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ConnectinGEO

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Coordinating an Observation Network of Networks EnCompassing saTellite and *In-situ* to fill the Gaps in European Observations

Deliverable D3.4

Report on observations, measurements and gaps in observation systems reported by the communities

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Acronyms

CEOS	Committee on Earth Observation Satellites
DAB	Discovery and Access Broker
EARSC	European Association of Remote Sensing Companies
EC	European Commission
ECV	Essential Climate Variables
EEA	European Environment Agency
ENEON	European Network of Earth Observation Networks
EO	Earth Observation
EOV	Essential Ocean Variables
EV	Essential Variables
GISC	GMES *in-situ* Coordination Project
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GCOS	Global Climate Observing System
GMES	Global Monitoring for Environment and Security
NMM	Network Metadata Model
OGC	Open Geospatial Consortium
SBA	Societal Benefit Area
SDG	Societal Development Goals
UNEP	United Nations
VOS	Voluntary Observing Ship
WMO	World Meteorological Organization

Table of Contents

List of Figures

List of Tables

1. Introduction

Earth observation (EO) is generally organized into satellite and *in-situ* based observation (hereafter, it is assumed *in-situ* includes all observation systems and networks excluding space-based observations, such as land, ocean and airborne systems and their associated ancillary data[1]). For satellite-based EO, the Committee on Earth Observation Satellites (CEOS) ensures international coordination of civil space-based Earth observation programs and promotes exchange of data to optimize societal benefit and inform decision making for securing a prosperous and sustainable future for humankind. However, no such mandate or global coordination group exists for the *in-situ* observation community.

At the international level, there are a number of UN organizations, which have significant efforts related to *in-situ* observations: e.g. the World Meteorological Organization, the UN Economic Commission for Europe, UNEP, the Arctic Council and others. At the European level, various efforts exist to coordinate *in-situ* observations. These include national or service-based efforts supported by the European Commission (EC) and particularly the European Environment Agency (EEA). In addition, there are also project-based efforts, which can be multi-national and multi-domain or domain and sector specific activities. Furthermore, new data streams are presenting themselves, for example citizen science, with networks and associations developing around them. Efforts have previously been undertaken to map out the *in-situ* EO networks across Europe, e.g. the FP7 Global Monitoring for Environment and Security (GMES) *in-situ* coordination (GISC) Project. The Copernicus Program is also interested in *in-situ* data to validate EO based products and services. For example, the GMES Atmosphere Core Service already discussed ways to develop a harmonized *in-situ* component: https://www.wmo.int/pages/prog/arep/gaw/Task-Team-Obs-Req/GMES_Atmosphere_Core_Service_Implementation_Group_Final_Report.pdf.

Clearly, however, networks are constantly in flux with some disappearing or merging along with new networks forming. Hence, this report has used the results of the GISC Project as a starting point, but reflects as much as possible new networks that have recently formed or were not previously considered. Networks are classified according to broad themes around the Group on Earth Observations (GEO) eight Societal Benefit Areas (SBAs), with efforts underway to map these to the Sustainable Development Goals (SDGs) and essential variables (EVs).

While numerous gap analyses have previously been performed regarding EO, the field is dynamic with some gaps closing and new ones opening, hence novel gap analyses in the ConnectinGEO context are warranted. A multi-faceted approach has been undertaken in ConnectinGEO towards gap analyses, with initial efforts described here. These will however be followed up in WP6 which is dedicated to centralize the gap analysis and set priorities. Multiple gap analyses are proposed in order to begin to identify the various gaps in measurements identified by the numerous networks and communities. These include open surveys conducted across the geospatial data community, sector-specific research exercises, expert opinion solicited from the various ConnectinGEO partners and quantitative analysis of the GEO Discovery and Access Broker (DAB). Based on the

[1] 2016 GEO white paper on GD-06

assembled networks and communities from all the efforts listed above, numerous gaps can already be identified.

With the heterogeneous landscape of *in-situ* networks operating in Europe and the numerous gaps existing in EO, the EC together with GEO have proposed that a European Network of Earth Observation Networks (ENEON) could be established to provide Europe's *in-situ* networks with a common framework. Numerous *in-situ* networks operate across Europe underpinning European Earth observation; however they are not supported by a common framework. A common framework will aid the *in-situ* community in terms of identifying gaps and setting priorities, infrastructure, standards, interoperability, data policy and sustainability. ENEON will map existing networks to the SDGs, SBAs and EVs, demonstrating the crucial role that *in-situ* networks perform. Furthermore, ENEON will link the heterogeneous *in-situ* networks thereby presenting a unified voice to the EC, GEO, CEOS, the European Association of Remote Sensing Companies (EARSC), Copernicus and the wider community.

2. European *in-situ* Networks

Coordination of *in-situ* Earth observations is a daunting task; with even a cursory attempt to map the *in-situ* networks at the European level leading to the discovery of a large, incomplete and complex system. Nonetheless, some degree of global domain-specific coordination is in place for many *in-situ* observational topics and SBAs, along with national and regional/continental cross-domain efforts. Examples of global coordination of *in-situ* observations include, but are not limited to GEO BON (Biodiversity Observation Network), GCOS (Global Climate Observing System), GGOS (Global Geodetic Observing System), POGO (Partnership for Observation of the Global Oceans) and the former GTOS (Global Terrestrial Observing System). Actually, some of these global coordination efforts are relying on regional efforts (e.g. GeoBON is relying on EU-BON for Europe) with additional participation by more fine grain thematic networks and initiatives (e.g. the GeoBON participates in the Freshwater Information Platform (FIP) and Global Biodiversity Information Facility (GBIF). To make the situation more complex, more networks appear from time to time while others become inactive. ENEON has the commitment to maintain and enrich the graph inventory shown partially in Figure 1 (http://www.eneon.net/graph/index.htm).

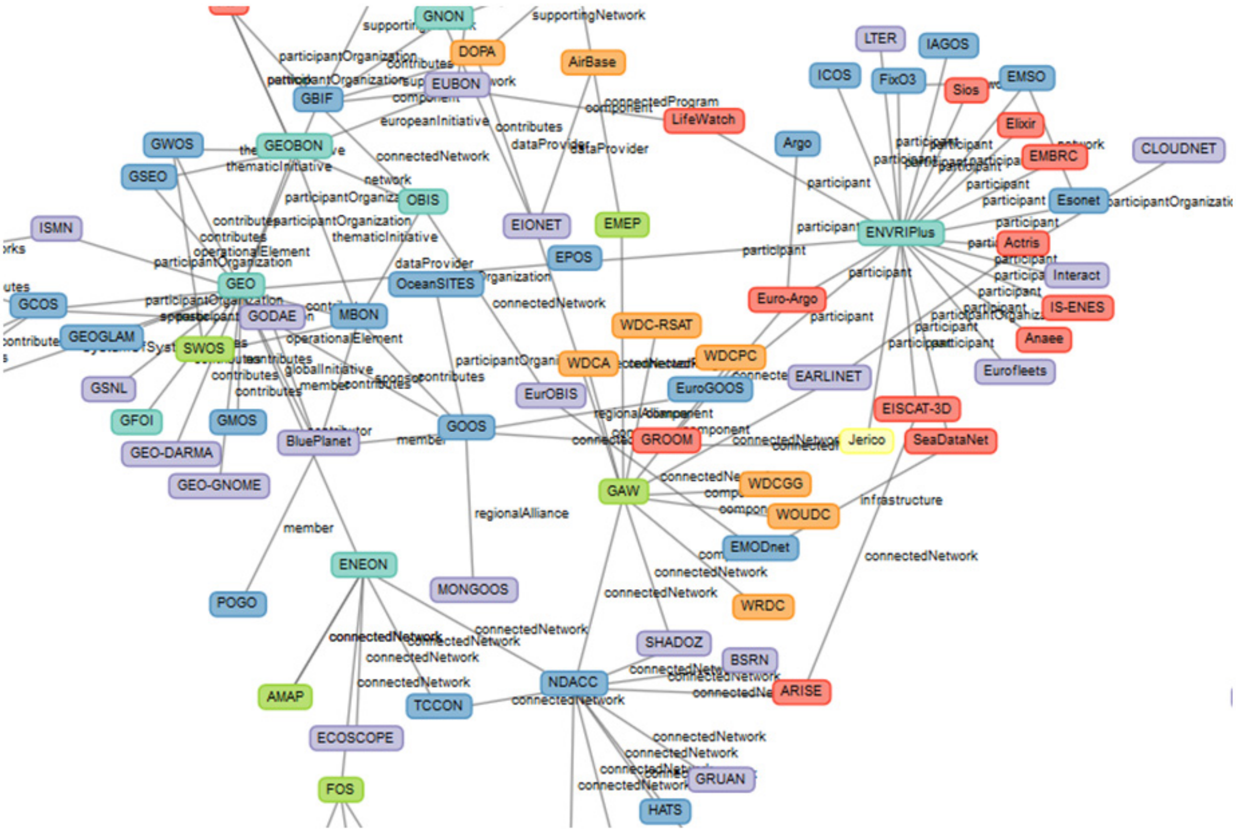

Figure 1. A portion of the European *in-situ* networks and their connectivity contained within http://www.eneon.net/graph/index.htm

Global coordination groups are complemented by regional frameworks (e.g. EuroGOOS - European Global Ocean Observing System) and monitoring platform specific coordination (e.g. Argo) that contribute to *in-situ* coordination. In Europe this is further complemented by specific project initiatives contributing to GEO including ENEON (European Networks of Earth Observation Networks) (created and maintained by H2020 ConnectinGEO (Coordinating an Observation Network of Networks EnCompassing saTellite and *In-situ* to fill the Gaps in European Observations)). Previously, the GMES *In-situ* Coordination (GISC) project, which was a key element of the Copernicus programme, completed a catalogue (database) of *in-situ* requirements for the GMES services (atmosphere, marine, land, emergency management).

As an illustration of the complex international and European panorama, it is worth to note that many networks are self-organized by scientific communities to consolidate observing systems while others come from a governmental or intergovernmental mandate such as the WMO. The later can also create systems and infrastructures (such as the Global Atmosphere Watch in the case of WMO). GAW is structured in several data centres such as Atmospheric deposition, Aerosols, Radiation, Reactive gases, Greenhouse gases, and Stratospheric ozone and UV radiation. Sometimes, they also contain scientific networks (in the case of GAW there are contributions from NDACC and SHADOZ) and programs (such as the European Monitoring and Evaluation Programme) and environmental agencies datasets (e.g. AirBase that is integrated in the EIONET, which is maintained by the EEA).

In the context of the ENEON, a series of workshops, meetings, and conference sessions have been organized to gather information specifically on European *in-situ* networks. Furthermore, online searches and discussions with relevant agencies including the EEA, EC, GEO, ESA and Copernicus have further added to the mapping of the European *in-situ* space. The notable ENEON related events are listed in Table 1.

Table 1 Series of events organized around the ENEON.

Location	Date	Workshop Number	URL
Paris, France	21-22/09/15	WS2	http://www.gstss.org/2015_Paris/
Vienna, Austria	22/04/16	-	http://meetingorganizer.copernicus.org/EGU2016/orals/21821
Berlin, Germany	19-21/05/16	WS4	http://www.ecsa2016.eu/sessions.html
Berlin, Germany	31/05/16	-	https://ec.europa.eu/easme/sites/easme-site/files/9_networks_of_earth_observation.pdf
Vienna, Austria	12-13/10/16	WS7	http://www.gstss.org/2016_Laxenburg_ENEON/

Important in this discussion is the definition of a network – what actually comprises a network. In ENEON we are defining the different kind of networks that we will include in the graph inventory of networks[2], and have the following draft list:

- [2] "Project" is not a category for networks. A project is only a way to make possible the creation and the sustainability of a network. Sometimes a project creates a network with the same name.

- **ObservationSystem** is a network that is building some sensor network and collecting data with them.
- **SystemOfSystems** is a network that has the objective of integrating "ObservationSystem"s in a bigger structure.
- **Infrastructure** is an "informatics" system that connects data, services and sensors to facilitate access to or processing of data.
- **DataCenter** is a data repository that is not really a network but needs a network to exist. It generally does not own the data but aggregates it in a single repository (in opposition to a system of systems that has a federated structure). Actually it could be argued that this category is out of scope of the ENEON but there are cases where if not included the complete picture is not understood (e.g. the WMO thematic data centers).
- **Program** is a network created/financed directly by the decision makers that is neither an observing system nor an infrastructure but e.g. a coordination effort.
- **Network** is anything that cannot be classified in the previous categories (except if formed by other "networks").
- **NetworkOfNetworks** a network connected to networks with the intention to aggregate them.

Before creating the graph inventory data model we looked for previous initiatives that had a metadata model to describe networks, finding the Network Metadata Model (NMM) that responds to the ILTER and LTER Europe requirements. It is meant to collect basic information on the network itself as well as the associated information provided within DEIMS. This includes the links to associated persons as well as research sites and datasets. For Networks managed as specific entries within DEIMS the affiliation of Research sites can be managed and the status of affiliation can be changed (see Figure 2). The content type Network applies therefore to ILTER/LTER networks especially. The Network data model is described here:
https://data.lter-europe.net/deims/documentation/network

After considering NMM, we have adopted a data model focused on capturing the relations between networks. This way each individual network is defined by a reduced set of properties but also includes links to other networks that specify the role of the link (see Figure 2). The model is closer to the modern web technologies and has been encoded in JSON-LD that can be dynamically converted into RDF and connected to the linked data. The model is also validated using a JSON schema shown in Appendix III.

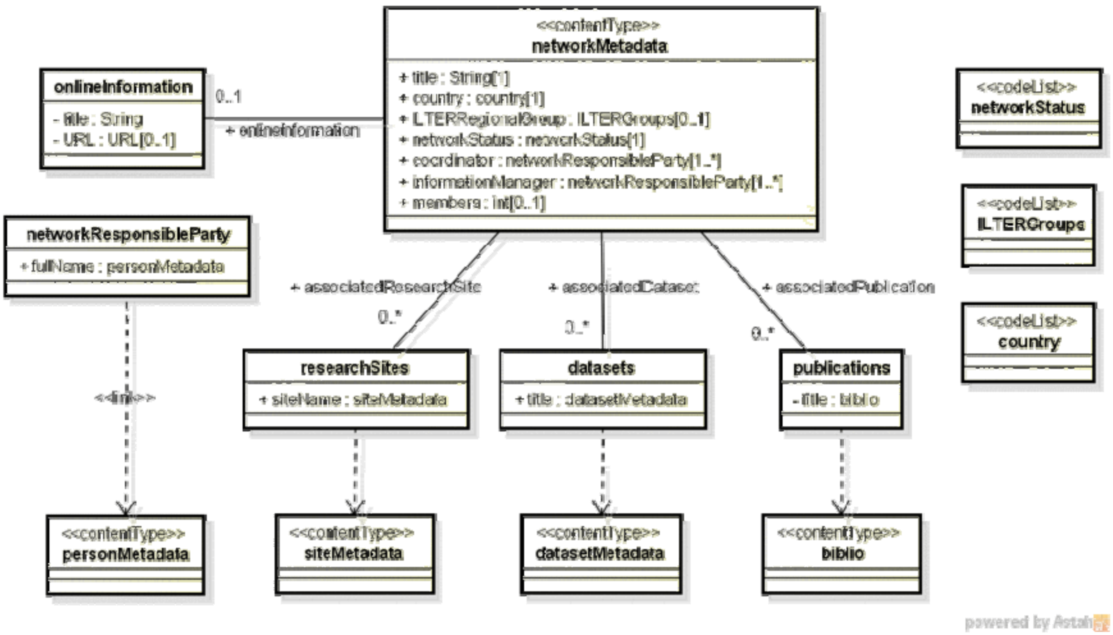

Figure 2. Data model for the Network Metadata Model used in DEIMS

The network database in maintained in a JSON-LD file that encodes the model shown in Figure 3. This JSON-LD file is used by a web application developed in ConnectinGEO based in an open source code found in GitHub called d3-process-map that uses the d3.js graphical library. The code has been adapted by CREAF to our purposes eliminating the need for a server application. It is able to dynamically generate the visualization shown in Figure 2 as well as to generate a full text list of all the information encoded for each network (e.g. Figure 3, an RDF representation using the jsonld.js library) and a table representation useful to generate the Appendix I table. Furthermore, the network database provides a full text description of each network in the graph with the option to export to RDF representation.

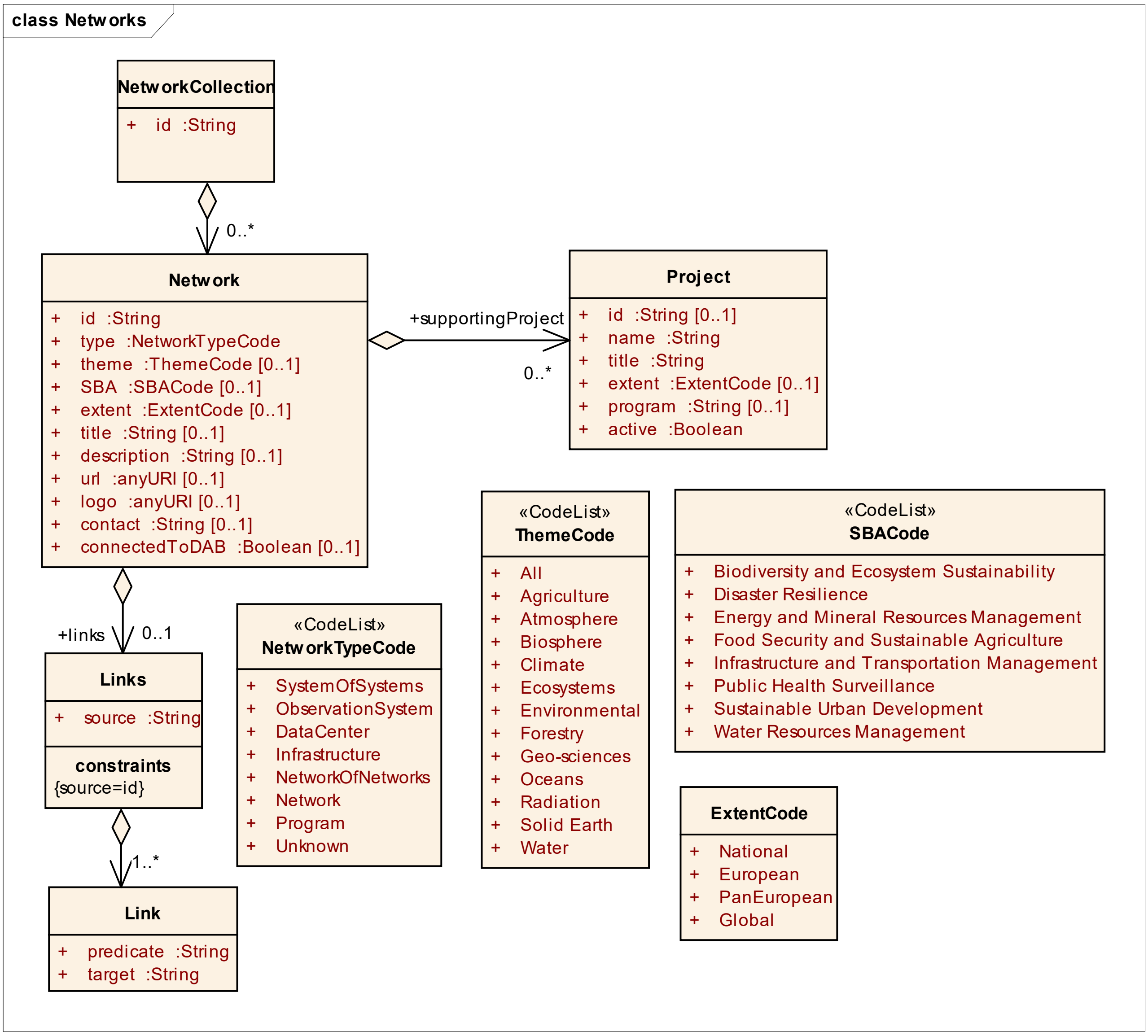

Figure 3. UML model for the networks database elaborated in ENEON

In summary, the result of the above efforts has led to the establishment of an initial graph of European *in-situ* networks (Figure 3), an initial listing of European *in-situ* networks (Appendix I) and the publication of the network diagram as a dynamic graph in the web: http://www.eneon.net/graph.
.
The contents of the network database will also be harvested for the SEE-IN KB[3] (Socio-Economic and Environmental Information Needs Knowledge Base) described in Deliverable D2.1, where the linkage of the networks to the SDGs and other user information will be established. In WP6, the SEE-IN KB is being used for more detailed gap analyses.

