consider the inclusion in such an ecosystem of new components and/or instruments and/or applications (i.e. at infrastructures, platforms, middleware and applications layers) to enable communities to contribute to the evolution of the GEOSS ecosystem and to benefit users and communities using GEOSS by making the new enhancements discoverable, accessible and usable.

In the first project cycle the following challenges and solutions have been analysed and proposed:

- From data discovery and access only to discovery and access to services, information, knowledge, tools models and algorithms.
- Retrace the journey of experiments leading to results through resources links to enable Reproducibility, replicability, reusability and robustness analysis
- Community Portals customisation freedom by developing an instrument that enable self-creation of community portals and views to foster a broader engagement of new communities and active contribution to GEOSS ecosystem
- From obsolete discovery download process publish paradigm to Leveraging Cloud technologies supporting **multi-Cloud approach** for actionable information generation

The following figure shows the current relations and the main service components (i.e. infrastructures and platforms) to be considered as part of the landscape and it will be further evolved as output of the WP3 tasks in the deliverable [RD-4].

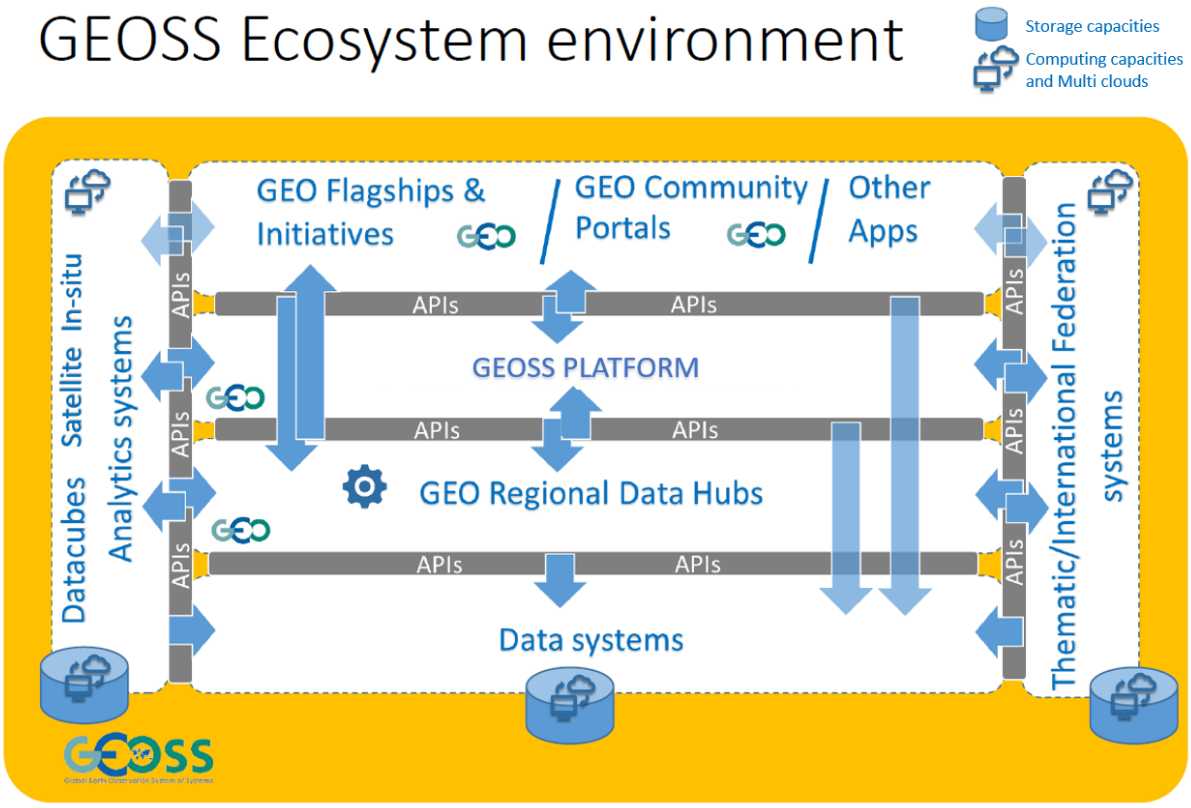


Figure 6 – Current GEOSS landscape for infrastructures and platforms to be considered

3.2 The GEOSS Portal and GEO DAB architecture

Looking at the Figure 6, due to the multiple APIs and various knowledge perspectives, each component has to be based on a layered architecture. The GEOSS Portal internal architecture of the main component - which is a Single Page Application search part - has been furtherly decoupled to support interoperability even better. The main extracted components of the search are:

- Search Presentation layers – targeted search with various perspectives and various concept models:
  - GEOSS common search – opensearch based resource discovery/download/access;
  - thematic search – supported with internal domain model search in the thematically predefined subdomains;
  - Wikipedia search;
  - Knowledge producer search – supported with GEO-DAB ontology model search of resources and services registered on the DAB;
  - Geo-spatial data visualisation with WMS integration. OGC WMSes are presented based on DAB or Data Providers services.
- Catalogue discovery:
  - DAB opensearch client + CSW metadata explorer;
  - Http(s) portal client for Wikipedia;
  - CKAN catalog browser – under development.

- Domain browser (ontology browser) - intermediate layer that translates the knowledge concept on the resources level like:
    - Core search to opensearch or CKAN or SciHub or other catalogues;
    - SDG concept to DAB view concept;
    - Core search to Wikipedia resources.

The front-end side is supported with Liferay based content management with user workspace functionalities for registered users.

