Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring

WP1: Mapping Geographical Capabilities

D1.7: "Report on the collection of metadata from existing network and on the proposed protocol for a common metadata format".

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[1] Introduction

Work Package 1 (WP1) of the GAIA-CLIM project is devoted to the geographical mapping of existing non-satellite measurement capabilities for the ECVs (Bojinskii et al., 2014) considered within GAIA-CLIM in the atmospheric, oceanic and terrestrial domains. The primary ECVs considered in this study are those identified as target variables in the project Grant Agreement, the full list is available within the accompanying deliverable D1.6.

Within WP1, Task 1.2 has the main objective to "prepare for the creation of a Virtual Observatory (VO) of ground based and satellite data by establishing common formats for metadata". Specific goals of Task 1.2 as given in the Grant Agreement are:

- To document and define system properties for each layer in a 'system of systems' approach to enable rigorous EO data characterization (in cooperation with Task 1.1)
- To provide a geographical identification, at the European and global scales, of current surface-based, balloon-based and airborne observing capabilities on an ECV by ECV basis for parameters which can be obtained using space-based observations from past, present and planned satellite missions.
- Preparation for the creation of a "Virtual Observatory" of ground-based and satellite data by establishing common formats for metadata.

Deliverables D1.6 and D1.7 complementarily describe the approach followed to review the existing observing capabilities and summarise the results of the geographical gap assessment and of the classification for each target ECV by the system of systems model based on the the Maturity Matrix Assessment (MMA), described in the deliverable D1.3.

In particular the D1.6 provides:

- An overview of the of existing non-satellite observing capabilities;
- A short description of the MMA and its application (fully documented in D1.3);
- The results of analysis obtained from the application of the maturity matrices collected during the 18 months of Task 1.2 activity, including a redundancy exercise to quantify the level of subjectivity of the MMA;
- Recommendations related to the maturity matrix data collection, the MMA usage, and the expected impact of the work carried out within Task 1.2.

The present D1.7 addresses the following aspects:

- The technical solution and the metadatabase collected in Task 1.2 as well as the proposed protocol for a common metadata format for GAIA-CLIM;
- The collected metadata and the related general statistics (i.e by ECV, by network, etc.);

- The statistics of the geographical representativeness in terms of density of measurements in the metadata database per 1000 km^2;

- The preliminary architecture of the Virtual Observatory (VO) for the visualization of the collected meta-dataset.

The current deliverable thus has the main objective to establish and document common metadata formats for the GAIA-CLIM Virtual Observatory (VO), including the information about the classification of each network in the 'system of systems' model described in D1.3, (i.e. Reference, Baseline and Comprehensive networks).

There was an agreement reached amongst Task 1.2 partners to ensure consistent approaches were followed for metadata collection and maturity assessment. This aspect was greatly facilitated by an in-person meeting hosted by KNMI in Amsterdam (4/5/16), which resolved a number of fundamental questions about the scoping of the task and ensured a degree of homogeneity in approaches. The task has led to the production of two deliverables, the present D1.7 and the accompanying D1.6.

This study is in line with the objectives of Copernicus Climate Change Service (C3S) services, to improve access to available in situ instrumental data records and to data streams from observing networks, as needed for climate change monitoring and climate science.

[2] Definitions of metadata used herein

Metadata is a term that can cover a multitude of aspects of the data. There is no single, universally recognised, approach to metadata collection or formatting. We therefore take the opportunity here to clarify what aspects of metadata we are considering within the present deliverable.

The U.S. Federal Geographic Data Committee (FGDC) describes geospatial metadata as follows:

"*A metadata record is a file of information, usually presented as an XML document, which captures the basic characteristics of a data or information resource. It represents the who, what, when, where, why and how of the resource. Geospatial metadata commonly document geographic digital data such as Geographic Information System (GIS) files, geospatial databases, and earth imagery but can also be used to document geospatial resources including data catalogues, mapping applications, data models and related websites. Metadata records include core library catalogue elements such as Title, Abstract, and Publication Data; geographic elements such as Geographic Extent and Projection Information; and database elements such as Attribute Label Definitions and Attribute Domain Values.*" (Federal Geographic Data Committee, 2016).

Metadata (data describing the data) is vital information embedded within an electronic file about a collection of data or a single data file. By accessing an electronic file's metadata, a user

can access a variety of information, such as why, where and how an observation was made, allowing users to make a quick selection of the appropriate-to-application datasets to extract from a data archive. In this way, metadata users can make an effective interpretation of observational data, while ensuring maximum usefulness of observations.

Two types of metadata are most commonly used: structural metadata and descriptive metadata. Structural metadata is data that describes the collections of data and how they were created. Descriptive metadata uses individual instances of application data or the data content to describe a resource for discovery and identification purposes.

In the context of EO, observations without metadata are of limited use. It is only when data is accompanied with sufficient metadata that the data can be interpreted in context and to its full potential. The Global Climate Observing System (GCOS) Climate Monitoring Principle 2.2.1(c) describes the relevance of metadata as follows: *"The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e. metadata) should be documented and treated with the same care as the data themselves."* (WMO, 2015).

The two types of metadata are more specifically defined for atmospheric sciences by the WMO under report n. 1160 (2015) by using two categories of metadata "Discovery metadata" and "Observational metadata"

These two types of categories are explained below:

Discovery metadata: Discovery metadata facilitate data discovery, access and retrieval and are consistent with the standard that is used within WMO Information System (WIS) for discovery of information shared through WIS (http://www.wmo.int/pages/prog/www/WIS/metadata_en.html).

Observational metadata: descriptive data about observational data; information that is needed to assess and interpret observations or to support design and management of observing systems and networks.

Within Task 1.2, Discovery metadata have been collected for an identified sub-set of the existing non-satellite capabilities which may be applicable for satellite data characterisation, and for the ECVs considered within GAIA-CLIM in the atmospheric, oceanic and terrestrial domains.

Subsequently, Observational metadata will then be collected only for those datasets selected for possible implementation within the GAIA-CLIM Virtual Observatory (VO) under WP5. These constitute solely the subset of measurements that have been assessed as potentially constituting "Reference" quality measurements, according to the Maturity Matrix Approach assessment described in the deliverable D1.3. This assessment is provided in the accompanying D1.6.

[3] Metadata standards adopted for GAIA-CLIM

In the present section, a description of the metadata standards adopted for the GAIA-CLIM "Virtual Observatory" is provided along with a discussion about the rationale for the adopted protocols for the metadata collection. The overall statistics of the initial metadata collection phase, which closed at the end of May 2016, are provided. Other considerations related to the metadata collection and usage, along with recommendations on the adoption of metadata formats are also considered.

A metadata international standard protocol is required to establish a common understanding of the meaning or semantics of the data, and to ensure correct and proper use and interpretation of the data by its owners and users. It establishes the necessary requirements, specifications and guidelines, thus ensuring adequate data uniformity and that observations are fit for purpose.

Thus, the use of a metadata standard:

–Allows communication between peers;

–Minimizes data integration time and costs

–Permits data operations under known conditions

An extensive list of metadata standards available for many different application fields is available at https://en.wikipedia.org/wiki/Metadata_standard.

For the purposes of clarity, a description is provided in the following two sub-sections of the main metadata standards for both the Discovery and Observational metadata, which Task 1.2 has adopted for the implementation of the GAIA-CLIM VO.

3a. Discovery metadata

The objective of the International Standards for discovery metadata is to provide clear procedures for the description of digital geographic data-sets so that users will be able to determine whether the data in a repository will be of use to them and how to access the data. These standards promote the proper use and effective retrieval of geographic data by establishing a common set of metadata terminology, definitions and extension procedures.

Numerous geographic metadata standards exist. The most commonly used are:

- Dublin Core,
- FGDC CSDGM,
- ISO19115 (UML)
- ISO19139 (XML)
- OGC WxS Capability Document

All these standards were considered as candidate approaches for GAIA-CLIM. ISO 19115 (ISO, 2014) was selected as the most suitable standard for geospatial data for GAIA-CLIM due to its very flexible format and easy customisation. Importantly, ISO 19115 is currently the most

widely used of the candidate standards Task 1.2 considered among major EU and international projects, programs and environmental and EO research infrastructures. A few examples of its application worldwide include:

- The NASA Earth Science Division (ESD) Base Metadata Requirements which makes use of an ISO 19115 metadata profile for NASA Earth science data;
- INSPIRE (Infrastructure for Spatial Information in the European Community) metadata profile is built upon EN ISO 19115;
- The WMO Core (WIS) is a profile of ISO19115;
- ESA-CCI (Climate Change Initiative) recommends to report in its observational metadata (based on the rules of the CF convention, discussed later in this document) also the discovery metadata adopting the ISO 19115 format.

The details of the ISO-19115 standard adopted is now further described below sufficiently for the reader to understand what Discovery metadata shall exist for the VO.

ISO-19115

This standard is part of the ISO geographic information family of standards (19100 series). It defines how to describe geographical information and associated services, including contents, spatial-temporal purchases, data quality, access and rights to use. ISO 19115 "Geographic Information – Metadata" (ISO, 2014) is the most widely used standard for geospatial metadata, because it is a very flexible format which provides the opportunity to customize the metadata profile for the needs of any specific application while keeping unchanged its core functionalities.

Figure 1 shows a schematic diagram of the general structure of the ISO 19115 format (diagram of the XML schema). An extensive description can be found at http://www.iso.org/iso/catalogue_detail.htm?csnumber=32579 (ISO website, but requires to pay subscription) or at http://www.ngdc.noaa.gov/wiki/index.php/ISO_Metadata_Standard.