[3] Knowing the Users and Meeting Their Information and Knowledge Needs. http://seeinkb.net/

3. Preliminary Gap Assessment

ConnectinGEO is conducting a thorough gap analysis based on the gaps in the information provided by current observation systems as well as the gaps in the systems themselves, derived from five different threads (see Deliverable D6.1 for details):

- **Top-Down thread 1.** Identification of a collection of observation requirements and specifications from generic goals for sustainability of the global civilization as expressed in the GEOSS Strategic Targets, the SDGs, and the adherence to the planetary boundaries (WP 2).
- **Top-Down thread 2.** Incorporation of material from international programs such as Future Earth, Belmont Forum, the Research Data Alliance and community assessments of socio-economic benefits of Earth observations (WP6).
- **Bottom-up thread 1.** A consultation process in the current EO networks, consisting of collaboration platforms, surveys and discussions at workshops and even involvement of citizen science (WP 3).
- **Bottom-up thread 2.** A careful analysis of the observations and measurements that are currently in GEOSS Discovery and Access Broker complemented by other means (e.g. scientific literature) (WP 4).
- **Bottom-up thread 3.** The realization of a series of real industry-driven challenges to assess the problems and gaps emerging during the creation of business opportunities (WP5).

This deliverable describes the initial findings from the bottom-up thread 1: Access to the dynamic gap table is provided here: http://www.connectingeo.net/gaps/ (Appendix IV). Furthermore, it is possible to provide additional gaps that are not currently documented by uploading via an online form (https://docs.google.com/forms/d/e/1FAIpQLSe--mXrHrSUkLk3cs56yUcLNn-bNqzrMKeylaXQvV5_ICF6kg/viewform).

The ConnectinGEO methodology (http://connectingeo.net/) will be applied to derive observation requirements from the information needs of the SBAs and other European Networks and international communities of practice with a particular focus on climate, natural resources and raw materials. To find possible gaps in the current networks, we will establish a consultation process in the ENEON, analyse the observation inventory, and create “challenges” where SMEs conduct pilots using GEOSS data to create added value and information. The analysis will include specifications, spatial and temporal extent, data licenses, data standardized access services and APIs, data documentation and data quality information. A variety of approaches are being used to address the gap assessment, described in the following sections following a description of generic gap types.

3.1. Generic Gap Types

Six generic gap types can be identified and applied to any non-satellite data provider. They are:

1. **Coverage**: In order to use a network of *in-situ* repositories for example as a Cal/Val provider to satellite measurements, it is crucial to have a wide distribution of

locations as well as a consistent long time series. Therefore, the most common gaps falling in this category are:

- Geographical/Temporal Coverage: A comprehensive scientific approach assessing the gaps in the current observing capabilities of the system of systems does not exist. Assessments are commonly performed without a scientific basis or using an ad hoc (non-systematic) approach. Often this is done on the basis of the experience gained by the international experts in the framework of research projects.

2. **Knowledge of uncertainties**: Limited availability or poor information of uncertainty estimates affects several repositories and propagates to applications when the data are assimilated into models. Progress here is critical to have long time series of consistent data samples, insensitive to the method of measurement and geographically uniform. Moreover, in order to assimilate data into models two aspects are important: First the filtering of bad data. This means that *in-situ* data should have been consolidated and/or come with enough quality information to allow filtering out the corrupted measurements. The second aspect is the weighing of the data during the assimilation process. When bringing data into a model, a weight factor is needed to compare what the model is predicting and what the measured data is saying. This weighing is determined by the uncertainty of the measurement (usually a standard deviation). So having proper quality assurance and having correct uncertainty information is important.

3. **Knowledge of comparator measurements** (i.e. validation uncertainties): In order to align and compare satellite data and *in-situ* data there are several steps that need to be taken. This includes quantity conversion (not only unit conversion, but also going from e.g. volume mixing ratios to number densities), regridding (vertical, spatial, and/or temporal) and/or smoothing (e.g. 'vertical smoothing' by applying an averaging kernel), etc. For each of these steps uncertainty needs to be propagated in order to give a confidence interval between the *in-situ* and satellite data. For uncertainty propagation uncertainties for all influential variables are needed as well (e.g. temperature and pressure profiles), and for regridding also covariance data (for the dimension in which regridding is performed). This additional uncertainty and/or covariance information is not always available. Furthermore, there are sometimes different algorithms to align the quantities (i.e. different ways of doing regridding). It shall be ensured that the estimation (and subsequent propagation) of uncertainties is discussed within the product documentation.

4. **Technical**: For *in-situ* data there are often multiple data providers delivering data for the same kind of instrument (i.e. within the same network). This is something that does not happen with the same frequency for satellite data, where there are often only one or very few providers for a specific data product. There are exceptions however (i.e. for GRACE, several groups provide the same data products which show significant differences. For satellite altimetry, inter-sensor differences are an issue. For SAR, we also have several satellites providing the same data product and there are consistency issues.). In *in-situ* networks, measurements are often provided in a sparse way and with an uncoordinated effort, leading to technical inconsistencies between products from different providers. A

harmonization effort has been done within the context of the NORS project. The main inconsistencies found in the *in-situ* data repositories are:

- Data policies: Different repositories have different data policies, lack of easy access or low speed access. They don't follow the same guidelines for levels of data and associated names.
- Lack of metadata harmonization: Metadata is defined as a set of data providing information about the observations or other derived data. Metadata in our case is an increasingly central tool in the data provider's environment, enabling large-scale, distributed management of resources. However, metadata standards have not been able to meet the needs of interoperability between independent standardization communities. Observations without metadata are of very limited use: it is only when accompanied by adequate metadata that the full potential of the observations can be utilized. Several efforts have been spent to improve the harmonization of metadata across the networks and international programs.
- Harmonization and consistency of data representation in tools across all repositories: the consequences of lack of harmonization in data representation among tools includes:
    - different interpretation of quantities and variables
    - different and/or unspecified units of measures
    - different ordering of data in multi-dimensional arrays
    - different representation of averaging kernels
    - non-compliance problems with regard to the specification

5. **Governance**: In many repositories, there is a general lack of documentation. This leads to missing Quality Indicators in many validation studies and to incoherent and poorly traceable validation results. It shall be ensured that all documentation of processing information provides accurate and clear details about the generation of a product and allows users to adequately assess the fitness-for-purpose of a product.

6. **Parameters gaps**: These gaps concern specifically the essential variables, with parameters that are missing or hardly traceable in the monitored ECV. This can include also auxiliary data to the ECV monitoring. These gaps are closely related to lack of knowledge of comparator measurements since one of the main sources of gaps in ECV is the lack of comparator measurements, even when data are available (see deliverables D2.2 and D2.3).

3.2. User Needs and Gaps Survey

A survey of user needs and gaps in European spatial data was completed by 52°North, resulting in 80 respondents from a variety of sectors and domains. A series of questions related to data coverage, quality, discovery, access, description and others were solicited.

The following subsections introduce the main findings of this survey.

3.2.1. Background Information on the Respondents

In total, there were 80 responses to the survey. First, some background information about the respondents was gathered.

As Figure 6 and Figure 7 illustrate, the respondents of the survey came from a broad range of institutions and backgrounds. The biggest share of participants was from a research background (academia and other research institutes). Thus, many participants of the query had the perspective of scientists working with different types of earth observation data. Other relevant blocks were participants from economy (SMEs and other private companies: 17 participants) as well as from government and administration (19 participants).

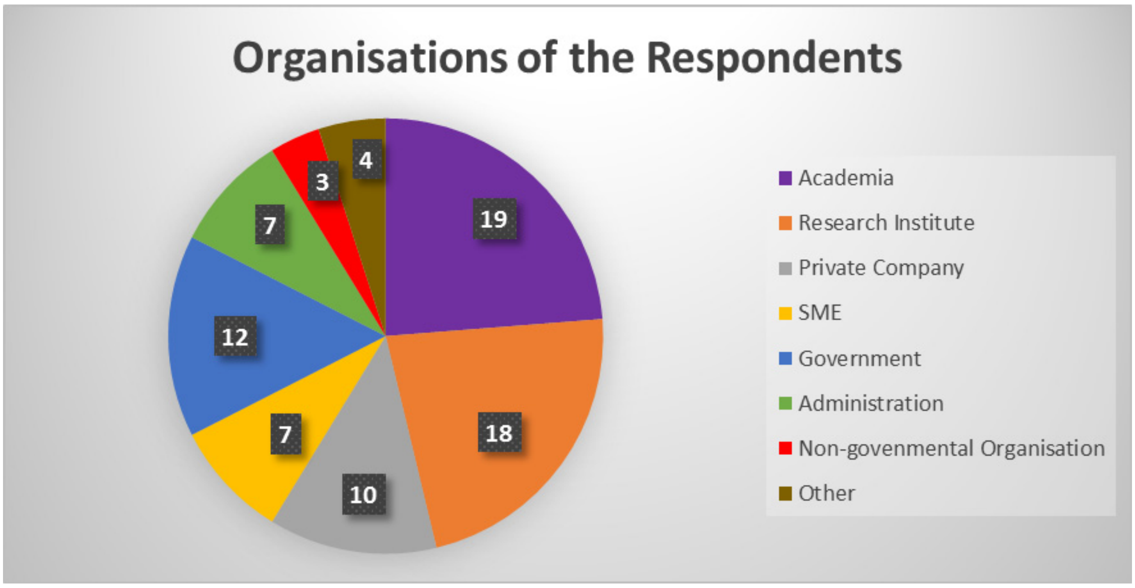

Figure 4. Organizations of the respondents

The thematic background of the participants was mainly in environmental sciences as well as earth observation (Figure 7). In the questionnaire, this question intentionally did not limit the number of answers, because a strict distinction between these domains is often not possible. Among the disciplines represented in the survey, especially hydrology (23), environmental protection (19), geochemistry (21), climate science (21) and ecosystems in general (20) were the most mentioned.

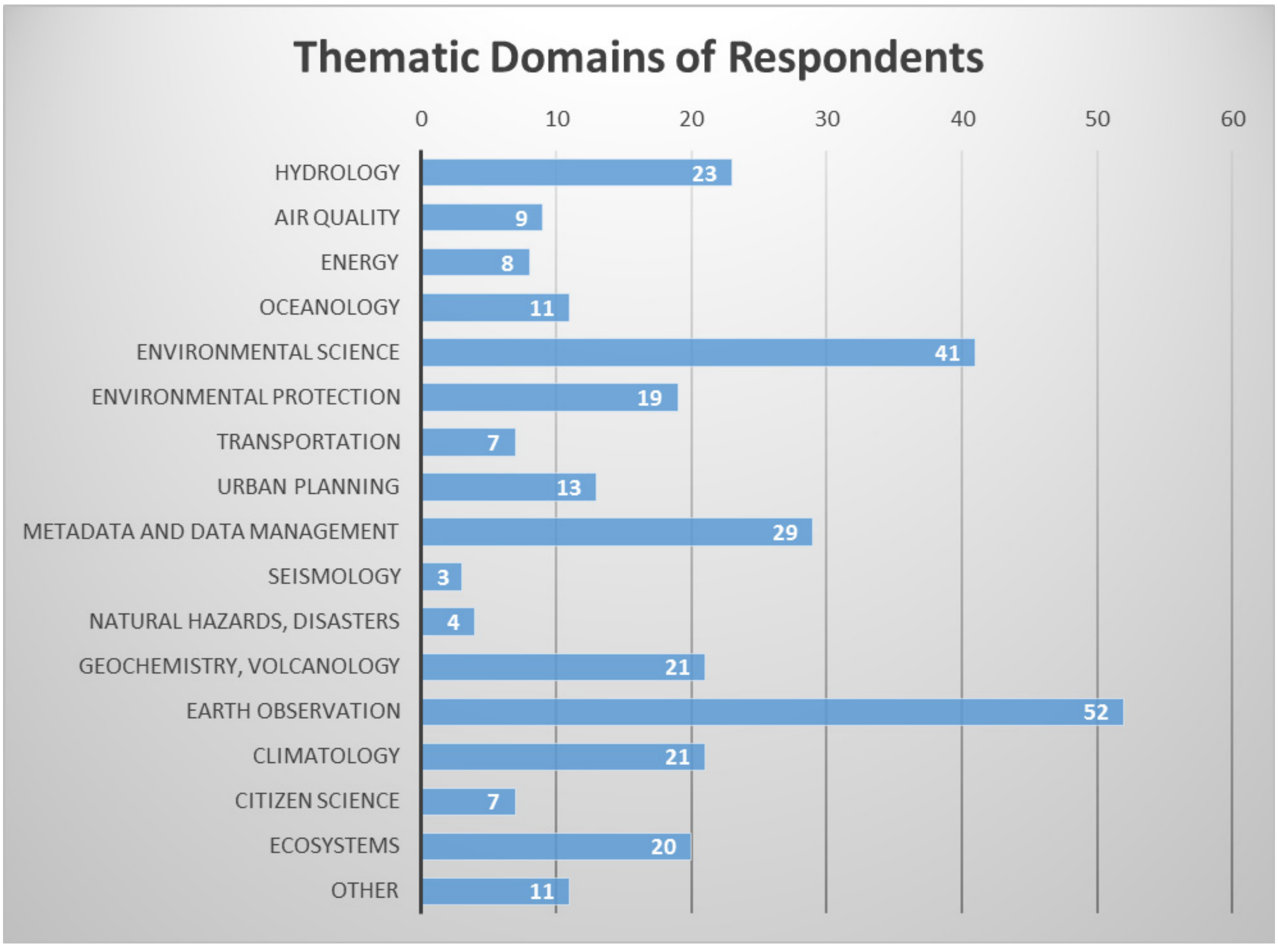

Figure 5. Thematic Domains of the Respondents

Among the participants, the awareness of the ENEON initiative was significant (26 of the 80 respondents. Although the questionnaire was distributed by the members of ConnectinGEO, it reached many participants beyond this immediate network. However, at the same time this number indicates that creating further awareness for the ENEON activities is needed.

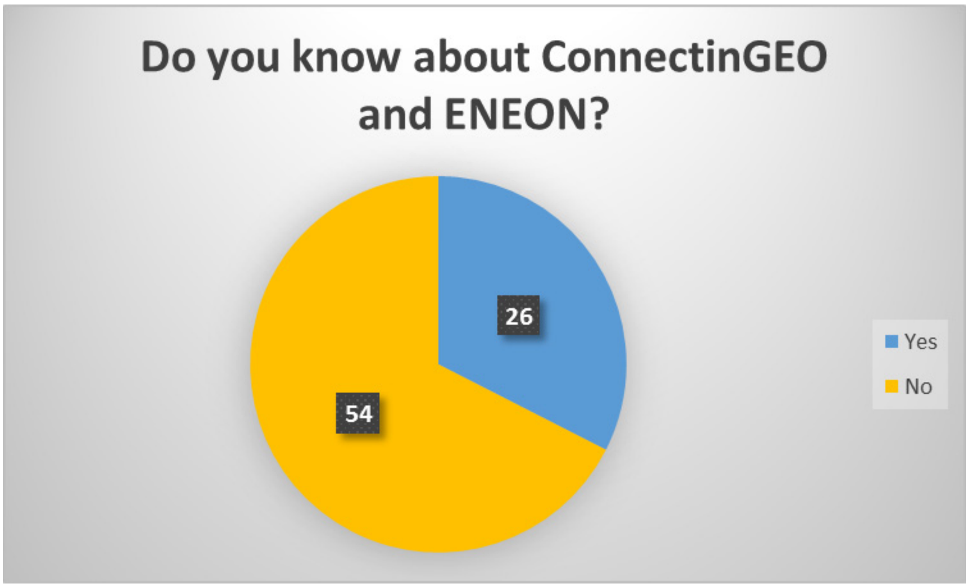

Figure 6. Awareness of Respondents about ENEON

Figure 8, Figure 9 and Figure 10, illustrate the familiarity of the respondents with GEOSS, Spatial Data Infrastructures and underlying standards. It becomes clear, that a large share of the participants is familiar with the idea of data sharing via Spatial Data Infrastructures (70 of the 80 participants) and GEOSS (63 of the 80 participants). However, standards for facilitating the interoperable sharing of observation data are a bit less known. 53 of the 80 participants indicated that they are in general familiar with the OGC standards and 22 participants were familiar with the OGC Sensor Web Enablement standards for sharing observation data. A result of this finding is a recommendation to further promote the use of standards for enabling the interoperable sharing of observation data. Especially the OGC Sensor Web Enablement standard have the potential to address the issues of inhomogeneous data formats and lacking data access options mentioned by several participants (see 3.2.2).

