Deliverable D1.1 – Report on data requirements

Lead Beneficiary: CMCC

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30/06/2025

Funded by
the European Union

Prepared under contract from the European Commission

Grant agreement No. 101185000

Project acronym:	**CONCERTO**
Project full title:	**Improved CarbOn cycle represeNtation through multi-sCale models and Earth obseRvation for Terrestrial ecOsystems**
Start of the project:	January 2025
Duration:	48 months
Project coordinator:	Manuela Balzarolo
Deliverable title:	Report on data requirements
Deliverable n°:	D1.1
Nature of the deliverable:	[Report]
Dissemination level:	[Public]
WP responsible:	WP 1
Lead beneficiary:	CMCC
Author/reviewers	**Authors**: Manuela Balzarolo, Maria Luisa Quarta **Reviewers**: Sara Totaro (CMCC) Daniele Peano (CMCC)
Citation:	Balzarolo, M. and Quarta M. L. (2025) CONCERTO ***D1.1. Report on data requirements***
Due date of deliverable:	Month n° 6
Actual submission date:	Month n° 30/06/2025
Deliverable status:	Submitted

Version	Status	Date	Author(s)/Reviewer
1.0	Draft	22/05/2025	Manuela Balzarolo – CMCC – 1st Draft
2.0	Draft	27/05/2025	Manuela Balzarolo – CMCC – Finalisation of 1st draft
2.1	Review	27/05/2025	Sara Totaro – CMCC – Review
2.2	Review	30/06/2025	Daniele Peano – CMCC – Review
3.0	Final	30/06/2025	Sara Totaro – CMCC – proofreading, layout, submission

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List of Abbreviations

DMP	Data Management Plan
ECVs	Essential climate variables
EO	Earth observation
FAIR	FAIR Findable, Accessible, Interoperable, and Reusable,
INSPIRE	Infrastructure for Spatial Information in the Europe
ISO	International Organization for Standardization
WG	Working group
WP	Work package
WMO	World Meteorological Organization

Executive summary

Deliverable 1.1 – Report on data requirement details the activities performed in task 1.1. and explain the methodology for metadata collection. This methodology supports the integration from various sources, which is essential for achieving a comprehensive understanding of the terrestrial carbon cycle. Such integration enables the identification of key feedback mechanisms (e.g., changes in vegetation driven by climate change) that can influence carbon fluxes and stocks, highlighting the importance of continuous monitoring and harmonised data inputs.

A central focus during the first six months was the establishment of **common data standards**, in alignment with the guidelines outlined in *D6.8 – Data Management Plan* and *D1.2 – Report on CONCERTO data sharing framework*.

To support this, we conducted an **ontology exercise**, explained in Section 2, **aimed** at identifying and organising the key data needs linked to our project goals. This process helped us to define, for the first time, a standardised set of **common variable names and definitions**, ensuring consistency across all project activities and aligning with recognised **international data standards**. The list of variables will be continuously updated during the project lifecycle.

The datasets considered useful for the CONCERTO activities are described through an Excel template, the **Data Mapping Form** (DMF) which is described in details in Section 3.1 – available at this link – CONCERTO_Data_Mapping_Form.xlsm[1].

[1] **Access management** – In order to guarantee the privacy of CONCERTO's partners involved in this activity, the access to this form is regulated and upon request.

1. Introduction

The terrestrial carbon cycle, which involves the exchange of carbon between the atmosphere and biosphere, plays a pivotal role in regulating atmospheric CO_2 levels and, consequently, Earth's climate. By using multiple data sources and methods, the CONCERTO project aims to achieve some main objectives, as summarised in Figure 1.

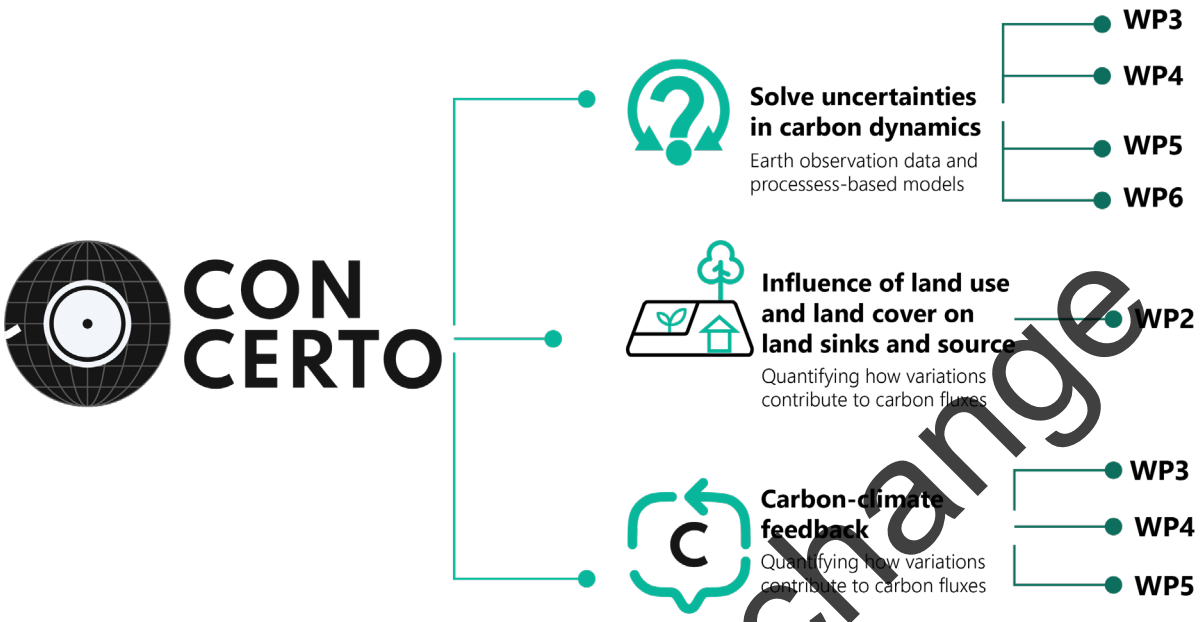

Figure 1. CONCERTO's objectives and relevant WPs addressing them.

- *Solve uncertainties in carbon dynamics* – Despite extensive studies using *in situ* measurements, Earth observation (EO) data and process-based models, the primary biophysical mechanisms governing ecosystem-carbon-climate interactions remain unclear. **CONCERTO's WP3, WP4, WP5 and WP6** will shed light on this topic.
- *Quantifying the influence of land use and land cover changes on land sink and source* **– WP2** will address how variations in land use contribute to carbon fluxes, leading to increased regional carbon emissions on seasonal to interannual scales. However, these changes do not necessarily result in long-term positive or negative feedback [1].
- *Improving the understanding of carbon-climate feedback* **–** Finally **WP3, WP5, W6** will address the complexity of carbon-climate feedback, with a focus on how changes in carbon allocation affect climate systems.

To achieve these objectives, CONCERTO brings together a diverse **range of scientific communities**, including data modellers, machine learning researchers, and other

domain experts and will require the extensive use of a variety of data to build and improve models, train machine learning algorithm and to validate model simulations.

It has been therefore of paramount importance to address the data requirements essential for achieving the project's objectives. This deliverable describes the methods adopted in CONCERTO to support the data collection and cataloguing, as well as to ensure that data are findable, understandable and reusable, in line with the FAIR (findable, accessible, interoperable, and reusable) principles (see details in DMP D8.6).

