GEO ESSENTIAL
ERA-PLANET

**Essential Variables workflows for resource efficiency and environmental management**

# Deliverable 2.2
# Unified list of EVs that reflects the cross-disciplinarity of the EV concept

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| **Creation date** | Dec. 13. 2018 |
| **Due date** | Sept. 30. 2018 |
| **Last revision date** | Dec. 13. 2018 |
| **Status** | Final |
| **Type** | Report |
| **Description** | This report is a description of the lists of defined Essential Variables (EVs) |
| **Right** | Public |
| **Language** | English |
| **Citation** | Bumberger et al. (2018) Unified list of EVs that reflects the cross-disciplinary of the EV concept. Technical Report, ERA-PLANET No 689443. |
| **Grant agreement** | ERA-PLANET No 689443 |

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# Introduction

Within the last decade, some efforts have been made to establish approaches to conceptually better combine the diversity of research activities in the Earth system sciences and communities. An important step forward is the establishment of the concept of essential variables for the description and monitoring of energy and material flows and system properties. Essential Variables (EVs) are “a minimal set of variables that determine the system’s state and developments, are crucial for predicting system developments, and allow us to define metrics that measure the trajectory of the system” (D2.2 ConnectinGEO 2016). The provision of consistent EV schemes supports the creation of analysis, models, and in-situ measurement and remote sensing techniques at different spatial and temporal scales. Mostly, the development of sets of EVs like the EBVs (Pereira et al. 2013, Kissling et al. 2018) is an ongoing experts and community process leading to an agreement on the essentiality of variables reflecting the community-specific description of the system. This community-specific approach poses significant challenges to the consistency of the EVs if different EV concepts are to be compared with each other.

Essential variables are merged into EV because they are defining a minimum set of essential measurements to capture major dimension of the status, their processes and changes of the bio-climate or geodiversity. From the point of view of physics it can be stated that the previous definitions of the EVs did not use consistent formula symbols and units. This poses difficulties for the enormous potential for merging the variables into a core set and additional domain-specific variables. One way of harmonizing the EVs would be to use the physical effects and relationships of the respective variables as an ordering principle. However, this would require that the existing EVs be consistently defined across the physical entities and relationships using a higher-level physical-mathematical as well as mechanistic concept. The present report is intended to take an inductive step in this direction to show different concepts for the standardization of existing and future EVs. The objective of the report is to describe the collection of the existing EVs lists in order to reflect the cross-disciplinarily of the EV concept. The conceptual representation in Figure 1 with a Venn diagram representing the conceptual overlaps of different sets of EV approaches as a first step in this direction (Lindstrom et al. 2012, Lausch et al., 2018). However, in order to enable a semantic link to different target systems, in Chapter 2 (Conceptual approach to standardizing the EV lists) possibilities are presented and considered in the creation of the current EV lists (Chapter 3). The use of this information and the mapping are then carried out in WP3, Task3.2 (Definition of cross-domain EVs for services and modelling).

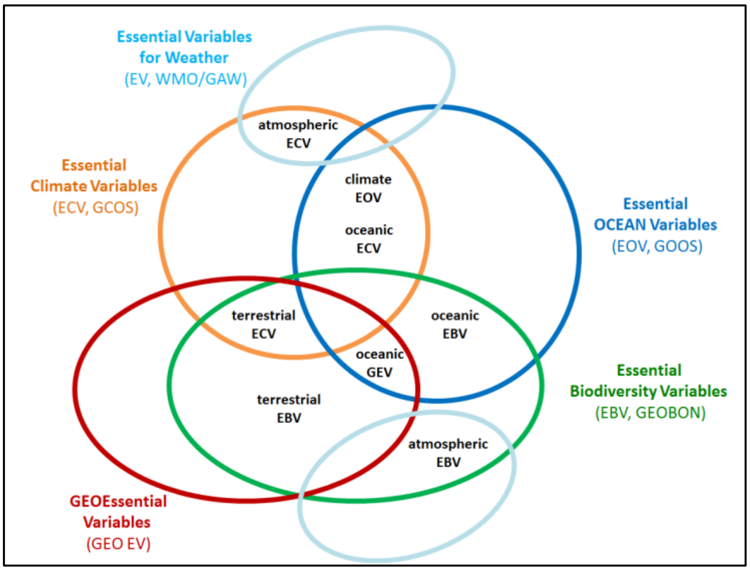


**Figure 1:** Conceptual overlap of all projects for defining Essential Variables; Essential Variables for Weather - EV, (led by WMO/GAW-World Meteorological Organization/Global Atmosphere Watch, Essential Ocean Variables – EOV (led by the GOOS-Global Ocean Observing System), Essential Climate Variables – ECV (led by GCOS-Global Climate Observing System), Essential Biodiversity Variables – EBV (led by GEO BON) and the GeoEssential Variables- GEO EV (led by the actual project http://www.geoessential.net/) (Figure from Lausch et al. 2018, modified after Lindstrom et al. 2012).

# Conceptual approach to standardizing EVs

Based on the previous project ConnectinGEO (EU Framework Program for Research and Innovation, SC5-18a-2014 - H2020) and the summaries of the existing EVs developed there, all relevant developments were examined by means of a comprehensive literature search. In particular, the focus was on the identification of coherent properties and overlaps, which can later be combined and harmonized by means of a meta-analysis. The underlying **Hypothesis 1** is that a variety of variables recur in all existing definitions. **Hypothesis 2** states that the essential relationships between the variables or groups of variables can be identified only by consistently recording the underlying physical entities and relationships. **Hypothesis 3** is that the variables can be mapped to different target systems (see Figure 2).

