ConnectinGEO - ENEON

Policy brief

Introduction

The Global Observation System of Systems (GEOSS) is an Earth Observation infrastructure that connects observation and data systems together for the benefits of nations and participant organizations. GEOSS created and maintained by the Groups on Earth Observations (GEO). GEO made extensive efforts to provide information on what is available: a core element for this is the GEOSS Discovery and Access Broker (GEO-DAB), which is part of the GEOSS Common Infrastructure.

ConnectinGEO (Coordinating an Observation Network of Networks EnCompassing satellite and IN-situ to fill the Gaps in European Observations, n° 641538) is an European Commission funded project in the H2020 program that started on 2015 with the aim to provide to link existing Earth Observation networks with science, private sector and with GEOSS and Copernicus stakeholders (Copernicus is the European Union Programme aimed at developing European information services based on satellite Earth Observation and in situ non-space data). Following this objective, other major achievements have been reached, mainly, the enablement of the European Network of Earth Observation Networks (ENEON), as well as the provision of a gap analysis among existing Earth Observation networks prioritizing the Sustainable Development Goals (SDG) as one important target and the Essential Variables (EV) as a framework.

After 2 years of intense work, this document summarizes the policy relevant outcomes and recommendations that ConnectinGEO produced. ConnectinGEO individual members will look to other minds of continue some of these activities after the end of the project and will execute project exploitation plan for the project results.

More information on these activities can be found at www.connectingeo.net and www.eneon.net.

ENEON

ENEON, is created to increase the connection between the existing European Earth Observation networks, particularly focused on the in-situ segment, and the relevant communities engaged in the assessments, forecasting, and projecting of future developments that can support EC, national governments, and other policy makers at all levels to formulate informed decisions. ENEON acts as a platform to promote emerging European networks and sensor deployment projects and makes them part of GEOSS or participants of the Copernicus Services. By this, ENEON ensures GEO is fulfilling the mandate coming from the nations of aggregating valuable Earth Observations resources in system of systems that is useful for them. While governments are involved in the achievement of the Sustainable Development Goals (SDG), GEOSS and ENEON are focusing the necessary data to monitor the progress towards these goals.

ENEON plays a major role in developing, validating, populating, and using the Socio-Economic and Environmental Information Needs Knowledge Base (SEE-IN KB) for virtual collaboration between providers, scientific and societal users, and, in particular, decision and policy makers. For this reason, an ENEON Commons portal is created to support the sharing and reuse of digital objects in a web space.