This deliverable shall be read in strict link to D8.6 (*Data management plan – DMP*) and D1.2 (*Report on CONCERTO data sharing framework*). These three deliverables contribute to define the **overarching data strategy** adopted by the Consortium. While the DMP is intentionally structured to offer a clear and descriptive overview of the principles, approaches, and governance mechanisms guiding data use in CONCERTO, this report provides the strategic foundation and technical implementation details on the process of building the data user requirements. The deliverable links are illustrated in Figure 2.

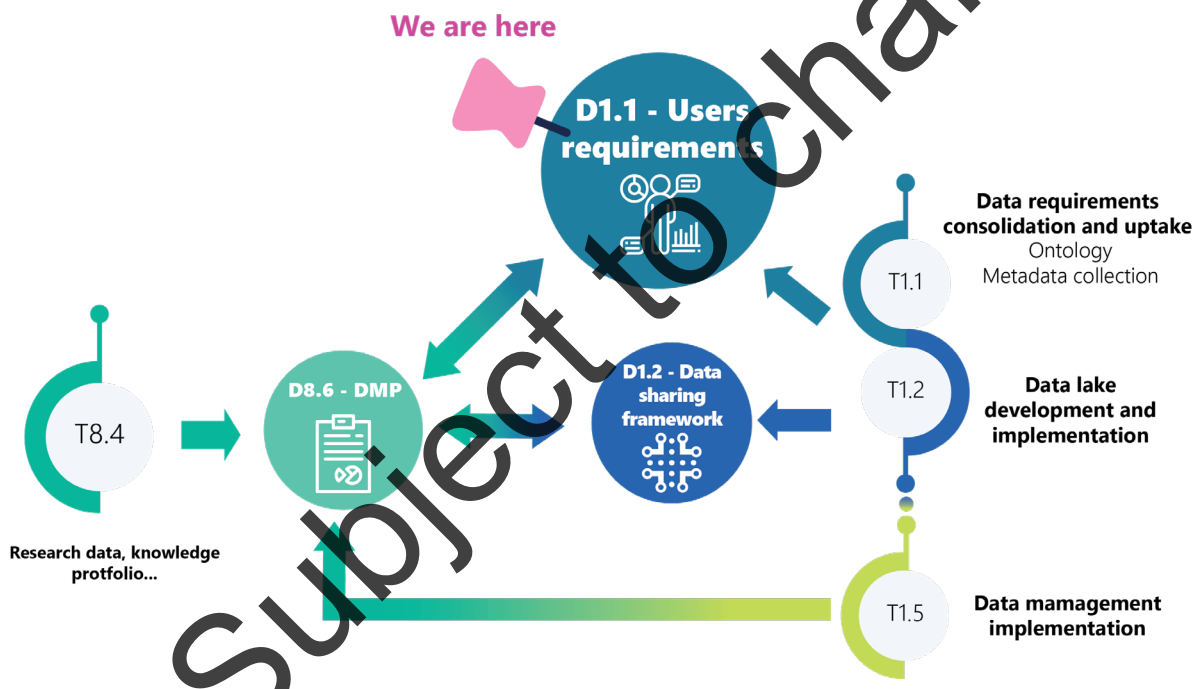

Figure 2. Interconnection and links between D1.1, D1.2 and D8.6. The link with the WP1 tasks is also explicated as these tasks are essential for the development of the CONCERTO infrastructure (T1.1 and T1.2) as well as for the implementation of the best practice.

As can be deducted by Figure 2, *Work Package 1 – Data sharing framework* is the main WP in CONCERTO dealing with the data management and has the overall objective to facilitate the construction of a data sharing framework, which will be populated with

the datasets that CONCERTO's researchers will deem relevant for the execution of the project activities. In addition to this, as shown in Figure 3, it aims at building a data framework and collect relevant data for the execution of the project activities.

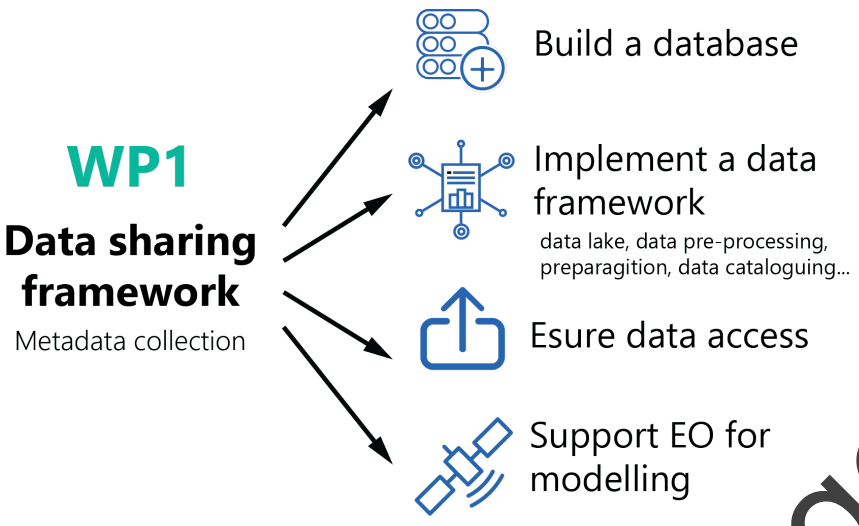

Figure 3. Main objectives of WP1.

2. Setting up a common minimum ontology

Since the beginning of CONCERTO (during its Kick-off Meeting), it became evident that the scientific communities involved in CONCERTO had differing interpretations of key technical terminology.

To facilitate effective collaboration and establish a shared foundation for communication—particularly around technical concepts—the consortium agreed to develop a **common minimum ontology**.

The ontology acts as a reference framework for all partners, ensuring consistent understanding and interpretation of key terms within the CONCERTO context. For this, a dedicated working group (WG), encompassing representatives from the different communities involved in CONCERTO, has been created and its activity will take place along the whole development of the project.

Moreover, the ontology will play a crucial role during the dissemination of project results, providing stakeholders with clear definitions and explanations of the terminology used. This will help ensure that the meaning assigned to each term in CONCERTO is transparent, consistent, and easily understood also by external audiences.

2.1. Validation of the Essential Climate Variables

The starting point to build CONCERTO's ontology are the Essential climate variables (ECVs) as defined by the World Meteorological Organization (WMO) [4]. As shown in Figure 4, the process that led to set CONCERTO's ontology has been participatory.