The current status is that the variables have been collected in lists and enriched with further properties of a relational model. First, two conceptual approaches for the enrichment were chosen:

i. The metadata enrichment of the individual variables with their physical units and dimensions. As a result, intensity, quantity and parametric variables can be distinguished later. In addition, this approach makes it possible to identify and analyze energy or material fluxes between the domains or state variables of the domains.

ii. Enrichment of the variables with metadata in order to be able to exemplary mapping the ecosystem integrity concept. This was chosen because it is currently discussed and implemented in integrated environmental long-term observatories (Mirtl et al. 2018, Mollenhauer et al. 2018). The consideration here would be a process or structure level (component 1) and can be mapped as budgets as well as biotic and abiotic diversity characteristics in another hierarchy level (component 2).

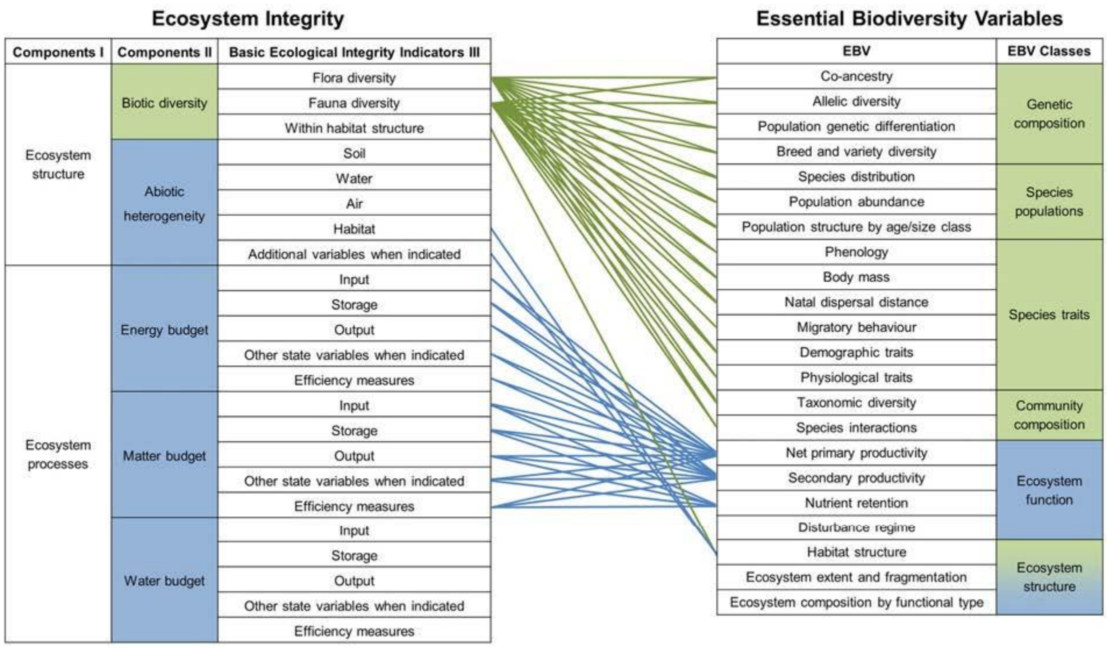


**Figure 2:** Ecosystem integrity (EI) and essential biodiversity variables (EBV) frameworks. Lines indicate examples of linkages, differences in resolution and complementarity of EI and EBV frameworks (green color refers to biotic and blue color to abiotic indicators or variables, respectively). Green lines indicate that three biotic EI indicators are relevant for 16 EBVs. Blue lines indicate that four biotic EBVs are relevant for 12 abiotic EI indicators. (Figure from Haase et al. 2018)

The purpose of this deliverable is to compile the up-to-date lists of essential variables. These are enriched with metadata to perform the analysis and standardization in WP3 (Task3.2). In the data model, it is possible at any time to make further enrichments, which seems particularly interesting for investigations on different spatial and temporal scales.

# Current Status of Essential Biodiversity Variables (EBV)

The GEO BON (Biodiversity Observation Networks (BON) is a part of GEO. The Group on Earth Observations) Initiative is coordinating the EV definition process for the biodiversity at the global scale, was started in 2012 and is embedded in the Convention on Biological Diversity (CBD) process during the last decades. In this discus, the Aichi goals were defined (1993) and are currently adjacent to the SDGs. It can be assumed that a merger will take place here. The Biodiversity Monitoring Program (Arctic BON) and the Asia Pacific BON (AP-BON) are existing regional BONs under the GEO BON general initiative. China, Colombia and France are national BONs already functioning. The first definition of EBVs was presented in 2013 (Pereira et al. 2013) and essentially covers the state that exists today and has been further developed within the community process (Geijzendorffer et al. 2016). A decisive process is a profound discussion of the EBV classes defined in the first instance. For example, the “Species Traits” were discussed and restructured by (Kissling et al., 2018). In a further process, where EBV were linked to RS, Aichi targets and SDG targets, three workshops held during 2015-2017. In the last workshop, over 40 international experts, identified nearly 120 remote sensing variables and concatenated them. The publication for that is in progress. Unlike ECV and EOV, EBVs are much more ecosystemic and biological and are primarily targeted at terrestrial systems. The embedding of abiotic factors and conditions are unfortunately not included at the moment. Another major change has evolved over the last two years as new definitions have been proposed for EBVs in the field of species distribution and abundance (Kissling et al. 2018, Schmeller et al. 2018). It can be assumed that a holistically accepted definition of EBVs will be completed in the next few years (Walters and Scholes, 2017). For the cross-cutting work in the field of biological-ecological EVs shows that standardization or at least the link between the EOVs (see also section Current Status of Essential Ocean Variables) and the EBVs is to be established

(Muller-Karger et al. 2018). For example, marine EBVs are to be based on primary species-based data at a level that can be used to estimate biodiversity indices.