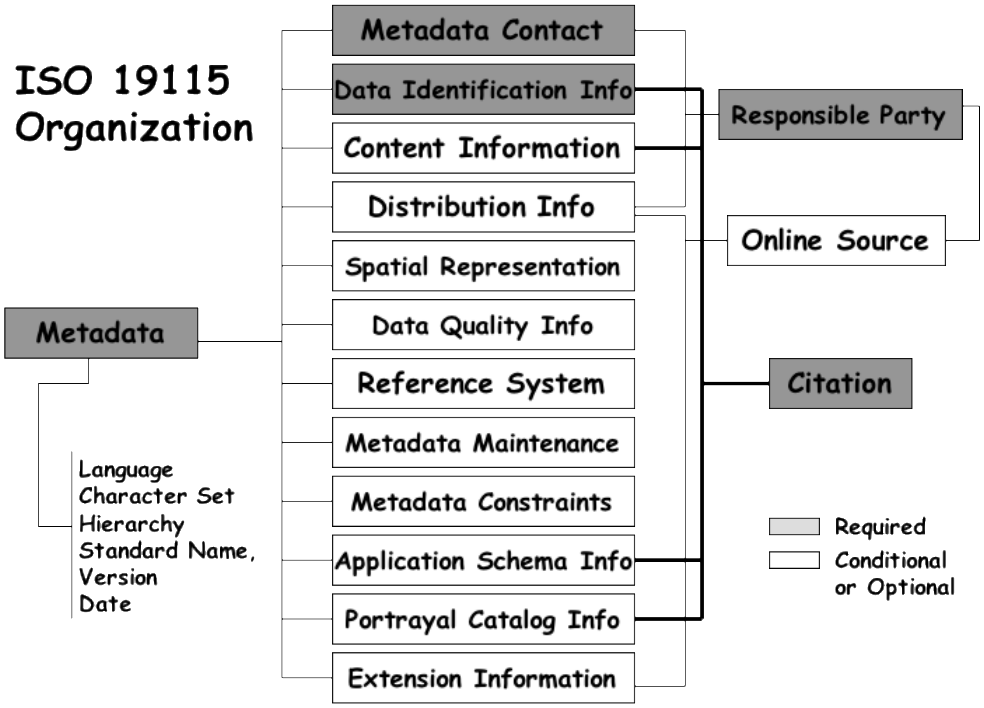

Figure 1: diagram of the XML schema of the ISO 19115 standard.

A core ISO 19115 profile has the following categories:

- Title
- Reference Date
- Responsible Party
- Geographic location
- Language
- Character set
- Topic Category
- Scale
- Abstract
- Format
- Extent
- Representation Type
- Reference System
- Lineage
- On-line Resource

The specific ISO core profile adopted for the needs of the GAIA-CLIM project is described in Appendix A where an example of the .xml file describing the discovery metadata for one of the stations reviewed within Task 1.2 is reported. It is also possible to interactively explore the GAIA-CLIM ISO-19115 profile at the webpage: http://gaiaclimmd.imaa.cnr.it where a web interface based on the GeoNetwork technology is available to fill in metadata and to access the whole discovery metadataset (open access, password protected). This GUI has been used by the Task 1.2 partners (CNR, BIRA, BKS, ECMWF, FMI, KNMI, MO, MPG, UBremen, UH) to fill

in the Discovery metadata for all the existing networks operating worldwide, reviewed by Task 1.2 (see D1.6).

3b. Observational metadata

For the observational metadata, the list of standards adopted in the EO community is quite extensive and includes both specific metadata files associated with each single measurement file and metadata information embedded in the measurements file in form of a header (e.g. NetCDF) or at the top of a hierarchal data format (i.e. HDF).

An extensive list of metadata standards accepted by NASA is available at https://earthdata.nasa.gov/user-resources/standards-and-references. Further examples not included in the NASA list but relevant for the measurements collected and envisaged to be made available through the GAIA-CLIM VO are:

- NASA-Ames (https://badc.nerc.ac.uk/help/formats/NASA-Ames/),
- GEOMS (http://avdc.gsfc.nasa.gov/index.php?site=1178067684), and
- CERIF (http://eurocris.org/cerif/feature-tour/cerif-16).

After careful consideration of the range of options it was decided to adopt WIGOS (WMO, 2015) and ESA-CCI (ESA, 2015) standards. The over-riding rationale was that these have the backing of WMO and ESA and are likely to therefore constitute long-lived and widely used standards in the target communities for the Virtual Observatory. The use of two standards increases usability for applications, but also complexity for data management. A case-study based comparison detailed in Table 1 (and discussed further in a later Sub-section) provides an overview of their overlaps and differences in view of simplifying the adoption from a technical point of view of these two formats for the VO GUI.

WIGOS FIELD	WIGOS VALUE	CCI-CF FIELD	CCI-CF VALUE
supervisingOrganization	WOUDC	title	WOUDC OZONSESONDE
contact	Rigel Kivi/Ricardo Sanchez	source	Rigel Kivi/Ricardo Sanchez
coordinatesReference	WGS84		
programmeNetworkAffiliation_Name	FMI-SMNA	institution	FMI-SMNA
applicationArea	Climate monitoring [as undertaken through the Global Climate Observing System, GCOS]		

siteInformation	Name:MARAMBIO Country:ATA lat.:-64.233 long.:-56.623 height:198		
stationPlatformName	MARAMBIO		
spatialExtent	from 198m to 33856m		
observedVariable-measurand_domain	Atmospheric		
stationPlatformModel	OzoneSonde	title	WOUDC OZONSESONDE
observedVariable-measurand_variable	Pressure		
stationPlatformType	land station		
observedVariable-measurand_modeOfObservation	*I (I=Instantaneous, T=Total, V=Variability)*		
		featureType	profile_id
dataPolicyUseConstraints	WMOOther		
observedVariable-measurand_subdomain	Atmospheric Pressure		
measurementUnit_name	Hecto-Pascals		
measurementUnit_abbreviation	hPa		
temporalExtent	6238 s		
representativenessOfObservation	Mesoscale		
programmeNetworkAffiliation_Definition	FMI-SMNA	institution	FMI-SMNA
regionOfOriginOfData	VII		
territoryOfOriginOfData_Name	Antarctica		
territoryOfOriginOfData_ISO3CountryCode	ATA	Country	ATA
stationPlatformUniqueIdentifier	233		
coordinatesSourceDevice	GPS		

stationStatus	*Operational/Reporting (All the stations mapped are operational)*		
sourceOfObservation	Automatic observation		
measurementObservingMethod	OzoneSonde	title	WOUDC OZONSESONDE
instrumentSpecifications	Name:ECC Model:Z Number:Z27256	station_name	ECC
#	#	sensor_name	ECC
#	#	sensor_model	Z
instrumentOperatingStatus	Operational		
coordinatesSourceDevice	GPS		
statusOfObservation	Primary		
dataFormat	WOUDC		
versionOfDataFormat	1		
aggregationPeriod	Beginning		
referenceTime	Time Server		
qualityFlag_BUFR	Good		
qualityFlag_OGC	Good		
qualityFlaggingSystem	Other quality flagging system		
traceability	Traceable to international standard		
		history 0.f	
		references	
		tracking_id	
		Conventions	CF1.6
		product_version	1.0
		start_time	111500
		date	2014-12-31

		STN	STN
		GAW_ID	89055.f
		serial_number	99.f
		time_zone	2.f
		MeteoSonde	RS92

Table 1: comparison of the fields available in the WIGOS and CF metadata standards for an Ozonesonde as an exemplar of both the metadata types and their interoperability.

The goal of the "Virtual Observatory", with respect to metadata provision, is to make available observational metadata and products related to a restricted set of existing networks following both WIGOS and ESA-CCI standards; allowing the users to have the option to download metadata in both formats. The main features of these two formats are now discussed.

WIGOS

Currently, the WIGOS metadata standard for the OSCAR WMO repository is under the advanced stages of development and implementation, with the first delivery expected by the end of 2016. GAIA-CLIM WP1 partners have discussed with WIGOS partners the opportunity to start implementing the new WMO observational metadata standard in the GAIA-CLIM VO. In order to make this possible and as a result of the different project timelines in the implementation of the observational metadata standards of WIGOS and GAIA-CLIM, a compromise has been identified: an XSD schema file compliant to the tables describing the WIGOS metadata standard [3] has been elaborated on by CNR-IMAA to allow the observational metadata collection for the GAIA-CLIM VO. Technical differences with the final format alighted upon by the WIGOS team may therefore exist. Any such differences will be resolved as soon as the WIGOS team releases the official XSD schema file for the OSCAR repository to ensure full compliance. The GAIA-CLIM collected metadata will also be provided to WMO / Meteoswiss who maintain the OSCAR surface database so that they can populate this database for the benefit of all WMO members and data users.

The analysis of the WIGOS metadata standard has allowed us to identify the following associated advantages and disadvantages.

Advantages of this format include:

- It is the standard adopted for the WMO-OSCAR repository that will become operational from 2018, and as a WMO data standard its adoption will be extensive and at the global scale;
- It provides a very precise XML schema with homogeneous rules to fill in the metadata with the capability to reduce the number of "degrees of freedom" in any metadata collection involving a large number of partners.