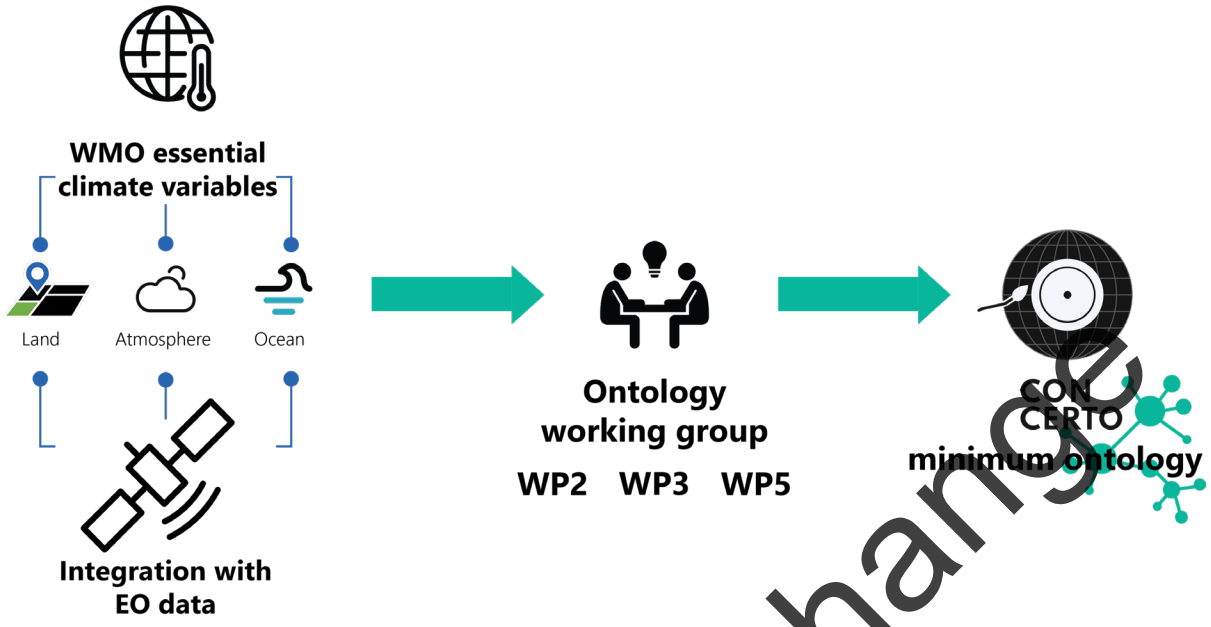

Figure 4. Process to build CONCERTO's minimum ontology process.

With the goal to establish clear and shared definitions, representatives from different WPs have worked together in the WG. They analysed and discussed those variables that have been identified as problematic or ambiguous in terms of interpretation across the different scientific communities involved in the project, suggesting minor modifications where necessary. These definitions will then be adopted within CONCERTO as the project's common understanding, serving as a reference for all partners and external stakeholders.

2.2. Variables from other sources

Furthermore, to capture the variety of inputs utilised by CONCERTO researchers, definitions and data from the following sources have also been considered:

- *in situ* measurements,
- EO data,
- process-based and land surface models,
- integrated carbon observation networks.

Variables relevant to the ecological components of the carbon cycle [4], which are essential for the project development, have also been included in the list (source has been indicated as 'Terrestrial Carbon Cycle' variables).

To clarify the intended use of these variables, the Working Group (WG) has also defined the concepts of input and output variables. **Input variables** are those used to parameterise and run models; they may include both ECVs and ecological variables. **Output variables**, on the other hand, are estimated by models using input variables. Notably, an output variable may also serve as an input for subsequent applications—either within the CONCERTO project or by external stakeholders, such as sister initiatives (e.g. the HE NextGenCarbon project) or other interested parties.

The list of these variables, their sources and other main attributes is reported in Annex1.

3. Methodology for metadata collection

In order to perform the activities as described in the Description of Action (DoA), CONCERTO will collect, store, and make available to the project partners and its stakeholders a series of datasets.

3.1. Data Mapping Form

Being the project in its initial phase, a complete set of information required to accurately define the metadata for the datasets that will be generated by the project is not yet available. Therefore, the datasets considered useful for the CONCERTO activities will be initially described through an Excel template, the **data mapping form** (DMF, CONCERTO_Data_Mapping_Form.xlsm[1]).

The metadata description methodology adopted in this project is based on a standardised and structured spreadsheet template designed to systematically capture information across all stages of the data value chain. This includes metadata related to data origin (e.g. source, product, and responsible partner), scientific characterisation (such as variable names, definitions, domains, and subdomains), data generation and processing methods, and detailed information on access conditions, licensing, and intended reuse. The template ensures harmonisation across datasets and partners by promoting common terminology, naming conventions, and variable categorisation, thereby facilitating semantic interoperability.

Priority will be given to input data and to those generated as final outputs. Assessments and any selections may also concern certain intermediate products that are particularly useful to partners and stakeholder communities.

Each metadata record contributes to the transparency, traceability, and long-term usability of the data, supporting robust research workflows and cross-disciplinary integration. Furthermore, the methodology is explicitly aligned with the four foundational FAIR principles. It enhances findability through structured fields for unique identifiers and standardized naming; accessibility via clearly specified access modes, restrictions, and links; interoperability through the adoption of recognized scientific classifications and metadata standards where applicable; reusability by providing comprehensive contextual information, including data examples, quality indicators, and licensing terms.

This approach enables all project partners to describe their datasets consistently, while supporting the integration of metadata into the Data Lake that will be implemented in the context of *Task 1.2 - Data Lake development and implementation*.

3.2. Data Mapping Form Structure

The DMF (CONCERTO_Data_Mapping_Form.xlsm[1]) is composed by a series of data sheets.

- **Instructions:** contains the definition of the different fields to guide the users during the filling process;
- **Template:** where the project partners will report the metadata for the dataset of interest (one row per dataset);
- **Sample naming convention:** contains the guidelines for naming the dataset that will be provided;
- **Partners' short names:** including the list of abbreviations for the CONCERTO partners (useful to build the above naming convention);
- **Variable list:** containing the list of variables selected to build the CONCERTO ontology (see section);
- **Check sheet:** used to categorise and keep track of all the missing information as well as of data duplication.

Each row in the DMF corresponds to a unique dataset, which refers to a specific variable from the variable list and is described using a consistent set of metadata fields as listed below:

- **ID**: unique identifier for reference and traceability;
- **data source** and **product**: origin and specific output or dataset name;
- **variable name**, **variable domain**, **variable subdomain**, **scientific area**: define the thematic scope and scientific context of the data.
- **variable definition**: provides a clear and standardised explanation of the variable's meaning;
- **variable type**: allows the partners to specify whether the described dataset is going to represent an input, an output or both for the models' implementation, where input all variables that can be measured through the Earth system observations are considered, while as output all the derived variables are included;
- **existing/foreseen data**: specifies whether the data currently exists or will be generated;
- **type**, **IoT**, **format**, **size**: capture the technical specifications, including data type (e.g., big data, remote sensing), IoT integration, file format, and data volume.
- **time coverage**, **area coverage**, **spatial resolution/scale**, **temporal resolution**, **release frequency**: describe the spatial-temporal characteristics of the dataset;
- **licence**: details legal permissions and restrictions for reuse;
- **creator** and **creator affiliation**: identify the responsible data producer and institution;
- **access mode**, **access restrictions**, **access links**, **access preference**: specify how the data can be accessed, including technical means (e.g., API or web interface), legal constraints, and direct URLs;
- **metadata standard**: lists any existing metadata schema or standard adopted (e.g., ISO, INSPIRE);
- **stakeholders**: notes actors with interests in the data (e.g., users, maintainers, beneficiaries);
- **data example**: provides a sample named following the project naming convention to support the data lake implementation;
- **data described by**: provides the reference of the partner describing the dataset, as contact point to be used in case of issues/questions related to the dataset;
- **task interested**: links the data to specific project tasks, ensuring traceability within work packages;
- **comments**: offers space for additional notes, clarifications, or relevant context.

The DMF has been developed and **co-designed** with the support of a selected number of partners, who validated its structure providing preliminary data descriptions,

offering critical feedback on its applicability, and ensuring its alignment with real-world data management needs across various domains.

After having consolidated the DMF structure with the support of a selected group of partners, the template is going to be shared with the rest of the Consortium to allow all partners to provide their input in terms of metadata descriptions. Building on the existing Excel-based metadata collection template, a dedicated **metadata management system** is under implementation at the time of writing.

3.3. Explorer – the metadata management system

The Explorer is a graphical user interface designed to offer an interactive and user-friendly way to discover, explore, and access datasets within the CONCERTO portfolio.

In the current phase of the project, development is focused on creating a generic interface that supports a two-step search process, as illustrated in Figure 5.