## Current Status of Essential Climate Variables (ECV)

The Essential Climate Variables (ECVs) are internationally well recognized since more than one decade and many of them are essential also in other areas. A recent definition describes the variables as “a physical, chemical, or biological variable or a group of linked variables that critically contributes to the characterization of Earth’s climate” (Bojinski et al., 2014). This definition is widely accepted by the scientific community and endorsed by the United Nation Convention on Climate Change (UNFCCC) as well as other international bodies. The ECVs are identified in three domains: atmosphere (responsible are the Global Climate Observing System by the World Meteorological Organization (GCOS-WMO)), ocean (responsible are the Global Ocean Observing System (GOOS)) and land (responsible are the Food and Agriculture Organization (FAO)). This shows that a number of variables were initially defined as climate-relevant and the bottom-up process for the introduction of further variable classes led to diversification in the individual areas. Included in the system of ECVs are a variety of infrastructures and programs being used operationally to make predictions regarding the Earth's climate and will be further developed (WMO 2015).

## Current Status of Essential Ocean Variables (EOV)

The Global Ocean Observing System (GOOS) is a programme executed by the Intergovernmental Oceanographic Commission (IOC) of the UNESCO and is coordinating the EV definition process for the oceans at the global scale. The first approach is pursued by the "Framework for Ocean Observing" with the aim of "advancing global sustainable ocean observations in the next decade" (Lindstrom et al., 2012). The framework is designed for observation of ocean observations with a focus on Essential Ocean Variables (EOV) to ensure that the assessments are cross-platform to provide an optimal global view for each EOV. There are three relevant panels for the development of the EOVs: the Physics and Climate Expert Panel (provided by the Ocean Observations Panel for Climate (OOPC)), the Biogeochemistry Expert Panel (provided by the International Ocean Carbon Coordination Project (IOCCP)) and the GOOS Biology and Ecosystems Panel. The development of the EOVc begins with the spatially explicit description of ecosystems and predicts how these systems are affected by anthropogenic pressures and has been demonstrated as an example in Australia (Hayes et al. 2015). From a scientific-methodological point of view, the developed EOVs are very consistent, as they consistently evaluate all existing and future observatories on different scales. This led to the current description of the EOVs, which, with a few exceptions, are defined consistently and are continuously updated (Miloslavich et al. 2018). As described in the status of essential biodiversity variables, there is currently a process of integrating species-based maritime and terrestrial EVs, which is a step in the right direction towards standardization (Muller-Karger et al., 2018).

## Current Status of other sets of Essential Variables

In addition to the featured EVs, there are a number of other activities that have worked on and / or are still working on the development of EVs in specific areas. However, according to the authors, a number of these can be standardized among the already presented EVs. For example, the Agriculture and Nutrition Initiatives (GEOGLAM and others) are using target variables to address food security (Stok et al. 2016). Another topic is the development of essential variables or indicators in the field of health, where the process is very confusing and mostly related to the treatment of certain diseases (Blas et al. 2016). Beyond the mentioned domains, researchers have recently begun to identify critical social determinants of development and refined these determinants based on their feasibility, reliability, validity, and usefulness to policymakers. Furthermore, these system's approaches composite indices with social and economic dimensions for tracking progress to development targets (Reyers et al. 2017).

# Conclusion

In summary, it can be stated that initiatives in the individual communities have become increasingly common in recent years for the establishment of essential variable sets. There are advanced concepts in climate science (ECVs), ocean science (OCVs) and in biodiversity research (EBVs). The process of final definition and establishment of EBV will not be completed until 2022. Other ideas in other communities (e.g. social sciences) exist conceptually but are not in a particularly advanced state. Further progress can be expected in all communities over the next few years with the further development and provision of consistent practices and standards, particularly in the context of digitization. In order to advance data-driven science concepts on different spatial and temporal scales, generic definitions of relevant processes and the underlying variables (essential variables) are required in all sciences. This procedure brings in particular the earth system sciences into unprecedented possibilities for the integration of most different data sources by means of semi-automatic and / or automated procedures. Key steps in this direction are (i) the unified definition of the existing essential sets of variables, and (ii) the identification of cross-domain essential variables to allow links between the domains and allow ranking of all variables.

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# Appendix: Current Single EV lists

## Essential Biodiversity Variables (EBV)

| EBV Domain | EV | EV Subvariables | Unit (SI) | EV EI Component | Scientific domain |
|---|---|---|---|---|---|
| EBV | Genetic composition | Co-ancestry | - | Biotic diversity | Biology |
| | | Allelic diversity | - | Biotic diversity | Biology |
| | | Population genetic differentiation | - | Biotic diversity | Biology |
| | | Breed and variety diversity | - | Biotic diversity | Biology |
| EBV | Species populations | Species distribution | - | Biotic diversity | Biology |
| | | Population abundance | - | Biotic diversity | Biology |
| | | Population structure by age/size class | - | Biotic diversity | Biology |
| EBV | Species traits | Phenology | - | Biotic diversity | Biology |
| | | Body mass | - | Biotic diversity | Biology |
| | | Natal dispersion distance | - | Biotic diversity | Biology |
| | | Migratory behavior | - | Biotic diversity | Biology |
| | | Demographic traits | - | Biotic diversity | Biology |
| | | Physiological traits | - | Biotic diversity | Biology |
| EBV | Community composition | Taxonomic diversity | - | Biotic diversity | Biology |
| | | Species interactions | - | Biotic diversity | Biology |
| EBV | Ecosystem function | Net primary productivity | kg s^-1 | Energy budget, Matter budget | Biology |
| | | Secondary productivity | kg s^-1 | Energy budget, Matter budget | Biology |
| | | Nutrient retention | kg m^3 | Energy budget, Matter budget | Biology |
| | | Disturbance regime | - | Biotic diversity | Biology |
| EBV | Ecosystem structure | Habitat structure | - | Biotic diversity | Biology |
| | | Ecosystem extent and fragmentation | - | Biotic diversity | Biology |
| | | Ecosystem composition by functional type | | Biotic diversity | Biology |