Disadvantages of this format include:

- The available options for the mandatory field "variables" and "networks" are based on a list which does not include all the ECVs, sometimes using names that are not consistent with GCOS, and therefore cannot easily be used to collect metadata for all the existing observing capabilities reviewed within Task 1.2;
- Many relevant fields are designed to be "free string variables", like uncertainty, spatial extent, temporal extent etc. For GAIA-CLIM many of these fields represent critical aspects. Since each metadata compiler can write this crucial information in the WIGOS format in an arbitrary way this serves to increase the heterogeneity of the collected metadataset for GAIA-CLIM critical aspects;

Overall, the design and pilot implementation of this format has been strongly driven by traditional surface-based meteorological data collection, and its adoption might be challenging for other measurement techniques such as profiles, column averages etc. used in GAIA-CLIM. Cooperation between the GAIA-CLIM project and WIGOS metadata team has been established to work together on the possible refinement of the WIGOS metadata standard to better serve atmospheric column and profile measurements. This work shall continue for some time and any resulting updates incorporated in WP1 data and product delivery to the VO.

ESA-CCI

The ESA Climate Change Initiative (CCI) is a programme generating a set of validated, error-characterised, Essential Climate Variables (ECVs) from existing satellite observations (http://cci.esa.int/sites/default/files/CCI_Data_Requirements_Iss1.2_Mar2015.pdf). The aim is to make the CCI datasets as widely usable as possible, to a broad set of user communities including hitherto non-traditional users. To this purpose a common format for data and metadata conventions has been established as part of the programme.

CCI projects shall produce data according to the CCI Data Standards Requirements:

- Produced in netCDF-4 (classic) format;
- Conform with NetCDF Climate and Forecast (CF) Metadata Convention (Eaton et al., 2011);
- CF standard names used for the main variables, including the global attributes.
- ACDD (Attribute Convention for Dataset Discovery) used for data discovery.

The choice of CF convention for CCI data products ensures it will be possible to extract the metadata from the files to a number of standard metadata formats, e.g. ISO19115, FGDC, etc, as required by data discovery systems. The CCI projects shall create INSPIRE compliant metadata records for each dataset.

Although this standard has been developed for satellite data, extending its application to non-satellite data shall not present any problems since the ESA-CCI format is fully built upon the existing CF conventions (http://cfconventions.org) which are applicable to gridded and point data types. The Climate and Forecast (CF) metadata convention has been developed over more than a decade by the climate science community. CF has been developed by volunteers, and its development and sustainability may therefore not be entirely guaranteed in the future. It is intended for use with climate and forecast data arising from atmosphere, surface and ocean

model-generated data and comparable observational datasets. The convention has the following key objectives:

- Locate data in space–time and as a function of other independent variables, to facilitate processing and graphics production
- Identify data sufficiently to enable users of data from different sources to decide what is comparable, and to distinguish variables in archives
- Framed as a NetCDF standard, but most CF ideas relate to metadata design in general and not specifically to NetCDF, and hence can be contained in other formats such as XML

In addition, CF provides some basic "discovery" metadata in global attributes, like

- Title
- Institution
- Source history
- References
- Comment

Further details of the CF convention, the list of variables already defined, and the rules for the definition of new variables can be found at http://cfconventions.org/Data/cf-documents/overview/viewgraphs.pdf or at http://www.cgd.ucar.edu/cms/eaton/cf-metadata. Examples of adoption of the CF convention are: PCMDI and MIP, PRISM, ESMF, NCAR, Hadley Centre, GFDL, various EU projects. Compliance checking with CF conventions is possible for NetCDF files using the checker hosted at http://titania.badc.rl.ac.uk/cgi-bin/cf-checker.pl.

ESA-CCI data and metadata standards currently have different levels of maturity for the different sub-communities involved in CCI. For example, probably the most mature are Aerosol CCI products which use metadata following the CF convention (all AOD datasets now use CF-1.4; AAI uses CF-1.6 and GOMOS CF-1.5). In agreement with the entire CCI program (guided by the Data Standards Working Group), naming of global attributes and common variables (e.g. time and space grid, etc.) have been harmonized and are used by Aerosol CCI.

The study of the CF convention as implemented in ESA-CCI has identified a number of advantages to the approach:

- The use of the NetCDF format which is well-known, easy to read with many tools to read, write and check the consistency of the format, and it is freely available to users;
- CF conventions are widely used by the ground based measurements community;
- CF1.6 convention is also widely used by climate and weather modellers.
- There is considerable flexibility in the number of variables that can be defined.
- In the framework of ESA-CCI, the discovery metadata have been extended compared to the CF convention with a recommendation to provide these according to the ISO-19115 standards.

Main disadvantages identified by ESA CCI activities are:

- The rules defined in the CF convention ensure a homogenous structure in the definition of any new variables; but the definition by each different community or project of its own metadata standard based on the CF convention may increase the level of heterogeneity (minimum number of variables provided, what is mandatory, what is optional etc.) in the metadata and data.
- While it is true that different applications may require the adoption of different variables to characterize measurements, products and related uncertainties, from the perspective of discovery and appropriate use, observational metadata should be harmonized to facilitate the data usage from different sources by any kind of user (modellers, satellite agencies, environmental and protection agencies, …..).

Proposed protocol for serving Observational metadata formats

The adoption of two different standards, WIGOS and ESA-CCI, for the Observational metadata, to be served through the GAIA-CLIM "Virtual Observatory", will aid interoperability between WMO and Copernicus Programme activities. A comparison between these standards has been carried out in order to understand the limitations of this choice with respect to the services which shall be offered to future users of the GAIA-CLIM VO, and to identify ways for them to be easily harmonized. For the GAIA-CLIM Virtual Observatory, the idea is to be able to ingest both the different metadata formats in order to create a "unified list" of information that should allow users to retrieve the measurements metadata in their preferred format. Next steps will be defined in agreement with the WP5 team who is in charge of the creation of the VO.

Table 1 shows the comparison between the two metadata standards applied to a case study of an ozonesonde available through the WOUDC (http://woudc.org/) for the station of Marambio (64°14'42"S, 56°39'25"W, 5 m a.s.l.). It is clear that this solution, although technically not perfect, can to a first approximation overcome the differences between the two formats. A simple conversion between the two formats is feasible for those variables that can be directly reconciled as being equivalent (e.g. contact / source). However, a complete conversion is not possible due to the differences shown in Table 1 whereby there is no equivalence of fields. This would create missing fields unless metadata is collected for both types of metadata concurrently.

[4] Collected information and general statistics

Having alighted on a set of metadata schema to follow, each Task 1.2 participant, on the basis of their expertise in particular networks, was tasked to fill in pre-populated fields for networks to which they were assigned. Under guidance provided by CNR to remaining partners, available as Appendix B, the collection has been arranged to ensure a consistent collection of metadata into a common structure which could subsequently be managed by the Virtual

Observatory and interactively visualized through the related GUI. The metadata collection was performed adopting an ISO-core profile customized for the specific needs of the GAIA-CLIM project, specified through the xml schema reported in Appendix A.

A summary of discovery metadata collected in this exercise, along with statistics describing the global coverage of the collected metadata under Task 1.2 is presented in Table 2. The review has identified 54 plausible networks and 2 aircraft permanent infrastructures for EO Characterisation in the context of GAIA-CLIM currently operating on different spatial domains and measuring different ECVs using one or more measurement techniques. The full list of networks along with their main related information (e.g. measured ECVs, measurement technique, official website) is provided in Appendix C. Complete discovery metadata have been collected for all the stations belonging to 49 among the 54 networks (88% of the total). In total, 24599 metadata records for the reviewed stations are available. The station discovery metadata have been gathered both using official documentation available on the web and following the recommendations provided by the network PIs and data managers. The maturity matrices collected and discussed in D1.6 cover about 75% of the surveyed stations (or mobile platforms).

General information

total number of networks: 56
Total number of networks filled with metadata: 49 (88 % of total)
Number of stations/mobile platforms: 24599
Number of stations/mobile platforms with the maturity matrix: 36 (75 %)

Table 2: General information of the measurement described by the collected discovery metadataset.

Particularly challenging has been to find the station start date of operations in very many cases, which has not generally been recorded. This may not in all cases correspond to the start date of the digital records even if these are readily available to check. Furthermore, for mobile observation platforms (e.g. ships, aircraft), challenges have been found in finding and reporting metadata. The GAIA-CLIM metadataset include discovery metadata mostly for marine weather 'stations', ships and drifting buoys (floats) that, since they are not at a fixed location, have been reported instead at fixed times. Coverage is transient as ships change routes, remain in port, are decommissioned and change ownership. In all likelihood, ships will also avoid the severest weather leading to challenges in producing representative measurements. The same processing caveats apply for aircraft platforms. At present the GAIA-CLIM metadataset does not include any discovery metadata for the aircraft observation programs (e.g E-AMDAR, IAGOS). Task 1.2 partners have faced substantive challenges to transfer and convert the existing aircraft metadata into the GAIA-CLIM ISO-compliant metadata profile. It is envisioned that this will be resolved in time for the metadata visualization through the VO GUI, currently under implementation.

All the collected metadata are available on the CNR GAIA-CLIM web interface (gaiaclimmd.imaa.cnr.it, password required) or through a QGIS-based desktop application available upon request: this tool allows the user to visualize using GIS technology both the existing satellite and non-satellite observing capabilities. Tables 3 to 7 now highlight various relevant aspects of the collected metadata.

