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Deliverable 8.4 – WP8 Prioritisation and selection of the Essential Variables (mainly, EBVs and ECVs) to be measured by the different field observatories and to be included in the EV VRE service

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Deliverable number:	D8.4
Work package:	WP8
Intermediate Objective:	
Deliverable type:	X Document, report
•	☐ Websites, patent filings, videos, etc.
•	• ☐ Other: please specify .....
Dissemination level:	X Public
•	• ☐ Restricted
Estimated delivery (bimester):	B6
Actual delivery date:	21/10/2023
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Note:	•

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System - CUP B53C22002150006 (D.D. n. 130/2022)
Funded by EU - Next Generation EU
Mission 4 “Education and Research” - Component 2: “From research to business” -
Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

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1. INTRODUCTION

1.1 ITINERIS - WP8 main goals

Each European environmental Research Infrastructure (RI) addresses specific issues, focusing on domains such as atmospheric or marine or spheres of interest such as biosphere or geosphere. In the Earth System the different compartments are highly interconnected with dynamics, cycles and interactions encompassing all spatial and temporal scales. Owing to this complexity, emergent environmental questions need to be tackled with system-thinking and cross-disciplinary approaches. The activities of WP8 use data, information and knowledge generated by the individual RI to create a system of Virtual Research Environments (VREs) and provide services where RIs from different disciplinary domains are harmonized to deal with scientifically and societally relevant topics.

This systemic approach will support the Italian role in several RIs and help taking a leading role to address complex, multi-disciplinary challenges. For each selected topic, a VRE is implemented. VREs represent innovative eScience facilities designed to address scientific and applied questions requiring serious effort in data harmonization, analysis, modelling and computational power. VREs are planned with a modular structure with semantic services for data discovery, harmonization and interoperability, data analysis and modelling services and workflows. Data from multiple sources and analysis and modelling tools is integrated in the VREs, allowing users to gain insight into the problems at hand. Users can then add their own data and analysis methods to respond to changing scientific and practical needs.

1.2 Tasks of 8.4 activity

The ITINERIS 8.4 activity is dedicated to the development of a VRE for Essential Variables (EVs) to allow visualisation and analysis of specific variables through web services and web tools. The EVs VRE will focus on:

i. variables described in the two global frameworks of Essential Biodiversity Variables (EBVs) and Essential Climate Variables (ECVs);

ii. outputs from the ITINERIS marine domain (WP5) and terrestrial biosphere (WP6), in terms of provided data, observed parameters, and deployed sensors;

iii. data and repositories available on the web;

iv. data collected at the sites belonging to the Italian Long-Term Ecological Research (LTER-Italy) network and to the eLTER Research Infrastructure.

The EV VRE will be an interactive web application developed using Shiny framework within the R environment. A dashboard will allow interaction with the EVs identified as priorities (prioritisation is the subject of this deliverable), allowing their selection, analysis and visualisation according to the researcher's outline.

Specific connectors (webhooks) will be developed to collect resources/data from domain repositories (e.g. OBIS, GBIF), geographic web services or general-purpose open repositories (e.g. Zenodo, B2Share). The collected raw data will then be transformed into specific EVs.

The features of the EV VRE will be:

- Data analysis and aggregation: specific tools will allow the aggregation of different raw data sets from various RIs and web resources to obtain EVs;

- Data visualisation: this tool will allow the visualisation of both raw and aggregated EVs through graphs or maps. Standard data representation methods, typical for each domain will be used;

- Collaboration and sharing: within the VRE, researchers will be able to collaborate and share their expertise in creating EV data streams and visualising them for different purposes.

The EV VRE will have a priority focus on the eLTER-RI sites. These will be considered as geographical locations where the EV VRE will prioritise its activities. For this reason, the below mentioned criteria adopted to prioritise the EVs take into particular account the data, the existing tools and the activities already existing within eLTER-RI for each variable.

2. THE ESSENTIAL VARIABLES (EVs) FRAMEWORKS

Essential variables (EVs) are variables known to be critical for observing and monitoring a given facet of the Earth system. Many professional organizations - the World Meteorological Organization, the United Nations Environment Program, the International Science Council, and the Group on Earth Observations (GEO) to name a few - have sponsored the collaboration of institutions across the World to identify essential variables in their respective fields of study. These include oceanography, climatology, biodiversity, and geodiversity. Having a common set of accurate and sustained measurements, coupled with standards for data collection and dissemination, ensures the usability of data across multiple platforms and agencies.