# Essential Climate Variables (ECV)

| EV Domain | EV | EV Subvariables | Unit (SI) | EV EI Component | Scientific domain |
|---|---|---|---|---|---|
| ECV_Atmosphere | Precipitation | | m | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Pressure | | N/m² | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Surface Radiation Budget | Surface ERB longwave | W/m² | energy budget | Physics |
| ECV_Atmosphere | Surface Radiation Budget | Surface ERB shortwave | W/m² | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Surface Wind | surface wind speed | m/s² | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Surface Wind | surface wind direction | rad | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Temperature (surface) | temperature (surface) | K | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Temperature (surface) | Daily maximum and minimum temperature | K | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Water Vapour (surface) | | % | abitotic heterogeneity | Physics |
| ECV_Atmosphere | Earth Radiation Budget | Top-of-atmosphere ERB longwave | W/m² | energy budget | Physics |
| ECV_Atmosphere | Earth Radiation Budget | Top-of-atmosphere ERB shortwave (reflected) | W/m² | energy budget | Physics |
| ECV_Atmosphere | Earth Radiation Budget | Total solar irradiance | W/m² | energy budget | Physics |
| ECV_Atmosphere | Earth Radiation Budget | Solar spectral irradiance | W/(m²*m) | energy budget | Physics |
| ECV_Atmosphere | Lightning | | | energy budget | Physics |
| ECV_Atmosphere | Temperature (upper-air) | Tropospheric Temperature profile | K | energy budget | Physics |
| ECV_Atmosphere | Temperature (upper-air) | Stratospheric Temperature profile | K | energy budget | Physics |
| ECV_Atmosphere | Temperature (upper-air) | Temperature of deep atmospheric layers | K | energy budget | Physics |
| ECV_Atmosphere | Water Vapour (upper air) | Total column-water vapour | mol/mol | energy budget | Physics |
| ECV_Atmosphere | Water Vapour (upper air) | Tropospheric profiles of water vapour | mol/mol | energy budget | Physics |
| ECV_Atmosphere | Water Vapour (upper air) | Lower-stratospheric profiles of water vapour | mol/mol | energy budget | Physics |
| ECV_Atmosphere | Water Vapour (upper air) | Upper tropospheric humidity | mol/mol | energy budget | Physics |
| ECV_Atmosphere | Wind (upper-air) | wind speed (upper-air) | m/s² | energy budget | Physics |
| ECV_Atmosphere | Wind (upper-air) | wind direction (upper-air) | rad | energy budget | Physics |
| ECV_Atmosphere | Aerosols properties | Aerosol optical depth | scalar | energy budget | Physics |
| ECV_Atmosphere | Aerosols properties | Single-scattering albedo | scalar | energy budget | Physics |
| ECV_Atmosphere | Aerosols properties | Aerosol-layer height | m | energy budget | Physics |
| ECV_Atmosphere | Aerosols properties | Aerosol-extinction coeff. Profile near tropopause | scalar | energy budget | Physics |
| ECV_Atmosphere | Aerosols properties | Aerosol-extinction coeff. Profile mid stratosphere | scalar | energy budget | Physics |
| ECV_Atmosphere | Carbon Dioxide, Methane and other Greenhouse gases | Tropospheric CO2 column | | energy budget | Chemistry |
| ECV_Atmosphere | Carbon Dioxide, Methane and other Greenhouse gases | Tropospheric CO2 | mol/mol | energy budget | Chemistry |
| ECV_Atmosphere | Carbon Dioxide, Methane and other Greenhouse gases | Tropospheric CH4 column | | energy budget | Chemistry |
| ECV_Atmosphere | Carbon Dioxide, Methane and other Greenhouse gases | Tropospheric CH4 | mol/mol | energy budget | Chemistry |
| ECV_Atmosphere | Carbon Dioxide, Methane and other Greenhouse gases | Stratospheric CH4 | mol/mol | energy budget | Chemistry |
| ECV_Atmosphere | Cloud Properties | Cloud amount | scalar | energy budget | Physics |
| ECV_Atmosphere | Cloud Properties | Cloud Top Pressure | N/m² | energy budget | Physics |
| ECV_Atmosphere | Cloud Properties | Cloud Top Temperature | K | energy budget | Physics |
| ECV_Atmosphere | Cloud Properties | Cloud Optical Depth | scalar | energy budget | Physics |
| ECV_Atmosphere | Cloud Properties | Cloud Water Path(liquid an ice) | kg/m² | energy budget | Physics |
| ECV_Atmosphere | Cloud Properties | C, effective particle radius (liquid + ice) | m | energy budget | Physics |
| ECV_Atmosphere | Ozone | Total column ozone | | energy budget | Chemistry |
| ECV_Atmosphere | Ozone | Troposphere Ozone | mol/mol | energy budget | Chemistry |
| ECV_Atmosphere | Ozone | Ozone profile in upper and lower stratosphere | mol/mol | energy budget | Chemistry |
| ECV_Atmosphere | Ozone | Ozone profile in upper strato-and mesosphere | mol/mol | energy budget | Chemistry |