Measurement type

Table 3 highlights the different sources of data for which metadata have been collected by measurement type. There are to date no metadata collected for the aircraft platforms E-AMDAR and IAGOS. This relates to issues over conversion and conformance to the metadata standards adopted. It is envisaged that we shall be able to incorporate these at a later date. There are several thousand observations available in the metadatabase for each of the remaining measurement types.

Measurement type	Count
AIRCRAFT	15
COLUMN	5838
PROFILE	8027
SURFACE	9457
TOWER	1262

Table 3: Statistics obtained grouping the collected metadata for each measurement type.

Vertical extent

Table 4 shows that most of the stations in the metadatabase perform measurements in the lower troposphere (<= 8000 m, 60 % of the total), and among these approximately 64% perform surface-only measurements. Table 4 is built relying on the altitude officially reported by the networks themselves. For most satellite characterisation activities it is likely that measures through much of the atmospheric column shall be required such that the number of candidate stations suitable for a given application will be much smaller than the total station count.

LT (<= 8000m): 14726 (60% of the surveyed stations)
LT (<= 8000m) Surface: 9447
LT (<= 8000m) Profile: 4017
LT (<= 8000m) Tower: 1262
C (>= 30000m): 9838 (40% of the surveyed stations)
C (>= 30000m) Column: 5838
C (>= 30000m) Profile: 4000

Table 4: Number of discovery metadata collected as a function of the typical vertical extent of the measurement technique utilized by the existing observing networks; "LT" stands for Lower Troposphere while "C" for measurements over the whole atmospheric column using a vertically integrated or a profiling measurement technique.

Network by network

Metadata has been collected for a total of 49 networks consisting of national, regional, and global networks governed under a range of auspices and mechanisms (Table 5). Because the GAIA-CLIM project aims to consider Reference type measurements that are of the very highest quality, many of the candidate networks considered are small. Twenty of the networks consist of fewer than 50 sites and seven more of between 50 and 100 sites. There also exists a degree of redundancy whereby a single station can often contribute to multiple networks and so is counted several times over. For example, the Lauder facility in New Zealand is a contributing site to NDACC, GRUAN, TCCON and BSRN.

Network	Stations	Metadata
ACTRIS	71	71
AD-Net	20	20
AERONET	1248	1248
AGAGE	12	12
AMeDAS	948	948
ARGO	3917	3917
ARM	15	15
BSRN	64	64
CAPMoN	31	31
CARSNET	50	50
CASTNET	100	100
CAWNET	20	20
CREST	4	4
EANET	42	42
Earlinet	27	27
EMEP	245	245
EPA	2166	2166
ESRL	200	200
EUREF	265	265
EuroSkyRad	13	13
Fluxnet	587	587
GAW GALION	74	74
GAW PRf	29	29
GPS-Met	618	618
GRUAN	17	17
GSN	848	848
GUAN	171	171
ICOS	29	29
IDAF	10	10
IGS	428	428
IMPROVE	194	194
LALINET-ALINE	10	10
MESONET	138	138
MPLNET	15	15
MWRnet	81	81
NDACC	73	73
NPS	113	113
RAOB	1483	1483
RBSN	5392	5392
Scripps	13	13
SHADOZ	19	19

SKYNET	24	24
SMEAR	5	5
SUOMINET	963	963
SURFRAD	8	8
TCCON	27	27
TOLNET	5	5
USCRN	139	139
WOUDC	351	351

Table 5: Statistics obtained grouping the collected metadata for each network; the number of stations belonging to each networks is also reported. Redundancies among the network (i.e. a site belonging to two or more networks) are possible.

ECV by ECV

The GAIA-CLIM project identified a number of target ECVs for which to develop improved capabilities for satellite data characterisation using non-satellite measurements. These ECVs drove the selection of networks summarised previously in Table 5. The breakdown by ECVs being measured at each site is given in Table 6. In this case even more so than for the networks case there is a propensity for single sites to contribute to multiple ECVs. Clearly, sites that contribute to multiple ECVs may be preferential targets for a sustained cal/val service because they provide an ability to characterise regions of radiance space that are dependent upon multiple ECVs, such as much of the IR spectrum.

ECV	Stations	Metadata
AEROSOL	3689	4867
CARBON DIOXIDE	825	854
CARBON MONOXIDE	560	611
METHANE	244	279
NITROGEN DIOXIDE	569	614
NOX	31	31
OZONE	2077	2761
TEMPERATURE	7084	9519
temperature, salinity	3917	3918
WATER VAPOR	6016	6506

Table 6: Statistics obtained grouping the collected metadata for each ECV; the number of stations belonging to each networks is also reported.

Table 7 further breaks the ECV by ECV analysis down to consider the measurement type in addition. There are, for most ECVs, far fewer profile measurements than there are surface, tower or column measurements. Given that remote sensing typically measures a bulk property of a large vertical atmospheric slice, these profile measurements are likely to be of particular import in any level1b comparisons undertaken by the Virtual Observatory. There are very few profile measurements available for a number of the ECVs, in particular some of the trace gases.

ECV	Featuretype	Stations	Metadata
AEROSOL	column	1439	1485
AEROSOL	profile	152	183
AEROSOL	surface	2115	3179
AEROSOL	tower	20	20
CARBON DIOXIDE	column	27	27
CARBON DIOXIDE	profile	33	33
CARBON DIOXIDE	surface	177	178
CARBON DIOXIDE	tower	609	616
CARBON MONOXIDE	column	43	45
CARBON MONOXIDE	profile	51	51

CARBON MONOXIDE	surface	484	495
CARBON MONOXIDE	tower	20	20
METHANE	column	43	45
METHANE	profile	51	51
METHANE	surface	168	172
METHANE	tower	11	11
NITROGEN DIOXIDE	column	38	38
NITROGEN DIOXIDE	profile	38	38
NITROGEN DIOXIDE	surface	531	536
NITROGEN DIOXIDE	tower	2	2
NOX	surface	31	31
OZONE	aircraft	15	15
OZONE	column	421	724
OZONE	profile	241	446
OZONE	surface	1552	1574
OZONE	tower	2	2
TEMPERATURE	profile	1563	1751
TEMPERATURE	surface	6723	7765
TEMPERATURE	tower	3	3
temperature, salinity	profile	3917	3918
WATER VAPOR	column	3582	3817
WATER VAPOR	profile	1559	1748
WATER VAPOR	surface	344	344
WATER VAPOR	tower	590	597

Table 7: Statistics obtained grouping the metadata for the each combination of an ECV with a measurement type; the number of stations belonging to each networks is also reported.

Geographical representativeness

Simply counting by number of observational assets ignores questions about geographical representativeness of the existing measurement stations. Availability of observations tends to correlate with both population and wealth such that the vast majority of high-quality measurements, in particular, are undertaken in the developed world leading to an uneven distribution. To provide a more quantitative assessment of the existing geographical gaps in the non-satellite observing system of systems at the global scale, an analysis of the density of measurements per continent has been carried out. Further development and analysis is to be carried out in Tasks 1.3 through 1.5, which are dedicated to these aspects of the problem.

Table 8, summarises the density of measurements in 1000 km by 1000 km boxes (about 10°x10° degrees at the equator) for each atmospheric ECV and by different measurement types. A very small number of measurements are not included in this table, like those performed on towers for CH_4 (11 stations). The measurement density has been calculated for the number of stations available over seven continental zones: Africa, Europe (includes European North Pole areas), Asia, North America (includes Greenland), South America, Oceania and Antarctica. The cells in red are those where a density less than 1 station per box is found.

	Aerosol			CO2			CO		CH4			
	column	profile	surface	column	profile	surface	profile	surface	column	profile	surface	tower
Africa	3.54	0.10	0.33	0.07	0.00	0.20	0.07	0.20	0.13	0.07	0.20	0.00
Europe	22.62	7.98	26.26	0.91	0.00	2.63	0.61	3.13	1.51	0.61	2.93	1.11
Asia	9.09	1.20	0.89	0.11	0.02	0.27	0.07	0.31	0.16	0.07	0.31	0.00
North America	19.36	0.62	112.63	0.25	0.87	1.49	1.03	14.37	0.41	1.03	1.40	0.00
South America	4.92	0.95	0.06	0.00	0.06	0.28	0.06	0.17	0.00	0.06	0.17	0.00
Oceania	4.52	0.26	4.13	0.39	0.00	1.29	0.39	1.42	0.77	0.39	1.03	0.00
Antarctica	0.98	0.24	0.33	0.00	0.00	0.16	0.00	0.08	0.00	0.00	0.08	0.00
	NO2			O3			Temperature		Water Vapor			
	column	profile	surface	column	profile	surface	profile	surface	column	profile	surface	tower
Africa	0.07	0.07	0.33	1.22	0.76	0.30	8.04	29.77	5.99	8.04	0.00	0.86
Europe	0.71	0.71	2.93	19.90	7.88	0.40	23.13	100.49	60.49	21.81	0.20	22.02
Asia	0.22	0.22	0.40	3.51	1.49	0.31	12.53	63.49	11.67	12.49	0.20	2.02
North America	0.08	0.08	18.79	5.00	5.33	61.06	11.60	46.98	77.29	11.93	13.34	8.01
South America	0.11	0.11	0.00	1.96	1.34	0.00	6.15	29.96	9.00	6.15	0.00	1.51
Oceania	0.39	0.39	0.26	5.03	4.13	0.39	12.64	40.64	16.26	13.16	0.52	3.74
Antarctica	0.33	0.33	0.00	2.77	1.63	0.08	1.39	7.17	1.39	1.30	0.00	0.00

Table 8. Density of measurements in 1000 km by 1000 km boxes by measurement type and by ECV. Cells with a value less than 1 are highlighted in red.