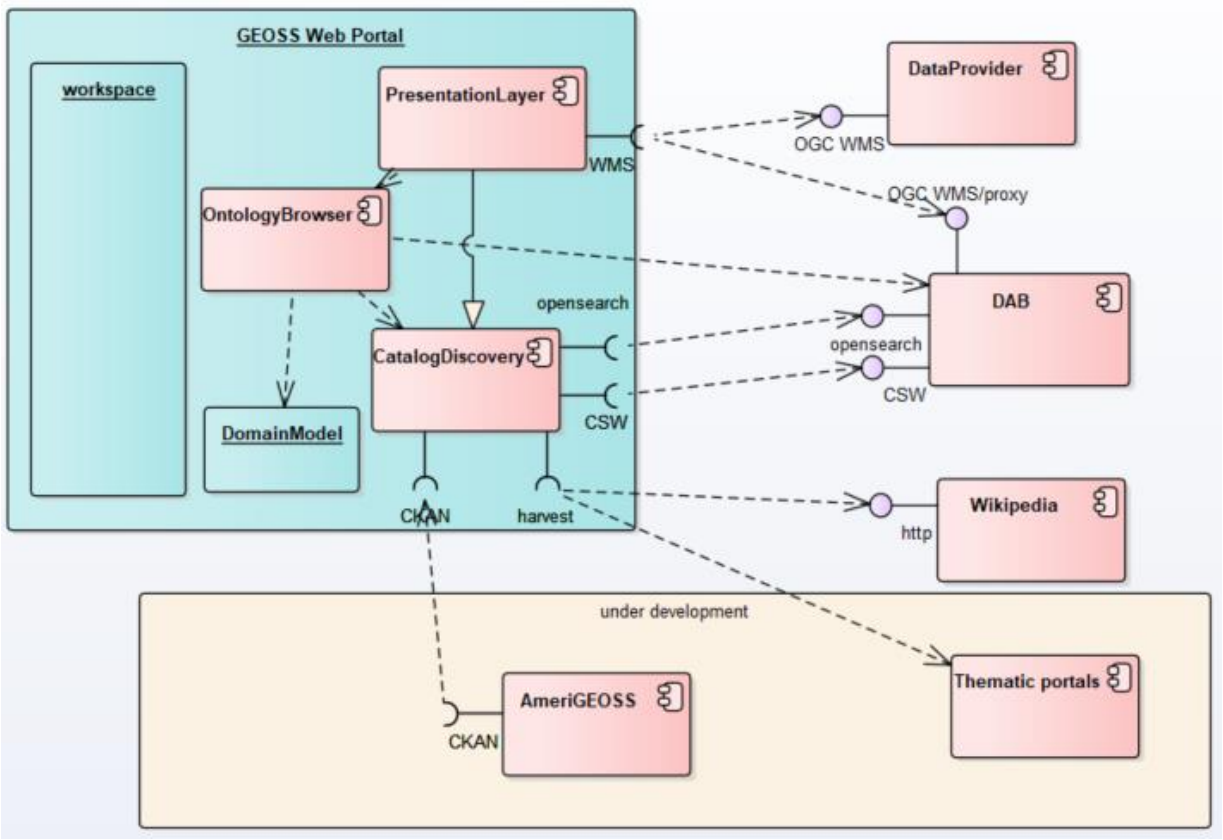
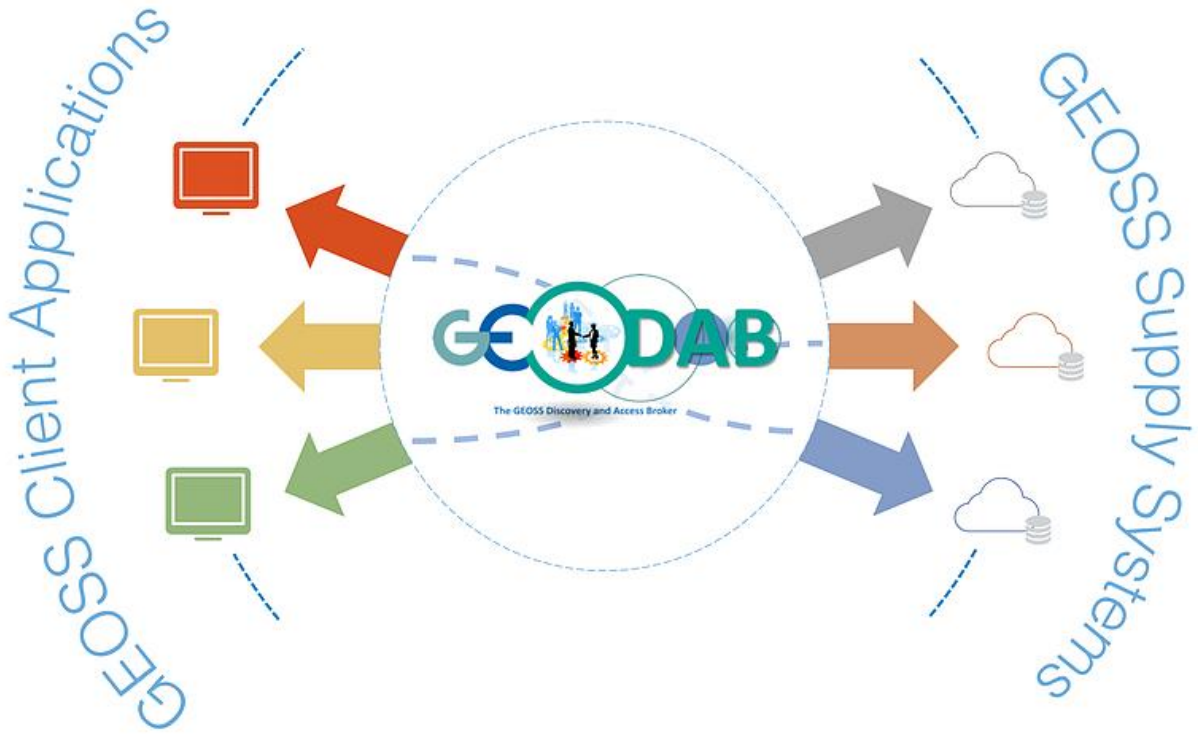