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|---|---|---|---|---|---|
| ECV_Atmosphere | Precursors (supporting the Aerosol and Ozone ECVs) | NO2 tropospheric column | | energy budget | Chemistry |
| ECV_Atmosphere | Precursors (supporting the Aerosol and Ozone ECVs) | SO2,HCHO tropospheric columns | | energy budget | Chemistry |
| ECV_Atmosphere | Precursors (supporting the Aerosol and Ozone ECVs) | CO tropospheric column | | energy budget | Chemistry |
| ECV_Atmosphere | Precursors (supporting the Aerosol and Ozone ECVs) | CO tropospheric profile | mol/mol | energy budget | Chemistry |
| ECV_Land | Above-ground biomass | | kg/m² | energy budget | Biology |
| ECV_Land | Albedo | directional-hemispherical reflectance | (W/m²)/(W/m²) | energy budget | Physics |
| ECV_Land | Albedo | bi-hemispherical reflectance | (W/m²)/(W/m²) | energy budget | Physics |
| ECV_Land | Anthropogenic Greenhouse Gas Fluxes | Emissions from fossil fuel use, industry, agriculture and waste sectors. | kg | energy budget | Chemistry |
| ECV_Land | Anthropogenic Greenhouse Gas Fluxes | Emissions/ removals by IPCC land categories | kg | energy budget | Chemistry |
| ECV_Land | Anthropogenic Greenhouse Gas Fluxes | Estimated fluxes by inversions of observed atmosph | m³/(m²s) | energy budget | Chemistry |
| ECV_Land | Anthropogenic Greenhouse Gas Fluxes | Estimated fluxes by inversions of observed atmospheric composition - national | m³/(m²s) | energy budget | Chemistry |
| ECV_Land | Anthropogenic Greenhouse Gas Fluxes | Hi-res CO2 column concentrations to monitor point sources | | energy budget | Chemistry |
| ECV_Land | Anthropogenic Water Use | | m³ | water buget | Physics |
| ECV_Land | Fire | Burnt Areas | m² | energy budget | Physics |
| ECV_Land | Fire | Active fire maps | m² | energy budget | Physics |
| ECV_Land | Fire | Fire radiative power | W/m² | energy budget | Physics |
| ECV_Land | Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) | maps of FAPAR for modelling | W/m² | energy budget | Physics |
| ECV_Land | Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) | maps of FAPAR for adaptation | W/m² | energy budget | Physics |
| ECV_Land | Glaciers | Glacier area | m³ | water buget | Physics |
| ECV_Land | Glaciers | Glacier elevation change | m | water buget | Physics |
| ECV_Land | Glaciers | Glacier mass change | kg | water buget | Physics |
| ECV_Land | Groundwater | Groundwater volume change | m³ | water buget | Physics |
| ECV_Land | Groundwater | Groundwater level | m | water buget | Physics |
| ECV_Land | Groundwater | Groundwater recharge | m³ | water buget | Physics |
| ECV_Land | Groundwater | Groundwater discharge | m³ | water buget | Physics |
| ECV_Land | Groundwater | Wellhead level | m | water buget | Physics |
| ECV_Land | Groundwater | Water quality | | matter budget | Chemistry |
| ECV_Land | Ice Sheets and ice shelves | Surface Elevation Change | m | water buget | Physics |
| ECV_Land | Ice Sheets and ice shelves | Ice velocity | m/s² | water buget | Physics |
| ECV_Land | Ice Sheets and ice shelves | Ice mass change | kg | water buget | Physics |
| ECV_Land | Ice Sheets and ice shelves | Grounding line location and thickness | | water buget | Physics |
| ECV_Land | Lakes | Lake water level | m | water buget | Physics |
| ECV_Land | Lakes | Water Extent | m | water buget | Physics |
| ECV_Land | Lakes | Lake surface water temperature | K | abitotic heterogeneity | Physics |
| ECV_Land | Lakes | Lake ice thickness | m | water buget | Physics |
| ECV_Land | Lakes | Lake Ice Cover | m² | water buget | Physics |
| ECV_Land | Lakes | Lake Colour (Lake Water Leaving Reflectance) | (W/m²)/(W/m²) | energy budget | Physics |
| ECV_Land | Land cover | Land cover | | abitotic heterogeneity | Physics |
| ECV_Land | Land cover | Land Use | | abitotic heterogeneity | Physics |
| ECV_Land | Land Surface Temperature | Land Surface Temperature | K | abitotic heterogeneity | Physics |
| | Heat fluxes | Latent Heat flux | W/m² | energy budget | Physics |
| ECV_Land | Heat fluxes | Sensible Heat flux | W/m² | energy budget | Physics |
| ECV_Land | Leaf Area Index (LAI) | Leaf Area Index (LAI) | | energy budget | Physics |
| ECV_Land | Permafrost | Thermal State of Permafrost | K | water buget | Physics |