The analysis reported in Table 8 will be discussed within GAIA-CLIM WP6 with the aim to strengthen the description and analysis of existing gaps reported in the GAID (e.g gap G1.15) and potentially to provide new gaps for future GAID versions. At present, the cells in red of Table 1 can be used to identify those geographical areas where further analysis of the benefits of establishment of new measurement stations and/or measurement programs is warranted. This shall, at least partially, be addressed under Task 1.3 through 1.5 and we shall assess the geographical gaps in the existing observing system in subsequent WP1 deliverables on a robust scientific basis.

[5] Virtual Observatory design for the visualization of collected meta-dataset

The visualization of the metadatabase collected by Task 1.2 of the GAIA-CLIM project, currently available using the CNR geo-webportal, will be transitioned such as to be available through the GUI of the VO. This Section describes progress to date but final delivery is foreseen only later in the project (August 2017) as outlined in the Grant Agreement.

The list of functionalities requested to the GUI (i.e. the features by which the data can be filtered), following the discussions held at the Metadata Meeting, among Task 1.2 partners in Amsterdam on the 04th May 2016, are:

- Topic category code (Climatology meteorology, atmosphere; Environment, Health, Oceans...)
- Start date and end date
- Minimum value
- Maximum value
- Discipline (Atmospheric Science…)

- Instrument
- Product (temperature, water vapour…)
- Platform (fixed, mobile...)
- Feature Type (profile, column, surface….)
- Maturity matrix score (at a network level)

To each of these features there corresponds a data field in the Metadata (in XML or JSON data format) that has been prepared as outlined and summarised in the preceding Sections. Figure 2 highlights the current vision for a GUI interface in the context of the broader development and implementation of the VO. The GUI will offer summary statistics related to any search results. Initially this shall consist of counting the sites in a user-selected area and by certain search criteria, but further summary statistics shall be developed based upon identified needs and any pilot user feedback. The exact format (diagrams, tables) of this output is subject to further discussions under Task 1.3 and WP5 activities during the remainder of the project.

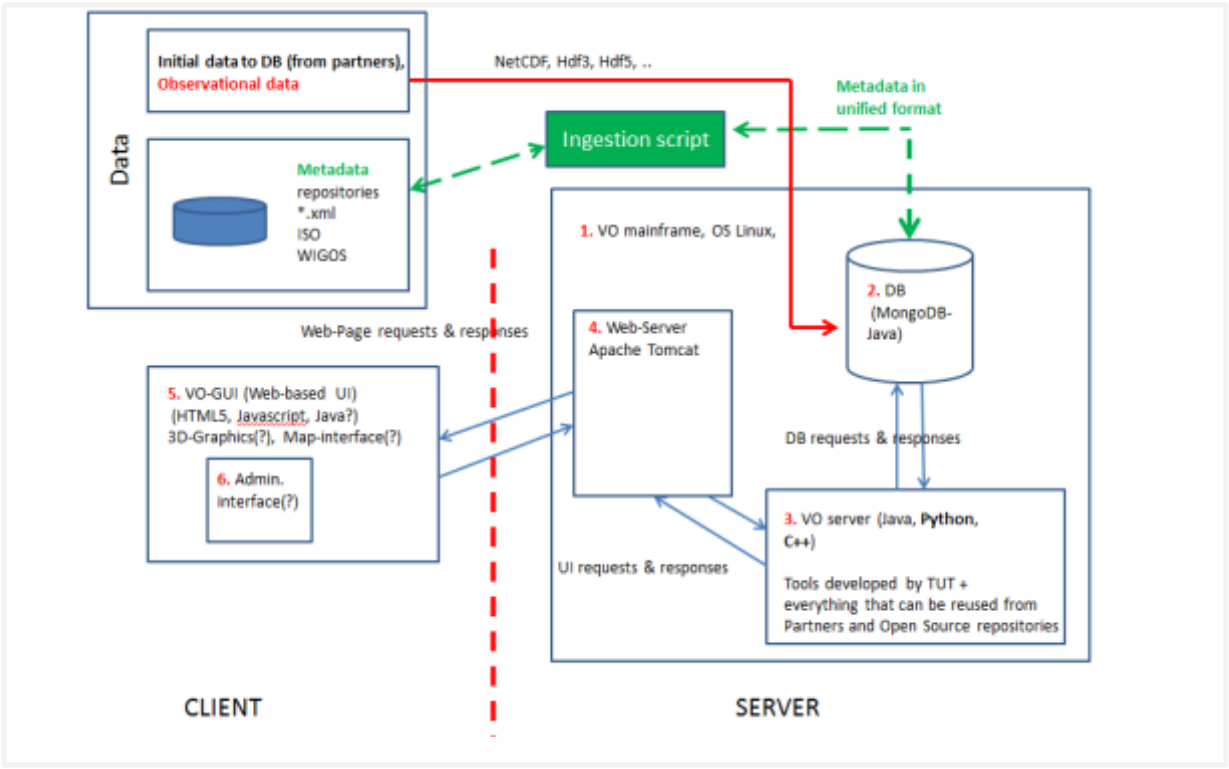

Figure 2: Preliminary sketch of the VO architecture – Client (as VO GUI), Server with DB, Web-Server and Server Software supporting the VO and GUI functionalities

Two fundamental classes of metadata queries are foreseen, and both will be supported:

- Geospatial queries; e.g. the user gives the geo-coordinates of interest to them and the GUI outputs the results in the requested bounding box
- Per-satellite query; e.g. to characterise a single satellite whereby the GUI plots/overplots the satellite FOV (single or composite) for the list of platforms relevant to GAIA-CLIM within some specified match-up thresholds in both time and space.

Servicing satellite queries and visualizing the overpass FOV will be implemented by CNR as a CESIUM-applet within Task 1.3 that is to be integrated into the VO at a later stage of the project.

Implementation of the GUI and key functionalities are driven by the needs of the user community as determined in the GAIA-CLIM user survey and to be supplemented by the two remaining user workshops. A set of generic features, including operations with metadata and as described below, has been agreed upon to alight on an architecture and to implement a first version of the GUI and VO from which further development can continue. We anticipate the further development to be an ongoing process that will be reflected in agile programming techniques. The VO is designed as a client-server application (Figure 2) with a number of web-based tools that implement the functionalities related to the operations with metadata (initial phase), as well as with observational data (second development phase).

The metadata shall be realised in a MongoDB environment that shall include both Discovery metadata and Observational metadata as outlined in Section 3. The easiest way forward to implement the required functionality is by developing a "unified metadata format" (UMDF) that holds relevant parameters common to all original data and both Observational metadata types adopted. Such a UMDF preserves the original metadata as an additional field «original xml» at the end of each database document[1] in a MD collection, thus preserving the ability to export the original data upon request if needed.

Each database document (comprising metadata for a certain site) has a field «observation_data_present» with Boolean values «False/True», indicating whether Observational Data exists in the DB or not. This option helps to organise a link between the metadata and observational data in the VO.

Metadata, as well as observational data at a later stage, is read into the VO DB by an «Ingestion Script» (Fig. 2, Fig. 3) that creates the UMDF structure from the original data. The Ingestion script is currently in its beta stage. Some initial data ingestion has been made, but the script needs to be developed further to handle all supported input data formats correctly and to filter duplicates. An inverse of the Ingestion Script is planned to serve as a data extraction tool for the «original metadata».

1 The equivalent to an entry or record in a classical database is called a 'document' in a non-sql database like Mongo and is treated like an object in programming terms.

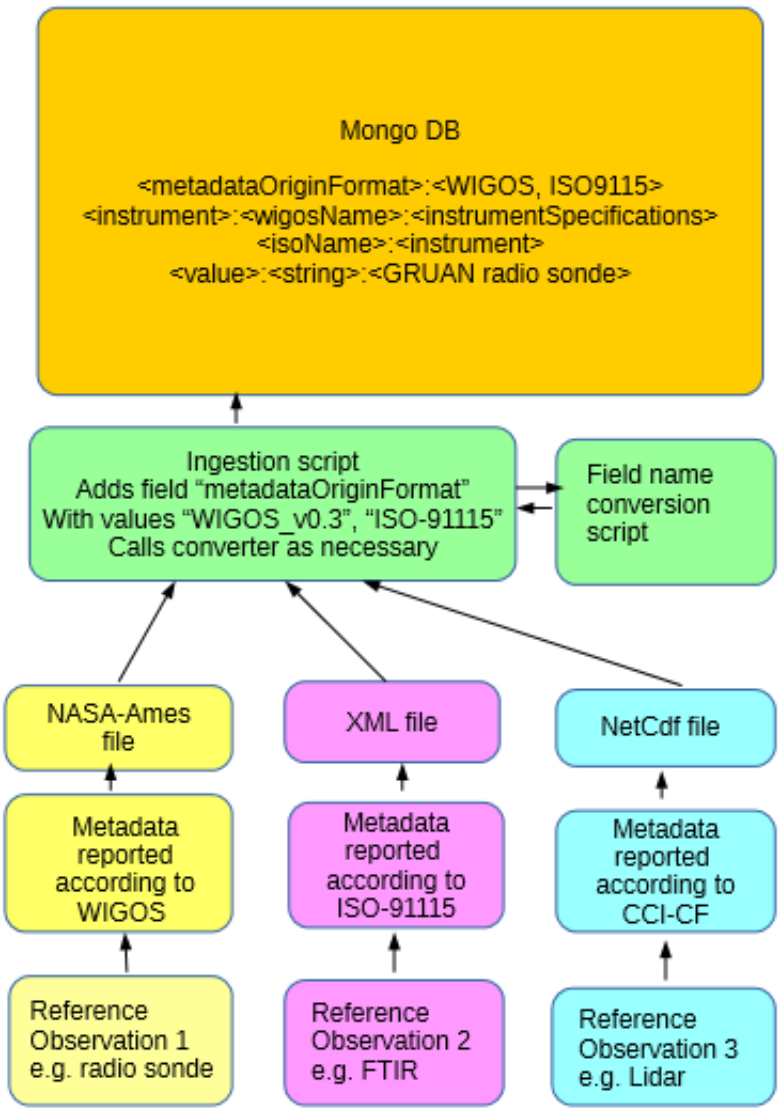

Figure 3: Draft of the scheme for the development of a "unified metadata format" (UMDF) which will be implemented in the GAIA-CLIM VO.