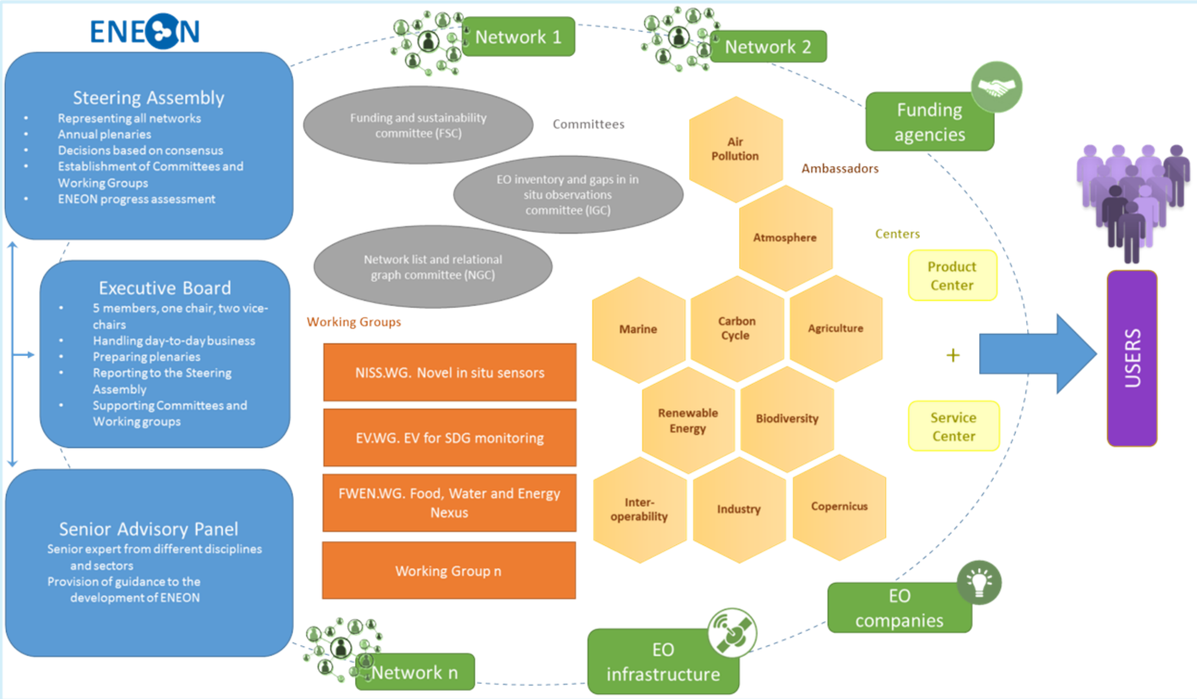

Figure 1. ENEON structure

ENEON is taking an active role in pushing in-situ observations in GEOSS through the GEOSS Foundational Task on “GEOSS in-Situ Earth Observation Resources”: http://www.earthobservations.org/activity.php?id=134.

Earth Observation in-situ networks mapping

Mapping the in-situ networks at the European level has led to the discovery of a large, complex and incomplete system. Individual networks exercise the coordination within each topic. The graph is a tool to improve interaction and knowledge across scientific disciplines and to decide on which domains extra coordination is still needed

Through ENEON, a lively, web based dynamic graph on existing European Earth Observation networks has been created www.eneon.net/graph. Each individual network is described, including links to other networks and specifying the role of the relation. Technically, the network database is maintained in a JSON-LD file that can be dynamically converted into RDF and connected to the linked data. The graph representation is based on an open source code available at GitHub called d3-

process-map that uses the d3.js graphical library. The graph also incorporates the possibility of provide feedback for further improvement.