Consistent measurements of EVs, as identified by subject matter experts, need to be maintained over time to accurately serve as a means to monitor and assess change to Earth systems, including the atmosphere, biosphere, land, and ocean. Expert panels, consisting of scientific and technical individuals from academia, international space agencies, government organizations, and non-governmental organizations review the requirements for EV observations, including temporal frequency and spatial resolution. Subsequently, they match these requirements to the capabilities of existing instruments, ranging from moorings to satellites.

The Global Climate Observing System (GCOS) has identified a set of atmosphere, land, and ocean variables as Essential Climate Variables (ECVs).

The Global Ocean Observing System (GOOS) has developed the Essential Ocean Variables (EOVs), that focus on the physics of the ocean system, the biogeochemistry, and the biology and ecosystems.

Essential Biodiversity Variables (EBVs) capture the essential dimensions of biodiversity so that the state of biodiversity can be monitored and understood. They were developed by the Group on Earth Observations Biodiversity Observation Network (GEO BON).

2.1 Essential Biodiversity Variables (EBVs)

Biodiversity is the variety of life on Earth, including the variation of genes, species, and ecosystems. Current estimates for species, for example, suggest that Earth is home to at least 2 million to 6 billion species. These species, along with their associated ecosystems provide humans with a variety of critical "ecosystem services" including food, fiber, clean water, pollination, flood protection, recreation, and many more. However, ocean pollution and overfishing are among the causes of a rapid loss of biodiversity such as land use change from agriculture and urbanization, and climate change. Moreover, reducing the rate of biodiversity loss and averting dangerous biodiversity change are international goals, reasserted by the Aichi Targets for 2020 by Parties to the United Nations (UN) Convention on Biological Diversity (CBD).

GEO BON proposed a set of EBVs (Figure 1) to be used in monitoring programs and to understand patterns and changes in Earth's biodiversity. The EBVs have been grouped into six classes or sub-categories: genetic composition, species populations, species traits, community composition, ecosystem structure, and ecosystem function.

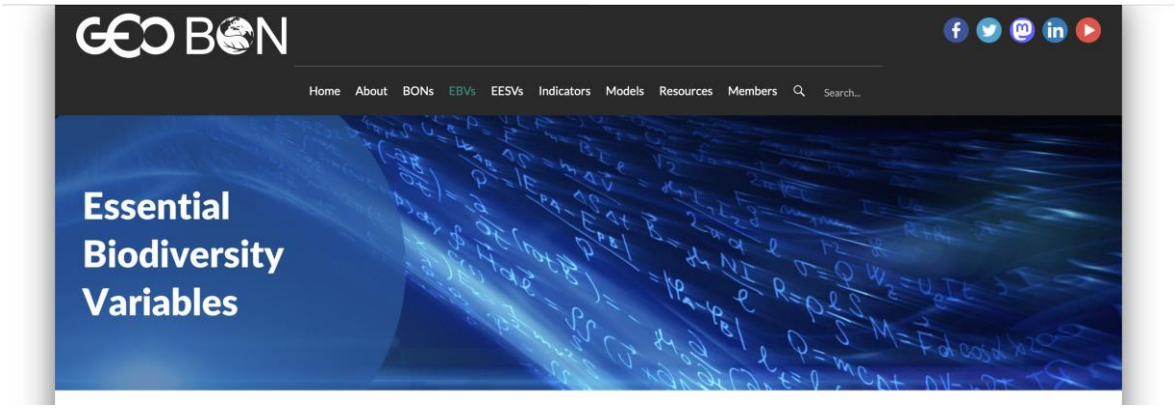

Figure 1 - The main website of the GEO BON (https://geobon.org/ebvs) dedicated to the EBVs framework.

The concept of EBVs was introduced to advance the collection, sharing, and use of biodiversity information, providing a way to aggregate the many biodiversity observations collected through different methods such as in situ monitoring or remote sensing. EBVs can be visualised as biodiversity observations at one location over time, or in many locations, aggregated in a time series of maps.

The process towards operationalising EBVs requires collecting biodiversity observations by individuals and groups, depositing raw data into databases using standard formats and metadata, and processing the data. The collected information could help to detect and model biodiversity changes for scientific, policy, and sustainable development applications. The underlying drivers and pressures of biodiversity change can then be identified and modelled. Validation of modelling can then feed into global and regional policy processes to explain observations, to improve forecasting of biodiversity change, and to produce global assessment reports.