Figure 7 - GEOSS Portal and GEO-DAB Architectures

The GEO DAB transparently connects GEOSS Portal to the resources shared by the GEOSS Data provider. The main goal is to facilitate cross and multi-disciplinary discovery and access of disparate data and information interconnecting several hundreds of autonomous and heterogeneous Supply Systems. The GEO DAB applies the broker pattern, which separates users of services (GEOSS Client Applications) from providers of services (GEOSS Supply Systems). When a client needs a service, it queries a broker via a service interface. The broker then forwards the client's service request to a server, which processes the request. The GEO DAB presently provides broker components for discovery, access and semantics-enabled search.



The main components of the layered architecture are:

- **Data Harmonization**: this layer provides harmonized discovery and access to heterogeneous data systems. The heterogeneity of data sources is hidden, resources appear as a single data source.
- **Data Access**: this layer provides data discovery and access functionalities to heterogeneous data systems.
- **Data Processing**: this layer enriches discovery and access with processing and semantics services.

4. The Enhancements

Strategic Actions lines are the high-level areas for which enhancements have been investigated. Within GPP the following strategic lines have been identified:

- Components-based: APIs, Views, Widgets, Customised GEOSS Portal, Middleware, GEOSS Infrastructure, GEOSS Platform components
- Community-driven: GEO Activities, Initiatives, Flagships and communities' portals, EU Projects, communities' applications
- Reusability, Reproducibility, Replicability: knowledge sharing, experiments replicability, reproducibility and reusability, actionable information generation

Components-based enhancements refer to all those enhancements to components and/or tools (APIs, Views, Widgets etc) that are made necessary to address the applications needs and are being implemented to fulfil GEO users' requirements and use cases.

Community-driven enhancements refer to all those enhancements coming from the GEO communities (Activities, Initiatives, Flagships) and EU projects (EIFFEL, e-Shape) requirements that drive new evolutions of GEOSS, GEOSS Platform, applications and services and middleware components to support community's needs.

Reusability, Reproducibility and Replicability enhancements refer to all those enhancements that will drive GEOSS evolution in support the scientific paradigm for replicate, reproduce and reuse experiments and enable knowledge sharing capabilities within the GEOSS Platform and GEO Communities and to trigger the generation of actionable information

In particular for the First evolution cycle the following enhancements have been identified and implemented in GPP:

- Components-based
  - DAB enhancements: harvesting of new catalogues and resources, and the creation of a dedicated view for the AfriGEO Community Portal implementation
- Community-driven
  - SDG 15.3.1 Land Degradation enhancements related to the possibility to exploit customisable AOI over Africa for the three mandatory resources: Land cover, Productivity and Soil carbon maps over 3 specified regions Rwanda, Ghana, Uganda, Lesotho, Switzerland and Italy
  - AfriGEO custom community Portal that allowed the AfriGEO community to get access to the customized community Portal package to be installed on their own premises. Customisation is related to DEA (Digital Earth Africa) data registration, View generation, Logo of the portal and whished thematic
- Reusability, Reproducibility and Replicability
  - Virtual Earth laboratory component enhancements to allow the generation of additional knowledge from the SDG 15.3.1 algorithm with statistics and to enable the possibility to select different cloud resources providers to better satisfy users computing resources needs and familiarity.

4.1 Components-based Enhancements: APIs, Views, Widgets, Customised GEOSS Portal, Middleware, GEOSS Infrastructure, GEOSS Platform components

4.1.1 DAB

DAB is the main data provider of the portal. It serves with high content resource entries and datasets with filters, catalogues, and views. It also provides a registry of other Data Providers.
The latest data sources which were brokered/updated by the DAB are:

- DIONE Catalogue
- Digital Earth Africa (DEA)
- Webservice Energy Catalogue
- TWIGA
- Data Integration and Analysis System (DIAS) – Japan
- Federated EO Gateway (FedEO) – CEOS
- South African Environmental Observation Network (SAEON)
- PANGAEA

Besides, some of the most relevant brokering activities were recently described and published in dedicated papers (Roncella et al., 2022) (Roncella et al., 2022a).
Finally, a specific view for the AfriGEO Community Portal was created based on AfriGEO community requests.

4.2 Community-driven Enhancements: GEO Activities, Initiatives, Flagships and communities' portals, EU Projects, communities applications

4.2.1 SDG 15.3.1 Land Degradation

Avoiding, reducing and reversing land degradation and restoring degraded land is an urgent priority to protect the biodiversity and ecosystem services that are vital to life on Earth. There is an immediate need to enhance national capacities to undertake quantitative assessments and corresponding mapping of their degraded lands.

The user wants to calculate the related SDG indicator 15.3.1 at the national scale, based on the official GPG 2.0 guidance document from UNCCD, using the GEOSS platform. The objectives of this indicator include the dissemination of knowledge on land degradation. The GEOSS Portal enables the user to independently start the computation of chosen resources in terms of land degradation and visualize the outcome in various forms and also add it to a customized dashboard.

The users shall be also enabled to add the finished dashboard in My Workspace menu and share it with the specified users.

The user could be enabled to share the dashboard with all the GEOSS users, upon verification by the Administrator.