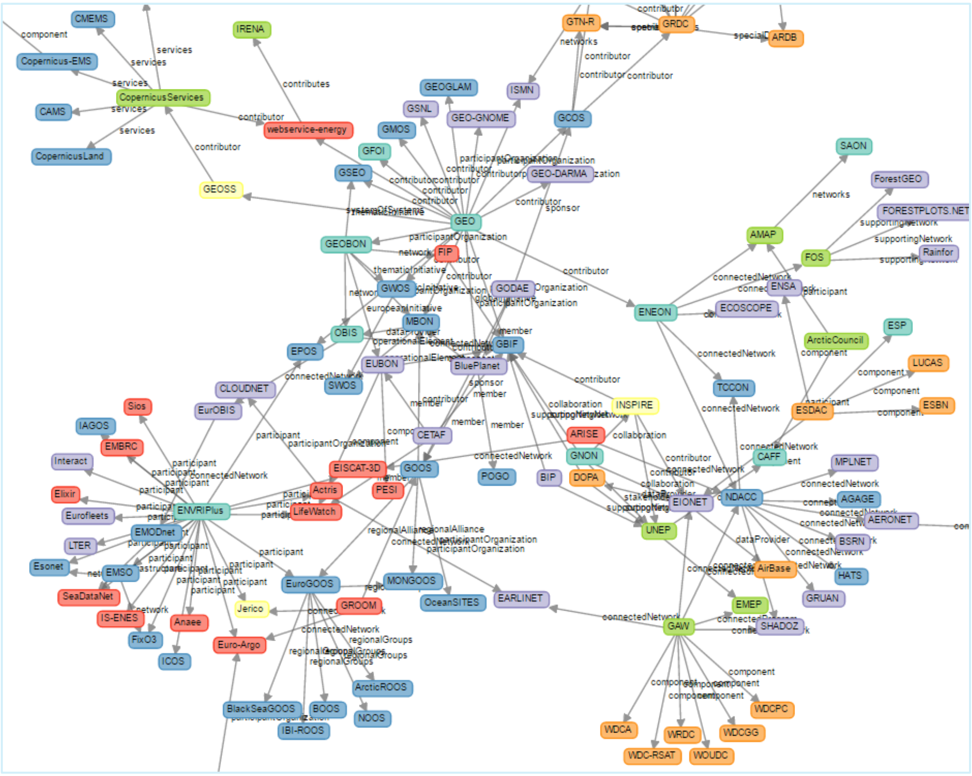

Figure 2. ENEON graph of in-situ EO European networks

Figure 3. Export to RDF representation

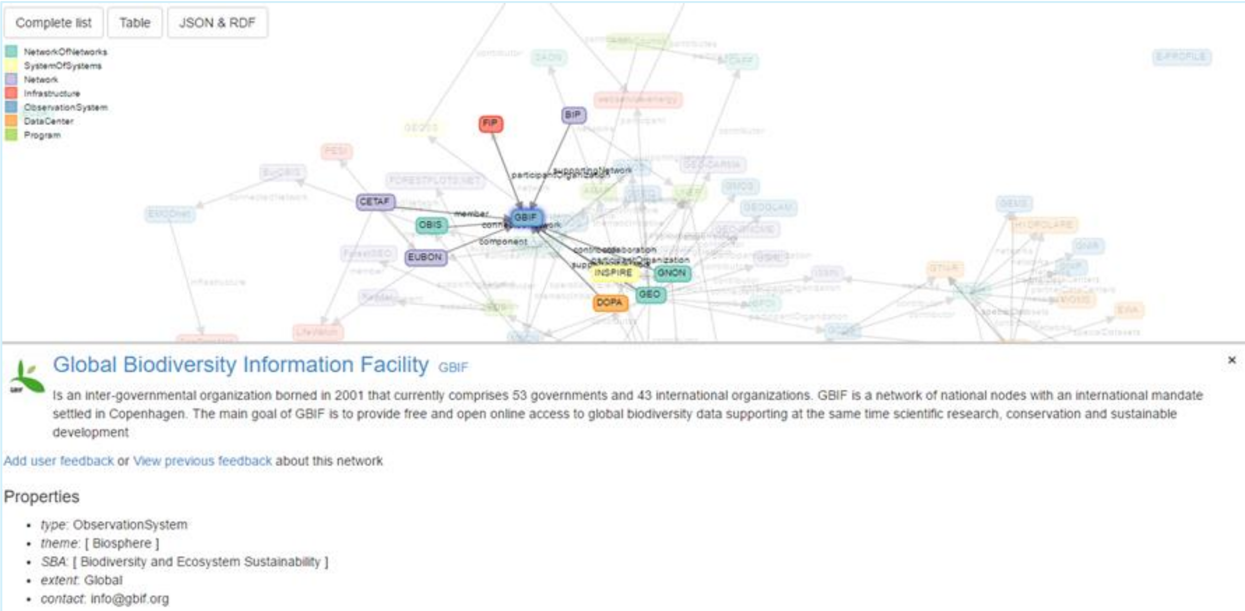

Figure 4. Description of each network, relation to other networks and possibility to provide feedback

ENEON interoperability experiments

Market opportunities has been explored through a set of interoperability experiments on providing access to in-situ measurements.

One example illustrates the business opportunities created by having more information about renewable energies by incorporating data that SME and solar companies already own through a WebGIS Client (http://insitu.webservice-energy.org/jsClient-0.2.0/#map) based on the 52N SWE (Sensor Web Enablement) solution following OGC SOS (Sensor Observation Service) standard. Showing the potential of this energies will help achieving an economy less dependent on fossil fuels

This platform enables (i) visualisation of sensor locations on a map, (ii) visualisation of measurements as time series as plots and in tabular form, (iii) display of sensor metadata at different levels of detail, (iv) computation and statistical representation of time series according to the types of in-situ measurements (e.g. solar 2D view, wind roses), and (v) download of observation data for offline processing.