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|---|---|---|---|---|---|
| ECV_Land | Permafrost | Active Layer Thickness | m | water buget | Physics |
| ECV_Land | River Discharge | River discharge | $m^3$ | water buget | Physics |
| ECV_Land | River Discharge | Water Level | m | water buget | Physics |
| ECV_Land | River Discharge | Flow Velocity | m/s | water buget | Physics |
| ECV_Land | River Discharge | Cross-section | | water buget | Physics |
| ECV_Land | Snow | Area covered by snow | $m^2$ | water buget | Physics |
| ECV_Land | Snow | snow depth | m | water buget | Physics |
| ECV_Land | Snow | snow water equivalent | $m^3$ | water buget | Physics |
| ECV_Land | Soil Carbon | %Carbon in soil | kg/kg | abitotic heterogeneity | Chemistry |
| ECV_Land | Soil Carbon | Mineral soil bulk density to 30 cms and 1m | $kg/m^3$ | abitotic heterogeneity | Physics |
| ECV_Land | Soil Carbon | Peatlands total depth of profile, area and location | | abitotic heterogeneity | Physics |
| ECV_Land | Soil Moisture | Surface soil moisture | % | abitotic heterogeneity | Physics |
| ECV_Land | Soil Moisture | Freeze/thaw | | abitotic heterogeneity | Physics |
| ECV_Land | Soil Moisture | Surface inundation | | abitotic heterogeneity | Physics |
| ECV_Land | Soil Moisture | Root-zone soil moisture | % | abitotic heterogeneity | Physics |
| ECV_Ocean | Ocean Surface Heat Flux | Latent Heat Flux | $W/m^2$ | energy budget | Physics |
| ECV_Ocean | Ocean Surface Heat Flux | Sensible Heat Flux | $W/m^2$ | energy budget | Physics |
| ECV_Ocean | Sea Ice | Sea Ice Concentration | | water buget? | Physics |
| ECV_Ocean | Sea Ice | Sea Ice Extent/Edge | $m^2$ | water buget | Physics |
| ECV_Ocean | Sea Ice | Sea Ice Thickness | m | water buget | Physics |
| ECV_Ocean | Sea Ice | Sea Ice Drift | m/s | water buget | Physics |
| ECV_Ocean | Sea Level | Global Mean Sea Level | m | water buget | Physics |
| ECV_Ocean | Sea Level | Regional Sea Level | m | water buget | Physics |
| ECV_Ocean | Sea State | Wave Height | m | water buget | Physics |
| ECV_Ocean | Sea Surface Salinity | Sea Surface Salinity | kg/l | water buget | Physics |
| ECV_Ocean | Sea Surface Temperature | Sea Surface Temperature | K | water buget | Physics |
| ECV_Ocean | Subsurface Curents | Interior Currents | m/s | water buget | Physics |
| ECV_Ocean | Subsurface Salinity | Interior Salinity | kg/l | water buget | Physics |
| ECV_Ocean | Subsurface Temperature | Interior Temperature | K | water buget | Physics |
| ECV_Ocean | Surface Currents | Surface Geostrophic Current | m/s | water buget | Physics |
| ECV_Ocean | Surface Stress | Surface Stress | | energy budget/water | Physics |
| ECV_Ocean | Inorganic Carbon | Interior ocean carbon storage. At least 2 of: Dissolved Inorganic Carbon (DIC), Total Alkalinity | | matter budget/water | Chemistry |
| ECV_Ocean | Inorganic Carbon | pCO2 (to provide Air-sea flux of CO2) | kg/m | matter budget/water | Chemistry |
| ECV_Ocean | Nitrous Oxide | Interior ocean N2O | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Nitrous Oxide | N2O air-sea flux | $mol/m^2*s$ | matter budget/water | Chemistry |
| ECV_Ocean | Nutrients | Interior ocean Concentrations of silicate, phosphate, nitrate | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Ocean Colour | Water Leaving Radiance | $W \cdot sr^{-1} \cdot m^{-2}$ | water budget | Physics |
| ECV_Ocean | Ocean Colour | Chlorophyll-a Concentration | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Oxygen | Interior ocean Oxygen concentration | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Transient Tracers | Interior ocean CFC-12 | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Transient Tracers | Interior ocean CFC-11 | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Transient Tracers | Interior ocean SF6 | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Transient Tracers | Interior ocean tritium | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |
| ECV_Ocean | Transient Tracers | Interior ocean 3He | kg/kg; $m^3/m^3$ | matter budget/water | Chemistry |

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|---|---|---|---|---|---|
| ECV_Ocean | Transient Tracers | Interior ocean 14C | kg/kg; m³/m³ | matter budget/water | Chemistry |
| ECV_Ocean | Transient Tracers | Interior ocean 39Ar | kg/kg; m³/m³ | matter budget/water | Chemistry |
| ECV_Ocean | Marine Habitat Properties | Coral Reefs | m² | abitotic heterogeneity | Physics |
| ECV_Ocean | Marine Habitat Properties | Mangrove Forests, Seagrass Beds, Macroalgal Communities | m² | abitotic heterogeneity | Physics |
| ECV_Ocean | Plankton | Phytoplankton | | matter budget/water | Chemistry |
| ECV_Ocean | Plankton | Zoo plankton | | matter budget/water | Chemistry |