Flow

1. The user connects to the GEOSS platform and does a search for "Land degradation".
2. The user obtains a number of resources that matches his search criteria.
3. The user can discover (or a pre-selection can be made) of the required sub-indicators (see data domain) available in the GEOSS platform and selects the most suitable for his/her needs.
4. The user can discover different data, services and knowledge and their relationship associated to the SDG 15.3.1 indicator. The user can then navigate deeper into the different sources.
5. The user discovers a dedicated model to compute the SDG indicator
6. The user realizes that there is a Service associated to this model. The GEOSS Platform associates the model to the actual processing services that enable its computation, which the user can access and run in a user-friendly way. In particular, the user can inspect the process workflow and search and select data as input to the service. In addition, the user has the capability to choose a Cloud computing platform of preference among the available (these include all the DIAS Platforms and Amazon Web Services).
7. In case the user has registered newly data, it will be possible the discover and select them as input to the service.
8. The user can now start the computation on the selected infrastructure and wait for the results
9. The user can visualize the outputs in a dedicated dashboard (that can be further elaborated/modified and shared afterwards).
10. The created dashboard can be added in My Workspace, the user who created the dashboard can chose between sharing his work with other specific users or to render it accessible to all

the platform users. In this case the User who created the dashboard should become a data provider or need the Administrator authorization.

The procedure regarding the acceptance or rejection by the Administrator is the following :

a. Administrator can reject the dashboard creation and provide information why the rejection happened. User, that created the dashboard can then update it according to the provided information or discard the whole process.
b. Administrator can accept the dashboard and in this case this dashboard will be accessible for both User, that created it and Users, that are looking for similar data in within the system. The data will be obtainable within the information tab.

4.2.1.1 WORKFLOWS and NEW DATASETS Registration

In order to implement the new features of the SDG15.3.1 it has been updated the name of the model, to make it more generic from "European Model" to a more generic "Land Degradation Service". This allows the user to run the model not only over a predefined European area, but also to some African regions and like: RWANDA, GHANA, UGANDA and SWITZERALND, ITALY, LESOTHO, and EUROPE.

New datasets have been prepared and registered by the DAB and made discoverable and accessible via the GEOSS Portal. The following datasets have been made available:

- EUROPE: Land Productivity, Soil Carbon, Land Cover
- ITALY: Land Productivity, Soil Carbon, Land Cover
- SWITZERLAND: Land Productivity, Soil Carbon, Land Cover
- LESOTHO: Land Productivity, Soil Carbon, Land Cover
- UGANDA: Land Productivity, Soil Carbon, Land Cover
- RWANDA: Land Productivity, Soil Carbon, Land Cover
- GHANA: Land Productivity, Soil Carbon, Land Cover

Another feature added is the possibility to process a map of land degradation and an excel file with statistics about the different parameters and regions of the Land degradation and the possibility to select among two different cloud providers. Currently only AWS and EOSC are available.

4.2.1.2 List of functionalities not implemented

It is still under implementation:

- the Custom dashboard features
- the possibility to add user own datasets
- The possibility to add user selected AOI
- To enable the sematic link among the resources available to support the paradigm of Replicability, Reproducibility, Reusability (see session 4.3)
- To enable the user the Selection of different Cloud provider

4.2.2 AfriGEO Community Portal

The AfriGEO initiative seeks to identify challenges and put in place measures to enhance Africa's participation in, and contribution to, GEOSS. This participation will support the continent's efforts to

bridge the digital divide and build a knowledge-based economy using GEO networks and GEOSS infrastructure.

The main requirement is to deliver for the AfriGEO a frontend component of the GEOSS Platform that will allow to set up on AfriGEO premises a Community portal with a look and feel present in the GEOSS Portal. Due to the time limitation, delivering the complete solution with a set-up tool and decomposed backend components is impossible. Therefore, certain functionalities, such as those requiring logging in or those not part of the Operational system (present in other environments such as SIT, UAT or Development), will not be present within this first step.

The end product is an installation package which needs to be deployed according to instructions and configured via configuration files on the User premises.

The design and solution proposed in this first step is a proof of concept. We want to clarify that this temporary solution will be scratched later in the project to make space for a new solution with a new architecture approach.

4.2.2.1 Technical specification

This chapter describes what software and hardware requirements must be met to set up the GEOSS Platform's frontend components.

AfriGEO component is a standalone static website with Vue.js (version 2) based Single Page Applications for a Search and Yellow Pages modules and static HTML5 / CSS3 / JavaScript content pages. It can be hosted on any service that provides static website support (FTP, Cloud hosting, VPS).

Minimal hosting Hardware requirements:

- CPU: minimum 2 vCPU/Cores (single-threaded), 4 vCPU (2 cores with hyperthreading or 4 physical cores) recommended
- RAM: 4 GB at minimum
- Hard Disk: 25GB at minimum, including space for the OS installation (not including the need for backups, other services, etc.)

Software:

- A Linux distribution of choice (Ubuntu/Debian/Fedora/Rocky Linux)
- A web server of choice – nginx/Apache HTTPD/Lighttpd (nginx recommended)
- Software allowing remote access possibility, to upload the web application package (for example vsftpd for FTP functionality, or properly configured SFTP on SSHD)

Libraries and plugins:

Name	URL	License
Axios	https://github.com/axios/axios	MIT License
Open Layers	https://github.com/openlayers/	BSD-2-Clause license

	openlayers	
Vue.js	https://github.com/vuejs/vue	MIT License
Vuex	https://github.com/vuejs/vuex	MIT License

NOTE: Requirements and technical specifications will be changed when the Mirror Site Tool Scenario is developed.