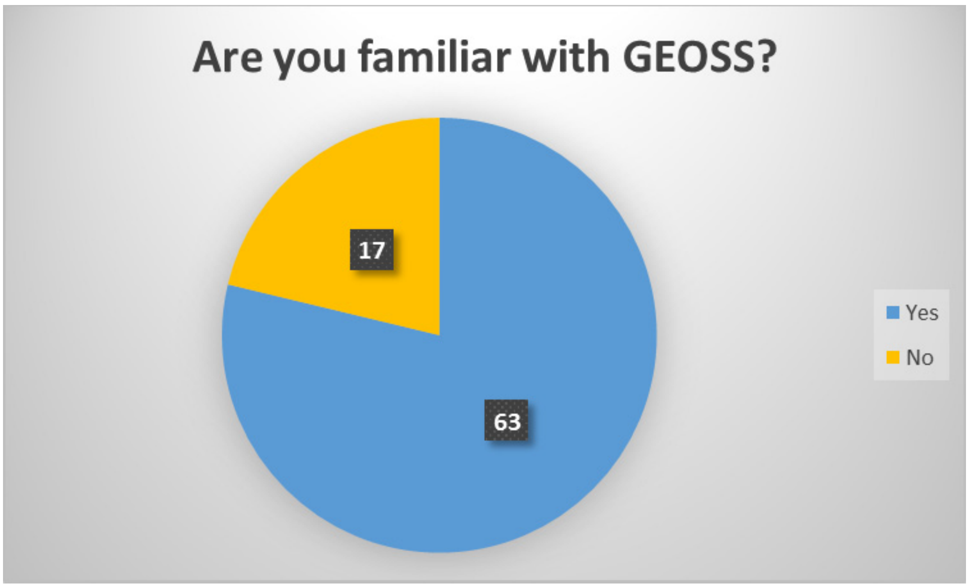

Figure 7. Familiarity with GEOSS

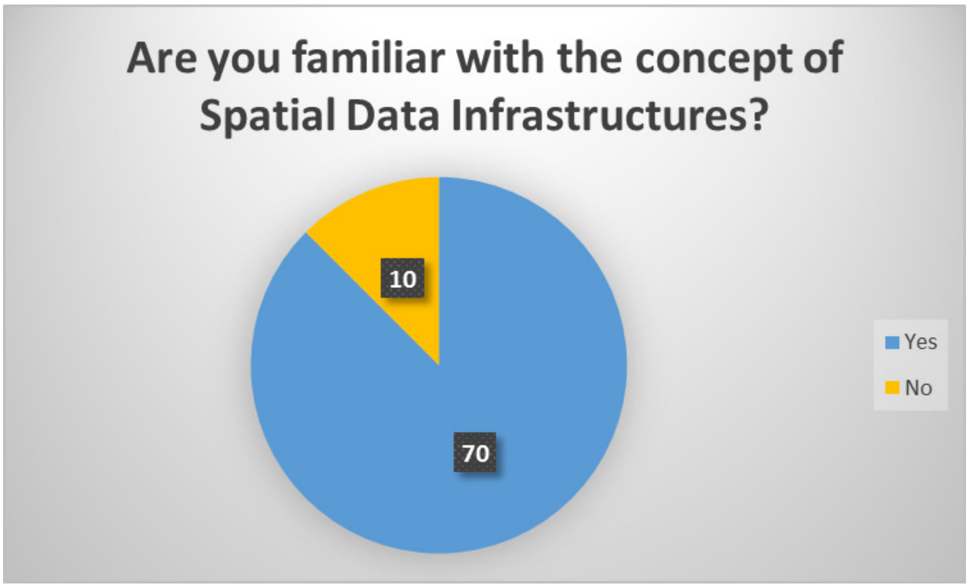

Figure 8. Familiarity with the Concept of Spatial Data Infrastructures

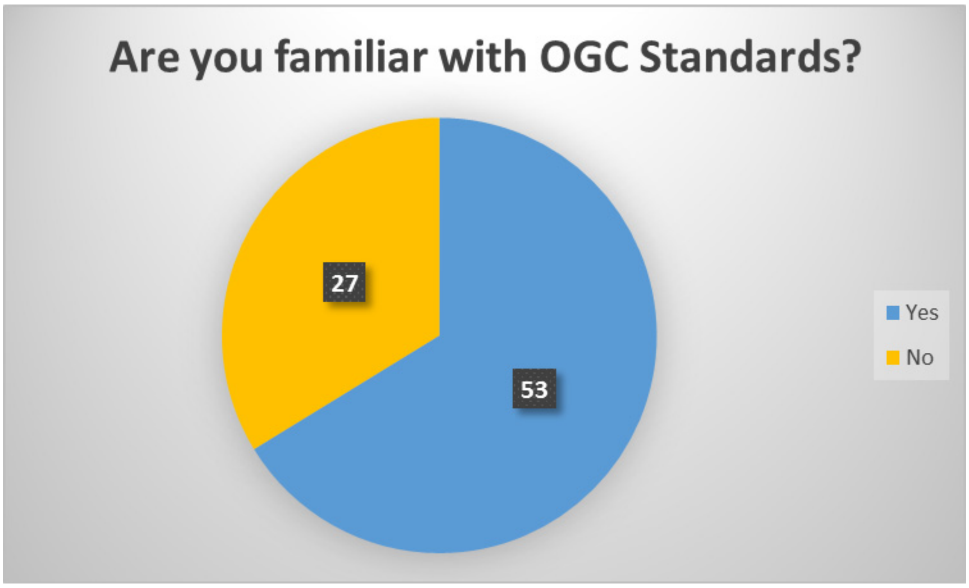

Figure 9. Familiarity with OGC Standards

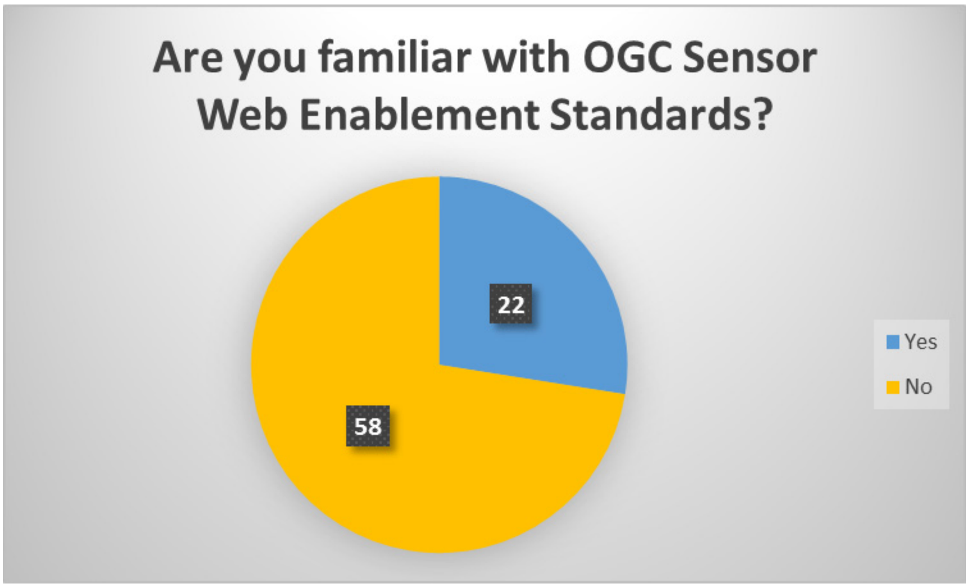

Figure 10. Familiarity with OGC Sensor Web Enablement Standards

3.2.2. Identified Issues

This section presents the issues mentioned by the respondents regarding the availability and access to observation data.

Figure 11 shows a summary of the issues mentioned in the answers to the survey (please note: the categories in the diagram summarize multiple issues; survey participants were allowed to select multiple of these issues from a pre-defined list). When analyzing the responses, it becomes clear that most of the issues mentioned belong to the topics of data coverage and data access/exploitation. Besides this, also the lack of data offered under open data licenses, unclear/lacking data quality, and insufficient discovery mechanisms are significant issues.

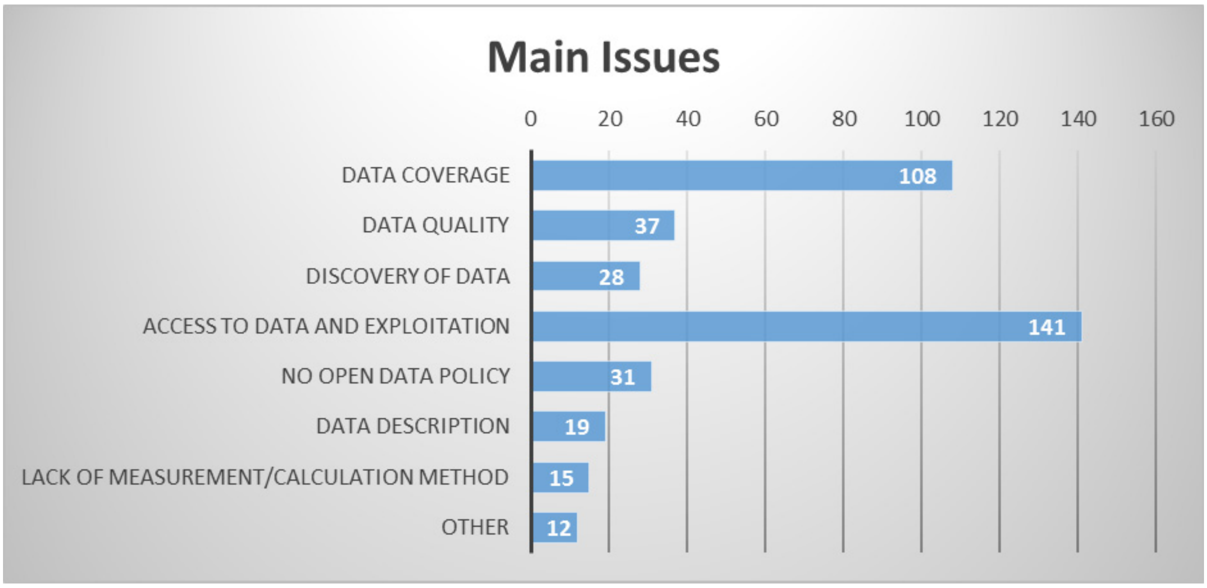

Figure 11. Main Issues Mentioned by the Respondents

Figure 12 provides a more detailed view on the issues regarding data access and exploitation. The issue mentioned by the largest number of respondents concerns difficulties with data access. Typical problems mentioned by the participants in further comments are the lack of direct data downloads as well as the need to contact many different data providers to access comprehensive data sets for larger regions. Other important issues are difficulties to deal with heterogeneous data formats, which sometimes lack documentation, unclear semantics of the available data, and funding issues that make the collection of missing data difficult. This emphasizes the relevance of several ConnectinGEO objectives: promote standardization and interoperability, provision of metadata, and encouraging the sharing of observation data sets.

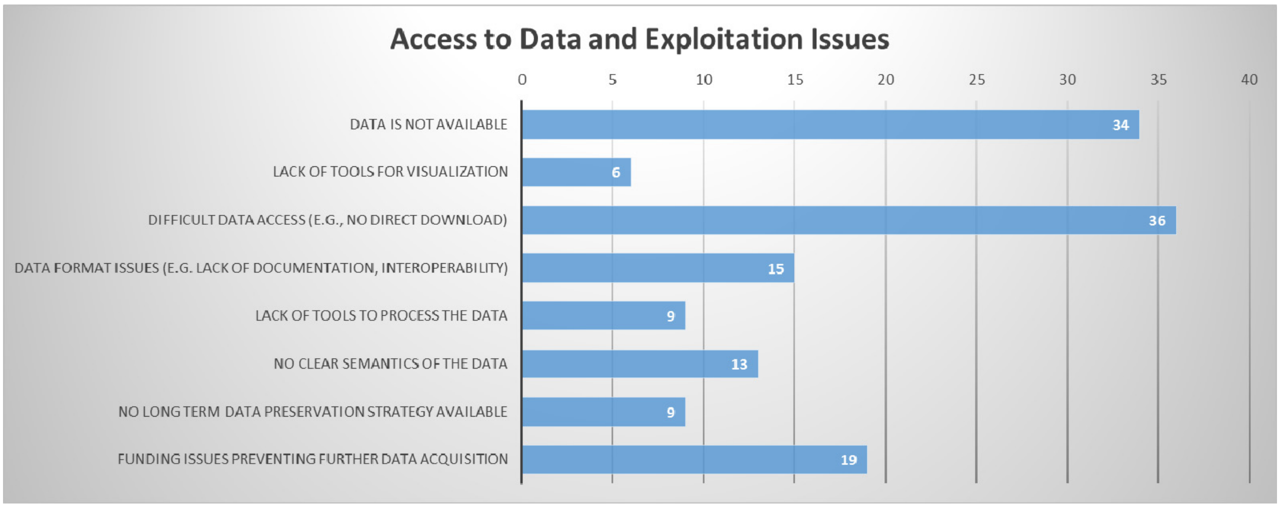

Figure 12. Issues with Data Access and Exploitation

Regarding the data coverage issues,

Figure 13 provides a more detailed view. It can be seen, that both, spatial and temporal coverage as well as resolution are insufficient for several of the respondents. Thus, new data products as well as additional sensing capabilities to increase spatio-temporal coverage and resolutions would be beneficial for many data consumers.

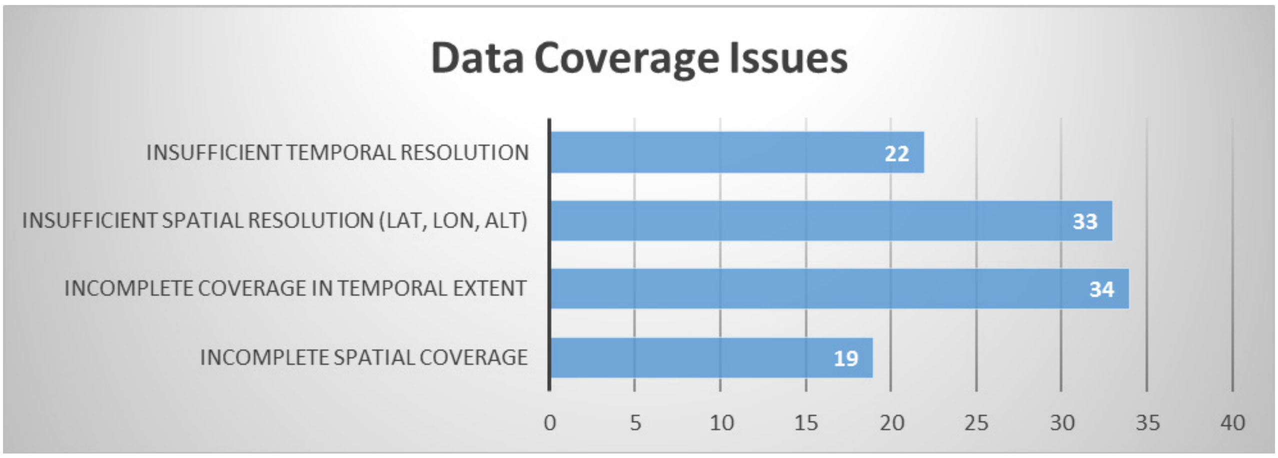

Figure 13. Data Coverage Issues

3.2.3. Wishes for Additional Data Sets and Technology

For collecting user needs and wishes for additional data sets as well as technological solutions, the questionnaire offered the opportunity to provide free text answers.

The technology needs of the respondents comprised especially the following aspects:

- Central repository/portal offering discovery/access to data sets (7 responses)
- Direct data download (in harmonized formats) (14 responses)

Both of these aspects are highly relevant for ConnectinGEO and emphasize the need for better data discovery solutions as well as portals/tools for directly downloading the needed data sets. Besides these aspects, there were further wishes such as the increased use of Linked Data technology as well as public cloud infrastructures for the processing of observation data sets.

Concerning desired additional data sets, the replies were very diverse and covered many different domains. This corresponds to the broad range of thematic backgrounds of the respondents. However, as satellite data are relevant for nearly all domains, the desire for higher resolution data was often mentioned (17 responses). Among the different domain-specific data needs, especially hydrological data (e.g. river discharge, irrigation data, data on water extraction) and climate data have to be noted.

3.3. Community Gap Assessments

Deliverable 6.1 indicates the following process for the bottom-up thread 1: *A consultation process in the current EO networks, consisting of collaboration platforms, surveys and discussions at workshops and even involvement of citizen science.*

After some consideration, the methodology has been restructured in the following sub-steps:

- Elaborate a list of networks of Earth observation for all relevant topics considering focussing on and *in-situ* segments (keeping in mind satellite and airborne).
    - Consider other possible data producers such as SME and private sectors and Citizens Observatories.
    - Take into account an equilibrium of data producers networks (ObservationSystems, DataCentres and SystemOfSystems types) and stakeholders and consumers (processing and modelling Infrastructures, Programs, Networks and NetworksOfNetworks types)
- Consult these collectives using questionnaires and organize regular workshops.
    - Consider the ENEON activities as a way to stimulate debate around gap analysis.
- Elaborate a list of reports and scientific papers that are using the current networks of data producers
- Elaborate a list of requirements, gaps and priorities based on the results of the questionnaires and workshops
- Communicate to the results of the consultation process and make them review and validate it.

To make this gap analysis possible the project has nominated thematic ambassadors that have the mission to connect to their respective communities in the ENEON and collect the gaps known by these communities. This is the list of ambassadors in the project:

- Air Pollution Ambassador: NILU
- Atmosphere Ambassador: BIRA
- Marine Ambassador: CSIC
- Carbon Cycle Ambassador: CMCC
- Agriculture Ambassador: IIASA
- Biodiversity Ambassador: CNR
- Renewable Energy Ambassador: ARMINES

These ambassadors have contributed to the gap analysis in different degrees explained in the following subsections. In addition to them, three other ambassadors in ENEON can be instrumental in recording other kind of gaps in the second loop (and their findings will be reported in next deliverables. These ambassadors are:

- Interoperability Ambassador: 52N
- Industry Ambassador: EARSC
- Copernicus Ambassador: IIASA

3.3.1. Air Pollution

In particular four major initiatives deal with air quality monitoring and services in the European Domain (focus here is on surface level measurements indicative of human/ecosystem exposure). Below is a short summary of their activities/capacities and some potential venues for further developments:

EIONET/AQFD monitoring: The Air Quality Framework Directive sets requirements related to air quality observations. Sites are located at locations with different influence from local emission sources ranging from local to rural/background. Monitoring is mainly addressing substances for which air quality limit values exist, but recently the scope has been extended to also cover information, which can be used to assess emission sources and atmospheric transport. The number of sites in Europe exceeds 2000. “Gaps”: Station density uneven in a regional/global perspective, AQ info may not be relevant for personal exposure and health metrics, potential use of small sensors may provide additional capabilities, urban supersites do largely not exist, or are not coordinated on an international level (needs also to be linked with regional/background supersites operated by EMEP/GAW/ACTRIS.

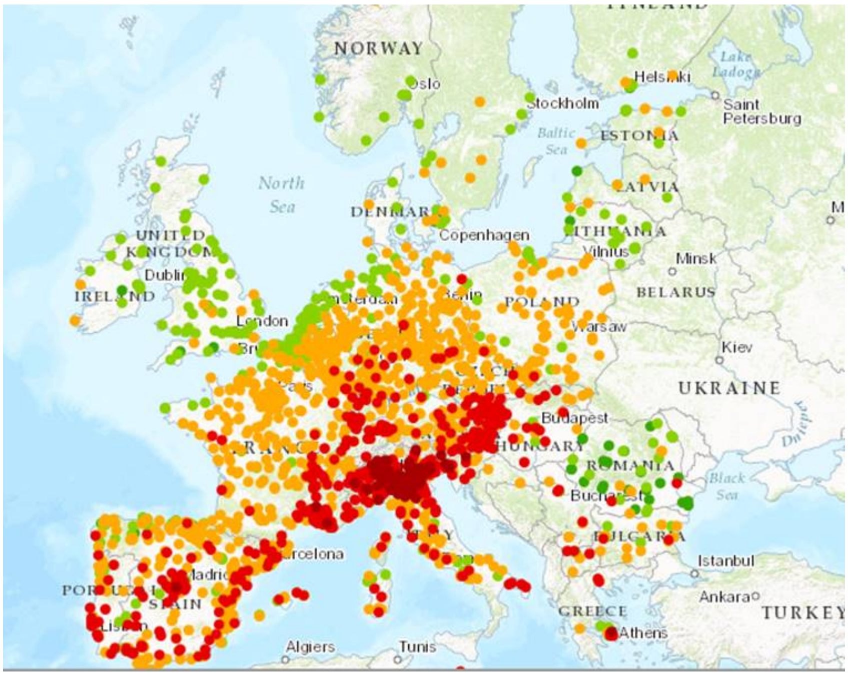

Figure 14. EIONET/AQFD monitoring

EMEP observations: Address regional scale (transboundary fluxes) transport of air pollution on an international level. Sites are located distant from local sources and levels are generally low as compared to urban scale. Data quality needs to be high to derive temporal and spatial trends, and data are highly used to develop atmospheric chemistry and transport models. The activity includes a very wide range of chemical and physical variables. The network also includes so-called supersites, operated in collaboration with programmes and projects like WMO-GAW, ACTRIS and others. GAPS: data availability is low in parts of the region of interest. Many parties have difficulties to comply with monitoring obligations, and with data quality objectives. Long term-data series exist going back to the early 1970ies. Focus areas are acidification, eutrophication, ozone and precursors, particulate matter, heavy metals and persistent organic compounds (see eg. Tørseth et al 2012).

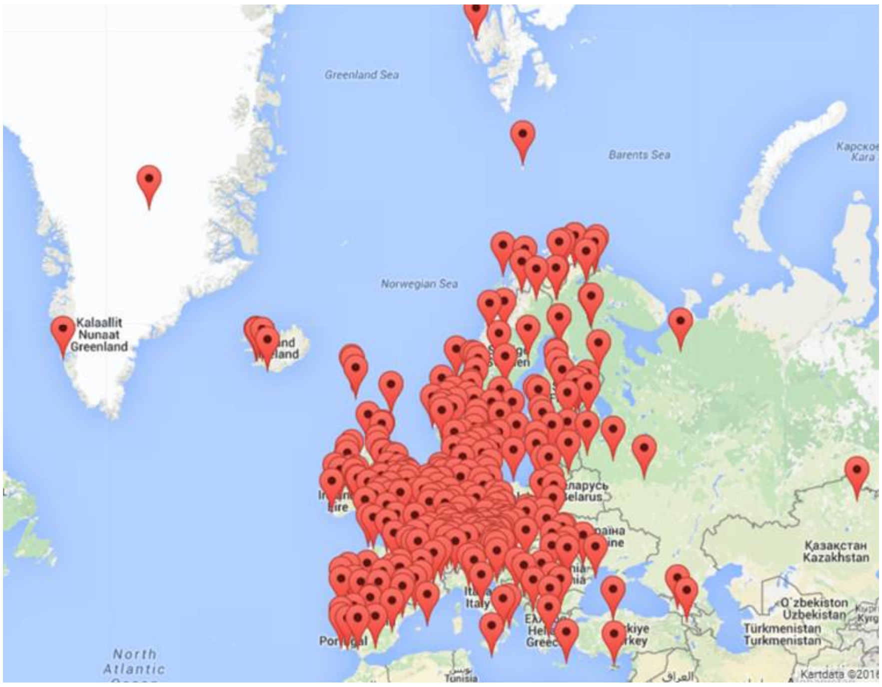

Figure 15. EMEP observations

WMO Global Atmosphere Watch: WMO-GAW addresses atmospheric composition on the global scale, and governs measurements of greenhouse gases, stratospheric ozone, radiation, atmospheric deposition, reactive gases, aerosols and urban air quality. There is a close collaboration between EMEP and WMO-GAW within Europe, both in relation to regional background sites, and the more extensive supersites (see also ACTRIS below). WMO-GAW has recently adopted its Strategy for 2016-2019, and its Implementation Plan is currently being developed. Below is a map of GAW affiliated sites.