Figure 5. Schematic overview of the two-step data search supported by the Explorer.

Figure 6 shows the Explorer interface for the two steps.

The technical details on how Explorer is set up and works are found in *D1.2 – Report on CONCERTO Data Sharing Framewok*.

As well as the DMF, the metadata management system is fully digitalised and will be subject to continuous updates, following the data requirements that will be collected during the project implementation. For this reason, 6-months checks and updates to its structure are foreseen, assuming that a consistent amount of feedback from the partners is collected. Quality checks and data curation procedures will also be applied regularly to ensure that there is no data duplication.

Figure 6. Explorer: dataset discovery – interface for the two steps.

4. Conclusions

This document reports on the approach establishing CONCERTO for data requirements. To provide shared data definitions, an initial working group aiming at developing a minimum ontology requirement has been set up within the various groups involved in CONCERTO. Based on this, a Data Mapping Form gathers the definitions, sources, and availability of the data fields required in the project following the Data Management Plan, described in *D8.6*. Moreover, the data requirement workflow introduced also ensures that the data adheres to the FAIR principles.

References

REF NUMBER	DOCUMENT / LINK
1	Regulation (EU) 2021/695 establishing Horizon Europe
2	EU Horizon Europe Data Management Template. https://www.openaire.eu/images/Guides/HORIZON_EUROPE_Data-Management-Plan-Template.pdf
3	Govind, A., Kumari, J., 2014. 'Understanding the Terrestrial Carbon Cycle: An Ecohydrological Perspective', *International Journal of Ecology* (4), 1-18
4	Hari, M., Tyagi, B., 2022. 'Terrestrial carbon cycle: tipping edge of climate change between the atmosphere and biosphere ecosystems' (2), 867-890.

Annex 1

CONCERTO's common minimum ontology

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Aerosols	Atmosphere	Atmospheric Composition	Physical properties	Atmospheric aerosols are minor constituents of the atmosphere by mass, but a critical component in terms of impacts on the climate and especially climate changes. Aerosols influence the global radiation balance by directly scattering solar radiation and indirectly through influencing cloud reflectivity, cloud cover and cloud lifetime.
ECV	Carbon Dioxide, Methane & Other Greenhouse Gases	Atmosphere	Atmospheric Composition	Carbon cycle and other GHGs	The atmospheric abundance of carbon dioxide (CO_2), the dominant human-produced greenhouse gas, has increased by about 50% since pre-industrial times due to the proliferation of fossil fuel combustion. Methane (CH_4) is also a strong greenhouse gas; its atmospheric abundance has more than doubled since the pre-industrial era because of human activities. Other significant greenhouse gases include nitrous oxide (N2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6).

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Clouds	Atmosphere	Atmospheric Composition	Hydrosphere	The variable properties of clouds determines the clouds profound effects on radiation and precipitation. They are influenced by and in turn influence the motion of the atmosphere on many scales. They are affected by the presence of aerosols, and modify atmospheric composition in several ways, including the depletion of ozone when they form in the polar stratosphere.
ECV	Inorganic Carbon	Ocean	Biogeochemical	Carbon cycle and other GHGs	The ocean is a major component of the global carbon cycle, absorbing enormous quantities of carbon in natural cycles driven by the ocean circulation, biogeochemistry and biology. Since seawater has very high capacity for absorbing carbon, the ocean has an inhibitory effect on the atmospheric accumulation of carbon dioxide and related greenhouse effect. The net ocean carbon uptake depends significantly on chemical and biological activity, and therefore it varies due to changing oceanic conditions and ecosystem composition. The chemical pathways of the inorganic carbon in the ocean mean that this uptake causes a decline in ocean pH, also known as ocean acidification.
ECV	Lakes	Land	Hydrology	Hydrosphere	Information on changes in lake level and area is required on a monthly basis for climate assessment purposes. Approximately 95% of the volume of water held globally in approximately 4 000 000 lakes is contained in the world's 80 largest lakes.
ECV	Ocean Colour	Ocean	Biogeochemical	Biosphere	Ocean colour is the radiance emanating from the ocean normalized by the irradiance illuminating the ocean. Products derived from ocean colour remote sensing (OCRS) contain information on the ocean albedo and information on the constituents of the seawater, in particular, phytoplankton pigments such as chlorophyll-a. OCRS products are used to assess ocean ecosystem health and productivity, and the role of the oceans in the global carbon cycle, to manage living marine resources, and to quantify the impacts of climate variability and change.
ECV	Ocean Surface Heat Flux	Ocean	Physical	Physical properties	Surface heat flux is exchange of heat, per unit area, crossing the surface between the ocean and the atmosphere. It consists of the turbulent and the radiative components. These fluxes are major contributors to the energy and moisture budgets, and are largely responsible for

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
					thermodynamic coupling the ocean and atmosphere at global and regional scales, and variability of these fluxes is in part related to large-scale variability in weather and climate patterns.
ECV	Oxygen	Ocean	Biogeochemical	Biosphere	Oxygen (O2) is essential for nearly all multicellular life. Subsurface oxygen concentrations reflect a balance between supply through circulation and ventilation and consumption by respiratory processes. Changes in either of these processes is susceptible to lead to changes in O2 distribution. A global ocean O2 observing network will act as a sensitive early warning system for trends that climate change is causing. Ocean deoxygenation (decline in O2 concentration) is under way in part because of ocean warming and increased stratification, but also because of increased nutrient loads in the coastal ocean. Deoxygenation has been largely under the radar to most people including policy advisers and decision makers. Yet it is deoxygenation that will have profound implications not just for ecosystems but also for communities and economies that depend on a healthy ocean.
ECV	Ozone	Atmosphere	Atmospheric Composition	Carbon cycle and other GHGs	Ozone (O3) is a naturally occurring trace gas in the stratosphere that inhibits harmful UV radiation from reaching Earth's surface. Ozone in the troposphere is a pollutant, harmful to all living things. Ozone is strongly linked to climate by its influence on Earth's radiation budget. The amount of ozone in the global stratosphere began to decrease in 1980 due to catalytic reactions with chlorine and bromine from man-made CFCs and other halocarbons. Severe, seasonal depletions over Antarctica ("ozone hole") have occurred annually since 1985. Thanks to the Montreal Protocol, an international treaty enacted to curtail the production and consumption of ozone-depleting substances, stratospheric ozone levels are expected to return to pre-depletion values.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Permafrost	Land	Cryosphere	Snow and Ice	The properties of frozen ground react sensitively to climate and environmental changes in high-latitude and high-altitude regions. This includes the temperature distribution in the permafrost layer and the depth of the overlying active layer where seasonal freezing and thawing occur. Changes in these quantities have important impacts on terrain stability, coastal erosion, surface and subsurface water, the carbon cycle and vegetation development.
ECV	River Discharge	Land	Hydrology	Hydrosphere	River-discharge measurements have essential direct applications for water management and related services, including flood protection. They are needed in the longer term to help identify and adapt to some of the most significant potential effects of climate change. The flow of freshwater from rivers into the oceans also needs to be monitored because it reduces ocean salinity, and changes in flow may thereby influence the thermohaline circulation.
ECV	Sea Level	Ocean	Physical	Physical properties	Sea Level is one of the primary indicators of global climate change. Change in the global mean sea level provides a measure of the net change in ocean mass due to melting of glaciers and ice sheets, and net change in ocean volume due to thermal expansion. Sea level observations characterize inter-seasonal variability such as ENSO. On the regional scales, changes in sea level can be far larger than the globally averaged value due to changes in temperature, salinity and circulation. Along many continental margins vertical land displacement associated with crustal adjustments to past and current land ice melt also cause regional variations in apparent sea level independent of the ocean. Coastal sea level change is a major driver of societal impacts.
ECV	Snow	Land	Cryosphere	Snow and Ice	Snow refers to forms of ice crystals that precipitate from the atmosphere (usually from clouds) and undergo changes on the Earth's surface. Snow cover on the ground plays a significant role in the climate system due to its high albedo, heat insulation and contribution to soil moisture and runoff, thus an important variable in monitoring climate change.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Subsurface Salinity	Ocean	Physical	Hydrosphere	The global subsurface salinity observing system is vital for closure of the global hydrological cycle, estimates of oceanic evaporation and precipitation, and halosteric component of sea level change. Subsurface salinity are required to calculate in situ density and ocean freshwater transports, respectively, and coincident subsurface observations of salinity, temperature and pressure provide an estimate of the ocean geostrophic velocity. In addition, subsurface salinity is used to derive large-scale gridded climate products including ocean velocity, mixed-layer depth, density stratification, sea level and indirect subsurface ocean mixing used in many weather and climate applications.
ECV	Above-ground Biomass	Land	Biology	Biosphere	Vegetation biomass is a crucial ecological variable for understanding the evolution and potential future changes of the climate system. Photosynthesis withdraws CO2 from the atmosphere and stores carbon in vegetation in an amount comparable to that of atmospheric carbon. Vegetation systems have the potential either to sequester more carbon in the future or to contribute as an even larger source. Depending on the quantity of biomass, vegetation cover can have a direct influence on local, regional and even global climate, particularly on air temperature and water vapour.
Terrestrial C cycle	AGC, Above ground carbon [4]	Land	Biology	Biosphere	Carbon stored in living plant tissues above surface of earth