EBVs are scalable, meaning the underlying observations can be used to represent different spatial or temporal resolutions required for the analysis of trends. For example, ecological community data collected at a location from different sampling events or methods can be combined into a single time series. The aggregated data may indicate the change in ecological communities across the region.

Developing and applying EBVs requires local, national, and international adoption of standard approaches to collect, store, and share biodiversity and environmental observations.

The full set of EBVs is listed at the link: https://github.com/EuropaBON/EBV-Descriptions/wiki.

2.2 Essential Climate Variables (ECVs)

In the 1990s, gaps in knowledge of climate and declining core observational networks in many countries led to calls for a systematic observation of a limited set of critical variables. To provide guidance, the Global Climate Observing System (GCOS) program developed the concept of ECVs, which has since been widely adopted in science and policy circles. An ECV is a physical, chemical, or biological variable or a group of linked variables that significantly contributes to the characterization of Earth's climate. ECV datasets provide the empirical evidence needed to understand and predict the evolution of climate, guide mitigation and adaptation measures, assess risks and attribute climatic events to underlying causes, and underpin climate services. ECV are identified based on the following criteria:

> Relevance: the variable is critical for characterizing the climate system and its changes.
> Feasibility: observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
> Cost effectiveness: generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage where possible of historical datasets.

GCOS has identified a set of 55 atmosphere, land, and ocean variables (Figure 2). The atmosphere ECVs cover both surface and upper-air atmosphere, as well as atmospheric composition. Land ECVs cover the hydrosphere, cryosphere, biosphere, and anthroposphere. Ocean ECVs cover physical, biogeochemical, and biological/ecosystems disciplines. In order to fully understand Earth's integrated system and the interactions therein, among various elements that affect climate, the ECVs are accompanied by descriptions of the measurement requirements for spatial and time scales. the types of observing platforms currently employed, existing capability gaps, and future observing opportunities are also noted. ECVs undergo periodic review and updates, ensuring that newly feasible variables (ones that technology has now made practical) are added as appropriate.

The full list of ECVs can be found at the link: https://library.wmo.int/index.php?lvl=notice_display&id=22135