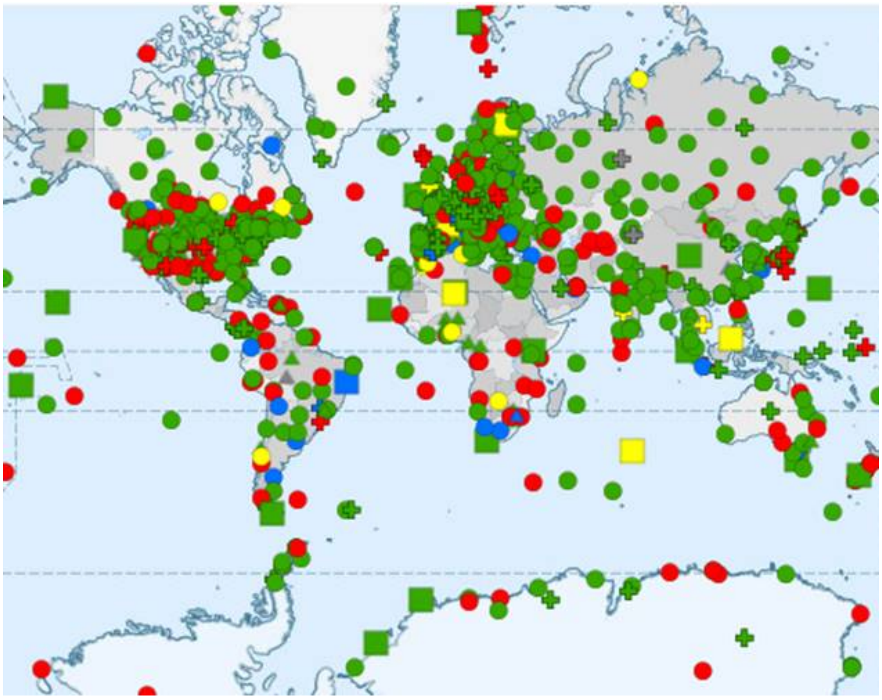

Figure 16. WMO Global Atmosphere Watch

ACTRIS is a European Research Infrastructure for the observation of Aerosols, Clouds and Trace gases. The project funds efforts related to data quality and services to users, while the running costs are covered through contributions from partners or other programmes (including such as national contributions to the EMEP and GAW programmes described above. GAPS: A major challenge for ACTRIS has thus been to sustain the operational parts of the activities. The sites also rely on a wide range of basic variables to be measured, and this also needs the commitment from countries to be sustainable.

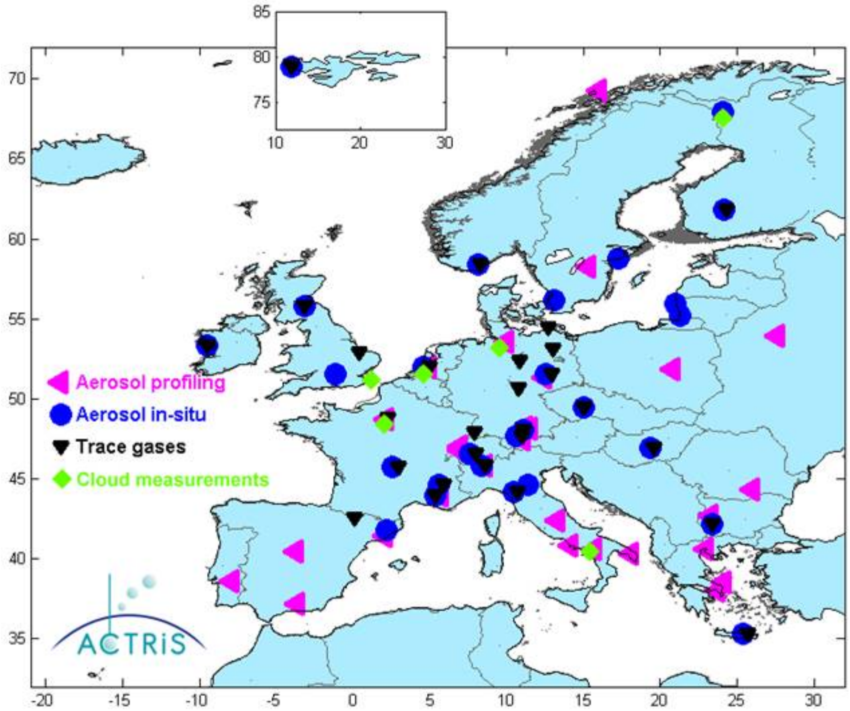

Figure 17. ACTRiS European Research Infrastructure

3.3.2. Atmosphere

The aim of the Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring (GAIA-CLIM) project is to improve our ability to use ground-based and sub-orbital observations to characterise satellite observations for a number of atmospheric Essential Climate Variables (ECVs). The key outcomes will be a “Virtual Observatory” facility of co-locations and their uncertainties and a report on gaps in capabilities or understanding, which shall be used to inform subsequent Horizon 2020 activities. http://www.gaia-clim.eu/

The objective of this GAID (http://www.gaia-clim.eu/system/files/workpkg_files/640276_Living%20Gap%20Assessment%20Document%20v2_1Mar.pdf) is to identify and assess – through careful analysis against both existing and envisaged user requirements – yet unfulfilled user needs (‘gaps’) in the observation capability of Essential Climate Variables (ECVs) within the sphere of the GAIA-CLIM project.

3.3.3. Marine

Among the three Earth physical compartments, atmosphere, land and ocean, the ocean has been the most challenging to monitor. As for the atmosphere, there is a need to sample a huge domain with scales and associated processes that spans from millimetres to a few seconds, typically of diffusive processes, to thousands of kilometres and centennial scales characteristic of paleoclimate variability. Two additional relevant considerations are: i) the difficulties to monitor within a strongly corrosive media submitted to energetic phenomena that often damage the equipment and ii) the need to have self-contained autonomous systems in order to ensure long term monitoring. Thus general costs, sustainability, coverage and resolution are typically the main issues that have to be faced by marine networks.

In the project, a first approach to gaps of the marine component has been based on the last GCOS report (WMO, 2015), in which a systematic review on the present status of essential climate variables (ECV) and associated observational networks is carried out. The rationale is that the set of ECVs contains a great number of essential ocean variables (EOV) but in the upper end of the spatio-temporal spectrum of scales (long times and global ocean scales). Thus, there are feedbacks and inheritances between the gaps in marine ECVs and gaps in EOVs. The GCOS review has been complemented with additional sources from reports and peer-reviewed literature devoted to specific variables and addressing challenges and limitations of present technologies (see References).

A special focus on the Argo program (figure 18) has been put for collecting and identifying gaps in the marine sector. The reason is that, apart from the intensive monitoring that remote sensing provides, the Argo program can be considered as the major and most relevant source of *in-situ* data about the ocean. According to data reported in the period 1900-2016, there was a total of 375.940 CTD (Conductivity, Temperature and Pressure) profiles while for the period 2006-2016 there was a collection of 1.522.202 autonomous Argo profiles, representing in terms of information content a factor of four in a decade compared to a century. These are remarkable numbers making Argo play a central role for some relevant EOVs (T, S, O_2, …), compared with previous, but still valuable and complementary sampling strategies (VOS, moorings, etc.).

Finally, we have addressed gaps for almost all the physical EOVs, for some of the biogeochemical EOV's and a few EOV's on the marine ecosystems which are both less documented from a gap analysis point of view and where EV sets have been only recently established.

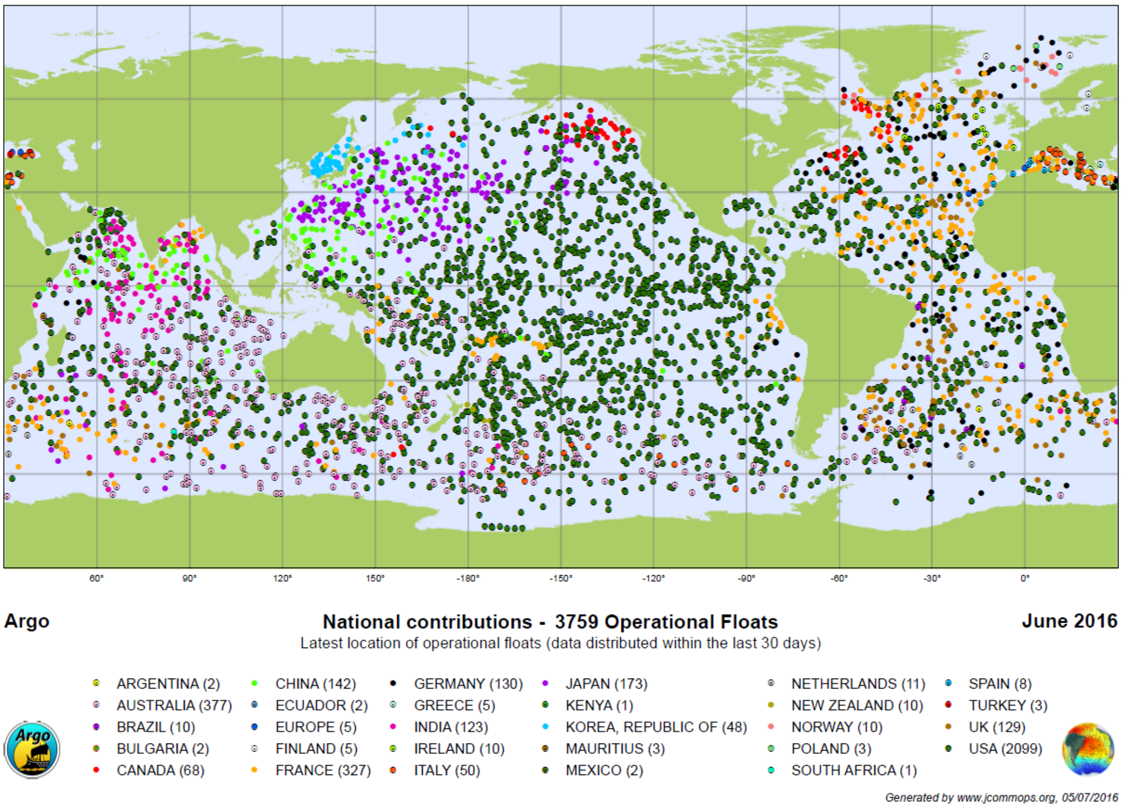

Figure 18. Operational Argo network by June 2016 by country contribution. Source: http://www.jcommops.org/board?t=Argo

3.3.4. Carbon Cycle

As regards carbon observations in particular, a recent paper (Ciais et al., 2014) analyzed the state, challenges and observational requirements of a global carbon monitoring system. Among the challenges that Ciais et al. (2014) highlighted are: i) bring remote-sensing measurements to a level of long-term consistency and accuracy so that they can be efficiently combined in models to reduce uncertainties, in synergy with ground based data; ii) bring tight observational constraints on fossil fuel and land use change emissions, for providing policy-relevant observations that are alternative to the expected self-reported (by countries, in the frame of the UNFCCC Paris Agreement) emissions inventories; iii) significantly increase the resolution and density of in situ and remotely sensed data; and iv) advance with the modelling tools and applications.

Despite the significant progress in the recent years, there are still many gaps of different nature that impede a full exploitation of the potential of the carbon observations and the derived information. There is a dramatic need to fill these gaps in the next decade. Most important gaps are:

- Outside of Western Europe and the US, current monitoring networks are spatially relatively sparse, when considering the heterogeneity of ecosystems and anthropogenic and natural carbon fluxes (Africa, South-East Asia, Siberia, Amazon). This is also important for ground validation of satellite observations.
- Hotspots of high change dynamics and high flux densities e.g. in high latitudes, particularly permafrost regions or tropical forests may require denser observational networks than currently achieved.

- New anthropogenic activities such as unconventional gas production may require adopted observations.
- The sparseness of data leads to uncertainties that limit the practical effectiveness of the results outside the well-covered domain.
- Data are sometimes collected and analyzed using different protocols and methodologies, leading to interoperability issues.
- Lack of sustained international archive centres, securing the long-term preservation of data.
- Occasional individual station's short-sighted data policies, limiting data access and sharing.
- Data streams are often uncoordinated and unclear among too many data portals.
- Lack of regional and local capacities to use and interpret data and tools: need for more capacity building.
- Translation problems in turning scientific results into policy-relevant information, requiring a much more intense science-stakeholder dialogue.

3.3.5. Agriculture

Large knowledge gaps remain related to the effects of land management, in particular those human-induced changes in terrestrial ecosystems that do not result in conversions in land cover. Erb et al., (2016) review the gaps in both knowledge and data contributing to a strategic prioritization of research efforts across multiple disciplines, including land system research, ecological research and Earth system modelling. Their findings suggest that in the land management sector the majority of the data is still poor, while our understanding is often less of a barrier (Table 2).

Table 2 Classification of management activities

	Data advanced	Data poor
Understanding advanced	▪ Crop harvest ▪ Irrigation	▪ Forest harvest ▪ Tree species selection ▪ Grazing and mowing ▪ N-fertilization
Understanding poor	…	▪ Crop species selection ▪ Artificial wetland drainage ▪ Tillage ▪ Fire management ▪ Crop residue management[1]

[1] Separated here from crop harvest

3.3.6. Biodiversity

In the field of Biodiversity and Ecosystems there is a standard way of collecting samples in the field. The ECOPotential projects main objective is to provide EO observations for a better and continuous description of biodiversity and ecosystems. The 2016 GeoBON conference program contained several efforts in the same direction and several working groups that followed the talks emphasized the hopes that this community has in remote sensing possibilities to develop a set of products and services that respond to the Essential Biodiversity Variables and Essential Ecosystem Services Variables demands.

There are at least 6 recent papers (see References) and a report that summarize the possibilities that EO offers in combination with *in-situ* observation networks. The examination of these papers will give us the necessary information that is missing and how *in-situ* measurements needs to adapt to help in calibrating and validating the data products since current *in-situ* campaigns are done in a way that does not always consider EO needs. This is a generic problem for many Copernicus services.

3.3.7. Renewable Energy

Within the framework of the ConnectinGEO project, particular attention has been paid to in-situ measurements for renewable energies with a focus on solar, wind and marine. Numerous gaps covering these 3 renewable energy resources have been identified, namely:

- Scarcity of accurate in situ measurements in most of the world. Large networks measuring radiation, such as GAW, BSRN have a limited coverage.
- National meteorological networks are by definition limited and in addition, many of them do not measure radiation, except sunshine duration.
- No existing standard and interoperable access to in-situ measurement time series.
- No easy access by SMEs to meteorological measurements because of costs.
- Scarcity of accurate in situ measurements in coastal areas for marine renewable energies. Bathymetry, type of floor, tides, swell, currents.

Within the Task 5.2 (The industry energy challenge) a first effort to provide access to such measurements has been carried out through the release of an open, standard (OGC compliant) and interoperable platform offering time series of in-situ measurements for the renewable energy community. This platform is accessible at: http://insitu.webservice-energy.org and it is part of the Webservice-Energy SDI (Spatial Data Infrastructure): http://www.webservice-energy.org

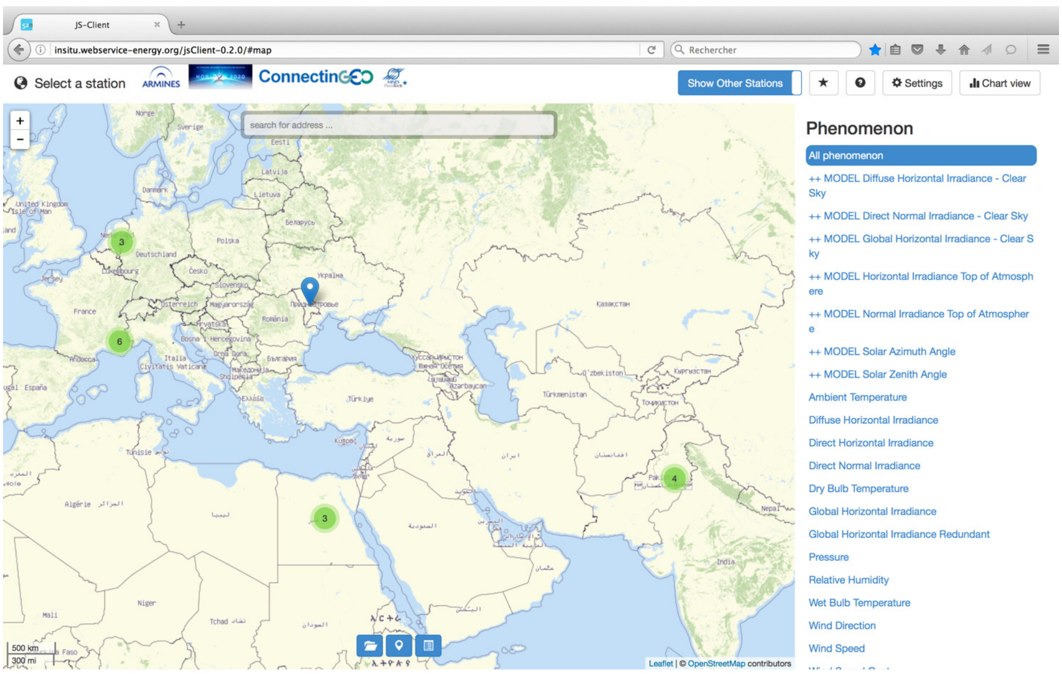

Figure 19. The Renewable Energy in-situ platform: Geo-localization of a station of interest

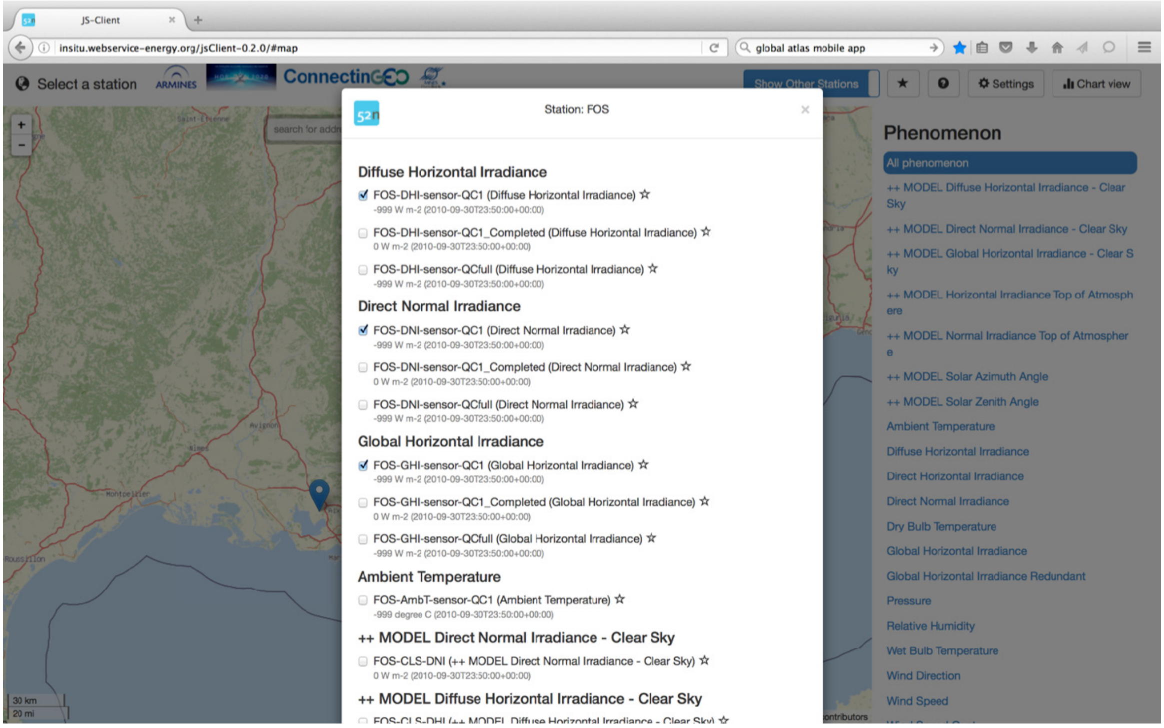

Figure 20. The Renewable Energy in-situ platform: Selection of the measurements of interest

Figure 21. The Renewable Energy in-situ platform: Display and download of measurements of interest

Thanks to the existence of the platform, several presentations have been made at renewable energy conferences, workshops and training for practitioners, leveraging opportunities that do exist to extend the preliminary list of data providers that have initially shared their in-situ measurements on the platform. This has led to the concept of a "Meta-Network" where opportunities exist to get access to in-situ measurements coming from numerous PV plant operators all over Europe. PV plant operators collect in-situ measurements as part of their daily operations. An extra effort is needed to identify, convince them, access and connect their data. As a result and with the support of this newly created platform, one could gather under this "Meta-Network" private providers offering access to their in-situ measurements under open, standard and interoperable technologies enforcing GEOSS recommendations. This Meta-Network complements existing well-known meteorological networks (e.g. WRDC, GAW, BSRN).