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Albedo	Land	Biology	Energy	The land surface albedo is the ratio of the radiant flux reflected from Earth's surface to the incident flux. It is a key forcing parameter controlling the partitioning of radiative energy between the atmospheric and surface. In the case of vegetation, a reference surface is typically defined at or near the top of the canopy and must be specified explicitly. Surface albedo depends on natural variations highly variable in space and time as a result of terrestrial properties changes, and with illumination conditions and human activities and is a sensitive indicator of environmental vulnerability.
ECV	Anthropogenic Greenhouse Gas Emissions	Land	Human Use of Natural Resources	Biosphere	Global anthropogenic emissions of Greenhouse gases (CO2, CH4, N2O and F-gases) continue to be emitted at an annual rate that is not yet significantly decreasing. The global warming potential of each of the greenhouse gases and their long residence time in the atmosphere are causing increased surface temperature and climate change. The scientific community illustrated with inverse models and data assimilation how consistent the reported inventories and the atmospheric observations are, which is taken up also in few national inventory reports (e.g. UK, Switzerland, Australia).
ECV	Anthropogenic Water Use	Land	Human Use of Natural Resources	Hydrosphere	Data on water extractions by sector and available renewable freshwater provide key information on the availability of freshwater and the amount of water stress in a country. Climate Change is projected to reduce renewable surface-water and groundwater resources significantly in most dry subtropical regions. In contrast, water resources are projected to increase at high latitudes. Climate change is also projected to reduce raw water quality, posing risks to drinking water quality, even with conventional treatment. The availability of freshwater plays a crucial role in food production and food security.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
Terrestrial C cycle	AR, autotrophic respiration [4]	Land	Biology	Biosphere	The sum of respiration (CO2 production) by all living parts of primary producers (plants) per unit ground area and time (e.g. g C m-2 y-1). It can also be considered as the loss of photo-assimilated compounds due to the costs associated primarily with growth and maintenance (therefore the common separation in growth- and maintenance respiration). AR can be divided into aboveground (e.g. leaf and wood respiration) and belowground (e.g. root respiration).
Terrestrial C cycle	BGC, Below ground carbon [4]	Land	Biology	Biosphere	Carbon stored in living plant tissues below surface of earth
Terrestrial C cycle	CUE, carbon use efficiency [4]	Land	Biology	Biosphere	Defined as CUE = NPP / GPP, represents the proportion of gross assimilated C used for NPP. Note also BPE (biomass production efficiency) that represents the proportion of gross assimilated C used for biomass production, thus NPP excluding the production of non-structural C compounds (it is a ratio, thus unitless).
ECV	Earth Radiation Budget	Atmosphere	Upper Atmosphere	Energy and Temperature	The Earth Radiation Budget (at the top of the atmosphere) describes the overall balance between the incoming energy from the sun and the outgoing thermal (longwave) and reflected (shortwave) energy from the earth. It can only be measured from space. The radiation balance at the top of the atmosphere is the basic radiative forcing of the climate system. Measuring its variability in space and time over the globe provides insight into the overall response of the system to this forcing.
CONCERTO	Ecosystem biomass	Land	Biology	Biosphere	The biomass of an ecosystem refers to the total standing living and dead biomass, comprising both above- and belowground. However, we can also consider a specific ecosystem pools (e.g. leaf biomass, wood biomass, root biomass) or above- and belowground biomass. Units e.g. g C m-2