4.2.2.2 Elements in the Portal

Within the installation package following elements of the portal shall be present:

- **Configuration file:**
  - Logo image source
  - Site name
  - External API URLs
  - Menu elements
  - List of views and default view

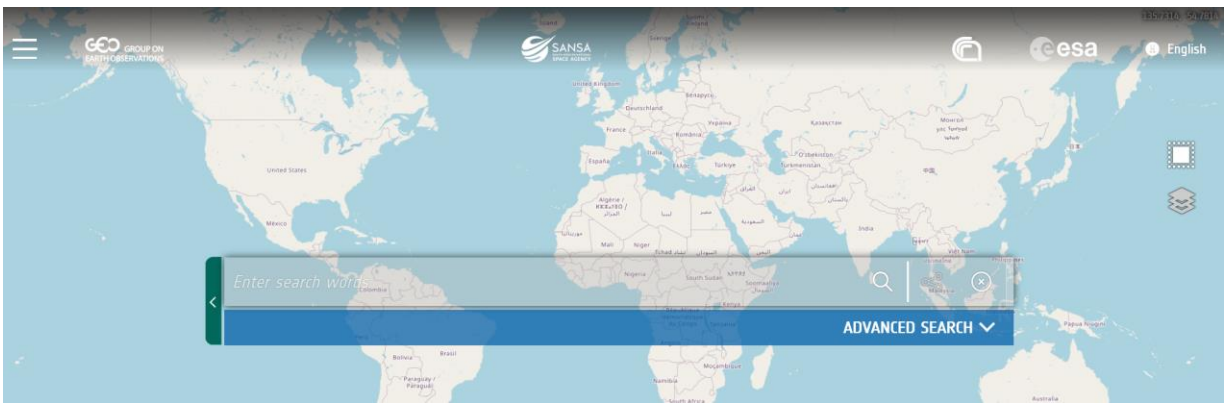


Figure 8 - AfriGEO Community Portal, homepage

The configuration file will contain all necessary configuration details, saved as a JSON text file.

- **Pages:**
  - General Information

- Terms and Conditions
- Release notes
- Help Desk
- Documentation
- Tutorials
- Yellow Pages

Each page will be delivered as an empty one for the User to set up its description. This will be possible via the source code of the page. The only exception will be Yellow Pages, which will fetch the data about data providers via the DAB endpoint and present them similarly to GEOSS Portal.

- **Menu:**
  - About
  - User Support
  - Community Portals (menu you will consist of static links leading to currently present Community Sites and Geoss Portal)
  - Yellow Pages

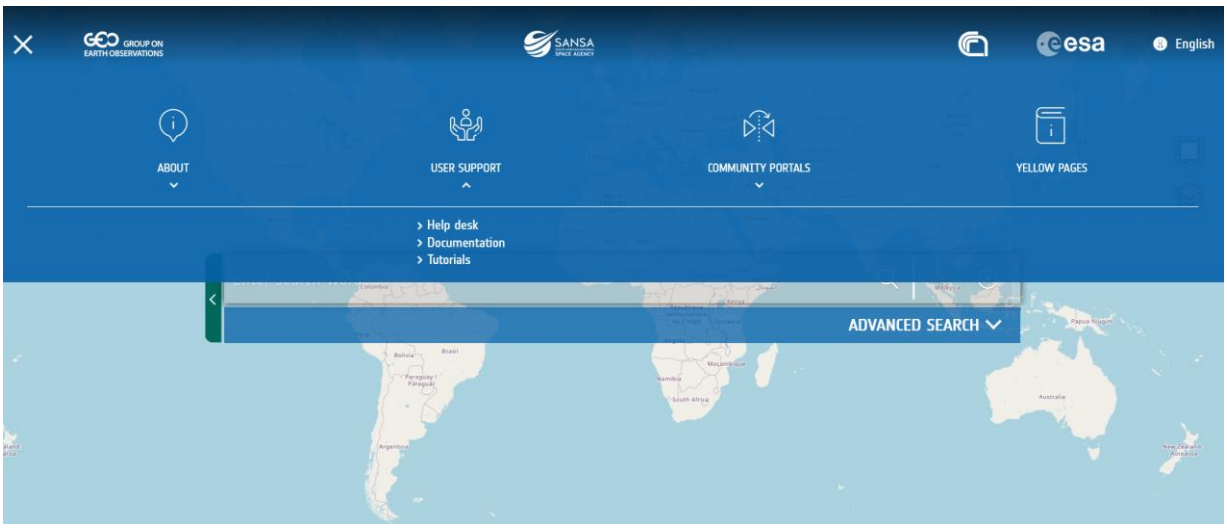


Figure 9 - AfriGEO Community Portal, Menu

- **Search component:**
  - Possibility to run a search via DAB component (dedicated endpoint to be configured via configuration files)
  - Advance search with a dedicated list of catalogues and views. A view can be chosen by default, which will be used to search for datasets. (to be decided if the view should only consist of AfriGEO or other views as well)
  - Continent and Country or Coordinates filter

- Relation of the selected area
- Date range filter
- Facet filters built based on the response from the DAB component

- **Yellow Pages component**
  - Possibility to run a search for a data provider via the DAB database
  - Results sorting and pagination
  - Result entry with logo, title, description, link, traits and link sharing
- **Map component**
  - Base map provider
  - Area of Interest
  - Layers including comparison tool

4.2.2.3 List of functionalities not implemented

Hereafter there is a list of functionalities that will not be accessible due to the short implementation time or the fact that they are not yet operational.

- Geolocation and "Did you mean" component,
- Running workflow processes via VLAB,
- Enrichment of the resources,
- Saving searches,
- Tutorial mode,
- Send feedback,
- Extended View,
- Additional sources outside of DAB,
- Statistics,
- My workspace (with all its contents),
- Sign in,
- "See also" and "Popular" search hints,
- Survey.