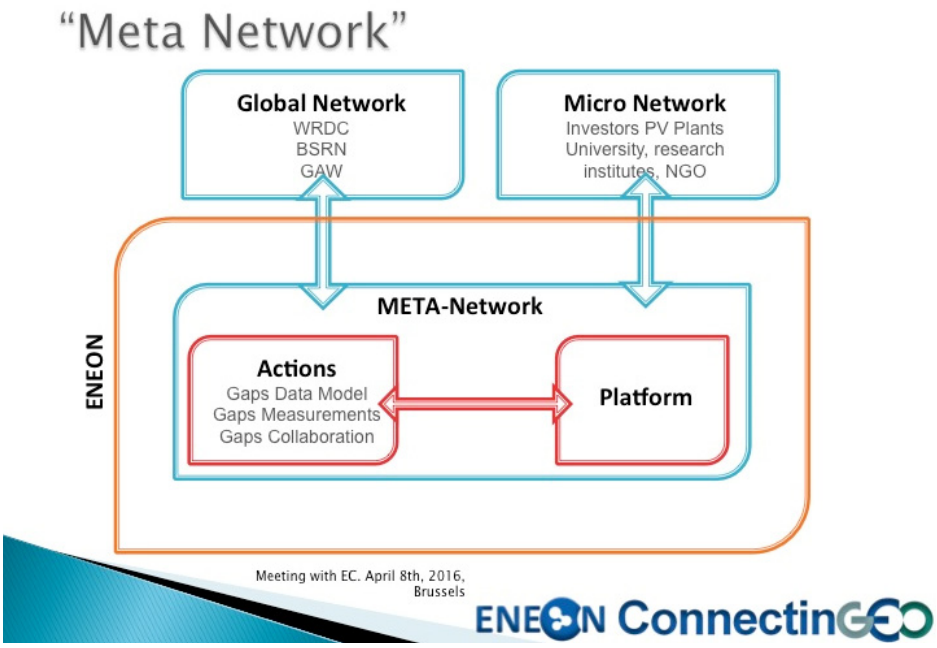

Figure 22. The "Meta Network" as presented at the mid-term review meeting (April 8th 2016, Brussel).

3.4. GEO DAB Gap Analysis

A major effort in ConnectinGEO involves enhancing the capabilities of the GEO DAB to allow for quantitative gap analysis. The focus here is on developing an observation inventory, which requires enrichment of the existing metadata – currently a weak point which prevents accurate gap analysis. Enrichers are being developed which will add or improve the metadata while providing various dashboard style tools to visualize the results. Initial efforts are visible here: http://oi.geodab.eu/oi-client/home/. **Error! No s'ha trobat l'origen de la referència.** shows an example of a query of abstracts containing the word 'in-situ'.

Figure 23. A query of the GEO DAB searching the abstract for the keyword in-situ.

4. Way Forward

With the growing realization that *in-situ* networks both across Europe and around the globe lack coordination, efforts are underway to improve this situation. Discussions around the GEO task GD-06 have led to the following items being suggested as a way forward for the near future:

Analyse the current trends and develop new scenarios for *in-situ* measurements, coordination, and access to data, which would allow inclusion of new types of data (such as drones, citizens' observatories) and their provenance. The regional scale would be considered as the reference to start.

Promote and coordinate non space-based observing systems (including both *in-situ* and remote sensing airborne, land and ocean based systems, collectively denote here as *in-situ* systems) to provide long-term continuous observations of all components of the Earth System (atmosphere, ocean, terrestrial, ice, solid earth). Identify critical gaps in existing observational networks with a particular focus on: the needs of developing countries, the need for continuity of observations, and the potential benefits of enhanced observing systems. Individual Earth observing systems operated by national, regional and international entities are integral to GEOSS.

Identify data resources needed by GEO (including flagships, initiatives and community activities) to achieve the objectives of the GEO Strategic Plan. Coordinate increased interoperability of *in-situ* data including new data flows from the private sector and the public, and develop global and regional datasets supporting the GEO community.

Compile global perspectives on existing plans for new *in-situ* observing networks and develop common strategies and actions to ensure sustained observations. Advocate adequate resources to maintain systems that provide continuity of observations.

Promote coordination of *in-situ* and space based observation networks to provide calibration and validation sources, to fill measurement gaps, and to promote technology sharing and infusion between the two communities. Promote communication between the *in-situ* and space measurement communities by sponsoring workshops, side events, and educational material as needed.[4]

Given the strategic importance of GD-06, CREAF is now leading the task and together with Tiwah is drafting the content of a report that will be provided by several experts in the task. This report will be presented to the next GEO Plenary in November in St. Petersburg.

[4] 2016 GEO white paper on GD-06

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Appendices

Appendix I – European/Global *in-situ* "Network" Database (beta version – 19/07/16)

Theme	Type	Extent	Name	URL
All	NetworkOfNetworks	European	European Network of Earth Observation Networks *(ENEON)*	http://www.eneon.net
All	NetworkOfNetworks	Global	Group on Earth Observation *(GEO)*	www.earthobservations.org
All	SystemOfSystems	Global	Global Earth Observation System of Systems *(GEOSS)*	http://www.GEOGLAM-crop-monitor.org
Atmosphere	Network	Global	AErosol RObotic NETwork *(AERONET)*	http://aeronet.gsfc.nasa.gov/
Atmosphere	Infrastructure	European	Actris - Aerosols, Clouds, and Trace gases Research InfraStructure *(Actris)*	http://www.actris.net/
Atmosphere	ObservationSystem	Global	Advanced Global Atmospheric Gases Experiment *(AGAGE)*	http://agage.mit.edu/
Atmosphere	DataCenter	European	European Air quality dataBase *(AirBase)*	http://acm.eionet.europa.eu/databases/airbase/
All	Program	European	Arctic Monitoring and Assessment Programme *(AMAP)*	http://www.amap.no/
Ecosystems	Infrastructure	European	ANAEE - Infrastructure for Analysis and Experimentation on Ecosystems *(Anaee)*	http://www.anaee.com/
All	DataCenter	Global	Arctic Runoff Data Base *(Arctic-HYCOS)*	http://arctic-hycos.net/Arctic-HYCOS/Home.html
All	DataCenter	Global	Arctic Runoff Data Base *(ARDB)*	http://www.bafg.de/GRDC/EN/04_spcldtbss/41_ARDB/ardb.html
Atmosphere	Infrastructure	European	Atmospheric dynamics InfraStructure in Europe *(ARISE)*	http://arise-project.eu/
Oceans	ObservationSystem	Global	Argo *(Argo)*	http://www.argo.ucsd.edu/
Oceans	Infrastructure	European	Association of European Marine	http://www.assemblemarine.org/

			Biological Laboratories *(ASSEMBLE)*	
Oceans	Network	Global	Biodiversity Indicators Parnership *(BIP)*	http://www.bipindicators.net/
Biosphere	NetworkOfNetworks	Global	BirdLife International *(BirdLife)*	http://www.birdlife.org/
Oceans	Network	Global	Oceans and Society: Blue Planet *(BluePlanet)*	http://www.oceansandsociety.org/
Radiation	Network	Global	Baseline Surface Radiation Network *(BSRN)*	http://bsrn.awi.de/
Atmosphere, Energy	ObservationSystem	European	Copernicus Atmosphere Monitoring Service *(CAMS)*	http://atmosphere.copernicus.eu/about-cams
Biosphere, Ecosystems, Environment, Forestry	ObservationSystem	European	Copernicus Land Monitoring Service *(CopernicusLandMonitoringService)*	http://www.copernicus.eu/main/land-monitoring
Oceans, Environment	ObservationSystem	European	Copernicus Marine Environment Monitoring Service *(CMEMS)*	http://www.copernicus.eu/main/marine-monitoring
Atmosphere	Network	European	CLOUD-NET *(CLOUDNET)*	http://www.cloud-net.org/
Biosphere	DataCenter	European	Digital Observatory for Protected Areas *(DOPA)*	https://dopa.jrc.ec.europa.eu/
Atmosphere	Network	European	EARLINET *(EARLINET)*	www.earlinet.org
Biosphere	Network	European	A national forum for biodiversity research observatories *(ECOSCOPE)*	http://www.inra.fr/en/Scientists-Students/Agroecology/All-reports/Environmental-research-infrastructure/ECOSCOPE-SOERE
Forestry, Disasters	DataCenter	European	Gliders for Research, Ocean Observation and Management *(EFFIS)*	http://forest.jrc.ec.europa.eu/effis/about-effis
Environment	Network	European	European Environment Information and Observation Network *(EIONET)*	https://www.eionet.europa.eu/
Atmosphere	Infrastructure	European	Eiscat_3D - The Next Generation Radar for Atmospheric and Geospace Science *(EISCAT-3D)*	https://eiscat3d.se/

Biosphere	Infrastructure	European	ELIXIR - European Life-science Infrastructure for Biological Information *(Elixir)*	https://www.elixir-europe.org/
Oceans	Infrastructure	European	EMBRC - European Marine Biological Resource Centre *(EMBRC)*	http://www.embrc.eu/
Oceans	ObservationSystem	European	European Marine Observation and Data Network *(EMODnet)*	http://www.emodnet.eu/
Oceans	ObservationSystem	European	EMSO - European Multidisciplinary Seafloor and water-column Observatory *(EMSO)*	http://www.emso-eu.org/
All	Infrastructure	European	European Network for the Earth System Modelling *(IS-ENES)*	https://verc.enes.org/
Atmosphere	Program	Global	European Monitoring and Evaluation Programme *(EMEP)*	http://www.emep.int/
All	NetworkOfNetworks	Global	ENVRIPlus: Supporting environmental research with integrated solutions; the Earth is our lab *(ENVRIPlus)*	http://www.envriplus.eu/
Solid Earth	ObservationSystem	European	European Plate Observing System *(EPOS)*	https://www.epos-ip.org/
Biosphere	Network	European	European Biodiversity Observation Network *(EUBON)*	http://www.eubon.eu
Environment,Geo-sciences	Network	European	EUropean Facility for Airborne Research *(Eufar)*	http://www.eufar.net/
Oceans	Infrastructure	European	European infrastructure for Argo *(Euro-Argo)*	http://www.euro-argo.eu/
Oceans	Network	European	Towards an Alliance of European Research Fleets *(Eurofleets)*	http://www.eurofleets.eu/
Oceans	ObservationSystem	European	European Ocean Observing System *(EuroGOOS)*	http://eurogoos.eu/
Oceans	Network	Pan-	European node of Ocean	http://www.eurobis.org

		European	Biogeographic Information System *(EurOBIS)*	
Water	DataCenter	Global	European Water Archive *(EWA)*	http://www.bafg.de/GRDC/EN/04_spcldtbss/42_EWA/ewa_node.html
Biosphere	Infrastructure	European	Freshwater Information Platform *(FIP)*	http://www.freshwaterplatform.eu
Oceans	ObservationSystem	European	Fixed point Open Ocean Observatory network *(FixO3)*	http://www.fixo3.eu/
Atmosphere	ObservationSystem	Global	FLUXNET *(FLUXNET)*	https://daac.ornl.gov/FLUXNET/fluxnet.shtml
Forestry	Network	Global	Center for Tropical Forest Science and Forest Global Earth Observatories *(ForestGEO)*	http://www.ctfs.si.edu/
Forestry	Network	Global	FORESTPLOTS.NET *(FORESTPLOTS.NET)*	http://www.forestplots.net/
Forestry	Program	Global	Forest Observation System *(FOS)*	http://forest-observation-system.net/
Atmosphere	Program	Global	Global Atmosferic Watch *(GAW)*	http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html
Biosphere	ObservationSystem	Global	Global Biodiversity Information Facility *(GBIF)*	http://www.gbif.org
Climate	ObservationSystem	Global	Global Climate Observation System *(GCOS)*	http://www.wmo.int/pages/prog/gcos/index.php
Water	ObservationSystem	Global	Global Environment Monitoring System *(GEMS)*	http://www.gtn-h.info/about/the-network/gpcc/
Biosphere	NetworkOfNetworks	Global	Group on Earth Observation Biodiversity Observation Networks *(GEOBON)*	http://GEOBON.org
Disasters	Network	Global	Data Access for Risk Management *(GEO-DARMA)*	https://www.earthobservations.org/activity.php?id=49
Agriculture	ObservationSystem	Global	Global Agricultural Monitoring *(GEOGLAM)*	http://www.GEOGLAM-crop-monitor.org
Biosphere,	Network	Global	GEO Global Network for Observation	http://www.earthobservations.org/ts.php?id=224

Ecosystems, Environment			and Information in Mountain Environments *(GEO-GNOME)*	
Ecosystems, Environment, Forestry	Network	Global	Geo Wiki Land Cover Citizen Science *(GeoWiki)*	www.geo-wiki.org
Forestry	NetworkOfNetworks	Global	Eye on Global Network of Networks *(GFOI)*	http://www.gfoi.org/
Water	Infrastructure	Global	Global Groundwater Information System *(GGIS)*	http://www.un-igrac.org/global-groundwater-information-system-ggis
Health	DataCenter	Global	Global Health Observatory *(GHO)*	http://www.who.int/gho/en/
Water	NetworkOfNetworks	Global	Global Groundwater Monitoring Network *(GGMN)*	http://www.un-igrac.org/special-project/ggmn-global-groundwater-monitoring-network
Environment	ObservationSystem	Global	Global Mercury Observation System *(GMOS)*	http://www.gmos.eu/
Water	ObservationSystem	Global	Global Network of Isotopes in Precipitation *(GNIP)*	http://www.gtn-h.info/about/the-network/gnip-gnir/
Water	ObservationSystem	Global	Global Network of Isotopes in Rivers *(GNIR)*	http://www.gtn-h.info/about/the-network/gnip-gnir/
Environment	NetworkOfNetworks	Global	Eye on Global Network of Networks *(GNON)*	http://www.eoesummit.org/blog/initiative/eye-on-global-networks-of-networks/
Oceans	Network	Global	Global Ocean Data Assimilation Experiment *(GODAE)*	www.godae.org
Biosphere, Environment, Forestry	Network	Global	Global Observation for Forest Cover and Land Dynamics *(GOFC-GOLD)*	http://www.gofcgold.wur.nl/index.php
Oceans	ObservationSystem	Global	The Global Ocean Observing System *(GOOS)*	http://www.ioc-goos.org/
Water	DataCenter	Global	Global Precipitation Climatology Centre *(GPCC)*	http://www.gtn-h.info/about/the-network/gpcc/
Water	DataCenter	Global	Gliders for Research, Ocean Observation and Management	http://www.bafg.de/GRDC/EN/Home/homepage_node.html

			(GRDC)	
Oceans	Infrastructure	European	Gliders for Research, Ocean Observation and Management *(GROOM)*	http://www.groom-fp7.eu/doku.php
Atmosphere	Network	Global	GCOS Reference Upper-Air Network *(GRUAN)*	http://www.dwd.de/EN/research/international_programme/gruan/home.html
Disasters	Network	Global	GEO Geohazards Supersites and Natural Laboratories *(GSNL)*	http://www.earthobservations.org/gsnl.php
Biosphere, Ecosystems	ObservationSystem	Global	Global System of Ecosystem Observatories *(GSEO)*	http://geobon.org/become-a-bon/thematic-bons/
Water	NetworkOfNetworks	Global	Global Terrestrial Network - Hydrology *(GTN-H)*	http://www.gtn-h.info/
Water	DataCenter	Global	Global Terrestrial Network for River Discharge *(GTN-R)*	http://www.bafg.de/GRDC/EN/04_spcldtbss/44_GTNR/gtnr_node.html
Biosphere, Ecosystems	ObservationSystem	Global	Global Wetland Observing System *(GWOS)*	http://geobon.org/become-a-bon/thematic-bons/
Atmosphere	ObservationSystem	Global	Halocarbons & other Atmospheric Trace Species Group *(HATS)*	http://bsrn.awi.de/
Water	DataCenterA	Global	International Data Centre on the Hydrology of Lakes and Reservoirs *(HYDROLARE)*	http://hydrolare.net/
Atmosphere	ObservationSystem	European	In-service Aircraft for a Global Observing System *(IAGOS)*	http://www.IAGOS.org/
Water	ObservationSystem	Global	International Groundwater Resources Assessment Centre *(IGRAC)*	http://www.un-igrac.org/
All	SystemOfSystems	European	Infrastructure for Spatial Information in the European Community (INSPIRE) 14.03.2007 *(INSPIRE)*	http://inspire.ec.europa.eu/
All	Network	European	International Network for Terrestrial Research and Monitoring in the Arctic *(Interact)*	http://www.eu-interact.org/

Solid Earth, Water	Network	Global	International Soil Moisture Network *(ISMN)*	https://ismn.geo.tuwien.ac.at/
Oceans	SystemOfSystems	European	Joint European Research Infrastructure Network for Coastal Observatories *(Jerico)*	http://www.jerico-ri.eu/
Biosphere, Ecosystems	Infrastructure	European	E-Science European Infrastructure for Biodiversity and Ecosystem Research *(LifeWatch)*	http://www.lifewatch.eu/
Ecosystems, Biosphere	Network	European	Long-Term Ecosystem Research in Europe *(LTER)*	http://www.LTER-europe.net/
Ecosystems, Biosphere	DataCenter	European	Land use and land cover survey *(LUCAS)*	http://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey
Oceans, Atmosphere	ObservationSystem	Global	Maritime Aerosol Network *(MAN)*	http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html
Biosphere, Ecosystems	ObservationSystem	Global	Marine Biodiversity Observation Network *(MBON)*	http://geobon.org/become-a-bon/thematic-bons/
Oceans	Network	European	European Network of Marine Research Institutes and Stations *(Mars)*	http://www.marsnetwork.org/
Oceans	Network	European	Network of leading MESOcosm facilities to advance the studies of future AQUAtic ecosystems from the Arctic to the Mediterranean *(MESOAQUA)*	http://mesocosm.eu/
Oceans	Network	Global	Mediterranean Operational Network for the Global Ocean Observing System *(MONGOOS)*	http://www.mongoos.eu/
Atmosphere	Network	Global	NASA Micro-Pulse Lidar Network *(MPLNET)*	http://mplnet.gsfc.nasa.gov/
Atmosphere	ObservationSystem	Global	Network for the Detection of	http://www.ndsc.ncep.noaa.gov/

			Atmospheric Composition Change *(NDACC)*	
Oceans	NetworkOfNetworks	Global	Ocean Biogeographic Information System *(OBIS)*	http://www.iobis.org/
Oceans	ObservationSystem	Global	OceanSITES *(OceanSITES)*	http://www.oceansites.org/
Biosphere	Infrastructure	European	Pan-European Species directories Infrastructure *(PESI)*	http://www.eu-nomen.eu/pesi/
Oceans	ObservationSystem	Global	Partnership for Observation of the Global Oceans *(POGO)*	http://ocean-partners.org/
Forestry	Network	Global	Amazon Forest Inventory Network *(Rainfor)*	http://www.rainfor.org/
Oceans	Infrastructure	Pan-European	SeaDataNet *(SeaDataNet)*	http://www.seadatanet.org/
Atmosphere	Network	Global	Southern Hemisphere ADditional OZonesondes *(SHADOZ)*	http://croc.gsfc.nasa.gov/shadoz/
All	Infrastructure	European	Svalbard Integrated Earth Observing System *(Sios)*	http://www.sios-svalbard.org/
Biosphere	Infrastructure	European	Synthesis of Systematic Resources *(SYNTHESYS)*	http://www.eu-nomen.eu/pesi/
Biosphere, Environment, Ecosystems	Program	European	Satellite-based Wetland Observation Service *(SWOS)*	http://swos-service.eu/
Atmosphere	ObservationSystem	Global	Total Carbon Column Observing Network *(TCCON)*	http://www.tccon.caltech.edu/
All	Program	Global	United Nations Environment Programme *(UNEP)*	http://www.unep.org
Atmosphere	DataCenter	Global	World Ozone and Ultraviolet Radiation Data Centre *(WOUDC)*	http://www.wmo.int/pages/prog/arep/gaw/ozone-uv.html
Atmosphere	DataCenter	Global	World Data Centre for Aerosols *(WDCA)*	http://www.wmo.int/pages/prog/arep/gaw/aerosols.html

Atmosphere	DataCenter	Global	World Data Centre for Greenhouse Gases *(WDCGG)*	http://www.wmo.int/pages/prog/arep/gaw/ghg.html
Atmosphere	DataCenter	Global	World Data Center Precipitation chemistry *(WDCPC)*	http://www.wmo.int/pages/prog/arep/gaw/PrecipitationChemistry.html
Atmosphere	DataCenter	Global	World Data Center for Remote Sensing of the Atmosphere *(WDC-RSAT)*	http://wdc.dlr.de/
Atmosphere, Health	Network	Global	Working Group on Effects *(WGE)*	http://www.unece.org/environmental-policy/conventions/envlrtapwelcome/convention-bodies/working-group-on-effects.html
Water	DataCenter	Global	World Glacier Monitoring Service *(WGMS)*	http://wgms.ch/
Atmosphere	DataCenter	Global	World Radiation Data Centre *(WRDC)*	http://www.wmo.int/pages/prog/arep/gaw/solar-radiation.html

Appendix II - Citizen Science Workshop Report

The First International ECSA Citizen Science Conference 2016 is aimed at policy makers, science founders, scientists, practitioners in the field of citizen science, Non-Governmental Organisations and interested citizens. This trans-disciplinary conference will highlight, demonstrate and debate the innovation potential of citizen science for science, society and policy, and its role within open science and innovation.