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
CONCERTO	Ecosystem total biomass	Land	Biology	Biosphere	The biomass of an ecosystem refers to the total standing living and dead biomass, comprising both above- and belowground. However, we can also consider a specific ecosystem pools (e.g. leaf biomass, wood biomass, root biomass) or above- and belowground biomass. Units e.g. g C m-2
Terrestrial C cycle	ER, ecosystem respiration [4]	Land	Biological	Biosphere	The respiration of all organisms summed per unit ground area and time, ER = AR + HR (e.g. g C m-2 y-1)
ECV	Evaporation	Land	Hydrology	Hydrosphere	Terrestrial evaporation is an important process in the global water cycle. It acts like an air conditioner for the surface, as it absorbs radiation (latent heat) that otherwise would be used to warm up the atmosphere (sensible heat). At the same time, water vapour acts as a greenhouse gas by trapping radiation in the lower atmosphere. Evaporation acts as a climate change diagnostic, being very sensitive to changes in atmospheric composition and the Earth's radiation balance. Moreover, it plays a crucial role in dampening the intensification of drought and heatwave events, it is a pivotal variable for agriculture that determines the needs for irrigation, and it constrains human water management.
ECV	Evaporation from Land	Land	Hydrology	Hydrosphere	Terrestrial evaporation is an important process in the global water cycle. It acts like an air conditioner for the surface, as it absorbs radiation (latent heat) that otherwise would be used to warm up the atmosphere (sensible heat). At the same time, water vapour acts as a greenhouse gas by trapping radiation in the lower atmosphere. Evaporation acts as a climate change diagnostic, being very sensitive to changes in atmospheric composition and the Earth's radiation balance. Moreover, it plays a crucial role in dampening the intensification of drought and heatwave events, it is a pivotal variable for agriculture that determines the needs for irrigation, and it constrains human water management.
Terrestrial water cycle	Evapotranspiration	Land	Hydrology	Hydrosphere	Evapotranspiration is the sum of all processes by which water moves from the land surface to the atmosphere via evaporation and transpiration.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Fire	Land	Biology	Biosphere	Fires have impacts on several identified radiative forcing agents. While they can be a natural part of many ecosystems, they have a strong human control, particularly in Tropical ecosystems. Fires contribute to the build-up of CO2 through deforestation and forest degradation, emissions from peatland fires, and alterations of fire regimes(more frequent, larger or more severe fires). They also emit CH4, and are a major source of aerosols, CO and oxides of nitrogen, thus affecting local and regional air quality. Estimates of greenhouse gas emissions due to fires are essential for realistic modelling of climate and its critical component, the global carbon cycle. Fires caused deliberately for land clearance (agriculture and ranching) or accidentally (lightning strikes and human error) are a major factor in land-cover variability and change, and hence affect fluxes of energy and water to the atmosphere.
ECV	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	Land	Biology	Biosphere	Solar radiation in the spectral range 400–700 nm, known as photosynthetically active radiation (PAR), provides the energy required by terrestrial vegetation to produce organic materials from mineral components. The part of this PAR that is effectively absorbed by plants is called FAPAR. FAPAR is related to, but different from, Leaf Area Index, which describes the amount of leaf material in the canopy. FAPAR plays a critical role in assessing the primary productivity of canopies, the associated fixation of atmospheric CO2 and the energy balance of the surface. Monitoring FAPAR provides information on the amount and health cycle of vegetation.
ECV	Glaciers	Land	Cryosphere	Snow and Ice	Glacier changes provide independent and reliable evidence of climate change. Past, current and future glacier changes impact global sea level, the regional water cycle, and may increase local hazard risks.
CONCERTO	GPP	Land	Biological / Ecosystems	Biosphere	Sum of gross C fixation by autotrophic C-fixing tissues per unit ground area and time (e.g. g C m-2 y-1). In principle, it considers both photosynthesis and chemoautotrophy, thought chemoautotrophy is a small component of CO2 fixation globally.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Groundwater	Land	Hydrology	Hydrosphere	It is estimated that groundwater accounts for about 30% of the world's total freshwater resources, and it is by far the largest available reservoir of liquid freshwater. Groundwater counts in average for one third of the freshwater consumed by humans, but at some parts of the world, this percentage can reach up to 100%. Climate change affects groundwater recharge rates through changes in precipitation and evapotranspiration. However, attributing observed groundwater change to climate change is difficult because of the influence of land-use change and groundwater abstraction. The extent to which groundwater recharge and storage has already been affected by climate change is widely unknown. Climate change can also affect groundwater through saltwater intrusion in coastal aquifers as sea level rises.
Terrestrial Carbon Cycle	HR, heterotrophic respiration [4]	Land	Biology	Biosphere	The respiration rate of heterotrophic organisms (animals and microbes) summed per unit ground area and time (e.g. g C m-2 y-1).
ECV	Ice Sheets and Ice Shelves	Land	Cryosphere	Snow and Ice	The understanding of the timescale of ice sheet response to climate change has changed dramatically over the last decade. Rapid changes in ice-sheet mass have surely contributed to abrupt changes in climate and sea level in the past.
ECV	Leaf Area Index	Land	Biology	Biosphere	The Leaf Area Index (LAI) of a plant canopy or ecosystem, defined as one half of the total green leaf area per unit horizontal ground surface area, measures the area of leaf material present in the specified environment. On sloping surfaces, the leaf area should be projected to the underlying ground along the normal to the slope. This dimensionless variable varies between 0 and values of about 10 or so, depending on local conditions. It partly controls important mass and energy exchange processes, such as radiation and rain interception, as well as photosynthesis and respiration, which couple vegetation to the climate system. Hence, LAI appears as a key variable in many models describing vegetation–atmosphere interactions, particularly with respect to the carbon and water cycles.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Land Cover	Land	Biology	Biosphere	Land cover is the observed (bio)-physical cover on the Earth's surface. It influences climate by modifying water and energy exchanges with the atmosphere and by changing greenhouse gas and aerosol sources and sinks. Land-cover conditions are inherently dynamic (i.e. seasonality) and distributions are linked to regional climatic conditions, so changes in cover can be due to climate change on a regional scale as well as directly due to human activities.
ECV	Land Surface Temperature	Land	Biology	Energy and Temperature	The Land Surface Temperature (LST) is the skin temperature of ground. It is mainly a product of albedo, the vegetation cover and the soil moisture. From a climate perspective, LST is important for evaluating land surface and land-atmosphere exchange processes, constraining surface energy budgets and model parameters, and providing observations of surface temperature change both globally and in key regions.
CONCERTO	Land use	Land	Human Use of Natural Resources	Biological	From DMP "Land use" is the term used to describe the human use of land. It represents human activities (urban/industry, agriculture, pastures), or less intensive and natural uses (forests, grasslands, bareground) in place at a given grid point.
ECV	Lightning	Atmosphere	Upper Atmosphere	Physical properties	Lightning is one of the most dramatic weather phenomena, causing many fatalities as well as substantial loss and damage for example by forest fires, damage to electrical infrastructure and other sectors every year all over the world. On top, even more damage is caused by the storms which generate lightning. This direct link to convection makes lightning also a potentially valuable indicator to track and understand trends in storminess, particularly under climate variability and change. In addition, lightning itself impacts the global climate by producing nitrogen oxides (NOX), a strong greenhouse gas.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Marine Habitats	Ocean	Biological / Ecosystems	Biosphere	Marine coastal regions are amongst the most productive systems of the planet, yet they are undergoing rapid transformations in response to intensifying human activities and global change. Regime shifts, abrupt transitions between alternative states, are increasingly observed in a wide range of coastal systems, including coral reefs, macroalgal forests, seagrasses and mangroves. These non-linear responses to deteriorating environmental conditions often result in considerable loss of ecosystem functions and services.
Terrestrial C cycle	NBP, Net biome production [4]	Land	Biology	Biosphere	NBP = NEE − Cefflux − Cinflux (or) NBP =GPP − ER − Alulc NEE with non-respiratory carbon loss and heterotrophic carbon gain (or) GPP with total ER and anthropogenic carbon flux
Terrestrial carbon cycle	NECB, net ecosystem carbon balance [4]	Land	Biology	Biosphere	NECB represents the overall ecosystem C balance from all sources and sinks (physical, biological, and anthropogenic). Originally defined by ecologists, a positive NEP indicates a C input to the ecosystem. NECB = -NEE + FCO + FCH4 + FVOC + FDIC + FDOC + FPC, where FCO is net carbon monoxide (CO) absorption (or efflux if negative); FCH4 is net methane consumption (or efflux if negative); FVOC is net volatile organic C absorption (or efflux if negative); FDIC is net dissolved inorganic C (DIC) input to the ecosystem (or net DIC leaching loss, if negative); FDOC is net dissolved organic C (DOC) input (or net DOC leaching loss, if negative), and FPC is the net lateral transfer of particulate (nondissolved, nongaseous) C into the ecosystem (or out of it, if negative) by processes such as animal movement, soot emission during fires, water and wind deposition and erosion, and anthropogenic transport or harvest (e.g. g C m-2 y-1).
Terrestrial Carbon Cycle	NEE, net ecosystem exchange [4]	Land	Biology	Biosphere	The net CO2 flux from the ecosystem to the atmosphere. Originally defined by atmospheric scientists, a positive NEE indicate a C input to the atmosphere (thus the sign of NEE is opposite to the sign of NEP). Note that, because of the different definition, even - NEE and NEP are different (e.g. - NEE includes CO2 fluxes due to fire, whereas NEP not) (e.g. g C m-2 y-1).