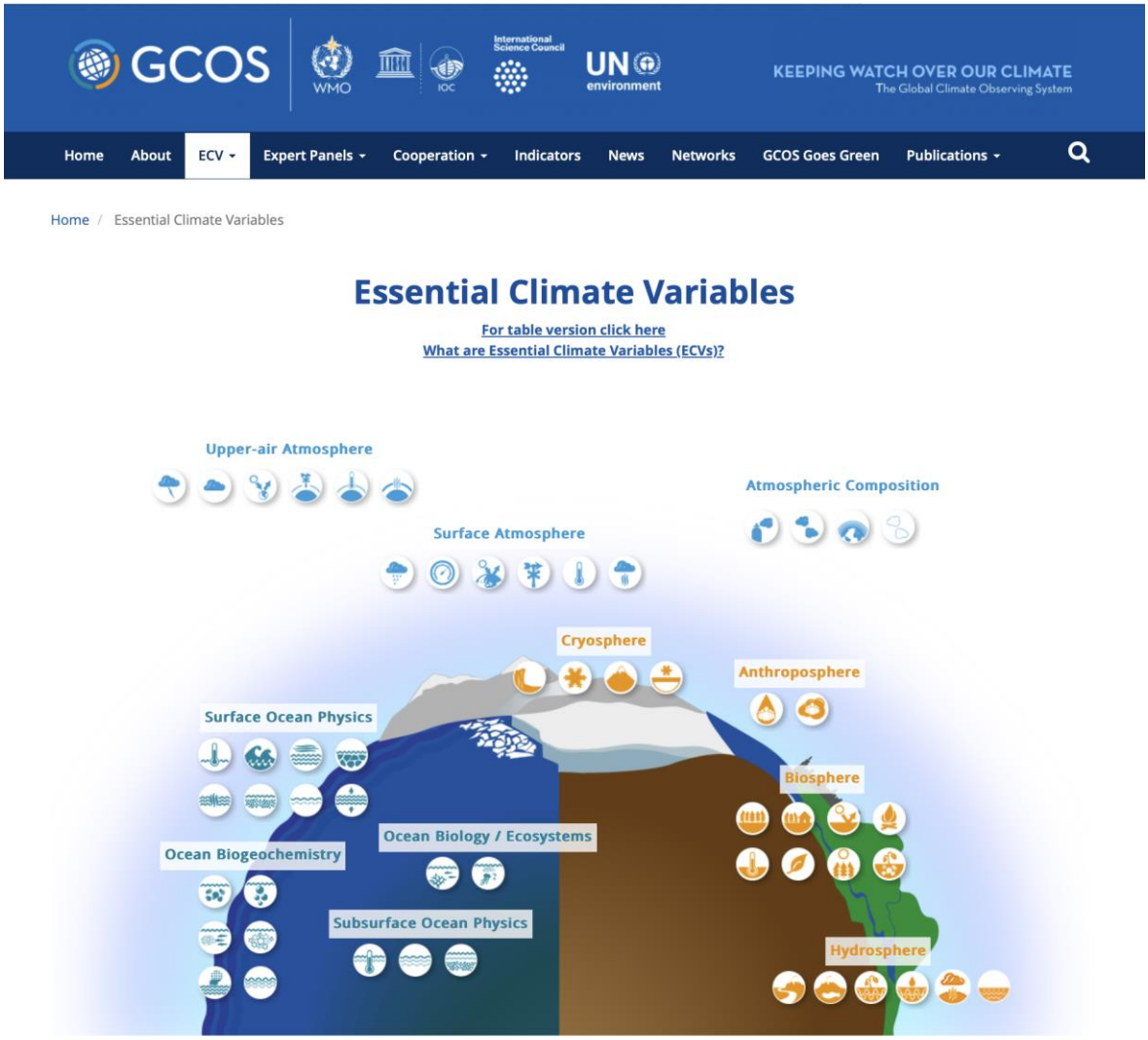

Figure 2 - List of ECVs related to the different spheres. The figure is taken from the World Meteorological Organisation (WMO) website (https://gcos.wmo.int/en/essential-climate-variables/), which is specifically dedicated to ECVs.

3. PRIORITIZATION OF EVs

While the main purpose of Action 8.4 is to build and implement the EVs VRE, the aim of this Deliverable is to produce a list of selected EBVs and ECVs, among those collected in the framework of the different RI, to be included into the EB VRE. For doing this, a set of evaluation criteria was defined.

3.1 Evaluation criteria

In this deliverable and for the purposes of Activity 8.4, the following criteria have been adopted to prioritise EVs:

Data availability

This criterion distinguishes EVs based on the data availability on the WEB. The lack of raw data available as open data with appropriate open licences is the first element that can lead to the inability to calculate or determine an EVs. Given the scope of the project, the data considered are:

- time series data measured and provided by eLTER sites/platforms that are already available or expected to be available in the near future;
- time series data measured, provided and already shared by other RIs (e.g. Euro-ARGO, JERICO, DANUBIUS, ICOS and EMSO) or European networks (e.g. ICP Forest) that are already available or expected to be available in the near future;
- existing data provided by third party repositories (see chapter number 5 for a comprehensive list).

Relevance for researchers

This criterion is based on the selection made by a number of researchers of the EBVs or ECVs within the marine, terrestrial, and freshwater sectors.

Each colleague was interviewed and then provided a list of significant variables, highlighting those of high relevance in their area of expertise.

Instrumentation availability and implementation

This criterion priorities EVs based on the presence of instruments/sensors that collect observations and measurements useful to be included as EVs.

The criterion takes into account the current instruments at eLTER sites involved in the project, as well as those scheduled to be acquired via ITINERIS.

Existence of similar VREs

This fourth criterion is based on the availability of VREs already published on the web that manage, provide, and calculate EVs. This criterion allows us to prevent duplication, promoting the creation of a really innovative VRE.

The criteria mentioned above were proposed to 12 colleagues, some of whom are also co-authors of this deliverable. They are experts in different fields and belong to different research infrastructures. These colleagues, thanks to their specific experience, were able to

provide an assessment, especially with regard to the criteria of relevance to research and availability of data, according to a principle of subjectivity guided by in-depth knowledge of the sector.

On the other hand, a principle of objectivity was applied to the criteria related to the availability of tools and the existence of similar VREs. In this case, we relied on the work already carried out by ITINERIS (D5.3 - Report on the GAP analysis of marine facilities and equipment and access procedures) and on the search for VREs on the web and on the D4Science.org gateway, also based on the knowledge of co-authors and contacted colleagues.