The three-day conference will showcase how both new and traditional ways of citizens working with scientist can enable the transformative enhancement of science-policy and social impact, scientific advancement, scientific literacy and empowerment. Of particular importance is the role of citizen science within wider agendas such as open science and innovation, and progressing towards responsible research and innovations.

http://www.ecsa2016.eu/index.html

Session Title:
Citizen science with small sensor networks complementing traditional *in-situ* observations - gaps, advances and limitations. From activism to collaboration in environmental measurements.

Date: Saturday May 21st 2016, 13:30

Session Chairs:

Jeroen Devilee Centre for Sustainability, Environment and Health (DMG) Dutch National Institute for Public Health and the Environment (RIVM) P.O Box 1, 3720BA Bilthoven, The Netherlands Email: jeroen.devilee@rivm.nl Phone: +31 (0) 30 2748672 Web: www.rivm.nl	Ian McCallum Ecosystems Services and Management Program (ESM) International Institute for Applied Systems Analysis (IIASA) Schlossplatz 1, 2361-Laxenburg, Austria Email: mccallum@iiasa.ac.at Phone: +43 (0) 2236 807-328 Web: www.iiasa.ac.at/ESM

Session Abstract:

Due to technological developments, citizen science with apps and small sensors has the potential to have a large impact on science and society. Owners of traditional environmental monitoring systems increasingly experience that citizens and societal actors can organize their own measurements. Where in the old days only expensive national measurements existed, nowadays these will be complemented by citizen science measurements by a growing number of stakeholders and citizens. By supporting this process, the owners of national measurements systems create tremendous possibilities to improve the quality and geographical exactness of national measurement systems.

Citizen scientists and researchers observe that many of the traditional measurements are costly, prone to government and research spending cuts and are poor or non-existent in some regions. Other necessary observations are simply not collected or are collected but lack the spatial and temporal resolution required to properly monitor the phenomenon. They see the raised awareness of citizen science (CS) as a means to address some of these important issues.

Consequently, those responsible for national environmental measurements systems, researchers and citizen scientists acknowledge that citizen science has the potential to generate new and previously unavailable information, or to complement existing measurements and at lower costs than traditional forms of *in-situ* measurement. However, a good overview of the contemporary possibilities and ambitions is lacking.

In the session proposed we will list CS efforts with small and cheap sensor networks that complement other forms of measurement, a description of which measurements are complementary, potential cost savings, quality assurance and known limitations. Moreover, we are very much interested in the organization of the process: cooperation in the calibration of sensors, ways to integrate CS data with official data, the design of a robust long running data collection process with societal partners, and the way that: 1) citizen learning will be enabled and; 2) citizen motivation for engagement will be optimized. This effort should lead to a peer-reviewed publication on the topic as it is of high relevance to CS in general.

Keywords: Citizen Science, *in-situ* monitoring, data quality, data governance, citizen learning, citizen motivation

Session type:
Suggest a short paper session – 5-10 minutes speed talks, followed by open panel discussion format led by session chairs and speakers. Would suggest a 90 minute session. Expected participant numbers would also help determine session type and length – hence this is still flexible.

Speakers:
Citizen observatories to complement space-borne
remote sensing: case study Red River Vietnam
Martine Rutten
Delft University of Technology, Netherlands

Sensors and citizens: how far can we get?
Ernie Weijers (Unable to attend)
Energy Research Centre of the Netherlands

The Dutch Environmental Protection Agency
finding its way into Citizen Science
Hester Volten, Joost Wesseling, Edith Putten, Annemarie Alphen,
Eric Tielemans
RIVM National Institute for Public Health and the Environment, Netherlands

Can low-cost sensors contribute to air quality
assessment and citizen science?

Nuria Castell
NILU, Norway;
Uri Lerner, Barak Fishbain
Technion Enviromatics
Laboratory, Israel;
Franck René Dauge, Philipp Schneider, Matthias Vogt,
Alena Bartonova
NILU, Norway

Augmenting Observations from Satellites with Crowdsourcing
Mazumdar Suvodeep, Stuart Wrigley, Fabio Ciravegna
University of
Sheffield, UK

Humans as sensors – complementing traditional land use measurements with citizen science
Inian Moorthy, Steffen Fritz, Linda See
IIASA, Austria

Minute taker: Joan Masó

2016 May 21.

Started at 13:45. About 40 people were present.

Name of the session: Citizen science with small sensor networks complementing traditional *in-situ* observations - gaps, advances and limitations. From activism to collaboration in environmental measurements

Chairs: Jeroen Devilee Dutch National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands; Ian McCallum International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

1.- Citizen observatories to complement space-borne remote sensing: case study Red River Vietnam

Martine Rutten Delft University of Technology, Netherlands

Chickasha NASA field validation campaign to characterize the soil and finding the soil moisture.
There is a need to raise awareness of water quality.
Air quality and Water quality are concerns in the Red River basin.
For rivers in RS we can see, color, turbidity and temperature. This is not much but can be used to detect anomalies. Then field teams are deployed to assess water quality. A game is used to teach how to do the field campaign. Also a community is trained for photointerpretation. A confusion matrix is used to assess de quality of the voluntaries classifications versus de “official results”. Then an application is used to ask voluntaries about their mistakes and if they want to rectify and which are the difficulties. In the future, they want to extent to Ecosystem services.

Q: Who assess the "official results" that is considered as ground truth.
Q: How successful the gaming is?
A: 300 people has used them. Awareness about plastic pollution has increased

2.- Sensors and citizens: how far can we get?

Ernie Weijers Energy Research Centre of the Netherlands
Speaker was not able to attend.

3.- The Dutch Environmental Protection Agency finding its way into Citizen Science

Hester Volten, Joost Wesseling, Edith Putten, Annemarie Alphen,
Eric Tielemans RIVM National Institute for Public Health and the Environment, Netherlands

Many trials with CS. We realize is not only a good idea: it is the future.
EPA: We are doing calibration and validation and acquiring data.
EPA followed 4 different projects. First conclusion, people ask for support on what they are interested in instead of "comply" with the reporting that the government has to do. Calibration and validation has to be done fast because sensors are changing constantly since they are not very good and need to be upgraded.
Opportunity: Hybrid network of different sensors integrated.

Question: How small sensors can be incorporated in networks (ammonia in natural areas example).
Q: Remote sensing is looking to have continuity (to respect old stadnards). Is this applicable to *in-situ*?.
A: reporting to government procedures are 30 years old. It does not ever require RS. WE need to convince them slowly.

4.- Can low-cost sensors contribute to air quality assessment and citizen science?

Nuria Castell NILU, Norway; Uri Lerner, Barak Fishbain Technion Enviromatics Laboratory, Israel; Franck René Dauge, Philipp Schneider, Matthias Vogt, Alena Bartonova NILU, Norway

Oslo use case. It is not possible to give personalized information to the people with the stations available. Citizens Observatories opportunities. Low cost sensors on buses, bicycles and people. Challenges in data quality in errors and long term measurement. Sensors need to be replaced often (this is not cheap anymore).
In NILU tested the sensors in controlled chambers and collocated with official sensors. In the lab sensors work fine. In the field the correlation are lower due to interferences between pollutants and T and relative humidity. Uncertainties are high.
The legislation differentiates between fixed measurements and indicative measurements. Low cost can be used as indicative measurements in some cases only: NO, PM10 (NO2, O3, CO and PM25 are not useful).
In 5 month 23% of sensors failed and needed to be replaced. A need for detect failures is needed.

With the current sensors spatial distribution is not possible and with cheap sensors we need to communicate uncertainty.
Apps and questionnaires are used to get the perceptions of the people.

Q: Are the low cost sensors improving?
A: Yes. During the project manufactures have been improving sensors during the project.

5.- Augmenting Observations from Satellites with Crowdsourcing

Mazumdar Suvodeep, Stuart Wrigley, Fabio Ciravegna University of Sheffield, UK

ESA funded 14 month exploratory project to know how to use CS can be used to complement RS. Focused in 4 demonstrations projects:
Pyrenees snow cover area complemented with skiers and hikers. No significant measurements were collected. Seems that users do not want to use their phones for that.
Traffic and pollution in Sheffield. Insurance driving behavior data is used to infer pollution hot spots (breaks increase particle emissions etc). It works well except in roundabouts.
Flood emergency mapping. Social media might be used between satellite recurrence periods. Large volumes of data but geolocation is very difficult. Youtube is useful if
Land use Corine. Croundsourcing some classes are difficult to categorize and there are places where public access is not allowed.

Q: the tests does not demonstrate how to use EO. This is for the fun of the CS.
Q: what is the value of social media if we have flooded areas are modeled?
A: is to prepare the satellite and now how and when the satellite data has to be got.

6.- Humans as sensors – complementing traditional land use measurements with citizen science

Inian Moorthy, Steffen Fritz & Linda See IIASA

Land cove maps don't agree. CS work started with GeoWiki since 2009 with 10000 users. Validate 3 land cover maps with Google aerial photographs. CS data resulted in at least 4 scientific publications.
Land use and coverage are frame survey. 270000 points. Each 3 years. FotoQuest Austria 2015. Go to lucas point and take a picture. The first person that goes to a point get more points. 200 people with 12000 pictures. Good for agricultural and artificial. Again some problems classificating more complicated classes. Fotoquest europe is coming up.
Landsense project starts in September. 17 partners including ECSA.

Q: how to choose the places that are accessible. Uncertainty
A: Disclaimer + a bottom saying place inaccessible. Some point has been removed others added. You cannot take a picture until they are very close
Q: data changes over time
A: the Google data close to the date of the map is used.

We finalized at 14:57

Summary:

Overall, the five talks focused around various forms of citizen science for land cover/land use and air quality measurements. Clearly all efforts described indicate initial efforts underway, with many challenges to be tackled. Quality of data captured is very much an issue with more efforts needed here before citizen science can be relied upon to complement or replace more traditional forms of *in-situ* data collection. Nonetheless, good examples were shown with much promise for the future.

Appendix III – JSON Schema for the ENEON Network database and graph

This is the JSON schema that describes the content of the JSON-LD file that validates the JSON-LD encoded version of the ENEON Network database and graph.

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         "description": "A collection of networks that will be releated to each other by its id and will appear as boxes in the graph",
         "type": "array",
         "items": {
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            "description": "A Network element of the graph (represented as a box)",
            "type": "object",
            "required": [ "id", "type" ],
            "properties": {
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               "description": { "type": "string", "description": "Textual description of the objectives and mission of the network" },
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               "logo": { "type": "string", "format": "uri", "description": "Logo of the network" },
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            }
         }
      },
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         "required": [ "source" ],
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         }
      },
      "supportingProject": {
         "title": "Projects supporting the networks",
         "description": "Projects supporting or funding the networks",
```

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        "items": {
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          "required": [ "name", "title", "active" ],
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            "name": { "type": "string", "description": "Acronym of the project"},
            "title": { "type": "string", "description": "Title of the project"},
            "extent": { "enum": ["National", "European", "Pan-European", "Global"] },
            "program":  {  "type":  "string",  "description":  "Program  funding  the project"},
            "active": { "type": ["null", "boolean"] , "description": "If it is still ongoing" }
          }
        }
      }
    }
}
```

Appendix IV – Current EO gaps detected in ConnectinGEO

Gap ID	Gap type	Theme	EV	Gap description	T	Traceability	Purpose
1	1.1	Climate	ECV: Temperature (Atmosphere upper-air)	The scarce of microclimatic data (air temperature) from the beneath of trees.	3	Pieter De Frenne and Kris Verheyen "Weather stations lack forest data"	Find out how temperatures are changing beneath the trees
2	2.3	Climate	ECV:Aerosols (aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, Aerosol Optical Depth (AOD) at multiple wavelengths, AAOD, water content, ratio of mass to AOD, vertical distribution of extinction).	Daily monitoring of inorganic compounds in precipitation	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Monitoring of inorganic compounds in precipitation (SO4, NO3, NH4, H+ (pH), Na+, K+, Ca2+, Mg2+, Cl-
3	2.3	Climate	ECV:Aerosols (aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, Aerosol Optical Depth (AOD) at multiple wavelengths, AAOD, water content, ratio of mass to AOD, vertical distribution of extinction).	Daily/weekly monitoring of heavy metals in precipitation	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Monitoring of heavy metals in precipitation As, Cd, Ni, Cd, Pb, Cu, Zn

4	2.3	Climate	ECV:Aerosols (aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, Aerosol Optical Depth (AOD) at multiple wavelengths, AAOD, water content, ratio of mass to AOD, vertical distribution of extinction).	Daily monitoring of Inorganic compuns in air	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Daily monitoring of inorganic compounds in air. SO2, SO4, NO3, HNO3, NH4,NH3, HCI,NA+, K+, Ca2+, Mg2+
5	2.3	Climate	ECV:Aerosols (aerosol mass, size distribution (or at least mass at 3 fraction sizes: 1, 2.5 and 10 micron), speciation and chemical composition, Aerosol Optical Depth (AOD) at multiple wavelengths, AAOD, water content, ratio of mass to AOD, vertical distribution of extinction).	Daily/hourly monitoring of NO2 in air	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Hourly/daily monitoring of NO2
6	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO,	Monthly monitoring of gas particle ratios of N-species	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Monthly monitoring of NH3, NH4, HCI, HNO3, NO3 (in combination with filtre pack sampling)

			OClO, ClONO 2, HDO, CFCs, HCFCs, HFCs, Rn, SF6)				
7	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO, OClO, ClONO 2, HDO, CFCs, HCFCs, HFCs, Rn, SF6)	Hourly monitoring O3	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Hourly monitoring of the ozone contained in the air
8	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO, OClO, ClONO 2, HDO, CFCs, HCFCs,	Monthly monitoring of PM mass in air PM 2.5, PM 10	3	EMET PROGRESS IN AC. Monthly monitoring	

			HFCs, Rn, SF6)				
9	2.3	Climate	ECV: All Global Numerical Weather Prediction (NWP) variables?(e.g. , PBL + Tropopause height) and others yet to be determined by WMO/GAW.	Not enouhgt temporal monitoring of Precipitation amount (RR), temperature (T), wind direction (dd), wind speed (ff), relative humidity (rh), atmospheric pressure (pr)	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 1	Daily and mounthly monitoring
10	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO, OClO, ClONO 2, HDO, CFCs, HCFCs, HFCs, Rn, SF6)	Acidification and eutrophication: Observations contributes to the assessment of nitrogen chemistry, influence by local emissions and dry deposition fluxes	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 2	Monitoring hourly/daily gas particle ratio (NH3/NH4, HNO3/NO3) and monthly Ammonia in emission areas (NH3)

11	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO, OClO, ClONO 2, HDO, CFCs, HCFCs, HFCs, Rn, SF6)	Photochemical oxidants: observations contributes to the assessment of oxidant precursors	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 2	Monitoring hourly NOx, hourly Light hydrocarbons, 8hourly twice a week Carbonyls, and hourly Methane.
12	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics), SO2 (surface and column), CH4, CO2, N2O, HCHO, HOx, Clx, ClO, BrO, OClO, ClONO 2, HDO, CFCs, HCFCs, HFCs, Rn, SF6)	Heavy metals: observations contributes to the assessment of mercury and heavy metals fluxes	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 2	Monitoring weekly mercury in precipitation, daily mercury in the air, weekly heavy metals in air

13	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics	Persistent organic pollutants: observations contributes to the assessment of persistent organic pollutants	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 2	Monitoring weekly POPs in precipitation and in the air
14	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics	Particulate matter: observations contributes to the assessment of particulate matter and its source apportionment	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 2	Monitoring daily/weekly: mineral dust in PM10 (Si, Al, Fe, Ca), Elemental and Organic Carbon. Hourly/daily: Aerosol absorption, Aerosol size number distribution (dN/dlogDp), Aerosol scatering. Hourly: Aerosol Optical Depth at 550 nm
15	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics	Tracers observations contributes to the assessment of individual long-range transport events and their source apportionment	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 2	Monitoring hourly: CO, Halocarbons (CFCs, HCFCsd, HFCs, PFCs, SF6)

16	2.3	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics	Research based and voluntary -monitoring: Observations contribute to the understanding of processes relevant for long-range transport of air pollutants and support model development and validation	3	EMET PROGRESS IN ACTIVITIES IN 2009-2019 AND FUTURE WORK. Level 3	Monitoring hourly: Dry deposition flux, Dry deposition flux of O3, Dry deposition flux of VOCs, Greenhouse gases, Hydrogen. Hourly\Daily: Hydrocarbons, NOy chemistry, Vertical profiles, OC fractionation, Major inorganics in both PM2.5 and PM10. Daily/weekly:Mercury speciation , Congener-specific Organic tracers PM2.5 and PM10.
17	8.1	Energy	RE-EV: Land use, Land cover (Renewable energy)	Develop high-resolution global land-cover and land-cover change data sets, based on international community consensus and including a robust accuracy assessment.	2	CA-01. GEO 2016 WORK PROGRAMME	Reduce inconsistencies between land cover products
18	7.1	Energy	ECV: Soil moisture (Land)	In mineral resources there is the lack dedicated EO system or program and currently use EO systems and programs from other SBAs.	2	CA-06. GEO 2016 WORK PROGRAMME	Develop global coverage by high-spectral resolution sensors
19	6.3	Water	ECV: All Global Numerical Weather Prediction (NWP) variables?(e.g. , PBL + Tropopause height) and others yet to be determined by WMO/GAW.	In order to gain an understanding of the physical processes that are related to water vapor, clouds, aerosols and precipitation, a new observation paradigm needs to be established that focuses on the physical processes rather just on the final quantity.	2	CA-06. GEO 2016 WORK PROGRAMME	Develop an observation strategy to improve the synergistic understanding between water vapor and clouds, and if feasible, aerosols and precipitation.
20	6.1	Disasters	Multiple (specified in the gap description)	There is not timely and reliable access toin situdata required in emergency events.	2	GEO 2016 WORK PROGRAMME. CA-027. Foster Utilization of Earth Observation Remote Sensing and In Situ Data for All Phases of Disaster Risk Management	Promote timely and reliable access to in situ data required in emergency events
21	7.2	Disasters	Multiple (specified in the gap description)	Combine the use of remote sensing and EO to better estimate overfloods	2	GEO 2016 WORK PROGRAMME. CA-028 Global Flood Risk Monitoring	Develop, test and apply methods to utilize satellite remote sensing and other Earth observations with models and maps to estimate location, intensity and duration of floods globally in real-time and a durable monitoring system of flood risk with climate