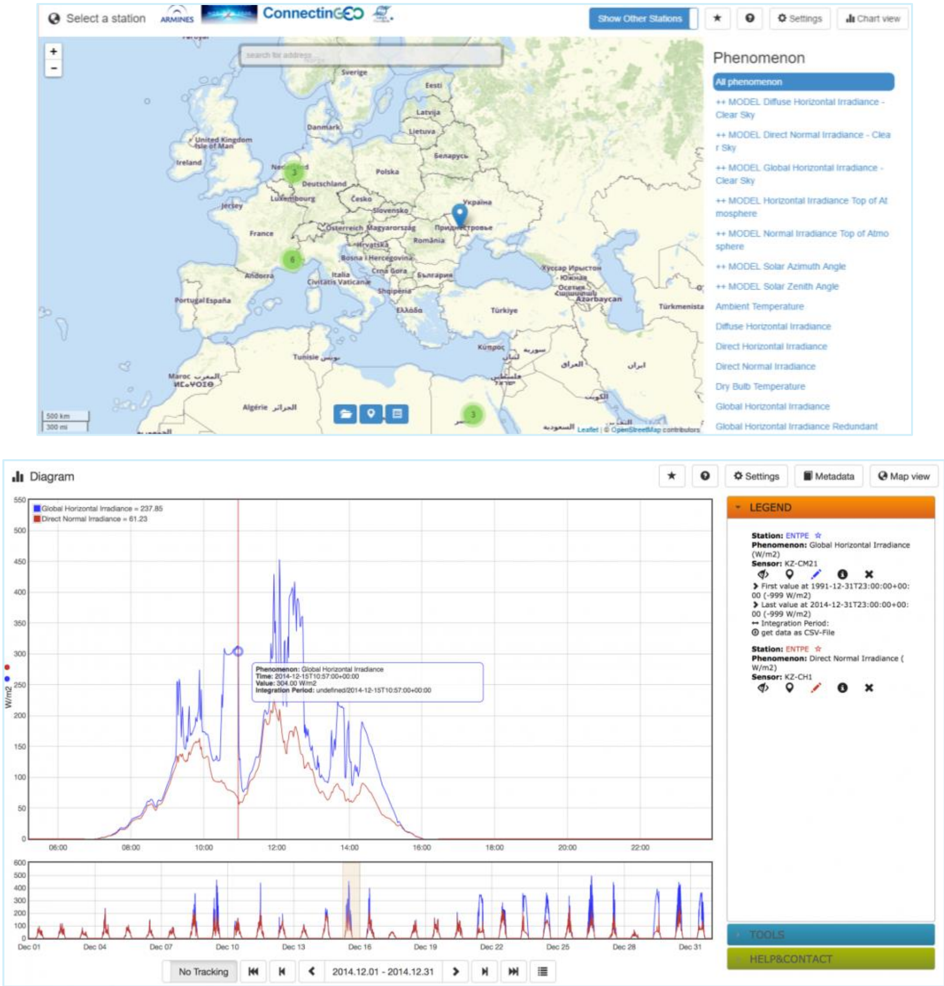

Figure 5. Solar energy SWE WebGIS Client time series visualization.

The ENEON commons portal

The ENEON Commons portal is supporting ENEON networks by providing an open and inclusive computer-based collaboration environment that facilitates the discovery, execution, reuse and creation of knowledge from in situ network's digital offerings and activities. In situ networks and infrastructures are able to present themselves in a comprehensive Earth Observation context, expose their offerings to a broader community and demonstrate their usefulness for addressing cross-domain issues. Policy makers are able to formulate questions and get interpretations and options from data providers working with their experts. Scientists are able to participate in the decision making process by transforming the observation data into actionable knowledge.

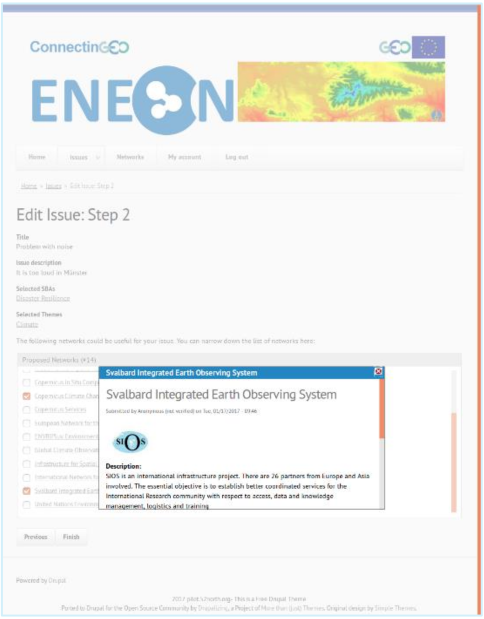

Figure 6. Preliminary ENEON commons interface

ConnectinGEO has conducted a pilot of the ENEON Commons, based on a pre-existing 52°North Web portal development was enhanced. The pilot involved three in situ Earth Observation networks (including the emerging Solar Renewable Energy Network, LTER-Europe and Citizens Science) that offer a comprehensive description of their offerings (observations variables and observation outcomes), and connection to the GEODAB. For the selected networks, experts are identified. Scientific and decision-making questions are accepted, automatically answered, redirected, and/or redirected for review by experts.

Essential Variables

ConnectinGEO also analysed the level of maturity and completeness of the concept of EV in all GEOSS SBA Coming from a Workshop in Bari, in June 2015, and reported in the public *D2.3: Proposal of EVs for selected themes*.

The concept of EVs is increasingly used in Earth Observation communities to identify and prioritize variables and observations that are key point to the missions of these groups. One of the purposes of this definition is to persuade funding agencies to maintain the costs of the networks that are monitoring these variables. Initial efforts were made by the Global Climate Observing System (GCOS) under the United Nations Framework Convention on Climate Change (UNFCCC), which developed a set of Essential Climate Variables (ECVs). GEO provides an important framework for the development of set of EVs for each SBA and thematic area, including Essential Ocean Variables (EOVs) for marine, chemical, and physical aspects of the oceans, and Essential Biodiversity Variables (EBVs) for biodiversity. A review of the current status is provided by Deliverable 2.2. In most cases, all these efforts utilized the so-called expert-based approach (EBA), where experts in the relevant field identify what they need and what is feasible to observe. In most cases, a link to the societal benefits is constructed after the domain-specific EVs have been identified.