The VO GUI will have the following functionalities for supporting operations with metadata:

- The user can choose any geographical area (on the map or by defining a latitude/longitude rectangle)
- The user can make choices between different data search/visualisation criteria supported by the GUI
- The user will have the possibility to export search results as CSV-files (different formats can be supported) for further processing with non-VO tools.
- Any additional information according to the data filtering criteria given thus far (number of sites in a selected area, number of sites in a certain network, available data, etc.) will be displayed in a dedicated «text window» and/or in a pop-up window.
- The user can launch extra tools as web-applets (e.g. visualization of satellite overpasses by CESIUM)

The GUI shall offer a map with different layers. The results (for example, some «coloured rectangles» corresponding to geographical locations of the sites) can be displayed on separate map layers (for example, according to the observational network (GRUAN, NDACC, TCCON etc.). Layering shall be possible both by ECV and by specified instrument.

Below we list the initial types of data requests to be implemented on the VO Server. These will be realised according to the REST specifications, with a detailed description to be forthcoming later in those project deliverables specifically related to the VO. Example applications foreseen include but are not limited to:

- Spatial filtering:
  a) Find all sites around a point (Lat, Lon) within a radius of x km
     find_in_radius(Lat, Lon, radius)
     Returns lat-lon for all sites found
  b) Find all sites within a (horizontal) rectangle
     find_in_rectangle(LatMin, LonMin,LatMax,LonMax)
     Returns lat-lon for all sites found
  c) Find all sites within a polygon
     find_in_polygon(array of ref points)
     Returns lat-lon for all sites found

Whatever is searched, spatial filtering must be done first (i.e. – always searching in area) which implies that each «find» function must have parameters specifying the search area.

- Temporal filtering (by sampling time):
  a) Find all sites offering measurements between DDMMYYYY and DDMMYYYY
     find_in_time(area , startOfOperation, UpToDDMMYYYY**) by start_of_operation[2],
     Returns lat-lon for all sites found

- Search by Instrument:
  a) find_instrument(area , instrument_type) by station_platform_model
     Returns lat-lon for all sites having an instrument (lidar, GNSS, ...)

- Search by Max Value (and by Min Value):
  a) find_extent_max(area , measurand, extent_maximumValue) by measurand_variable, extent_maximumValue
     Returns lat-lon for all sites, the range covered in km for the selected measurand

- Search by Network:
  a) find_in_network(area, networkName) by programme_network_affiliation_name
     Returns lat-lon for all sites, belonging to a network

- Search by Product:

[2] given by operator, to avoid searching all data while searching data from startOfOperation (01-01-2010) to (for example, 01-01-2015) by default – UpToDDMMYYYY=TODAY

a) find_ECV(area, ECV, subType[3]) by measurand_variable, feature_type[4]
Returns lat-lon for all sites offering measurements of a certain ECV (temperature, humidity, O3, aerosols, ...)

[6] Summary and recommendations

The work undertaken by GAIA-CLIM Task 1.2 has allowed us to compare different metadata standards and select the most appropriate solution for the implementation of the VO. The work in Task 1.2 has pre-populated metadata elements for a range of candidate measurement networks. As described in D1.6 these networks have in addition been assessed for suitability against the criteria laid down in Task 1.1 (cf. D1.3) to identify which plausibly meet the metrological conditions to enable closure on a comparison with satellite measurements (e.g Dirksen et al., 2014; Leblanc et al., 2016a; Leblanc et al., 2016b). The combined output of these two deliverables provides the basis for work in remaining WPs within GAIA-CLIM and the metadata basis to serve data via the Virtual Observatory.

The work has arisen two main general recommendations applicable to any metadata collection managed by measurement networks, research projects or infrastructures:

1. The most appropriate solution to report the Discovery metadata is to use ISO 19115 standards because of their flexibility which allows users to customize the metadata profile according to their specific needs while simultaneously preserving the basic features characterizing the standard and common to all the metadata providers using ISO19115. ISO19115 has been adopted by a large number of international research projects and initiatives. The ISO customized profile used within GAIA-CLIM by Task 1.2 is based on use of the "keyword" category to increase the volume of information reported in each metadata file describing a single measurement station.
   Smart extensions of the ISO format exist to adapt open geospatial standards to environmental science data, like the "Climate Science Modelling Language" (CSML), developed by University of Reading (Low and Woolf, 2011). This is an abstract data model defined using ISO/OGC approach (XML encoding based upon GML) which wraps existing data and provides data in the form of geographical "Features". The same "Feature Types" are used to model several different data types and, conversely, the same data type can be modelled as several different types of Feature. Another relevant example of CDM is the one developed by UNIDATA (http://www.unidata.ucar.edu/software/thredds/current/netcdf-java/CDM/), which is still based on different layers and on the use of Feature types and data types in analogy with the CSML model (UNIDATA, 2016). Upon discussion with C3S and remaining Lots, a smart extended version of the ISO19115 standard might be adopted as the unique metadata

[3] subType (column, profile, surface, tower)

[4] subType (column, profile, surface, tower)

format for both the Discovery and Observation metadata.

2. Observational metadata are currently collected using a broad range of different formats within different international initiatives and research projects. This led us to adopt both WIGOS format and the CF convention, dictated by the need to both satisfy the requirements to be complaint with WMO standards and to the ESA-CCI recommendations at the same time. An attempt to reconcile the two formats has been performed but the differences are substantial. This has inspired the idea to implemented a unified metadata format (UMDF): this may represent the first step to implement an abstract data model able to get the information at the input in any kind of format to classify them in a database and then to convert the metadata requested by the user in a set of different formats that meet their needs and expectations. This provides a user-friendly solution but comes at a considerable cost in terms of collection and management. While there remains heterogeneity in Observational metadata practices, this shall continue to represent a major impediment to effective usage of data.

At the moment, the substantial challenges in reconciling the broad range of Observational metadata formats used around the world imply that the adoption of a UMDF approach in support of an abstract data model might represent the optimal solution to the metadata reporting. However, for the broader observing system, which represents many more observational assets than have been pre-selected and considered by Task 1.2 this would be a very considerable challenge. Another option to consider in the future for the harmonization effort of metadata provided by the existing non-satellite observing capabilities may be based on the extensions of the ISO19115 format described above.

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Glossary

CESIUM	Cross-platform virtual globe for dynamic-data visualisation in the space and defense industries
ECV	Environmental Climate Variable
EO	Earth Observation
ESA	European Space Agency
ESA CCI	ESA, Climate Change Initiative
FGDC CSDGM	Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata. http://www.fgdc.gov/metadata/csdgm/
GCOS	Global Climate Observing System
GRUAN	GCOS Reference Upper-Air Network
GUI	Graphical User Interface
ISO	International Standard Office
NetCDF	Network Common Data Form
OGC	Open Geospatial Consortium
WMO	World Meteorological Organization
WIGOS-OSCAR	WMO Integrated Global Observing System, Observing System Capability Analysis and Review Tool
WIS	WMO Information System
UMDF	User-Mode Driver Framework