# Essential Ocean Variables (EOV)

| EV Domain | EV | EV Subvariables | Unit (SI) | EV EI Component | Scientific domain |
|---|---|---|---|---|---|
| EOV | Ocean Surface Vector Stress (OSVS) | Equivalent neutral winds | N*m^-2 | abiotic heterogenity | Physics |
| | | Stress equivalent neutral winds | N*m^-2 | abiotic heterogenity | Physics |
| | | Scalar stress | N*m^-2 | abiotic heterogenity | Physics |
| EOV | Sea State | Significant wave height | m | abiotic heterogenity | Physics |
| | | wave period | s^-1 | abiotic heterogenity | Physics |
| | | wave direction | | abiotic heterogenity | Physics |
| | | maximum wave height | m | abiotic heterogenity | Physics |
| | | swell | | abiotic heterogenity | Physics |
| | | directional spectrum | | abiotic heterogenity | Physics |
| | | whitecap fraction | m/s^-1 | abiotic heterogenity | Physics |
| EOV | Sea Ice | Ice extent and area | m and m^2 | abiotic heterogenity | Physics |
| | | ice concentration | % | abiotic heterogenity | Physics |
| | | ice thickness | m | abiotic heterogenity | Physics |
| | | ice motion | m*s^-1 | abiotic heterogenity | Physics |
| | | fast ice | m | abiotic heterogenity | Physics |
| | | ice type (first year, multi-year) | | abiotic heterogenity | Physics |
| | | ice salinity | % | abiotic heterogenity | Physics |
| | | snow cover thickness | m | abiotic heterogenity | Physics |
| | | surface freeze-up and melt time | s | abiotic heterogenity | Physics |
| | | melt pond coverage | m^2 | abiotic heterogenity | Physics |
| EOV | Sea Surface Height (SSH) | Sea level anomaly | m | abiotic heterogenity | Physics |
| | | sea surface height gradients | m/s | abiotic heterogenity | Physics |
| | | sea level extremes | m | abiotic heterogenity | Physics |
| | | tidal range | m | abiotic heterogenity | Physics |
| EOV | Sea Surface Temperature (SST) | Skin SST | K | abiotic heterogenity | Physics |
| | | subskin SST | K | abiotic heterogenity | Physics |
| | | near surface temperature at stated depth | K | abiotic heterogenity | Physics |
| | | bulk SST | K m^-3 | abiotic heterogenity | Physics |
| EOV | Subsurface Temperature | Foundation SST | K | abiotic heterogenity | Physics |
| | | Bulk SST | K m^-3 | abiotic heterogenity | Physics |
| EOV | Surface Currents | Near surface velocity at stated depth | m s-1 | abiotic heterogenity | Physics |
| | | surface geostrophic velocity | m s-1 | abiotic heterogenity | Physics |
| | | near-surface Ekman currents | kg m-1 s-1 | abiotic heterogenity | Physics |
| | | tidal currents | m s-1 | abiotic heterogenity | Physics |
| | | Lagrangian drift | m s-1 | abiotic heterogenity | Physics |
| | | Stokes velocity | m s-1 | abiotic heterogenity | Physics |
| | | surface speed | m s-1 | abiotic heterogenity | Physics |
| EOV | Ocean Currents (Subsurface) | 3-dimensional velocity components | m s-1 | abiotic heterogenity | Physics |
| | | geostrophic velocities | m s-1 | abiotic heterogenity | Physics |
| | | Ekman currents | kg m-1 s-1 | abiotic heterogenity | Physics |
| | | tidal currents | m s-1 | abiotic heterogenity | Physics |
| | | quasi-Lagrangian drift | m s-1 | abiotic heterogenity | Physics |
| | | speed | m s-1 | abiotic heterogenity | Physics |

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|---|---|---|---|---|---|
| EOV | Sea Surface Salinity (SSS) | Bulk surface salinity | mol kg-1 | abiotic heterogenity | Physics |
| | | skin surface salinity | mol kg-1 | abiotic heterogenity | Physics |
| | | near surface salinity at stated depth | mol kg-1 | abiotic heterogenity | Physics |
| EOV | Subsurface Salinity | Foundation | mol kg-1 | abiotic heterogenity | Physics |
| | | bulk SSS | mol kg-1 | abiotic heterogenity | Physics |
| EOV | Ocean Surface Heat Flux | Latent heat flux | W m^-2 s^-1 | energy budget | Physics |
| | | Sensible heat flux | W m^-2 s^-1 | energy budget | Physics |
| | | net short wave radiation | W m^-2 | energy budget | Physics |
| | | downward shortwave radiation | W m^-2 | energy budget | Physics |
| | | upward shortwave radiation | W m^-2 | energy budget | Physics |
| | | albedo | ratio | energy budget | Physics |
| | | net longwave radiation | W m^-2 | energy budget | Physics |
| | | downward longwave radiation | W m^-2 | energy budget | Physics |
| | | upward longwave radiation | W m^-2 | energy budget | Physics |
| | | photosynthetically available radiation | W m^-2 | energy budget | Physics |
| EOV | Oxygen | Dissolved Oxygen (O2) | mol kg-1 | matter budget | Biogeochemistry |
| EOV | Nutrients | Nitrate (NO3-) | mol kg-1 | matter budget | Biogeochemistry |
| | | Nitrite (NO2-) | mol kg-1 | matter budget | Biogeochemistry |
| | | Ammonium (NH4) | mol kg-1 | matter budget | Biogeochemistry |
| | | Phosphate (PO4) | mol kg-1 | matter budget | Biogeochemistry |
| | | Silicic acid (Si(OH)4) | mol kg-1 | matter budget | Biogeochemistry |
| EOV | Inorganic Carbon | Dissolved Inorganic Carbon (DIC) | mol kg-1 | matter budget | Biogeochemistry |
| | | Total Alkalinity (TA) | mol kg-1 | matter budget | Biogeochemistry |
| | | Partial pressure of carbon dioxide (pCO2) | Pa | matter budget | Biogeochemistry |
| | | pH | - | matter budget | Biogeochemistry |
| EOV | Transient Tracers | Chlorofluorocarbons (CFC-12, CFC-11, CFC-113, CCl4) | ratio | matter budget | Chemistry |
| | | Sulphur hexafluoride (SF6) | ratio | matter budget | Chemistry |
| | | tritium | ratio | matter budget | Chemistry |
| | | 3He | ratio | matter budget | Chemistry |
| | | 14C | ratio | matter budget | Chemistry |
| | | 39Ar | ratio | matter budget | Chemistry |
| EOV | Particulate Matter | Particulate Organic Matter (POM) | mol kg-1 | matter budget | Biogeochemistry |
| | | Particulate Organic Carbon (POC) | mol kg-1 | matter budget | Biogeochemistry |
| | | Particulate Organic Nitrogen (PON) | mol kg-1 | matter budget | Biogeochemistry |
| | | Particulate Organic Phosphorus (POP) | mol kg-1 | matter budget | Biogeochemistry |
| | | Particulate Inorganic Carbon (PIC) | mol kg-1 | matter budget | Biogeochemistry |
| | | Total Suspended Matter (TSM) | mol kg-1 | matter budget | Biogeochemistry |
| | | POC flux | kg m^-2 s^-1 | matter budget | Biogeochemistry |
| | | Calcium Carbonate (CaCO3) flux | kg m^-2 s^-1 | matter budget | Biogeochemistry |
| | | Biogenic Silica (BSi) flux | kg m^-2 s^-1 | matter budget | Biogeochemistry |
| EOV | Nitrous Oxide | Nitrous Oxide (N2O) | mol kg−1 | matter budget | Biogeochemistry |
| EOV | Stable Carbon Isotopes | 13C/12C isotope ratio of Dissolved Inorganic Carbon (DIC) | kg t^-1 | matter budget | Biogeochemistry |
| EOV | Dissolved Organic Carbon | Dissolved Organic Carbon (DOC) | kg t^-1 | matter budget | Biogeochemistry |
| EOV | Ocean Colour | under development | | | |