3.2 EVs Spheres

The ITINERIS project is formally divided into work packages covering the atmosphere (WP4), the marine domain (WP5), the terrestrial biosphere (WP6) and the geosphere-landsurface (WP7). Both terrestrial and freshwater biospheres are included in WP6.

Following this categorization, and considering that:

- i. the different frameworks, in particular the ECVs, also follow similar categorization;
- ii. other VREs in this WP will work on specific domains;
- iii. this activity is mainly aimed at the eLTER-RI, the EVs have been prioritized and selected for three of the domains: marine, terrestrial and aquatic (as freshwater).

4. PRIORITIZED EVs

By contacting the Domain Researchers and applying the other criteria described above, we were able to identify the following EVs as priorities.

In the next pages, the selected variables are summarised by a short description, a link to the page present in the two reference web portals (web page) and an indication of the variable or parameter needed for calculating or providing the variable itself (parameter(s) or variable(s)).

4.1 ECVs and EBVs selected for the marine domain

4.1.1 Ocean, Biogeochemical: Nutrients

EV type: ECV

Domain: Marine

Description: Nutrients are crucial for oceanic organisms. Nutrient data provides significant biogeochemical insights, with critical connections linking physical climate shifts and ecosystem fluctuations. Additionally, they can give valuable information on ocean mixing and climate phenomena, such as primary and export production modifications (nutrient transports dictate new production and are linked to export production), eutrophication, and alterations in phytoplankton

community composition. Therefore, it is essential to make precise observations of dissolved nutrient trends in both upper and deep ocean waters.

Web page: https://gcos.wmo.int/en/essential-climate-variables/nutrients/

Parameter(s) or variable(s): concentration of Silicate, Phosphate, Nitrate in water (e.g. ug/l or mg/l)

4.1.2 Ocean, Biogeochemical: Ocean Colour

EV type: ECV

Domain: Marine

Description: Ocean Colour (OC) is the radiance that originates from the ocean, normalized by the irradiance that illuminates it. Ocean Colour Remote Sensing (OCRS) derived products contain information on the ocean albedo and the constituents of seawater, specifically the pigments included in phytoplankton cells such as the chlorophyll-a. OCRS products are employed for the assessment of the wellbeing and output of ocean ecosystems, the analysis of the oceans' involvement in global carbon circulation, the management of living marine resources, and the determination of the repercussions of climate variability and change.

Web page: https://gcos.wmo.int/en/essential-climate-variables/ocean-colour/

Parameter(s) or variable(s): Chlorophyll-a Concentration (e.g. mg/m3 or ug/l)

4.1.3 Ocean, Biogeochemical: Oxygen

EV type: ECV

Domain: Marine

Description: Oxygen (O_2) is critical for the survival of almost all organisms. Oxygen levels in subsurface waters mirror a balance between supply primarily from circulation and ventilation and depletion from respiratory activities. Any alteration in either of these processes could result in changes in O_2 levels. Establishing a global network for observing oceanic O_2 concentrations will play a significant role as a sensitive early warning system for climate change-induced O_2 level fluctuations. Ocean deoxygenation, characterized by a decrease in O_2 concentration, is partially caused by ocean warming and increased stratification, as well as by growing nutrient loads in the coastal ocean. Despite its profound implications not only for ecosystems but also for societies and economies that rely on a healthy ocean, deoxygenation has gone unnoticed by many, including policymakers and decision-makers.

Web page: https://gcos.wmo.int/en/essential-climate-variables/oxygen/

Parameter(s) or variable(s): Dissolved Oxygen Concentration in water (e.g. mg/l)

4.1.4 Phenology of marine spring phytoplankton bloom

EV type: EBV

Domain: Marine

Description: Phenology is defined as “the study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life”. In many environments, including the upper water-column of oceans, the seasonal cycle sets much of the total environmental variability experienced by individual organisms and populations. The seasonal range of upper ocean environmental conditions

is typically greatest at mid and high latitudes, but substantial seasonal variations of environment and plankton biomass also occur in many tropical regions.

Web page: https://github.com/EuropaBON/EBV-Descriptions/wiki/Marine-Phenology-of-marine-spring-phytoplankton-bloom

Parameter(s) or variable(s): Day of start-of-blooming, Day of end-of-blooming, Blooming amplitude, Slope of the blooming up period, and Length of the blooming season

4.1.5 Marine ecosystem productivity

EV type: EBV

Domain: Marine

Description: Productivity within an ecosystem pertains to the proportion of energy that enters the ecosystem in the guise of biomass at a specific trophic level. It denotes the pace at which biomass develops within the ecosystem.