4.3 Re-usability, Re-producibility, Replicability enhancements

4.3.1 The Virtual Earth Laboratory (VLab)

The Virtual Earth Laboratory (VLab) is a framework that implements all required orchestration functionalities to automate the technical tasks required to execute a model on different computing infrastructures, minimizing the possible interoperability requirements for both model developers and users. VLab is conceived as a framework to support a science-informed decision-making process, which requires the generation of knowledge from collected data and scientific models. Although, current cloud technologies provide valuable solutions for addressing several of the Big Earth Data challenges. Building a workflow that implements a scientific process to generate knowledge on a multi-cloud environment is a complex task requiring multiple expertise on policy needs, different scientific domains, data and model interoperability, cloud services management. Therefore, it is necessary to automate, as much as possible, the technical tasks, in order to lower the existing barriers and allow the different stakeholders to focus on their specific fields of expertise.

Through VLab, modelers can publish models developed in different programming languages and environments. After being published on VLab, a model becomes available as a resource on the web for machine-to-machine interaction. Using the VLab RESTful APIs (documented in GPP Deliverable D3.2), software developers can build mobile and desktop applications exploiting the framework capabilities to run models. In this way, developers can build applications tailored to end-users, including policy-makers and decision-makers, widening the scope of models and their potential user audience.

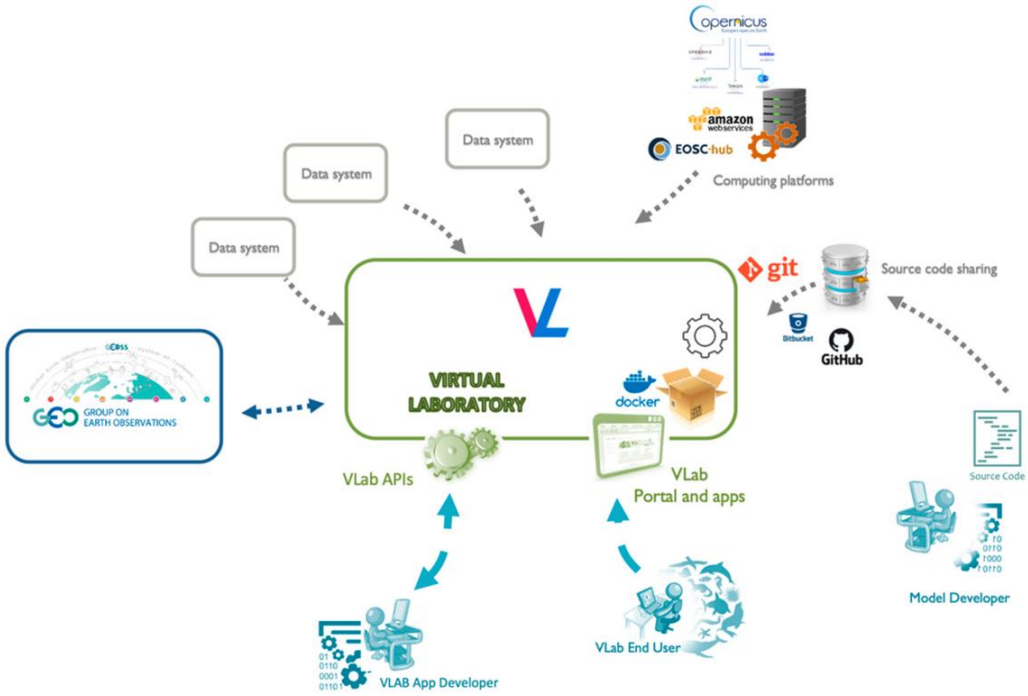


Figure 10 - Conceptual Framework of VLab Experimentation

VLab was developed in the context of different H2020 projects: ECOPotential, ERA-PLANET, ESOC-hub, and EDGE. In the context of GPP project, VLab was improved to support new requirements coming from the identified use cases. In particular, VLab APIs were enhanced to provide additional metadata about the produced outputs and request the execution on a specific cloud platform. Besides, a proof-of-concept component was implemented to enhance the support of multi-cloud environments.

Supporting Open Science Paradigm

Reproducibility, Replicability and Reusability are key concepts in the Open Science paradigm. Table 2 lists the current support of these three concepts by the VLab framework.

	Description	Supported	Required Enhancements
Reproducibility	Reproduce an experiment with same data and model implementation	Supported	
Replicability	Replicate an experiment using different data and same model implementation	Partially Supported [Users must know which datasets to use]	Enhancements required to automatically detect datasets which comply (at least syntactically and semantically) with model implementation requirements
Reusability	Reuse/apply the approach in different contexts, change the model implementation and/or data sources	Partially Supported [Same as above + users must know that two implementations realize the same model]	Same as above + need to semantically characterize model implementations

Table 2 - VLab Support for Open Science Paradigm

5. Requirements traceability

5.1 User Requirement traceability

This is the traceability matrix between the system required capabilities and the Use cases, User requirements found in document [RD-1] and the Jira Issue #, together with the information if the capability has been implemented on the operational platform or the proof of concept.

User Req.	UR Title	Section	System Req.	Use Case	Environment/ JIRA Ticket
UR-AFG-01	A dedicated portal for the AfriGEO community	4.2.2	SR-NFC-002	UC-AFG-01	Delivered Package
UR-AFG-02	The AfriGEO search keywords	4.2.2	SR-NFC-001	UC-AFG-01	Delivered Package
UR-AFG-03	The AfriGEO Region of Interest	4.2.2	SR-NFC-001	UC-AFG-01	Delivered Package
UR-AFG-04	The AfriGEO search domain	4.2.2	SR-NFC-001	UC-AFG-01	Delivered Package
UR-AFG-05	The AfriGEO filtering capabilities	4.2.2	SR-NFC-002	UC-AFG-01	Delivered Package
UR-AFG-06	Accessing data, information and knowledge from AfriGEO	4.2.2	SR-FUN-009	UC-AFG-02	Delivered Package
UR-LDG-01	SDG indicator 15.3.1 computation service discovery	4.2.1	SR-FUN-003	UC-LDG-01	UAT
UR-LDG-02	SDG indicator 15.3.1 computation service execution	4.2.1	SR-FUN-003	UC-LDG-01	UAT, partially
UR-LDG-03	Visual representation of SDG indicator 15.3.1 computations		SR-FUN-003	UC-LDG-01	In development
UR-LDG-04	My Workspace Dashboard		SR-FUN-003	UC-LDG-01	In development
UR-LDG-05	Acceptance of the visualizations		SR-FUN-003	UC-LDG-01	In development