In particular, 147 EVs were reviewed and analysed, leading to the conclusions that a complementary approach to the definition of EVs is necessary. The proposed Goal based approach focuses on the decision making process towards the sustainability of the planet and to understand how close we are to reach the planetary boundaries. Decisions makers should participate in the process of defining which variables are consider EV based on the requirements of the indicators to measure the planet status and evolution and should include also socioeconomic aspects.

Sustainable Development Goals

In July 2014 the States members of the UN reached an agreement on the 17 Sustainable Development Goals that are going to guide the nations for the next 15 years. The topics covered include ending extreme poverty and hunger, and guaranteeing human rights, peace, gender equality, as well as the preservation of the environment. To quantify the achievement toward the SDG 169 targets have been defined and, for each target, one of more indicators has been proposed. In the ConnectinGEO analysis of the SDG, only 30 indicators from the total 240 can be extracted with the combination of socio-economic data and Earth Observation (in-situ, airborne or remote sensing), and only 9 by Earth Observation information alone. For these 9, a link with EVs was proposed (complete results available in the ConnectinGEO deliverable *D2.3 Proposal of EVs for selected themes*).

- Goal 14: **Conserve and sustainably use the oceans, seas and marine resources for sustainable development**
    - Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from landbased activities, including marine debris and nutrient pollution
        - *Indicator 14.1.1 Index of Coastal Eutrophication (ICEP) and Floating Plastic debris Density*
            - *Related proposed EV: Ocean colour | Ocean acidity | Species populations (Species distribution, Population abundance, Population structure by age/size class) | Community composition (Taxonomic diversity, Species interactions) | Ecosystem structure (Habitat structure, Ecosys. extent and fragmentation, Ecosys. composition by functional type)*
    - Target 14.3: Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
        - *Indicator 14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations*
            - *Related proposed EV: Ocean acidity*
    - Target 14.4: By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at l
        - *Indicator 14.4.1 Proportion of fish stocks within biologically sustainable levels*
            - *Related proposed EV: Species populations (Species distribution, Population abundance, Population structure by age/size class)*

Figure 7. Example of proposed relation between EVs and SDGs

In-situ Earth Observation Gap Analysis

In the past Gap analyses have been conducted by many Earth Observation communities. In the Group on Earth Observations (GEO), the former Science and Technology Committee (STC) convened a dialog that culminated in a paper presented to the Executive Committee in 2011. Another example is the Horizon 2020 Project GAIA-CLIM that developed a gap analysis approach and applied it to climate change and atmospheric monitoring.

In general terms, a gap analyses require information on what is needed (i.e. observational requirements) and compare it with what is available (i.e. observations and knowledge) to meet some needs . In GEO, several efforts have been made to capture both sides of the problem. As an example, the GEO Work Plan Task US-09-01 conducted an extensive review of published documents to extract observational needs.

An important concept in linking current knowledge with observational requirements is to map both to a common list of Essential Variables (EVs). Several Earth Observation communities have developed set of theme-specific EVs using an expert-based approach, which starts from thematic expertise of Earth Observation feasibility and eventually links the resulting EVs to societal impacts. ConnectinGEO added a complementary goal-based approach, which starts with a set of agreed-upon societal goals and identifies the EVs required to support implementing the goals and monitoring process towards these goals.

Based on these previous efforts, ConnectinGEO developed an approach with five threads, known as the *ConnectinGEO Gap Analysis Methodology*.

- Top-down-1 (TDT1). Derivation of sustainability indicators needed to monitor progress towards GEOSS Strategic Targets and SDGs and infer the EV.
- Top-down-2 (TDT2). Incorporation of international programs such as the Future Earth, the Belmont Forum, and the Research Data Alliance.
- Bottom-up-1 (BUT1). Direct dialog with members of ENEON.
- Bottom-up-2 (BUT2). Through an observation inventory populated from the GEOSS GEO-DAB and the Socio-Economic and Environmental Information Needs Knowledge Base (SEE-IN KB).
- Bottom-up-3 (BUT3). SMEs participation in pilots to transfer experiences and generate new products based on open access GEOSS Earth Observation data.

The gap analysis carried out in the context of the project have been collected in the ConnectinGEO Gaps Table (CGT), which is an on-line table in the ConnectinGEO wiki available at
http://twiki.connectingeo.net/foswiki/bin/view/ConnectinGEOIntranet/GapAnalysisTable?cover=print.