Web page: https://github.com/EuropaBON/EBV-Descriptions/wiki/Marine-Marine-ecosystem-productivity

Parameter(s) or variable(s): Net primary production (e.g. $gC/m^2/year$), Biomass (e.g. gC/m^2), Surface chlorophyll-a concentrations (e.g. mg/m^2)

4.2 ECVs and EBVs selected for the terrestrial sphere

4.2.1 Surface temperature

EV type: ECV

Domain: Terrestrial

Description: Land Surface Temperature (LST) refers to the temperature of the ground surface. It is primarily influenced by albedo, vegetation cover, and soil moisture. Climate-wise, LST plays a crucial role in assessing land surface and land-atmosphere exchange processes, limiting surface energy budgets and model parameters, and offering observations of global and specific region surface temperature alterations.

Web page: https://gcos.wmo.int/en/essential-climate-variables/land-temperature/

Parameter(s) or variable(s): Land surface temperature (e.g. degree Celsius)

4.2.2 Precipitation

EV type: ECV

Domain: Terrestrial

Description: Precipitation, in liquid or solid form, is the foremost climate variable that directly impacts humans. It affects water resources, poses risks to life and livelihoods during floods, landslides and droughts, and influences infrastructure planning, leisure activities and other areas. Precipitation is interrelated with cloud properties, various terrestrial essential climate variables, and

ocean-surface salinity. It is indicative of the release of latent heat within the energy cycle, as well as being at the heart of the hydrological cycle.

Web page: https://gcos.wmo.int/en/essential-climate-variables/precipitation

Parameter(s) or variable(s): Dew Point Temperature (near Surface, e.g. degree Celsius), Relative Humidity (near surface, e.g. in percent), Air Specific Humidity (near surface, e.g. in percent), Rainfall (e.g. mm)

4.2.3 Terrestrial ecosystem productivity

EV type: EBV

Domain: Terrestrial

Description: Productivity within an ecosystem pertains to the proportion of energy that enters the ecosystem in the guise of biomass at a specific trophic level. It denotes the pace at which biomass develops within the ecosystem.

Web page: https://github.com/EuropaBON/EBV-Descriptions/wiki/Terrestrial-Terrestrial-ecosystem-productivity

Parameter(s) or variable(s): Gross primary production (e.g. $gC/m^2/year$), Net primary production (e.g. $gC/m^2/year$), and Biomass (e.g. gC/m^2)

4.2.4 Species distributions of selected terrestrial plants

EV type: EBV

Domain: Terrestrial

Description: The occurrence or likelihood of the presence of vascular plant species on land within adjacent areas (grid cells) over a period.

Web page: https://github.com/EuropaBON/EBV-Descriptions/wiki/Terrestrial-Species-distributions-of-selected-terrestrial-plants

Parameter(s) or variable(s): Binary presence/absence, Probability of occurrence

4.2.5 Terrestrial ecosystem phenology

EV type: EBV

Domain: Terrestrial

Description: The seasonal pattern of vegetation variation on land surfaces over time, detected through remote sensing within contiguous spatial units, or grid cells.

Web page: https://github.com/EuropaBON/EBV-Descriptions/wiki/Terrestrial-Terrestrial-ecosystem-phenology

Parameter(s) or variable(s): Day of start-of-season, Day of end-of-season, Day of maximum-of-season, Season amplitude, Length of season, Slope of the greening up/senescent period

4.3 ECVs and EBVs selected for the freshwater sphere

4.3.1 Lake Surface Water Temperature (LSWT)

EV type: ECV

Domain: Freshwater

Description: It is correlated with regional air temperatures and a proxy for mixing regimes, driving biogeochemical cycling and seasonality.

Web page: https://gcos.wmo.int/en/essential-climate-variables/lakes

Parameter(s) or variable(s): surface water temperature (e.g. degree Celsius)

4.3.2 Lake Water Level (LWL)

EV type: ECV

Domain: Freshwater

Description: A proxy fundamental to understand the balance between water inputs and water loss and their connection with regional and global climate changes.

Web page: https://gcos.wmo.int/en/essential-climate-variables/lakes

Parameter(s) or variable(s): -

4.3.3 Freshwater ecosystem productivity

EV type: EBV

Domain: Freshwater

Description: Productivity in an ecosystem refers to the percentage of energy that enters the ecosystem in the form of biomass at a particular trophic level. It is the rate at which biomass is formed in freshwater ecosystems and transitional waters.