APPENDIX A: ISO, WIGOS and CF1.6 metadata standards

```
<mdb:MD_Metadata xmlns:mdb="http://standards.iso.org/iso/19115/-
3/mdb/1.0"
                 xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance"
                 xmlns:cat="http://standards.iso.org/iso/19115/-
3/cat/1.0"
                 xmlns:cit="http://standards.iso.org/iso/19115/-
3/cit/1.0"
                 xmlns:gcx="http://standards.iso.org/iso/19115/-
3/gcx/1.0"
                 xmlns:gex="http://standards.iso.org/iso/19115/-
3/gex/1.0"
                 xmlns:lan="http://standards.iso.org/iso/19115/-
3/lan/1.0"
                 xmlns:srv="http://standards.iso.org/iso/19115/-
3/srv/2.0"
                 xmlns:mas="http://standards.iso.org/iso/19115/-
3/mas/1.0"
                 xmlns:mcc="http://standards.iso.org/iso/19115/-
3/mcc/1.0"
                 xmlns:mco="http://standards.iso.org/iso/19115/-
3/mco/1.0"
                 xmlns:mda="http://standards.iso.org/iso/19115/-
3/mda/1.0"
                 xmlns:mds="http://standards.iso.org/iso/19115/-
3/mds/1.0"
                 xmlns:mdt="http://standards.iso.org/iso/19115/-
3/mdt/1.0"
                 xmlns:mex="http://standards.iso.org/iso/19115/-
3/mex/1.0"
                 xmlns:mmi="http://standards.iso.org/iso/19115/-
3/mmi/1.0"
                 xmlns:mpc="http://standards.iso.org/iso/19115/-
3/mpc/1.0"
                 xmlns:mrc="http://standards.iso.org/iso/19115/-
3/mrc/1.0"
                 xmlns:mrd="http://standards.iso.org/iso/19115/-
3/mrd/1.0"
                 xmlns:mri="http://standards.iso.org/iso/19115/-
3/mri/1.0"
                 xmlns:mrl="http://standards.iso.org/iso/19115/-
3/mrl/1.0"
                 xmlns:mrs="http://standards.iso.org/iso/19115/-
3/mrs/1.0"
                 xmlns:msr="http://standards.iso.org/iso/19115/-
3/msr/1.0"
                 xmlns:mdq="http://standards.iso.org/iso/19157/-
2/mdq/1.0"
                 xmlns:mac="http://standards.iso.org/iso/19115/-
3/mac/1.0"
```

```
                  xmlns:gco="http://standards.iso.org/iso/19115/-
3/gco/1.0"
                  xmlns:gml="http://www.opengis.net/gml/3.2"
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APPENDIX B: GeoNetwork metadata

interface user guide

Gap Analysis for Integrated Atmospheric ECV Climate Monitoring (GAIA-CLIM)

Task 1.2: Guide to the metadata compilation

Authors: Emanuele Tramutola (CNR-IMAA) and Fabio Madonna (CNR-IMAA)

Table of contents

1. How to compile the metadata file

- Go to IMAA CNR Data Portal: http://gaiaclimmd.imaa.cnr.it
- Login with your credentials
- Choose you preferred language (though please note that the help with the compilation page is available in English only).
- Go to the menu on the top left of the page, scroll the arrow and go to “add new record”.
- In the following page, to add a new metadata file push the “CREATE” button

Now you can start filling your metadata following the guidelines or the help function. The example provided by the authors is pre-loaded in the page just for your convenience and must be modified.

To activate the help function please go the upper right side corner and push the eye icon. 

Scroll the arrow and activate the option “Tooltips”.

Now, the help function is active and it appears when you click in each one of the compilation windows of the metadata page.

At the end of the metadata compiling, push the “VALIDATE” button and, if there are no errors, push the button “SAVE AND CLOSE”.

The complied metadata file will be saved and you will able to visualize it in the catalogue directory, where you can decide also to edit or remove the inserted file.

When you finish your work please remember to sign out.

2. Metadata categories

2.1 Identification info

Title: This a characteristic, and often unique, name by which the resource is known. The value domain of this metadata element is free text. Please name the file using the name of the considered network and of the considered Essential Climate Variables (ECV) according to the table reported in the grant agreement and finally add the measurement type (profile, column...).

Date: Date of creation of metadata (Must select 'creation' from menu)

Entries available:

Entry	Description	Applicable for
creation	date identifies when the resource was brought into existence	start date of a data collection, start date of a cruise..
publication	date identifies when the resource was issued	paper publication date, dataset/resource release
revision	date identifies when the resource was examined or re-examined and improved or amended	
adopted	date identifies when resource was adopted	
deprecated	date identifies when resource was deprecated	
distribution	date identifies when an instance of the resource was distributed	
expiry	date identifies when resource expires	
inForce	date identifies when resource became in force	
lastRevision	date identifies when resource was last reviewed	
lastUpdate	date identifies when resource was last updated	
nextUpdate	date identifies when resource will be next updated	

released	the date that the resource shall be released for public access	
superseded	date identifies when resource was superseded or replaced by another resource	
unavailable	date identifies when resource became not available or obtainable	
validityBegins	time at which the data are considered to become valid. NOTE: There could be quite a delay between creation and validity begins	
validityExpires	time at which the data are no longer considered to be valid	

Abstract: This is a brief narrative summary of the content of the resource. Please follow the provided template.

Purpose: The reason for which the metadata is collected. You could also leave the one reported in the example.

Topic category code: The topic category is a high-level classification scheme to assist in the grouping and topic-based search of available spatial data resources. The user can choose across a list of categories.

Entries available:

Entry	Description
farming	rearing of animals and/or cultivation of plants. Examples: agriculture, irrigation, aquaculture, plantations, herding, pests and diseases affecting crops and livestock
biota	flora and/or fauna in natural environment. Examples: wildlife, vegetation, biological sciences, ecology, wilderness, sealife, wetlands, habitat
boundaries	legal land descriptions. Examples: political and administrative boundaries
climatologyMeteorologyAtmosphere	processes and phenomena of the atmosphere. Examples: cloud cover, weather, climate, atmospheric conditions, climate change, precipitation
economy	economic activities, conditions and employment. Examples: production, labour, revenue, commerce, industry, tourism and

	ecotourism, forestry, fisheries, commercial or subsistence hunting, exploration and exploitation of resources such as minerals, oil and gas
elevation	height above or below sea level. Examples: altitude, bathymetry, digital elevation models, slope, derived products
environment	environmental resources, protection and conservation. Examples: environmental pollution, waste storage and treatment, environmental impact assessment, monitoring environmental risk, nature reserves, landscape
geoscientificInformation	information pertaining to earth sciences. Examples: geophysical features and processes, geology, minerals, sciences dealing with the composition, structure and origin of the earth s rocks, risks of earthquakes, volcanic activity, landslides, gravity information, soils, permafrost, hydrogeology, erosion
health	health, health services, human ecology, and safety. Examples: disease and illness, factors affecting health, hygiene, substance abuse, mental and physical health, health services
imageryBaseMapsEarthCover	base maps. Examples: land cover, topographic maps, imagery, unclassified images, annotations
intelligenceMilitary	military bases, structures, activities. Examples: barracks, training grounds, military transportation, information collection
inlandWaters	inland water features, drainage systems and their characteristics. Examples: rivers and glaciers, salt lakes, water utilization plans, dams, currents, floods, water quality, hydrographic charts
location	positional information and services. Examples: addresses, geodetic networks, control points, postal zones and services, place names
oceans	features and characteristics of salt water bodies (excluding inland waters). Examples: tides, tidal waves, coastal information, reefs
planningCadastre	information used for appropriate actions for future use of the land. Examples: land use maps, zoning maps, cadastral surveys, land ownership
society	characteristics of society and cultures. Examples: settlements, anthropology, archaeology, education, traditional beliefs, manners and customs, demographic data, recreational areas and activities, social impact assessments, crime and justice, census information

structure	man-made construction. Examples: buildings, museums, churches, factories, housing, monuments, shops, towers
transportation	means and aids for conveying persons and/or goods. Examples: roads, airports/airstrips, shipping routes, tunnels, nautical charts, vehicle or vessel location, aeronautical charts, railways
utilitiesCommunication	energy, water and waste systems and communications infrastructure and services. Examples: hydroelectricity, geothermal, solar and nuclear sources of energy, water purification and distribution, sewage collection and disposal, electricity and gas distribution, data communication, telecommunication, radio, communication networks
extraTerrestrial	region more than 100 km above the surface of the Earth
disaster	Information related to disasters. Examples: site of the disaster, evacuation zone, disaster-prevention facility, disaster relief activities

Language: This is the language(s) used within the resource. The value domain of this metadata element is limited to the languages defined in ISO 639-2. You cannot edit directly this element, you have to choose from a list and then click to add.

Character encoding: Preferably this should be UTF-8.

Description: Description of the station (e.g. Name: St. Koloman AT0004R, Lat: 47.65, Lon: 13.2, Alt: 851.0 m a.s.l.)

Minimum value: Lowest vertical extent (e.g. altitude) contained in dataset. For vertically integrated measurement please write "column", for surface measurements please write "surface" and similarly for tower installation and aircraft, write "tower" or "aircraft".

Maximum value: Highest vertical extent (e.g. altitude) contained in dataset. For vertically integrated measurement please write "column", for surface measurements please write "surface" and similarly for tower installation and aircraft, write "tower" or "aircraft".

Maintenance and update frequency: frequency with which modifications and deletions are made to the data after it is first produced.

Entries available:

Entry	Description	Notes

continual	data is repeatedly and frequently updated	use fo data that is updated at a greater than daily frequency
daily	data is updated each day	
weekly	data is updated on a weekly basis	
fortnightly	data is updated every two weeks	
monthly	data is updated each month	
quarterly	data is updated every three months	
biannually	data is updated twice each year	
annually	data is updated every year	
asNeeded	data is updated as deemed necessary	applies to resources with 'completed' status
irregular	data is updated in intervals that are uneven in duration	
notPlanned	there are no plans to update the data	applies to resources with 'completed' status
unknown	frequency of maintenance for the data is not known	

2.1.1 Point of contact:

Role: Function performed by the responsible party

Entries available:

Entry	Description	Applicable for
author	party who authored the resource	
custodian	party that accepts accountability and responsibility for the data and ensures appropriate care and maintenance of the resource	archive
distributor	party who distributes the resource	
originator	party who created the resource	
owner	party that owns the resource	

pointOfContact	party who can be contacted for acquiring knowledge about or acquisition of the resource	data collector, contactable expert
principalInvestigator	key party responsible for gathering information and conducting research	chief scientist