22	5.4	Biodiversity	Multiple (specified in the gap description)	There are many excellent tools, protocols and software in use that facilitate effective biodiversity monitoring but these are not easily discoverable or available to all regions of the planet. As well, current efforts to monitor biodiversity are not interoperable, thereby limiting our ability to detect change and the underlying mechanisms driving change in biodiversity.	2	GEOBON- Global Biodiveristy Obvserbation	Aims to serve as a tecnology transfer, increase the interoperability and the accesibility of biodiversity data, models and tools
23	1.1	Biodiversity	EBV: Ecosystem function (Net primary productivity, Secondary productivity, Nutrient retention, Disturbance regime)	LIDAR global dataset	2	ECOPotential WP2 meeting. Cited Herique Pereira	Estimate biomass globally and with a good resolution. Carbon sequestration global estimation in forestry
24	2.3	Oceans	EOV: Sea Level (Physical surface)	Absence of a near real-time operational and timely manner a global coverage Sea Surface Height (SSH) for ocean and coastal areas	2	Sentinel- 3 Mission Objectives	Develop global coverage Sea Surface Height (SSH) for ocean and coastal areas
25	2.3	Oceans	EOV: Sea Ice (Physical surface) and EOV: Sea Level (Physical surface)	Absence of a near real-time operational and timely manner a enhanced resolution SSH products in coastal zones and sea-ice regions	2	Sentinel- 3 Mission Objectives	Enhanced resolution SSH products in coastal zones and sea-ice regions
26	2.3	Oceans	EOV: Sea Ice (Physical surface) and EOV: Sea Level (Physical surface)	Absence of in a near real-time operational and timely manner global coverage Sea Surface Temperature (SST) and sea-Ice Surface Temperature (IST)	2	Sentinel- 3 Mission Objectives	Global coverage Sea Surface Temperature (SST) and sea-Ice Surface Temperature (IST)
27	2.3	Oceans	EOV: Sea State (Physical surface)	Absence of in a near real-time operational and timely manner a global coverage ocean colour and water quality products	2	Sentinel- 3 Mission Objectives	Global coverage ocean colour and water quality products
28	2.3	Climate	ECV: Wind speed and direction (Atmosphere surface)	Absence of in a near real-time operational and timely manner a global coverage ocean surface wind speed measurements	2	Sentinel- 3 Mission Objectives	Global coverage ocean surface wind speed measurements
29	2.3	Oceans	EOV: Sea Level (Physical surface)	Absence of in a near real-time operational and timely manner a global global coverage significant wave height measurement	2	Sentinel- 3 Mission Objectives	Global coverage significant wave height measurement

30	2.3	Climate	ECV: Ozone and aerosol, supported by their precursors (Atmosphere composition)	Absence of in a near real-time operational and timely manner global coverage atmospheric aerosol consistent over land and ocean	2	Sentinel- 3 Mission Objectives	Global coverage atmospheric aerosol consistent over land and ocean
31	2.3	Climate	ECV: Water vapour (Atmosphere upper-air)	Absence of in a near real-time operational and timely manner a global coverage total column water vapour over land and ocean	2	Sentinel- 3 Mission Objectives	Global coverage total column water vapour over land and ocean
32	2.3	Biodiversity	ECV: Land cover,including vegetation type (Land)	Absence of in a near real-time operational and timely manner a global coverage vegetation products	2	Sentinel- 3 Mission Objectives	Global coverage vegetation products
33	2.3	Climate	ECV: Temperature (Atmosphere upper-air)	Absence of in a near real-time operational and timely manner a global coverage land ice/snow surface temperature product	2	Sentinel- 3 Mission Objectives	Global coverage land ice/snow surface temperature products
34	8.1	Biodiversity	Multiple (specified in the gap description)	No back-calibration of data archives for coherent time series compounded by changing methodologies.	2	O'Connor, B., Secades, C., Penner, J., Sonnenschein, R., Skidmore, A., Burgess, N. D., & Hutton, J. M. (2015). Earth observation as a tool for tracking progress towards the Aichi Biodiversity Targets. Remote Sensing in Ecology and Conservation,\x{fffd}1(1), 19-28.	Standardization in EO data and products
35		Biodiversity	Multiple (specified in the gap description)	No overseeing authority ensuring EO-based biodiversity observations are in line with user needs	2	O'Connor, B., Secades, C., Penner, J., Sonnenschein, R., Skidmore, A., Burgess, N. D., & Hutton, J. M. (2015). Earth observation as a tool for tracking progress towards the Aichi Biodiversity Targets.\x{fffd}Remote Sensing in Ecology and Conservation,\x{fffd}1(1), 19-28.	Designating leadership and institutional oversight
36		Biodiversity	Multiple (specified in the gap description)	Experts in EO data processing not trained in applied biodiversity concepts \x{2013} EO data products are not fit for purpose.	2	O'Connor, B., Secades, C., Penner, J., Sonnenschein, R., Skidmore, A., Burgess, N. D., & Hutton, J. M. (2015). Earth observation as a tool for tracking progress towards the Aichi Biodiversity Targets.\x{fffd}Remote Sensing in Ecology and Conservation,\x{fffd}1(1), 19-28.	Providing more opportunities for inter-disciplinary inter-disciplinary collaboration

37	7.1	Biodiversity	EBV: Genetic composition	The missing of Genetic composition data	2	Geijzendorffer, I. R., Regan, E. C., Pereira, H. M., Brotons, L., Brummitt, N., Gavish, Y., ... & Schmeller, D. S. (2015). Bridging the gap between biodiversity data and policy reporting needs: An Essential Biodiversity Variables perspective. Journal of Applied Ecology.	
38	7.1	Disasters	Multi EV (specified in the gap description)	There is the need to improve the availability of EO data to implement disaster risk reduction and resilience measures, during all disaster risk management phases	2	GI-16. GEO 2016 WORK PROGRAMME. GEO-DARMA = Data Access for Risk Managemen	To increase the availability and accuracy of risk related information, both satellite EO information combined with other sources of data (in-situ ground observations, socio-economic, model outputs)
39	1.1	Climate	ECV: Reactive Gases, Trace gases (incl GHG), Ozone Precursors (Total ozone, profile ozone, surface ozone, NO, NO2 (surface, column, profile), PAN, HNO3, NH3, CO, VOC (isoprene, terpenes, alcohols, aldehydes, ketones, alkanes, alkenes, alkynes, aromatics	Lack of spatial coverage in Indic Ocean and in the south hemishere	2	***http://www.iagos.fr/web/images/map/map_iagos.png***	Contact indic companies if available
40	6.3	Biodiversity	EBV: Community composition (Taxonomic diversity, Species interactions)	While the amount of information on biodiversity has increased greatly in recent years there are still major gaps in understanding which need to be filled, such as those related to taxonomy. Similarly much of the information which is currently available is often incomplete and/or in need of updating	2	Aichi targets Compilation. Target 19	
41	6.2	Biodiversity	Multi EV (specified in the gap description)	Information and technologies relating to biodiversity should be made more accessible and shared, subject to national legislation, so that it can be put to better use. Much of the information which is available is not effectively used as it is difficult to access.	2	Aichi targets Compilation. Target 19	Accessibility could be improved through the further development of the clearing-house mechanism at national and global levels.

42	3.1	Biodiversity	Multi EV (specified in the gap description)	Further efforts are also needed, at multiple scales, to improve biodiversity-related knowledge and reduce uncertainties around the relationship between biodiversity change, ecosystem services and impacts on human well-being	2	Aichi targets Compilation. Target 19	
43	1.1	Energy	RE-EV: Solar Surface Irradiance and its components (global, direct, diffuse)	Scarcity of accurate in situ measurements in most of the world. Large networks measuring radiation, such as GAW, BSRN have a limited coverage. National meteo networks are by definition limited and in addition, many of them do not measure radiation, except sunshine duration.	2, 5	IEA Solar Heating and Cooling Program, Tasks 36 and 46. GEO Task US-09-01a	Various. Ranges from establishing a bankable report for investment sseking to validation / calibration of Copernicus products and others
44	6.2	Energy	RE-EV. Multiple. Meteorology	No easy access by SMEs to meteorological measurements because of costs	5	ConnectinGEO. Exchanges with companies in various occasions, including Copernicus events	Various. Ranges from establishing a bankable report for investment sseking to validation / calibration of Copernicus products and others
45	1.1, 1.3	Energy	RE-EV. Multiple. Ocean	Scarcity of accurate in situ measurements in coastal areas for marine renewable energies. Bathymetry, type of floor, tides, swell, currents.	5	ConnectinGEO. Exchanges with companies in various occasions, including Copernicus events	Various. Ranges from establishing a bankable report for investment sseking to validation / calibration of Copernicus products and others
46	2.3	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Satelite observations do not cover the diurnal cycle	3	GCOS-195 Report	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
47	8.1	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Differences among SST products near the coasts.	3	GCOS-195 Report, Reynolds & Chelton, 2010	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
48	8.2	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Uncertainties in the adjutsments between different instruments along the time	3	GCOS-195 Report, Reynolds & Chelton, 2010	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
49	1.1	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Non-uniform distribution of in situ surface measurements. Argo are restricted to provide data at some topographically constraint areas (Caribbean Sea, South China Sea,etc.) and high latitudes.	3	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.

50	7.1	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Lack of in situ surface measurements from Argo buoys in marginal seas and shelf seas (i.e Baltic Sea, North Sea, Barents Sea etc.)	3	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
51	2.2	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Insufficient in situ surface measurements from Argo buoys. The number of measurements close to the surface (0 - 5 m) is around 20% of total profiles	3	Statistics from Coriolis Global Data Assembly Center (GDAC)	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
52	1.2	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Insufficient temporal coverage. Argo deployment started in 2000 and became fully operative in 2005 so less than the WMO 30 years definition of clima.	3	http://www.argo.ucsd.edu/About_Argo.html	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
53	??	CL, OC, WC, WE, DI, BI	Sea Surface Temperature	Drop of the number of Argo float deployments benneath 3200 in 2018.	3	Durack et al., 2016	Determine and understanding ocean-atmosphere heat and gas exchanges. In situ measurements necessary to cal/val satellite signals and sensor drift.
54		CL, OC	Sea Level	Spatial coverage. Insufficient number of stations.	3		Impact on coastal and islands communities. Necessary fro infrastructu
55		CL, OC	Sea Level	Capacity building ?. Lack of metadata in the position	3		Impact on coastal and islands communities. Necessary for coastal management and marine security.
56		CL, OC	Sea Level	Not enough simulatenous operation of altimeters (capacity ?)	3		Surface mesoscale features are adequately resolved with several altimeters working simulatenously. High resolution velocity fields are needed to resolve submesoscale motions.
57	1.3	CL, OC, WC, BI	Sea Surface Salinity	Insuficient temporal coverage. Time series are short because SSS missions and relatively new. SMOS was a proof of concept (2010-present). Aquarius ceased in (2011-2015). SMAP was conceived for soil moisture and now is being exploited for ocean SSS (2015-present)	3	GCOS-195 Report	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .

58	1.1	CL, OC, WC, BI	Sea Surface Salinity	Insufficient spatial coverage. SSS retrieval in marginal seas are difficult to obtain due to RFI contamination. SSS problematic for the land-sea transition. Signals are good up to several km near the continental coasts (50 km, SMAP and 800 km, SMOS).	3	Lagerloef et al, 2015 (available at ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs/v4/AQ-014-PS-0016_AquariusSalinityDataValidationAnalysis_DatasetVersion4.0and3.0.pdf) and Ballabrera, 2015 (avalaible at http://www.euro-argo.eu/content/download/91862/1123452/version/1/file/E-AIMS_D4.443-V2.pdf)	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .
59	8.1	CL, OC, WC, BI	Sea Surface Salinity	Products differ due to differences of onboard instrument configurations (e.g. real aperture radiometers versus synthetic aperture radiometers). Also different processing strategies produce different high levels products (L3, L4). Biases and non-linear effecrs at the level of brightness tempreature measurements exist between Aquarius and SMOS missions.	3	Pablos et al., 2014	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .
60	3.1 (?)	CL, OC, WC, BI	Sea Surface Salinity	In some regions, inadequate accuracy with respect to the mission target requirements (Amazonas river plume, northwestern Atlantic, North Pacific for Aquarius and western Pacific, Antartic Circumpolar current for SMOS)	3	Lagerloef et al, 2015 (available at ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs/v4/AQ-014-PS-0016_AquariusSalinityDataValidationAnalysis_DatasetVersion4.0and3.0.pdf) and Ballabrera, 2015 (avalaible at http://www.euro-argo.eu/content/download/91862/1123452/version/1/file/E-AIMS_D4.443-V2.pdf)	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .
61	7.1	CL, OC, WC, BI	Sea Surface Salinity	Insufficient spatial coverage by design. Argo does not measure salinity close to the surface (< 5 m) to avoid biofouling. Around 1% of data within 1 m.	3	Ballabrera, 2015 (avalaible at http://www.euro-argo.eu/content/download/91862/1123452/version/1/file/E-AIMS_D4.443-V2.pdf)	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .

62	7.1	CL, OC, WC, BI	Sea Surface Salinity	Insufficient spatial coverage related to marginal and shelf seas similar as for the SST	3	e.g Ballabrera, 2015 (avalaible at http://www.euro-argo.eu/content/download/91862/1123452/version/1/file/E-AIMS_D4.443-V2.pdf)	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .
63	1.3	CL, OC, WC, BI	Sea Surface Salinity	Insuficient temporal coverage. Time series are short because SSS missions and relatively new. SMOS was a proof of concept (2010-present). Aquarius ceased in (2011-2015). SMAP was conceived for soil moisture and now is being exploited for ocean SSS (2015-present)	3	GCOS-195 Report	SSS is essential for climate and water cycle changes derived from E-P fluxes over the ocean from basin to global scales. It is relevant to determine the surface density, freshwater transport and coastal ocean dynamics (river discharges). Further, in situ SSS measurement essential for cal/val satellite signals and sensor drift .
64	2.3	OC, DI, CL, HU	Sea State	Poor temporal coverage from altimeters for the involved scales.	3	GCOS-195 Report	Improve and validate sea state forecasts. Essential for marine security and marine trade.
65	2.1	OC, DI, CL, HU	Sea State	Lack of enough horizontal resolution (100 km) from SAR spectral and wave energy capabilities	3	GCOS-195 Report	Improve and validate sea state forecasts. Essential for marine security and marine trade for regional applications.
66	2.3	OC, DI, CL, HU	Sea State	Lack of enough temporal (6 h) from SAR spectra and wave energy capabilities	3	GCOS-195 Report	Improve and validate sea state forecasts for regional applications. Essential for marine security and marine trade.
67	7.1	OC, DI, CL, HU	Sea State	No data on spectra and nor directional information from altimeters. Several parameters not measured by present meteo-ocean buoys (wave breaking, whitcapping, rogue waves, Stokes drift)	3	GCOS-195 Report	Improve and validate sea state forecasts. Essential for marine security and marine trade.
68	1.1	OC, DI, CL, HU	Sea State	Poor offshore coverage	3	GCOS-195 Report	Improve and validate sea state forecasts. Essential for marine security and marine trade.
69	??	OC, DI, CL, HU	Sea State	Capacity building ?. Not much meteo-ocean buoys with directional spectra capabilities	3	GCOS-195 Report	Improve and validate sea state forecasts. Essential for marine security and marine trade.
70	8.1	OC, DI, CL, HU	Sea State	Capacity building ?. Lack of standardization in data reports with biases between networks of buoys.	3	GCOS-195 Report	Improve and validate sea state forecasts. Essential for marine security and marine trade.

71	2.1	DI, OC, WE, WA, HS, BI	Surface Current	Lack of enough resolution. Currents derived from SSH lacks of enough resolution to address ocean submesoscale processes.	3	GCOS-195 Report, Le Traon et al. 2016, Schiller et al. 2015	Surface mesoscale features are adequately resolved with several altimeters working simulatenously. High resolution velocity fields are needed to resolve submesoscale variability with large impact on seaborne commerce, fishing, strom surge, marine ecossytems,..
72	1.1	DI, OC, WE, WA, HS, BI	Surface Current	Insufficient spatial coverage of sea surface measurements. In coastal regions VHF radar measurements mainly cover USA coasts and few locations in Europe. In open ocean where coverage is mainly done with drifters (SVP program) fixed morings and ADCP onboard R/V the highest rate are approximately 1 data per 5\x{fffd} box from drifters.	3	GCOS-195 Report, Oke et al., 2015	To cover the range of space and time variability of coastal currents. Proved impact on forecasting products via data assimilation techniques at least for regional applications
73	1.3	DI, OC, WE, WA, HS, BI	Surface Current	Recovery of times series of surface currents is affected by lack of at least 4 altimeters working simultaneously in several periods needed to accurately assess ocean mesoscale variability.	3	GCOS-195 Report, Pascual et al, 2006,	Resolving adequately the variability of sea surface mesoscale currents is fundamental to infer non-local mass, energy and momentum at planetary scales
74	8,1 (?)	DI, OC, WE, WA, HS, BI	Surface Current	Lack of an international organism coordinating ocean surface currents.	3	GCOS-195 Report	To coordinate measurements and information from many heterogeneous ways and technologies to obtain sea surface currents.
75	1.3	CL, OC, HE, WA	Ocean Acidity	Insufficient data to cover the extent of variability that organisms observe.	2	Newton et al., 2015, GCOS-195 Report	Understanding global acidification conditions and improving the understanding of the ecosystem impacts and response to ocean acidification for warn-water coral reefs.
76	1.2	CL, OC, HE, WA	Ocean Acidity	Insufficient spatial coverage in Artic, Southern Oceans, "coral triangle" (south-east Asia) and off Peru.	2	Newton et al., 2015, GCOS-195 Report	Understanding global acidification conditions and improving the understanding of the ecosystem impacts and response to ocean acidification for warn-water coral reefs.
77	7.2	CL, OC, HE, WA	Ocean Acidity	Integration of physical, chemical and biological sensing.	2	Newton et al., 2015,GCOS-195 Report	Need of colocation of environmental data to solve the Ecosystem function characterized by primary and secondary production, orsganism interaction, nutrient cycling an material exchange.

78	7.1	CL, OC, HE, WA	Ocean Acidity	Identification of hot spots in the sense of threatened ecosystems	2	Newton et al., 2015,GCOS-195 Report	Understanding global acidification conditions and improving the understanding of the ecosystem impacts and response to ocean acidification for warn-water coral reefs.
79	5.1	CL, OC, WA, HE	Ocean Color	Lack of development and sharing of in situ databases and derived products of sufficient quality to use in cal/val satellite products.	2	GCOS-195 Report	Relevant to determine the marine albedo and assess the ocean ecosystem health and productivity and the role of the oceans in the global carbon cycle. Important to manage living marine resources and to quantify the impacts of climate variability and change.
80	8.1	CL, OC, WA, HE	Ocean Color	Limited linkage between ocean colour and ecosystem variables	2	GCOS-195 Report	Relevant to determine the marine albedo and assess the ocean ecosystem health and productivity and the role of the oceans in the global carbon cycle. Important to manage living marine resources and to quantify the impacts of climate variability and change.
81		CL, OC, WA, HE	Ocean Color	Risk of continuity of climate-research quality ocean colour radiance observations.	2	GCOS-195 Report	Relevant to determine the marine albedo and assess the ocean ecosystem health and productivity and the role of the oceans in the global carbon cycle. Important to manage living marine resources and to quantify the impacts of climate variability and change
82		CL, OC, WA, HE	Ocean Color	Difficulty in sustaining projects for cross-calibrating and merging OCR data across satellite sensors to support global and regional products	2	GCOS-195 Report	Relevant to determine the marine albedo and assess the ocean ecosystem health and productivity and the role of the oceans in the global carbon cycle. Important to manage living marine resources and to quantify the impacts of climate variability and change
83	5.6	CL, OC, WA, HE	Ocean Color	Need of continued R+T development (data streams, algorithms, products) for waters of type II where optical properties are not dominated by phytoplankton.	2	GCOS-195 Report	Relevant to determine the marine albedo and assess the ocean ecosystem health and productivity and the role of the oceans in the global carbon cycle. Important to manage living marine resources and to quantify the impacts of climate variability and change

84	1.2	CL, OC, WA, WE, BI, EN, HU	Temperature	Insufficient vertical coverage of measurements down 2000 m (more of the 50% of the ocean volume is whithin the layer deeper than 2000 m). XBT regular sections are concentrated around the first 750 m and in general below 700 m data are too sparse.	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo), IPCC (2013)	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.
85	8.1	CL, OC, WA, WE, BI, EN, HU	Temperature	Sub-surface temperatures estimates from available products have variations at different times and for differents periods.	2	IPCC (2013)	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.
86	6.5(6.6)	CL, OC, WA, WE, BI, EN, HU	Temperature	XBT metadata not always available.	2	GCOS-195 Report	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.
87	1.1	CL, OC, WA, WE, BI, EN, HU	Temperature	Non-uniform distribution of in situ surface measurements. Argo profilers by design provide data up to 2000 m leaving inaccessible topographically constraint areas (Caribbean Sea, South China Sea,etc.) and for high latitudes if dedicated deployments are not scheduled.	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.
88	7.1	CL, OC, WA, WE, BI, EN, HU	Temperature	Lack of in situ measurements from Argo buoys in shelf seas (i.e Baltic Sea, North Sea, Barents Sea etc.) and marginal seas	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.