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
	NEP, net ecosystem production				It is the imbalance between GPP and ER, NEP = GPP – ER. Originally defined by ecologists, a positive NEP indicates a C input to the ecosystem (e.g. g C m-2 y-1).
ECV	Nitrous Oxide	Ocean	Biogeochemical	Carbon cycle and other GHGs	Nitrous oxide (N2O) is an important climate-relevant trace gas in the Earth's atmosphere. In the troposphere it acts as a strong greenhouse gas and in the stratosphere it acts as an ozone depleting substance because it is the precursor of ozone depleting nitric oxide radicals. The ocean - including its coastal areas such as continental shelves, estuaries and upwelling areas - contribute about 30% to the atmospheric N2O budget.
CONCERTO	NPP, net primary production	Land	Biology	Biosphere	Defined as NPP = GPP – AR, it includes (i) the biomass production of primary producers (plants), comprising also the biomass production eaten by herbivores and (ii) the production of non-structural compounds used for multiple purposes (e.g. transfer to root symbionts, production of root exudates, VOCs). NPP is often divided in aboveground NPP (ANPP) when referring to aboveground organs/transfers or belowground NPP (BNPP) when referring to belowground organs/transfers. Units e.g. g C m-2 y-1.
ECV	Nutrients	Ocean	Biogeochemical	Biosphere	Nutrients are essential for ocean life. Nutrient data provide important biogeochemical information, and provide essential links between physical climate variability and ecosystem variability. They can provide additional information on ocean mixing and climate related phenomena such as changes in primary and export production (nutrient transports regulate new production which is correlated with export production), eutrophication and shifts in phytoplankton community composition. Therefore it is necessary to develop accurate observations of trends in dissolved nutrients in both upper- and deep-ocean waters.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Plankton	Ocean	Biological / Ecosystems	Biosphere	Plankton are at the base of the marine food web and generally not fished by humans. Changes in the plankton will have impacts on the rest of the marine ecosystem including on the carbon cycle, living marine resources used by humans and threatened marine species including apex predators. Climate variability significantly impacts plankton in the ocean, both the microflora (phytoplankton) and the microfauna (zooplankton), over both short and long timescales.
ECV	Precipitation	Atmosphere	Surface	Hydrosphere	Precipitation, either liquid or solid, is the most important climate variable directly affecting humans. Through either its duration, intensity and frequency or its lack of occurrence, it influences the supply of water, causes risks to life and livelihoods when associated with floods, landslides and droughts, and affects infrastructure planning, leisure activities and more. Precipitation is closely related to cloud properties, a number of terrestrial ECVs and to 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.
ECV	Precursors for Aerosols and Ozone	Atmosphere	Atmospheric Composition	Carbon cycle and other GHGs	Precursor species lead to the production of aerosols and ozone. Precursors include nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (CO) and formaldehyde (HCHO). Aerosols and ozone in the near-surface atmosphere can directly harm human health and produce detrimental environmental impacts (e.g., crop damage, acid rain). Reductions in near-surface aerosols and ozone have been observed in specific regions where the emissions of some precursors are regulated.
ECV	River discharge	Land	Hydrology	Hydrosphere	River-discharge measurements have essential direct applications for water management and related services, including flood protection. They are needed in the longer term to help identify and adapt to some of the most significant potential effects of climate change. The flow of freshwater from rivers into the oceans also needs to be monitored because it reduces ocean salinity, and changes in flow may thereby influence the thermohaline circulation.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Sea Ice	Ocean	Physical	Snow and Ice	Sea ice variability is a key indicator of climate variability and change in the polar regions. The primary parameters that define the state of sea ice include: concentration, area and extent, ice type, motion, deformation, age, thickness, and volume. The presence of sea ice strongly modifies surface waves and air-sea exchanges of heat, momentum, moisture and gases. Sea ice has a significant impact on the Earth's albedo and hence changes in Sea Ice impact the global energy budget. The properties of many water masses of the global ocean and strongly influenced determined freezing and melting processes in sea ice regions.
ECV	Sea State	Ocean	Physical	Physical properties	Sea State is the characterization of wave and swell, typically in terms of height, wavelength, period, and directional wave energy flux. Waves generated by ocean surface stress evolve from wind waves to swell through nonlinear dynamical processes.. Wave characteristics are modified by bathymetry when the depth of the water is comparable to the wavelength, and by surface currents. Sea state is most well known for its impacts on marine safety, marine transport and damage to structures. It is also a substantial modifier of air-sea exchanges of momentum, moisture and CO2. Waves also impact beach erosion, storm-related water damage (wave set-up contributes to storm surge), surface albedo, and transport of larva. Waves can also modify the growth or decay of sea ice.
ECV	Sea Surface Salinity	Ocean	Physical	Physical properties	Sea surface salinity observations contribute to monitoring the global water cycle (evaporation, precipitation and glacier and river runoff). On large scales, surface salinity can be used to infer long-term changes of the global hydrological cycle. Surface salinity, together with surface temperature, is indicative of the surface expression of ocean frontal features and eddies.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Sea Surface Temperature	Ocean	Physical	Energy and Temperature	Sea Surface temperature (SST) is a vital component of the climate system as it exerts a major influence on the exchanges of energy, momentum and gases between the ocean and atmosphere. SST largely controls the atmospheric response to the ocean at both weather and climate time scales. Daily variations in SST can exceed 3 degrees Celsius and could alter the surface energy budget by more than 10 Wm-2 over the tropics and subtropics. Therefore, the SST and horizontal gradients in SST are also important for coupling with the atmosphere for sub-seasonal to seasonal prediction timescales. The spatial patterns of SST reveal the structure of the underlying ocean dynamics, such as, ocean fronts, eddies, coastal upwelling and exchanges between the coastal shelf and open ocean.
ECV	Soil Carbon	Land	Biology	Biosphere	Carbon in soils occurs in organic and inorganic forms. The inorganic carbon is derived from weathered bedrock, is relatively inert and constitutes little to the carbon cycle. Soil organic carbon is derived from plant and other decaying matter and is a significant part of the carbon cycle. About 10% of the atmospheric carbon cycles through soils each year. Soil organic carbon represents the largest terrestrial carbon pool, amounting to about two to three times the net size of the biomass pools. Carbon sinks may be explained by changes in above-ground biomass on seasonal to decadal timescales, but soil organic carbon stocks become significant on longer timescales, and can be a significant source at all timescales after disturbances.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Soil Moisture	Land	Hydrology	Hydrosphere	Soil moisture is an important variable in land–atmosphere feedbacks at both weather and climate timescales. It plays a major role in partitioning the incoming radiation flux onto the land into fluxes of latent and sensible heat from the land to the atmosphere, and in separating precipitation into runoff, subsurface flow, and infiltration. Soil moisture is intimately involved in the feedback between climate and vegetation, as both local climate and vegetation influence soil moisture through evapotranspiration, while soil moisture is a determinant of the type and condition of vegetation in a region. Changes in soil moisture can accordingly have substantial impacts on agricultural productivity, forestry and ecosystem health.
CONCERTO	Soil nutrients	Land	Biological	Biological	The three main nutrients in soils are nitrogen (N), phosphorus (P) and potassium (K). Together they make up the well-known NPK. It includes pH too.
Terrestrial C cycle	SOC, Soil organic carbon [4]	Land	Biological	Biosphere	SOC = CF × D × BD × Ccon Carbon in terms of soil organic matter compounds in dry weight
CONCERTO	Soil texture	Land	Biological	Biological	Texture indicates the relative content of particles of various sizes, such as sand, silt and clay in the soil.
CONCERTO	Solar-induced chlorophyll fluorescence (SIF)	Land	Biology	Biosphere	Solar-induced chlorophyll fluorescence (SIF) is emitted during photosynthesis in plant leaves. It constitutes a small additional offset to reflected radiance and can be observed by sensitive instruments with high signal-to-noise ratio and spectral resolution
Terrestrial C cycle	SR, soil respiration [4]	Land	Biology	Biosphere	Typically refers to HR in soil and belowground AR (e.g. g C m-2 y-1).