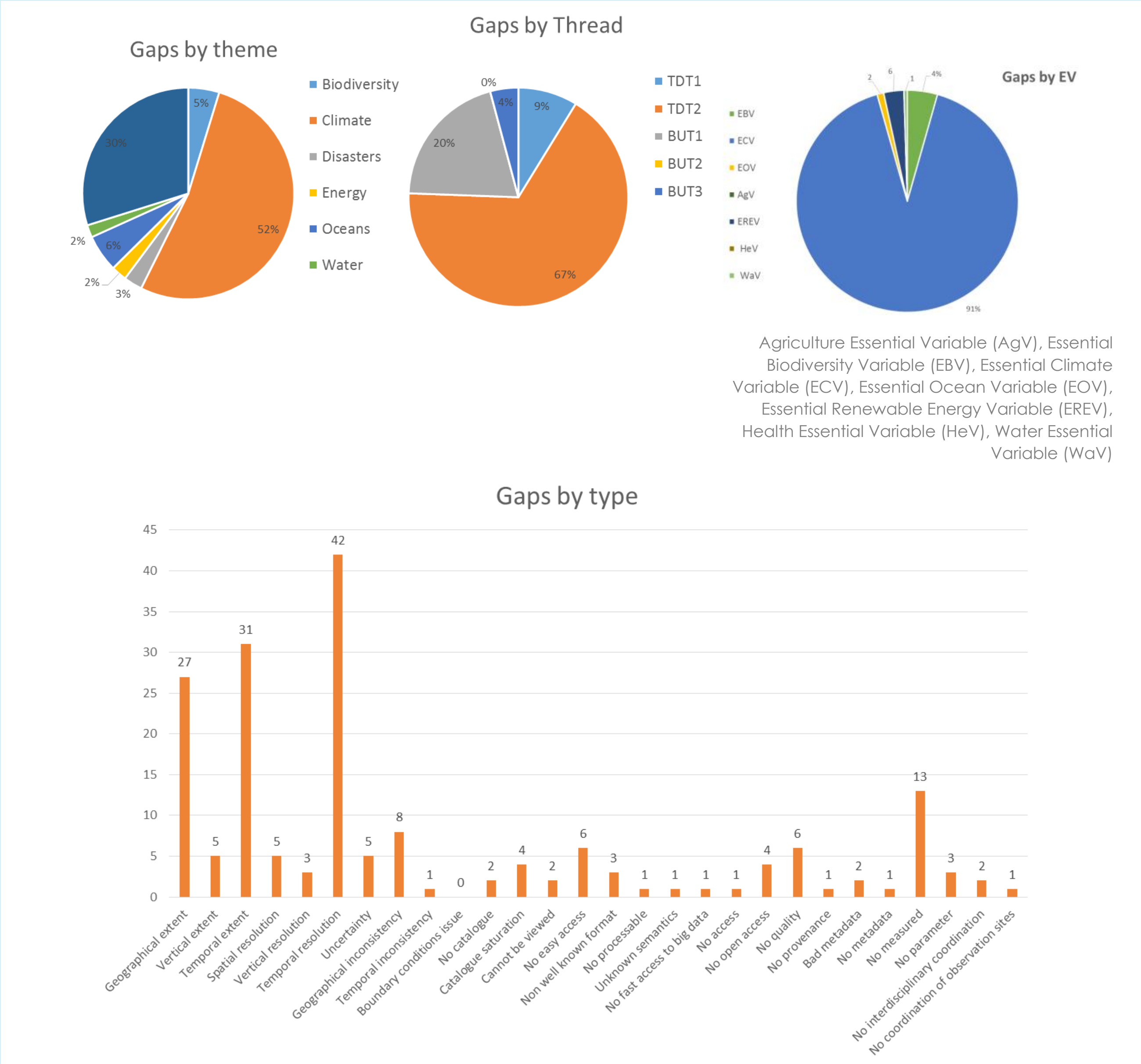

Figure 8. Main stats on identified EO in-situ gaps. From left to right, gaps shown by themes, gaps represented by threads of the methodology, gaps shown by EVs and gaps by type

The distribution of the gaps over themes is dominated the Climate theme with 52% of the gaps associated with this theme followed by the Ocean theme with 30% of the gaps. This uneven distribution is mainly due to the climate and ocean communities being the most active one in contributions to the CGT and has a more mature level of organization. Most of the gaps currently in the CGT resulted from TDT2 i.e., the review of published literature from international programs such as Future Earth, Belmont Forum, the Research Data Alliance and community assessments of socio-economic benefits of Earth Observations. BUT1 provided 20% of the gaps. These gaps come from the consultation process in the current Earth Observation networks, consisting of collaboration platforms, surveys and discussions at workshops and the involvement of citizen science. BUT3, i.e., gaps coming from the realization of a series of real industry-driven challenges to assess the problems and gaps emerging during the creation of business opportunities (see Section 4.5) contributed 4% of the currently published gaps. Concerning the gap type, most gaps are found with respect to required temporal resolution followed by temporal extent and geographical coverage.