Table 3. Requirements traceability

5.2 Scenarios vs system required capabilities

#	Code	Title	System Requirements
1.	S1	Resources discovery and access with linked information	SR-FUN-002 – Mirror Site SR-FUN-003 – SDG - 15.3.1 Dashboard SR-FUN-004 – Data discovery (with relationships to associated concepts) SR-FUN-005 – Service Discovery (with relationships to associated concepts) SR-FUN-006 – Information Discovery (with relationships to associated concepts) SR-FUN-007 – Inspection of search results SR-FUN-008 – Selection of search results SR-FUN-009 – Access to selected resource
2.	S2	Service Use	SR-FUN-003 – SDG - 15.3.1 Dashboard SR-FUN-010 – Service execution
3.	S3	Resources Registration	SR-FUN-003 – SDG - 15.3.1 Dashboard SR-FUN-011– Data provision (registration) SR-FUN-012 – Services provision (registration) SR-FUN-013 – Information provision (registration)
4.	S4	Promotion and collaboration.	SR-FUN-011– Data provision (registration) SR-FUN-012 – Services provision (registration) SR-FUN-013 – Information provision (registration)
5.	S5	Data providers (registration)	SR-FUN-001 – Yellow Pages Management
6.	S6	Exploiting discovery and access capabilities	SR-FUN-002 – Mirror Site SR-FUN-003 – SDG - 15.3.1 Dashboard SR-NFC-001 – Configurability of search domain SR-NFC-002 – Portal Customizability
7.	S7	Discovering experiment results	SR-FUN-006 – Information Discovery (with relationships to associated concepts) SR-FUN-007 – Inspection of search results SR-FUN-008 – Selection of search results SR-FUN-009 – Access to selected resource SR-FUN-013 – Information provision (registration)
8.	S8	Reproducing an experiment	SR-FUN-006 – Information Discovery (with relationships to associated concepts) SR-FUN-007 – Inspection of search results SR-FUN-008 – Selection of search results SR-FUN-009 – Access to selected resource SR-FUN-010 – Service execution SR-FUN-013 – Information provision (registration)

#	Code	Title	System Requirements
9.	S9	Replicating an experiment	SR-FUN-003 – SDG - 15.3.1 Dashboard SR-FUN-004 – Data discovery (with relationships to associated concepts) SR-FUN-006 – Information Discovery (with relationships to associated concepts) SR-FUN-007 – Inspection of search results SR-FUN-008 – Selection of search results SR-FUN-009 – Access to selected resource SR-FUN-010 – Service execution SR-FUN-013 – Information provision (registration)
10.	S10	Reusing an experiment	SR-FUN-003 – SDG - 15.3.1 Dashboard SR-FUN-004 – Data discovery (with relationships to associated concepts) SR-FUN-005 – Service Discovery (with relationships to associated concepts) SR-FUN-006 – Information Discovery (with relationships to associated concepts) SR-FUN-007 – Inspection of search results SR-FUN-008 – Selection of search results SR-FUN-009 – Access to selected resource SR-FUN-010 – Service execution SR-FUN-013 – Information provision (registration)

Table 4. Scenarios vs system required capabilities

5.3 System requirement capabilities vs User requirements

#	Code	Title	Linked User Requirements
1.	SR-FUN-003	SDG – 15.3.1 Dashboard	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-LDG-02 – SDG indicator 15.3.1 computation service execution UR-LDG-03 – Visual representation of SDG indicator 15.3.1 computations
2.	SR-FUN-004	Data Discovery (with relationships to associated concepts)	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-LDG-02 – SDG indicator 15.3.1 computation service execution
3.	SR-FUN-005	Service Discovery (with relationships to associated concepts)	UR-LDG-02 – SDG indicator 15.3.1 computation service execution
4.	SR-FUN-006	Information Discovery (with relationships to associated concepts)	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-LDG-02 – SDG indicator 15.3.1 computation service execution UR-AFG-06 - Accessing data, information and knowledge from AfriGEOSS
5.	SR-FUN-007	Inspection of search results	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-AFG-06 - Accessing data, information and knowledge from AfriGEO
6.	SR-FUN-008	Selection of search results	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-AFG-06 - Accessing data, information and knowledge from AfriGEO
7.	SR-FUN-009	Access to selected resource	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-AFG-06 - Accessing data, information and knowledge from AfriGEO
8.	SR-FUN-0010	Service Execution	UR-LDG-02 – SDG indicator 15.3.1 computation service execution
9.	SR-FUN-0011	Data Provision (Registration)	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery
10.	SR-FUN-0012	Service Provision (Registration)	UR-LDG-01 – SDG indicator 15.3.1 computation service discovery UR-LDG-02 – SDG indicator 15.3.1 computation service execution
11.	SR-FUN-013	Information Provision (Registration)	UR-LDG-03 – Visual representation of SDG indicator 15.3.1 computations
12.	SR-NFC-001	Configurability of search domain	UR-AFG-02 - The AfriGEO search keywords UR-AFG-03 - The AfriGEO Region of Interest UR-AFG-04 – The AfriGEO search domain
13.	SR-NFC-002	Portal customizability	UR-AFG-01 - A dedicated portal for the AfriGEO community UR-AFG-05 - The AfriGEO filtering capabilities