89	1.3	CL, OC, WA, WE, BI, EN, HU	Temperature	Insufficient temporal coverage. Argo deployment started in 2000 and became fully operative in 2005, so less than the WMO 30 years definition of clima. Note however that regular but sparse temperarture sections and measurements (bathythermographs, CTD and XBT sections) are available since 1980s and before.	2	http://www.argo.ucsd.edu/About_Argo.html	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.
90	2.3	CL, OC, WA, WE, BI, EN, HU	Temperature	Lack of high temporal resolution of in situ observations to cover diurnal cycle.	2	GCOS-195 Report	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry.
91		CL, OC, WA, WE, BI, EN, HU	Temperature	Drop of the number of Argo float deployments benneath 3200 in 2018.	2	Durack et al., 2016	To characterize deep water masses, to monitor the ocen heat content and to determine the general structure of the ocean circulation. Necessary to determine the geostrophic circulation, heat transport and steric sea level and indirectly to understand changes in the marine biology and biogeochemistry. To resolve the processes linking the surface with the ocean interior.
92	1.1	CL, DI, EN, WA, WE,HU,OC	Currents	Lack of sufficient spatial coverage for many climatic applications, specially in the Southern hemisphere.	2	GCOS-195 Report, Holloway et al., 2011, IPCC, 2013	Currents are essential to determine the transport of mass, energy and many other properties (nutrients, O2, sediments, etc.) from basin to global scales. They are necessary to determine absolute velocity fields complementing the geostrophic field from temperature and salinity measurements. Direct measurements of lateral and bottom boundary currents ara important to resolve Ekman transport of properties to constraint large-scale and basin ocean currents, from small to climate scales. Important for model validation.

93	1.3	CL, DI, EN, WA, WE,HU,OC	Currents	Lack of sufficient temporal coverage and extent for many climatic applications, in particular to monitor the meridional overturning circulation.	2	GCOS-195 Report, Holloway et al., 2011, IPCC 2013	Currents are essential to determine the transport of mass, energy and many other properties (nutrients, O2, sediments, etc.) from basin to global scales. They are necessary to determine absolute velocity fields complementing the geostrophic field from temperature and salinity measurements. Direct measurements of lateral and bottom boundary currents ara important to resolve Ekman transport of properties to constraint large-scale and basin ocean currents, from small to climate scales. Important for model validation.
94	7.1	CL, DI, EN, WA, WE,HU,OC	Currents	Present observing system is inadequate to directly measure the vertical component of currents.	2	GCOS-195 Report	Currents are essential to determine the transport of mass, energy and many other properties (nutrients, O2, sediments, etc.) from basin to global scales. They are necessary to determine absolute velocity fields complementing the geostrophic field from temperature and salinity measurements. Direct measurements of lateral and bottom boundary currents ara important to resolve Ekman transport of properties to constraint large-scale and basin ocean currents, from small to climate scales. Important for model validation.
95		CL, DI, EN, WA, WE,HU,OC	Currents	Lack of an international organism coordinating such kind of measurements at global scale. Governance ?	2	GCOS-195 Report	Currents are essential to determine the transport of mass, energy and many other properties (nutrients, O2, sediments, etc.) from basin to global scales. They are necessary to determine absolute velocity fields complementing the geostrophic field from temperature and salinity measurements. Direct measurements of lateral and bottom boundary currents ara important to resolve Ekman transport of properties to constraint large-scale and basin ocean currents, from small to climate scales. Important for model validation.

96	1.2	CL, OC, WA, HE	Oxygen	Insufficient vertical coverage of measurements down 2000 m (more of the 50% of the ocean volume is whithin the layer deeper than 2000 m). Historical classical Winkler method was based on discrete samples from ship cruises so measurements have long history but have limitations.	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	Determine the evolution of O2 necessary to sustain the life in the ocean. To assess the risk of ocean deoxygenation and the impact on marine ecosystems eventually as a response to global warming but also eutrophication. To identify ocean water masses related with ocean circulation patterns.
97	1.1	CL, OC, WA, HE	Oxygen	Non-uniform distribution of in situ surface measurements. Argo profilers by design provide data up to 2000 m leaving inaccessible topographically constraint areas (Caribbean Sea, South China Sea,etc.) and for high latitudes if dedicated deployments are not scheduled.	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	Determine the evolution of O2 necessary to sustain the life in the ocean. To assess the risk of ocean deoxygenation and the impact on marine ecosystems eventually as a response to global warming but also to eutrophication. To identify ocean water masses related with ocean circulation patterns.
98	7.1	CL, OC, WA, HE	Oxygen	Lack of in situ measurements from Argo buoys in shelf seas (i.e Baltic Sea, North Sea, Barents Sea etc.) and marginal seas	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	Determine the evolution of O2 necessary to sustain the life in the ocean. To assess the risk of ocean deoxygenation and the impact on marine ecosystems eventually as a response to global warming but also to eutrophication. To identify ocean water masses related with ocean circulation patterns.
99	1.3	CL, OC, WA, HE	Oxygen	Insufficient temporal coverage. Argo deployment started in 2000 and became fully operative in 2005 so half the WMO temporal definition of clima (30 years). Salinity observations is the third most-oft-observed water quality parameter after temperature and salinity.	2	GCOS-195 Report, JCOMMOPS (http://www.jcommops.org/board?t=Argo)	Determine the evolution of O2 necessary to sustain the life in the ocean. To assess the risk of ocean deoxygenation and the impact on marine ecosystems eventually as a response to global warming but also to eutrophication. To identify ocean water masses related with ocean circulation patterns.
100	1.1	CL, OC, HU, DI, EN	Sea Level	Spatial coverage. Insufficient number of stations.	2	GCOS-195 Report, GLOSS, 2012	Impact on coastal and islands communities and settlements. Essential for coastal infrastructure dessign, protection and maintenance (risk assessment) and for marine security (storm surges, tsunamis, etc). Sea Level is presently a key variable in data assimilation systems into ocean models.

101	6.6	CL, OC, HU, DI, EN	Sea Level	Lack of metadata in the position of gauges affect uncertainties.	2	GCOS-195 Report, GLOSS, 2012	Impact on coastal and islands communities and settlements. Essential for coastal infrastructure dessign, protection and maintenance (risk assessment) and for marine security (storm surges, tsunamis, etc). Sea Level is presently a key variable in data assimilation systems into ocean models.
102	8.1	CL, OC, HU, DI, EN	Sea Level	Reconcile altimetry measurements (SSH) and in situ sea level gauges for intercalibration purposes and reconstruct long tme series of sea level.	2	GCOS-195 Report, GLOSS, 2012	Sea level signal helps to identify, detect, surface mesoscale features adequately resolved with several altimeters working simulatenously. High resolution velocity fields are needed to resolve submesoscale motions for many applications related with marine trade and security.
103	7.2	CL, OC, HU, DI, EN	Sea Level	Not always guarantee the operation of enough simulatenous of altimeters (capacity ?)	2	GCOS-195 Report, GLOSS, 2012	Sea level signal helps to identify, detect, surface mesoscale features adequately resolved with several altimeters working simulatenously. High resolution velocity fields are needed to resolve submesoscale motions for many applications related with marine trade and security.
104	5.7	Climate	H2O, O3, T, CO2, CH4, aerosols	Missing agreement on levels of data and associated names across domains	2	GAIA-CLIM H2020- D1.3 GCOS AOPC Seidel et al., 2013	
105	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Unknown suitability of measurement maturity assessment	2	GAIA-CLIM H2020- D1.3	
106	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Missing evaluation criteria for assessing existing observing capabilities	2	GAIA-CLIM H2020- D1.1	
107	6.3	Climate	H2O, O3, T, CO2, CH4, aerosols	Lack of a comprehensive review of current sub-orbital observing capabilities for all the study of ECVs in atmospheric, ocean and land domains	2	GAIA-CLIM H2020- D1.4, D1.6, D1.8	
108	5.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Lack of unified tools showing all the existing observing capabilities for measuring ECVs with respect to satellite spatial coverage	2	GAIA-CLIM H2020- D1.4, D1.6, D1.8	
109	6.5	Climate	H2O, O3, T, CO2, CH4, aerosols	Lack of a common effort in metadata harmonization	2	GAIA-CLIM H2020- D1.4, D1.6, D1.8	

110	6.3	Climate	H2O, O3, T, CO2, CH4, aerosols	Need for a scientific approach for the assessment of gaps in the existing networks measuring ECVs	2	GAIA-CLIM H2020- D1.9
111	1.3	Climate	H2O, O3, T, CO2, CH4, aerosols	Evaluation of the effect of missing data or missing in temporal coverage of full traceability data provided by ground-based networks	2	GAIA-CLIM H2020- D1.9 Whiteman et al., 2011
112	1.2	Climate	CO	Limited availability of quantitative profiles; Insufficient verification of vertical information in satellite products	2	GAIA-CLIM H2020- D1.2
113	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Insufficiently traceable uncertainty estimates	2	GAIA-CLIM H2020- D1.3 Immler et al., 2010
114	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Traceable uncertainty estimates from baseline and comprehensive networks	2	GAIA-CLIM H2020- D1.1, D1.4 Immler et al., 2010
115	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Propagate uncertainty from well-characterized locations and parameters to other locations and parameters.	2	GAIA-CLIM H2020- n/a
116	5.2	Climate	H2O	Water vapor measurements with the lidar and microwave radiometer are often provided in a sparse way and under an uncoordinated effort	2	GAIA-CLIM H2020- D1.1, D2.1
117	1.1	Climate	H2O, O3, T, wind	There is currently limited aircraft data, for example in Eastern Europe.	2	GAIA-CLIM H2020- n/a
118	5.2	Climate	O3 (total column)	Northern Hemisphere bias in NDACC and PANDORA network sites distribution	2	GAIA-CLIM H2020- D1.1, D2.1
119	1.3	Climate	Aerosols	24/7 operation of lidar systems	2	GAIA-CLIM H2020- n/a
120	2.2	Climate	Aerosols	Lidar incomplete altitude coverage	2	GAIA-CLIM H2020- D2.2, D2.4
121	1.3	Climate	Aerosols	Incomplete collocation of sun and moon photometers with day and night time aerosol lidars	2	GAIA-CLIM H2020- n/a
122	1.3	Climate	Aerosols	Missing continued intercomparison with reference systems	2	GAIA-CLIM H2020- D2.2 Wandinger et al., 2015
123	3.1	Climate	Aerosols	Lack of rigorous aerosol lidar error budget availability	2	GAIA-CLIM H2020- D?.?; Earlinet
124	3.1	Climate	Aerosols	Need of Raman lidars or better multi-wavelength systems	2	GAIA-CLIM H2020- D2.2 Veselovskii et al., 2012
125	3.1	Climate	Aerosols	Need for assimilation experiments of lidar measurements	2	GAIA-CLIM H2020- D2.2 EU project website ACTRIS2: www.actris.eu

126	3.1	Climate	Aerosols	Reducing calibration uncertainties using a common reference standard	2	GAIA-CLIM H2020- D2.2 Leblanc et al., 2008 ?ISSI report? Is it also for aerosol?
127	2.3	Climate	H2O	Continuous operation of water vapor Raman lidars limited during daytime	2	GAIA-CLIM H2020- n/a
128	2.2	Climate	O3	Tropospheric O3 profile data is limited	2	GAIA-CLIM H2020- n/a
129	3.1	Climate	O3	Lack of rigorous tropospheric O3 lidar error budget availability	2	GAIA-CLIM H2020- Leblanc et al., 2008 ?ISSI report?
130	3.1	Climate	T	Lack of rigorous temperature lidar error budget availability	2	GAIA-CLIM H2020- Leblanc et al., 2008 ?ISSI report?
131	3.1	climate	T, H2O (+column), liquid H2O	MWR Missing standards maintained by National/International Measurement Institutes	2	GAIA-CLIM H2020- D2.1 Walker et al., 2011
132	3.1	Climate	T, H2O (+column), liquid H2O	Uncertainty of the MW absorption spectrum used in MWR retrievals	2	GAIA-CLIM H2020- D2.1
133	6.3	Climate	T, H2O (+column), liquid H2O	Automated MWR data quality control	2	GAIA-CLIM H2020- D2.1 EU Cost action TOPROF
134	6.3(1.3)	Climate	T, H2O (+column), liquid H2O	Calibration best practices and instrument error characterization	2	GAIA-CLIM H2020- D2.1 EU Cost action TOPROF
135	1.3	Climate	T, H2O (+column), liquid H2O	Homogenization of retrieval method	2	GAIA-CLIM H2020- D2.1 EU Cost action TOPROF
136	1.3	Climate	H2O, O3, CH4	Agreement on systematic vs. random part of the uncertainty and how to evaluate each part	2	GAIA-CLIM H2020- NORS_D4.3_UB.pdf
137	1.3	Climate	H2O, O3, CH4	Line of sight and vertical averaging kernel are only approximations of the real 3D averaging kernel of a retrieval	2	GAIA-CLIM H2020- NORS_D4.2_DUG.pdf
138	1.3	Climate	H2O, O3, CH4	Spectroscopic uncertainties	2	GAIA-CLIM H2020- Hase et al., 2012 Frankenberg et al., 2011
139	1.3	Climate	CO2, CH4	Current spectroscopic databases contain uncertainties	2	GAIA-CLIM H2020- Wunsch et al., 2011
140	1.3	Climate	O3, CO2, CH4	Cell measurements carried out to characterize ILS have their own uncertaintie	2	GAIA-CLIM H2020- Hase et al, 2012 Hase et al., 2013
141	1.3	Climate	CH4	possible SZA dependence in the retrieval during polar vortex overpasse	2	GAIA-CLIM H2020- n/a
142	1.3	Climate	CO2, CH4	In-situ calibration can be verified by involving new data	2	GAIA-CLIM H2020- Wunsch et al., 2011
143	1.3	Climate	H2O (column), O3 (column), CH4 (column)	TCCON calibration w.r.t. standards	2	GAIA-CLIM H2020- n/a

144	1.3	Climate	O3 (column)	Uncertainty of the O3 cross section used in the spectral fit	2	GAIA-CLIM H2020- NORS_D4.3_UB.pdf NDACC_UVVIS-WG_O3settings_v2.pdf
145	1.3	Climate	O3 (column)	Random uncertainty in spectral fit and AMF calculations	2	GAIA-CLIM H2020- NORS_D4.3_UB.pdf NDACC_UVVIS-WG_O3settings_v2.pdf
146	1.3	Climate	O3 (column)	Uncertainty in a priori profile shape for AMF calculation	2	GAIA-CLIM H2020- Hendrick et al., 2011
147	1.3	Climate	O3 (column)	Uncertainty in vertical averaging kernels	2	GAIA-CLIM H2020- Eskes and Boersma, 2003
148	1.3	Climate	O3 (column)	Uncertainty in PANDORA measurements	2	GAIA-CLIM H2020- Herman et al., 2015
149	1.3	Climate	O3 (tropospheric column)	Information content of MAX-DOAS tropospheric O3 measurements	2	GAIA-CLIM H2020- D2.1; Liu et al., 2006 Irie et al, 2011 Gomez et al., 2014
150	1.3	Climate	O3 (tropospheric column)	MAX-DOAS tropospheric O3 retrieval method	2	GAIA-CLIM H2020- Same as for G2.31
151	1.3	Climate	O3 (tropospheric column)	Random and systematic uncertainties of MAX-DOAS tropospheric O3 measurements	2	GAIA-CLIM H2020- D2.1; Liu et al., 2006 Irie et al, 2011
152	1.3	Climate	H2O (column)	Uncertainties of ZTD, given by a 3rd party (IGS)	2	GAIA-CLIM H2020- Ning, 2012
153	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Incomplete knowledge of spatiotemporal atmospheric variability at the scale of the inter-comparisons.	2	GAIA-CLIM H2020- D3-1 (incl. Annex 1, 2 and 3)
154	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Limited quantification of the impact of co-location criteria.	2	GAIA-CLIM H2020- D3-1 (incl. Annex 1, 2 and 3)
155	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Missing generic and specific standards for co-location criteria in validation work.	2	GAIA-CLIM H2020- D3-1 (incl. Annex 1, 2 and 3)
156	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Limited characterization of the multi-dimensional (spatiotemporal) smoothing and sampling properties of atmospheric remote sensing systems, and of the resulting uncertainties.	2	GAIA-CLIM H2020- D3-1 (incl. Annex 1, 2 and 3)
157	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Representativeness uncertainty assessment missing for higher-level data based on averaging of individual measurements.	2	GAIA-CLIM H2020- D3-1 (incl. Annex 1, 2 and 3)
158	3.1	Climate	H2O, O3, T, CO2, CH4, aerosols	Missing comparison error budget decomposition including errors due to sampling and smoothing differences.	2	GAIA-CLIM H2020- D3-1 (incl. Annex 1, 2 and 3)
159	3.1	Climate	T	Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances.	2	GAIA-CLIM H2020- Bell et al., 2008 Bohrmann et al., 2013 Doherty et al., 2015 Geer et al., 2010 Lu et al., 2011

160	3.1	Climate	H2O	Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances	2	GAIA-CLIM H2020- Same as for G4.01
161	1.1, 3.1	Climate	T, H2O	Where traceable uncertainty estimates exist for a model or reanalysis quantity, it is often limited to a few locations and parameters where reference datasets are available. Comprehensiveness is lacking for extension to locations and parameters where reference datasets are not available	2	GAIA-CLIM H2020- n/a
162	3.1	Climate	T, H2O	Datasets from baseline and comprehensive networks provide valuable spatiotemporal coverage, but often lack the characteristics needed to facilitate traceable uncertainty estimates	2	GAIA-CLIM H2020- WPs 1,2,3
163	3.1	Climate	T, H2O	Limited knowledge about how to propagate uncertainty from well-characterized locations and parameters to other locations and parameters.	2	GAIA-CLIM H2020- WP4 (+ Task 1.4/1.5)
164	3.1	Climate	T, H2O	Difficulty to assess the importance of natural variability in the total model-observation error budget	2	GAIA-CLIM H2020- WP4 (+ Task 1.4/1.5)
165	5.4	Climate	H2O, O3, T, CO2, CH4, aerosols	Access to data in multiple locations with different data policies and accessibility (e.g. speed of retrieving and unpacking, passwords)	2	GAIA-CLIM H2020- http://www.gruan.org http://tccon.ornl.gov/http://www.ndsc.ncep.noaa.gov/data/
166	5.4	Climate	H2O, O3, T, CO2, CH4, aerosols	Access to data in multiple data format and structure (e.g. granularity of data). Lack of standardized metadata	2	GAIA-CLIM H2020- http://www.ucar.edu/tools/applications_desc.jsp
167	5.3	Climate	H2O, O3, T, CO2, CH4, aerosols	Efficient data management to collocate observations needs to be improved	2	GAIA-CLIM H2020- CCI toolbox Giovanni GSICS
168	5.2	Climate	H2O, O3, T, CO2, CH4, aerosols	Usability of reference database needs to be ascertained: subset definition	2	GAIA-CLIM H2020- WP5
169	5.5	Climate	H2O, O3, T, CO2, CH4, aerosols	Usability of reference database needs to be ascertained: format	2	GAIA-CLIM H2020- WP5

170	5.3	Climate	H2O, O3, T, CO2, CH4, aerosols	Need for analysis tools to exploit reference database (visualization, intercomparison, statistics, etc.)	2	GAIA-CLIM H2020- ICARE multibrowse and associated graphical modules? Felyx project NOAA NPROVS
171	6.4	Climate		Incomplete development and/or application and/or documentation of an unbroken traceability chain of Cal/Val data manipulations for atmospheric ECV validation systems.	2	GAIA-CLIM H2020- D5.1 Keppens et al., 2015 (traceability chain) QA4ECV:http://www.qa4ecv.eu/ QA4EO: http ://qa4eo.org/
172	1.3	Climate		Missing quantification of additional uncertainties introduced in the comparison results due to differences in (multi-dimensional) sampling and smoothing of atmospheric inhomogeneity	2	GAIA-CLIM H2020- D5.1, D3.1 Lambert et al., 2012 Verhoelst et al., 2015 Fasso et al., 2014 Ignaccolo et al., 2015 ?EU FP6 GEOmon Technical Notes D4.2.1 and D4.2.2 (2008-2011)?