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Subsurface Currents	Ocean	Physical	Energy and Temperature	Observations of subsurface ocean velocity contribute to estimates of ocean transports of mass, heat, freshwater, and other properties on local, to regional and basin to global scales. They are essential in resolving the wind and buoyancy driven ocean circulation, and the complex vertical velocity structure, for example, in the major ocean boundary currents, tides, equatorial currents, wave propagations, ocean eddies. Vertical velocity profile information can be used to estimate the order of ocean mixing using fine-scale parameterizations of turbulent dissipation by internal wave breaking. Velocity estimates can be combined in data assimilation models to provide gridded global estimates of ocean circulation at varying temporal and spatial scales.
ECV	Subsurface Temperature	Ocean	Physical	Energy and Temperature	Subsurface temperature is a fundamental variable that is required to monitor variability and change in the physical environment of the ocean, energy flows, climate patterns and sea level. Many other physical variables are derived from subsurface temperature along with subsurface salinity, including subsurface density, geostrophic circulation, heat transport and steric sea level. Heat uptake by the global ocean accounts for more than 90% of the excess heat trapped in the Earth system in the past few decades. This ocean heat uptake helps to mitigate surface warming but, in turn, increases the global ocean volume through thermal expansion, and thus results in global-mean sea-level rise, accounting for about one third of the increase observed over the past few decades.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Surface Currents	Ocean	Physical	Physical properties	The surface ocean general circulation is responsible for significant surface transport of heat, salt, passive tracers and ocean pollutants. On basin scales, surface currents and their variations are a major player in climate to weather fluctuations. The boundary currents on each side of the ocean basins transport significant amounts of heat, salt and passive tracers. Western Boundary Currents in particular transport heat and properties polwards, moderating climate. Convergences/divergences, spiralling eddies, and filaments all contribute to vertical motions and mass exchange. Surface currents impact the steepness of surface waves, and are thus important for generating accurate marine sea state forecasts.
ECV	Surface Pressure	Atmosphere	Surface	Physical properties	The humidity of air near the surface of the Earth affects the comfort and health of humans, livestock and wildlife, the swarming behaviour of insects and the occurrence of plant disease. The humidity near the surface affects evaporation and the strength of the hydrological and energy cycles. Evaporation from the surface of the earth is the source of water in the atmosphere and so is responsible for important feedbacks in the climate system due to clouds and radiation
ECV	Surface Radiation Budget	Atmosphere	Surface	Energy and Temperature	The Surface Radiation Budget is a fundamental component of the surface energy budget that is crucial to nearly all aspects of climate, and needs to be monitored systematically
ECV	Surface Stress	Ocean	Physical	Physical properties	Ocean surface stress (OSS) is the two-dimensional vector drag at the bottom of the atmosphere and the dynamical forcing at the top of the ocean. OSS influences the air-sea exchange of energy, water and gases. OSS is important for determining the large scale momentum forcing of the ocean, and consequent ocean circulation including ocean upwelling regions. Accurate knowledge of stress magnitudes is also essential for reliable computations of air-sea heat fluxes as well as air-sea gas exchanges and mass fluxes.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Surface Temperature	Atmosphere	Surface	Energy and Temperature	Surface air temperature has profound and widespread impacts on both natural systems and on human lives and activities. It affects health, agriculture, energy demand and much more. Extremes of surface air temperature, both heat waves and extreme cold periods, are particular important for human health. Surface air temperature provides a key indicator of climate change, contributing to the "global surface temperature record". A goal of limiting changes in global surface temperature provides the measure for the Paris climate agreement.
ECV	Surface Water Vapour	Atmosphere	Surface	Hydrosphere	The humidity of air near the surface of the Earth affects the comfort and health of humans, livestock and wildlife, the swarming behaviour of insects and the occurrence of plant disease. The humidity near the surface affects evaporation and the strength of the hydrological and energy cycles. Evaporation from the surface of the earth is the source of water in the atmosphere and so is responsible for important feedbacks in the climate system due to clouds and radiation.
ECV	Surface Wind Speed and Direction	Atmosphere	Surface	Physical properties	Surface winds drive the exchange of momentum between the atmosphere and ocean, producing ocean waves and provides a key forcing of the ocean circulation responsible for the global transport of important amounts of heat and carbon. Extreme winds have huge social and economic impacts, most obviously during hurricanes and tropical cyclones, leading to loss of human life, damage to ecosystems, the destruction of infrastructure and loss of shipping.
ECV	Terrestrial Water Storage (TWS)	Land	Hydrology	Hydrosphere	TWS is the total amount of water stored in all continental storage compartments (ice caps, glaciers, snow cover, soil moisture, groundwater, surface water bodies, water in biomass). The change of TWS over time balances the budget of the water fluxes precipitation, evapotranspiration and runoff, i.e., it closes the continental water balance. TWS changes thus represent the net effect of climate variability and climate change as well as of anthropogenic impacts on the water cycle.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Transient Tracers	Ocean	Biogeochemical	Carbon cycle and other GHGs	Transient tracers are man-made chemical compounds released to the atmosphere at known quantities that can be used in the ocean to quantify ventilation, transit time distribution and transport time-scales. Measurement of transient tracers in the subsurface ocean thus provides information on the time-scales since the ocean was ventilated, i.e. in contact with the atmosphere. A combination of these tracers provide the means to constrain the transit time distribution (TTD) of a water-mass that allows inference of concentrations or fates of other transient compounds, such as anthropogenic carbon or nitrous oxide.
	Transpiration	Land	Hydrology	Hydrosphere	Transpiration is a part of the water cycle. Transpiration is defined as the process where water evaporates into the atmosphere through plants.
ECV	Upper-air Temperature	Atmosphere	Surface	Energy and Temperature	Temperature is one of the fundamental state variables for understanding and predicting the behaviour of the atmosphere. It is basic to the energy budget of the climate system as a whole through the temperature dependence of the long-wave radiation of energy from the atmosphere to space. Upper-air observations are of key importance for detecting and attributing climate change in the troposphere and stratosphere because the warming of the troposphere and the cooling of the stratosphere are unique fingerprints of anthropogenic GHG. They are needed for the development and evaluation of climate models, and for the initialization of medium term and seasonal forecasts.

Source	Variable name	Variable domain	Variable subdomain	Scientific Area	Variable definition
ECV	Upper-air Water Vapour	Atmosphere	Upper Atmosphere	Hydrosphere	Water vapour is the predominant gaseous source of infrared opacity in the atmosphere, accounting for about 60% of the natural greenhouse effect for clear skies. Water vapour condenses to produce clouds, changing radiative properties and releasing latent heat that drives or modifies atmospheric circulation systems. Water vapour in the lower stratosphere, though present only in small amounts, is radiatively significant. Consequently, there is potential for additional climate change feedbacks through perturbations of the processes that control the amount of water vapour in the stratosphere, such as the Brewer-Dobson circulation that strongly influences tropical tropopause temperatures and the amount of CH4 oxidized in the stratosphere.
ECV	Upper-air Wind Speed and Direction	Atmosphere	Upper Atmosphere	Physical properties	Wind is one of the fundamental state variables for understanding and predicting the behaviour of the atmosphere. It is basic to the working of the climate system through transport of heat, moisture and trace constituents. Measurements of wind are vital for initializing and verifying climate projections and for detecting, understanding and attributing variability and change in the climate system.