Table 5. System vs User Requirements Traceability

Annex A. References

[RD-1] D2.1 Use Cases Description and User Requirements Document – v1.0

[RD-2] D2.2 Functional and non-functional enhancements specification - v1.0

[RD-3] D3.2 Enhanced GEOSS Platform User Manual v1 with 1st set of applications

[RD-4] D3.3 The GEOSS Overarching Architecture

[WR-1] https://www.earthobservations.org/article.php?id=458

Annex B. Figures and Tables

List of Figures

List of Tables

Annex C. GEO DAB Standards

The table below provides an overview of all the standards handled by the GEO DAB

OGC CSW 2.0.2 AP ISO 1.0	INPE
OGC CSW 2.0.2 ebRIM EO	CKAN/DKAN
OGC CSW 2.0.2 ebRIM CIM	DCAT
ESRI GEOPORTAL 10	GI-cat
OAI-PMH 2.0	ESRI GEOPORTAL 10
OpenSearch 1.1	NCML-OD
OpenSearch 1.1 ESIP	BCODMO
OpenSearch GENESI DR	NCML-CF
CKAN	NetCDF-CF 1.4
CUAHSI HIS-Central	FTP populated with supported metadata types
ESRI REST API 10.3	WAF Web Accessible Folders
OGC WCS	GeoNetwork (2.2.0 or greater)
OGC WMS	Ecological Markup Language 2.1.1
OGC WFS 1.0.0, 1.1.0, 2.0.0	NERRS (National Estuarine Research Reserve System)
OGC WMTS	HMA CSW 2.0.2 ebRIM/CIM
OGC SOS 1.0.0, 2.0.0, 2.0.0 Hydro Profile	HDF
OGC WPS 1.0.0	IADC DB (MySQL)
OGC CSW 2.0.0 Core	GrADS-DS
OGC CSW 2.0.2 AP ISO 1.0	FedEO
OGC CSW 2.0.2 ebRIM/EO AP	ARPA DB (based on Microsoft SQL)
OGC CSW 2.0.2 ebRIM/CIM AP	ESRI Map Server
IRIS Station	SHAPE files (FTP)
IRIS Event	KISTERS Web - Environment of Canada
HYRAX THREDDS SERVER 1.9	Environment Canada Hydrometric data (FTP)
OAI-PMH 2.0 - Harvesting	OpenSearch 1.1
GBIF	Earth Engine
DIF	RASAQM
HYDRO	EGASKRO
UNAVCO	SITAD (Sistema Informativo Territoriale Ambientale Diffuso)
CDI 1.04, 1.3, 1.4	File System
ISO19115-2	GDACS
THREDDS 1.0.1, 1.0.2	GeoRSS 2.0
THREDDS-NCISO 1.0.1, 1.0.2	Degree catalog service 2.2
THREDDS-NCISO-PLUS 1.0.1, 1.0.2	OpenSearch GENESI DR
Healthsites API Json	

Table 6 - Standards handled by the GEO DAB

Annex D. Terminology

Acronyms and Abbreviations

EDGE	European Direction in GEOSS Common Infrastructure Enhancements
BON	Biodiversity Observation Network
CA	Consortium Agreement
CAMS	Copernicus Atmosphere Monitoring Service
C3S	Copernicus Climate Change Service
CEOS	Committee on Earth Observation Satellites
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
CNR-IIA	Consiglio Nazionale delle Ricerche – Istituto per l'Inquinamento Atmosferico
CO	Confidential
DESCA	Development of a Simplified Consortium Agreement
DEL	Deliverable
DG	Directorate-General
DN	Direct Negotiation
DOW	Description of Work
EAB	External Advisory Board
EC	European Commission
EGU	European Geosciences Union
EMS	Emergency Management Service
EO	Earth Observation
EOP	Earth Observation Programme
ESA	European Space Agency
ESAW	European Ground System Architecture Workshop
ESRIN	European Space Research Institute
EU	European Union
FP7	Seventh Framework Programme
GA	Grant Agreement
GCI	GEOSS Common Infrastructure
GEO	Group on Earth Observation
GEO DAB	GEO Discovery and Access Broker
GEOSS	Global Earth Observation System of Systems
GFOI	Global Forest Observation Initiative
GLAM	Global Agriculture Monitoring
GPE	GEOSS Portal Enhancements
GSNL	Geohazard Supersites and Natural Laboratories

GWOS	Global Wetlands Observing System
H2020	Horizon 2020
INT	Internal Note
IPR	Intellectual Property Right
JRC	Joint Research Centre
MOM	Minutes of Meeting
OTH	Other
PD	Project Director
PP	Programme Participants
PQMP	Project Quality Management Plan
PRE	Presentation
PSB	Project Strategic Board
PU	Public Usage
QA	Quality Assurance
QAS	Quality Assurance Support
RE	Restricted
SDG	Sustainable Development Goal
SUS	System Usability Scale
TBD	To Be Defined
TEP	Thematic Exploitation Platform
UNICEF	United Nations International Children's Emergency Fund
USGS	United States Geological Survey
UTB	User and Technical Board
WBS	Work Breakdown Structure
WGISS	Working Group on Information Systems and Services
WP	Work Package
WPL	Work Package Leader
UTF-8	8-bi Unicode Transformation Format
UTC	Coordinated Universal Time
RDBMS	Relational Database Management System
DDL	Data Definition Language
DML	Data Manipulation Language
TCL	Transaction Control Language
SMTP	Simple Mail Transfer Protocol
SSL	Secure Sockets Layer
TLS	Transport Layer Security
SPA	Single-page Application
API	Application Programming Interface
REST	Representational State Transfer
CORS	Cross-Origin Resource Sharing

CSP	Content Security Policy

Table 7 - Acronyms and Abbreviations