Gaps prioritization approach

Two approaches to prioritization were utilized in the project, feasibility-based ranking and expert-based ranking.

Feasibility-based ranking

Feasibility together with the potential impacts a gap would have, the estimated costs and the required time frame for closing the gaps are used to get an indication of the priority. The functional relationship used is

$$p = (f \cdot i) / (c \cdot t)$$

where p is priority, f feasibility, i impact, c cost, and t time frame. The estimation of impact is supported by a rank determined in the SEE-IN KB based on the number of links between a gap and other instances of users, applications, research needs, etc.

In total, 54 gaps could be assigned a priority rank based on this approach. The gaps with highest ranks are: *Lack of continuity and uniform temporal sampling in time series* (CGT-174), *Lack of tidal, ocean currents and water elevation prediction services* (CGT-175), *Lack of tools for Big Data analysis: merge time series, proper map and statistics visual representation* (CGT-176), *Insufficient accounting for environmental variables in SDG indicators* (SDG-GP-2), and *Skills required for matching providers and policy makers* (SDG-GP-6).

Expert-based ranking

Experts in several fields were engaged to review the collected gaps in the CGT and to select ten gaps each that had highest priority for them. The gaps of highest rank based on this approach are: *LIDAR global dataset* (CGT-23), *Lack of sufficient spatial coverage for many climatic applications, especially in the Southern hemisphere* (CGT-92), *No European in-situ cross-domain coordination initiative* (CGT-219), *Scarcity of accurate in situ measurements in most of the world* (CGT-43), *Scarcity of accurate in situ measurements in coastal areas for marine renewable energies* (CGT-45), *Ice sheet, Ice sheet mass change* (CGT-185), and *Missing high resolution data for terrestrial ecosystems structure and terrestrial ecosystems function* (CGT-222).

Final ranking

The 10 prioritized lists of gaps resulting from the two approaches are:

1. Lack of continuity and uniform temporal sampling in time series (CGT-174),

2. Lack of tidal, ocean currents and water elevation prediction services (CGT-175),
3. Lack of tools for Big Data analysis: merge time series, proper map and statistics visual representation (CGT-176),
4. Insufficient accounting for environmental variables in SDG indicators (SDG-GP-2),
5. Skills required for matching providers and policy makers (SDG-GP-6),
6. Glacier, Glacier dammed lakes - near continuous global mapping needed (CGT-180),
7. No coordination of observation sites (CGT-35),
8. Glacier, Facies, snowline - can be estimated from imagery, approximates equilibrium line (CGT-178),
9. Glacier, Glacier topography - inadequate resolution in most places (CGT-183), and
10. No European in-situ cross-domain coordination initiative (CGT-219).

Stimulation of the industry sector

A stimulation of the industry sector to the use of GEOSS data is promoted by means of the Earth Observation product award competition within ConnectinGEO together with EARSC.

Figure 9. Dissemination flyer of the EARSC-ConnectinGEO European EO Product of the year Award

"Rocket in your pocket" by *Jeobrowser* was selected as the winner of the first edition of the European Earth Observation Product of the Year. "Rocket in your pocket" provides a unique entry point to search, visualize and download Earth Observation products from various catalogues. Collections are available: for search: Sentinel-1, Sentinel-2, Landsat 8, SPOT 6-7, and Pleiades images, and for download: Sentinel-1, Sentinel-2 and Landsat 8 data. The database is updated daily from the CNES PEPS platform (Sentinels) and from the USGS platform (Landsat). One of the coolest feature is a density result map. Basically, each result of a search request is represented as a density layer.

Figure 10. Winners of the EARSC-ConnectinGEO European EO Product of the year Award

During the whole process about 16 companies got interested in the award and the finalists were: AnsuR Technologies (NO): GEO-ASIGN: the solutions for communication of operational Earth Observation data, Jeobrowser (FR): Rocket: the Earth in your pocket, Noveltis (FR): TIPS- Tidal Prediction Services: current and water elevation now only a click away and Planetek Italia (IT): Rheticus displacement: monitoring of terrain surface movements.