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|---|---|---|---|---|---|
| EOV | Phytoplankton biomass and diversity | Presence/Absence/Relative Abundance | | Biotic diversity | Biology |
| | | Diversity/Taxonomy | | Biotic diversity | Biology |
| | | Genomic information | | Biotic diversity | Biology |
| | | In vitro/In vivo pigment fluorescence | | Biotic diversity | Biology |
| | | Pigment concentration by spectrophotometry (chlorophyll a, b, HPLC pigments) | | Biotic diversity | Biology |
| | | Spectral reflectance (ocean color/remote sensing methods) | | Biotic diversity | Biology |
| | | Primary productivity (different methods) | | Matter budget | Biology |
| EOV | Zooplankton biomass and diversity | Biomass overall | | Biotic diversity | Biology |
| | | biomass or abundance (or presence/absence) by taxon | | Biotic diversity | Biology |
| | | functional group or size class | | Biotic diversity | Biology |
| EOV | Fish abundance and distribution | Number, biomass or abundance index of fish of different taxa per unit volume or area of water in a | | Biotic diversity | Biology |
| | | Numbers or biomass of fish by size/age/stage | | Biotic diversity | Biology |
| EOV | Marine turtle, bird and mammal abundance and | Species presence/absence | | Biotic diversity | Biology |
| | | Age | | Biotic diversity | Biology |
| | | Sex | | Biotic diversity | Biology |
| | | Count data | | Biotic diversity | Biology |
| | | Repeated individual presence (tracking/resights) | | Biotic diversity | Biology |
| EOV | Live coral | Live coral cover and areal extent | | Biotic diversity | Biology |
| | | Coral diversity (species, genera and functional type; and alpha, beta or gamma) | | Biotic diversity | Biology |
| | | Coral condition (diseases, bleaching, mortality (partial and full), predated, silted, other | | Biotic diversity | Biology |
| | | Total habitable substrate (less sand/silt substrates, structural complexity) | | Biotic diversity | Biology |
| | | Coral size classes (recruits/small corals, size class distribution) | | Biotic diversity | Biology |
| EOV | Seagrass Cover | Shoot density/cover | m^2 | Biotic diversity | Biology |
| | | Canopy height | m | Biotic diversity | Biology |
| | | Seagrass diversity (species) | | Biotic diversity | Biology |
| | | Areal extent of seagrass meadows | | Biotic diversity | Biology |
| | | Photosynthetic efficiency (measured with PAM) | | Energy budget | Biology |
| EOV | Macroalgal canopy cover | Canopy species diversity | | Biotic diversity | Biology |
| | | Canopy height | m | Biotic diversity | Biology |
| | | Stem density (kelps) | | Biotic diversity | Biology |
| | | Plant condition (qualitative: signs of necrosis and potential drivers, fouling and grazing) | | Biotic diversity | Biology |
| | | Plant size classes (including recruits) | | Biotic diversity | Biology |
| | | Photosynthetic efficiency | | Energy budget | Biology |
| | | Photosynthetic biomass | | Energy budget | Biology |
| | | Areal extent | m^2 | Biotic diversity | Biology |
| EOV | Mangrove cover | Mangrove fringe width and area | m^2 | Biotic diversity | Biology |
| | | Mangrove tree species composition and zonation | | Biotic diversity | Biology |
| | | Tree, algae, and phytoplankton primary production | | Biotic diversity | Biology |
| | | Canopy height and trunk girth | | Biotic diversity | Biology |
| | | Trunk and seedling density by species | | Biotic diversity | Biology |
| | | Soil profile, carbon/nutrient content, and C14 age | | Abiotic heterogeneity | Biology |
| | | Sediment and water column respiration | | Abiotic heterogeneity | Biology |
| | | Intertidal fish and invertebrate densities | | Biotic diversity | Biology |
| EOV | Ocean Sound | sound pressure | kg s^-2 m^-1 | Abiotic heterogeneity | Physics |
| | | particle motion (displacement, velocity, acceleration) | m, m s^-1, m s^-2 | Abiotic heterogeneity | Physics |
| EOV | Microbe biomass and diversity | under development | | | |
| EOV | Benthic invertebrate abundance and distributio | under development | | | |