Web page: https://github.com/EuropaBON/EBV-Descriptions/wiki/Freshwater-Freshwater-ecosystem-productivity

Parameter(s) or variable(s): Net primary production (e.g. $gC/m^2/year$), Biomass (e.g. gC/m^2), Surface chlorophyll-a concentrations (e.g. mg/m^2)

5. DATA REPOSITORIES

During this phase, we have also identified several repositories that will serve as data sources for the EVs VRE. Table 1 presents the list of these resources, which we obtained through the authors' direct knowledge, since they were directly involved in creating the database or they are already using these repositories as a source of data.

This list is not exhaustive, it will be periodically updated during the implementation of VREs. This will include the discovery of new online resources, as well as the release of new resources through the Application Programming Interface (API) or web services in an open and accessible format.

Table 1 – Each line presents detailed information about a repository, including a brief description, a hyperlink to access the resource online, a concise overview of the type of data, and most importantly, an indication of which of the selected EVs the repository can contribute to.

Repository name	Description	Web address	Data type	Contribution to EVs
eLTER Dataset Asset Registry	The data catalog of the eLTER research infrastructure	https://catalogue.lter-europe.net/elter/documents	All the dataset collected in the eLTER RI European sites	All EVs
B2Share	The B2Share data catalog customized by the German research institute Forschungszentrum Jülich (FZJ)	https://b2share.fz-juelich.de/communities	Contains datasets collected by: some eLTER RI sites, European CORDEX (EURO-CORDEX) initiative, and Helmholtz Association of German Research Centres	All EVs
LTER EDI and Data One	The environmental data repository that curates and maintains data from North American LTER sites	https://portal.edirepository.org/ and https://www.dataone.org	All the dataset collected in the North American LTER sites	All EVs
PANGAEA	The Open Access library aimed at archiving, publishing, and distributing georeferenced data from earth system research	https://www.pangaea.de	General-purpose dataset	All EVs
Zenodo	A general-purpose open repository to deposit research papers, data sets, and any other research	https://zenodo.org	General-purpose dataset	All EVs

	related digital artefacts			
iNaturalist	An online social network for sharing biodiversity information	https://www.inaturalist.org	Biodiversity observation	4.1.4, 4.2.3, 4.2.4, and 4.2.5
OBIS (Ocean Biodiversity Information System)	A global open-access data and information clearing-house on marine biodiversity	https://obis.org	Biodiversity dataset	4.1.4, 4.2.3, 4.2.4, and 4.2.5
GBIF (Global Biodiversity Information Facility)	An international network and data infrastructure for open access to data about biodiversity	https://www.gbif.org	Biodiversity dataset	4.1.4, 4.2.3, 4.2.4, and 4.2.5
GOOS (Global Ocean Observing System) BioEco Metadata Portal	A platform that provides data and metadata on the sustained ocean observing programs.	https://bioeco.goosocean.org	Oceanographic dataset	4.1.1, 4.1.2, 4.1.3, 4.1.4, and 4.1.5
GEO Bon (Group on Earth Observations Biodiversity Observation Network) EBV portal	A data portal for collect and share EBV raster data.	https://portal.geobon.org	EBV raster dataset	All EBVs
ESA (European Spatial Agency) Climate data Dashboard		https://climate.esa.int/en/odp		All ECVs
ESA Lakes Climate Change Initiative (Lakes CCI)	The Lakes Essential Climate Variable dataset repository	https://catalogue.ceda.ac.uk/uuid/a07deacaffb8453e93d57ee214676304	Lake remote sensing products	4.3.1, 4.3.2, and 4.3.3
NERC (Natural Environment Research Council) Data	The metadata catalogue of Natural Environment	https://data-search.nerc.ac.uk	Environmental dataset	All EVs

Catalogue Service	Research Council			
CEDA (Centre for Environmental Data Analysis) Archive	The UK's national data center for atmospheric and earth observation research	https://catalogue.ceda.ac.uk	Environmental dataset	All EVs
BioGeoChemical-ARGO	Data access portal of Argo sensors	https://biogeochemical-argo.org/data-access.php	Ocean biogeochemical observations	4.1.1, 4.1.2, 4.1.3, and 4.1.5 (for chlorophyll)

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