Recommendations

Indicator Assessment: A thorough analysis of all SDG targets should be conducted to identify additional process-focused indicators based on Earth Observation data that could be proposed to the Inter-Agency and Expert Group responsible for the revision of the SDG Indicator framework.

SDG Interdependencies: A comprehensive assessment of interdependencies between different SDGs and the associated targets should be conducted to ensure that synergies are exploited.

Mapping Earth Observation Actors: Beneficiaries, users, and applications depending on EO-based knowledge should be mapped as a basis for matching users to providers.

Cross-Domain and Cross-Sector Collaboration: Additional efforts should be made to increase collaboration between stakeholders in different disciplines and societal sectors dealing with complex issues such as the Food-Water-Energy Nexus and the interdependency of SDGs as a catalyst to trigger the collaboration, and building upon efforts such as ENEON.

Policy Development: EO based tools for scenario-based creation of transition knowledge and policy impact assessments should be developed in support of policy development. Of particular interest are tools that can answer "What if" questions and support scenario-based simulations.

Policy Validation: A concept of "Real-World Laboratory" should be developed, including the required traditional and emerging Earth Observation elements, for the validation of policies developed and implemented to achieve progress towards specific SDG targets.

In-situ Coordination: An European strong coordination of the in-situ observation networks should be achieved by securing the funding for a single European Network of Earth Observation Networks. In the midterm, EU member states and the EC should support ENEON by including it in as part of the next H2020 calls for proposals. In the long term EC should consider the inclusion of a new EIP in support of the in situ Earth Observations coordination.

Essential Variable Process: Policy makers should embrace the goal based approach for the identification of EVs and complement the traditional expert based approach.

Semantic Harmonization: Efforts to harmonize data-related semantics based on a vocabulary of Essential Variables and other automatic mechanism for enriching the dataset descriptions should be included for significantly improving data discovery, integration, and usability.

Data Integration: The development of a strategy and a platform for the integration of socio-economic and environmental data is recommended.

Data Gaps: Efforts to fund initiatives to cover the in-situ observational gaps prioritized by the ConnectinGEO project should be conducted to obtain the specified impacts.

Miniaturized Sensors: Companies should take advantage of the possibility of building and commercializing novel in-situ sensors that can be easily deployed on the field and cover several spatial and temporal gaps. To make that possible, companies need to guarantee a good level of accuracy and precise quantification of uncertainties.

Standards and Interoperability: Companies should be encouraged to work with standard bodies, such as IEEE and OGC, to agree on a common set of standards for in-situ observations and protocols to retrieve them. The implementations of these standards could bring a competitive advantage as well as preventing the data silos and the theological lock.

Big Data: The lack of computer resources and slow networks should be overcome to be able to address big data analytics. The necessary distributed computer infrastructure in Europe should be considered a priority for the new European Digital Economy.

Data Management Principals: Efforts to increase and improve data documentation, access, quality description, identification, citation, curation and preservation should be a core focus of the European node of GEOSS.

Conclusions

ConnectinGEO has provided a direct mechanism for in-situ coordination across domain and boundaries. Consequently, ENEON has become the coordinated representation of the in-situ networks in GEO. An example illustrating the previous situation is the case of coastal observations, which are fragmented and unevenly developed among European Seas. Although the data are public, little has been done to publicize the data (e.g., high resolution bathymetry, fishery data) and integrated data portals are not available. From ConnectinGEO, we encourage this coordination and promote ENEON as a leading European actor.

Standardization of data semantics and vocabularies are crucial to improve discovery, access, usability and gap analysis. It is important to overcome national policies and habits that still limit a correct data management and data access. For in-situ observation, there are a number of technical issues that need to be addressed, including quality assessment, harmonizing of in-situ repositories, data curation and data preservation, promotion of interoperable data management systems, increased transparency for models, methods, and documentation. For satellite data, access, sharing and quality are the issues deserving more attention.

Gaps related, but not limited to many of the EVs for SDGs are technological in nature, leading to low feasibility for closing the gaps. Examples are the EVs for coastal ecosystems (pollutants, plastics, marine litter, dissolved substances), where observation techniques for operational observations are not existing.

Gaps in the spatial and temporal coverage result from the fact that, for some EVs, there are few long time series that are uninterrupted. The costs of maintenance operations, discontinuities on funding and vandalism affect the sustainability of the networks.

In terms of capacity, there are gaps related to the collocation and multi-purpose usage of in-situ measurements. A focus on the SGD targets will help to facilitate the needed cross-cutting approach and the development of the required capacity.