processor	party who has processed the data in a manner such that the resource has been modified	
publisher	party who published the resource	
resourceProvider	party that supplies the resource	
sponsor	party that sponsors the resource	
user	party who uses the resource	
coAuthor	party who jointly authors the resource	
collaborator	party who assists with the generation of the resource other than the principal investigator	
contributor	party contributing to the resource	
editor	party who reviewed or modified the resource to improve the content	
funder	party providing monetary support for the resource	
mediator	a class of entity that mediates access to the resource and for whom the resource is intended or useful	
rightsHolder	party owning or managing rights over the resource	
stakeholder	party who has an interest in the resource or the use of the resource	

2.1.1.1 Party

Name: The name of organisation

Electronic mail address: E-mail of organization

2.1.1.2 Individual

Identification of, and means of communication with, person(s) and organisation(s) associated with the resource(s)

Name: Name of the responsible person

Position name: Role or position of the responsible person

2.1.2 Temporal Extent

The temporal extent defines the time period covered by the content of the resource. This time period may be expressed as an interval of dates expressed through the starting date and end date of the interval

Begin date: Time Period covered by the content – begin date. Please add the network/station starting operation for the measurement for the considered ECV and the considered measurements technique.

2.1.3 Descriptive keywords

Keyword: Common-use word(s) or phrase(s) used

Type: Methods used to group similar keywords

The following list describes the type required used in the template:

dataCentre: keyword identifies a repository or archive that manages and distributes data

discipline: keyword identifies a branch of instruction or specialized learning (e.g. default is Atmospheric science)

instrument: keyword identifies a device used to measure or compare physical properties (i.e. sonde lidar, FTIR, …)

product: keyword identifies a type of product (e.g. the measured ECV)

platform: keyword identifies a structure upon which an instrument is mounted (please say if the instrument is fixed, mobile, aircraft-based, ….)

temporal: keyword identifies a time period related to the dataset (e.g. typical sampling time, for example weekly, daily, continuous, ….)

featureType: keyword identifies a resource containing or about a collection of feature instances with common characteristics (please specify the measurement type as “profile”, “column”, “surface”, “tower”, aircraft”, similarly to the Excel table including the review of the existing network circulated in advance).

2.1.4 Resource constraints

Access constraints: limitation(s) placed upon the access of the data

Use constraints: limitation(s) placed upon the use of the data

Entries available for *Access constraints* and *Use constraints*:

Entry	Description	Notes
copyright	exclusive right to the publication, production, or sale of the rights to a literary, dramatic, musical, or artistic work, or to the use of a commercial print or label, granted by law for a specified period of time to an author, composer, artist, distributor	
patent	government has granted exclusive right to make, sell, use or license an invention or discovery	
patentPending	produced or sold information awaiting a patent	
trademark	a name, symbol, or other device identifying a product, officially registered and legally restricted to the use of the owner or manufacturer	
license	formal permission to do something	
intellectualPropertyRights	rights to financial benefit from and control of distribution of non-tangible property that is a result of creativity	
restricted	withheld from general circulation or disclosure	
otherRestrictions	limitation not listed	applies to data is public and in the archive, but not distributed by the archive - add more info in free text field
unrestricted	no constraints exist	
licenceUnrestricted	formal permission not required to use the resource	
licenceEndUser	formal permission required for a person or an entity to use the resource and that may differ from the person that orders or purchases it	
licenceDistributor	formal permission required for a person or an entity to commercialize or distribute the resource	

private	protects rights of individual or organisations from observation, intrusion, or attention of others	
statutory	prescribed by law	
confidential	not available to the public contains information that could be prejudicial to a commercial, industrial, or national interest	
SBU	although unclassified, requires strict controls over its distribution.	
in-confidence	with trust	

Other constraints: This is a free-text field where additional constraints can be added

2.2 Metadata

Language: This is the language in which the metadata elements are expressed.

Character encoding: Preferably this should be UTF-8

Title: (Identifier and onlineResource for a parent metadata record)

Date: The date which specifies when the metadata record was created or updated.

Entries available:

Entry	Description	Applicable for
creation	date identifies when the resource was brought into existence	start date of a data collection, start date of a cruise..
publication	date identifies when the resource was issued	paper publication date, dataset/resource release
revision	date identifies when the resource was examined or re-examined and improved or amended	
adopted	date identifies when resource was adopted	
deprecated	date identifies when resource was deprecated	

distribution	date identifies when an instance of the resource was distributed	
expiry	date identifies when resource expires	
inForce	date identifies when resource became in force	
lastRevision	date identifies when resource was last reviewed	
lastUpdate	date identifies when resource was last updated	
nextUpdate	date identifies when resource will be next updated	
released	the date that the resource shall be released for public access	
superseded	date identifies when resource was superseded or replaced by another resource	
unavailable	date identifies when resource became not available or obtainable	
validityBegins	time at which the data are considered to become valid. NOTE: There could be quite a delay between creation and validity begins	
validityExpires	time at which the data are no longer considered to be valid	

2.2.1 Identifier

A value uniquely identifying the resource; it is generated automatically.

2.2.2 Contact [1]

Role: Role of the person responsible for the creation and maintenance of the metadata (this section must contain data of the point of contact)

2.2.3 Contact [2]

Role: Role of the person responsible for the creation and maintenance of the metadata (this section must contain data of the principal investigator)

Entries available:

Entry	Description	Applicable for

author	party who authored the resource	
custodian	party that accepts accountability and responsibility for the data and ensures appropriate care and maintenance of the resource	archive
distributor	party who distributes the resource	
originator	party who created the resource	
owner	party that owns the resource	
pointOfContact	party who can be contacted for acquiring knowledge about or acquisition of the resource	data collector, contactable expert
principalInvestigator	key party responsible for gathering information and conducting research	chief scientist
processor	party who has processed the data in a manner such that the resource has been modified	
publisher	party who published the resource	
resourceProvider	party that supplies the resource	
sponsor	party that sponsors the resource	
user	party who uses the resource	
coAuthor	party who jointly authors the resource	
collaborator	party who assists with the generation of the resource other than the principal investigator	
contributor	party contributing to the resource	
editor	party who reviewed or modified the resource to improve the content	
funder	party providing monetary support for the resource	
mediator	a class of entity that mediates access to the resource and for whom the resource is intended or useful	
rightsHolder	party owning or managing rights over the resource	
stakeholder	party who has an interest in the resource or the use of the resource	

2.2.3.1 Party

Name: The name of the organisation as free text

Electronic mail address: A contact e-mail address as a character string

Linkage: A referring web site

2.2.3.1.1 Individual

Name: Name of the person responsible for the creation and maintenance of the metadata

Position name: Position of the individual in an organisation

2.2.4 Type of resource

Resource scope: list of scopes that identifies the type of resources

Entries available:

Entry	Description	Applies to
attribute	information applies to the attribute value	
attributeType	information applies to the characteristic of a feature	
collectionHardware	information applies to the collection hardware class	sensor, instrument
collectionSession	information applies to the collection session	
dataset	information applies to the dataset	file
series	information applies to the series	a set of files
nonGeographicDataset	information applies to non-geographic data	space weather data
dimensionGroup	information applies to a dimension group	
feature	information applies to a feature	

featureType	information applies to a feature type	
propertyType	information applies to a property type	
fieldSession	information applies to a field session	cruise
software	information applies to a computer program or routine	
service	information applies to a capability which a service provider entity makes available to a service user entity through a set of interfaces that define a behaviour, such as a use case	WMS
model	information applies to a copy or imitation of an existing or hypothetical object	
tile	information applies to a tile, a spatial subset of geographic data	
metadata	information applies to metadata	
initiative	information applies to an initiative	
sample	information applies to a sample	
document	information applies to a document	
repository	information applies to a repository	
aggregate	information applies to an aggregate resource	
product	metadata describing an ISO 19131 data product specification	
collection	information applies to an unstructured set	
coverage	information applies to a coverage	
application	information resource hosted on a specific set of hardware and accessible over a network	

Name: description of the scope

2.2.5 Alternative metadata reference

Unique Identifier and onlineResource for alternative metadata

Title: Alternative name by which the resource is known

2.2.6 Metadata linkage

Linkage: online location where the metadata is available

Function: function performed by the resource.

Entries available:

Entry	Description	Applies to
download	online instructions for transferring data from one storage device or system to another	an FTP site or downloadable zip file
information	online information about the resource	URLs with descriptive details about the resource
offlineAccess	online instructions for requesting the resource from the provider	
order	online order process for obtaining the resource	an interface for requesting the resource
search	online search interface for seeking out information about the resource	map viewers, search interfaces
browseGraphic	browse graphic provided	
browsing	online browsing provided	
completeMetadata	complete metadata provided	
emailService	online email service provided	
fileAccess	online file access provided	

upload	online resource upload capability provided	

2.2.7 Metadata standard

Citation for the standards to which the metadata conforms

Title: Here should be mentioned the standard ISO 19115-3.

APPENDIX C: list of networks

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Temperature (PROFILE)**	MESONET	Acoustic Sounding Systems	www.mesonet.org
		MWRnet	Microwave radiometer	cetemps.aquila.infn.it/mwrnet/
		NDACC	Lidar (Rayleigh/Raman)	www.ndsc.ncep.noaa.gov/
		EARLINET	Lidar (Rotational Raman)	www.earlinet.org
		ARM program	Lidar (Rotational Raman)	www.arm.gov
		GRUAN	Sonde	www.gruan.org
		GUAN	Sonde	www.wmo.int/pages/themes/climate/climate_data_management_exchange.php
		RAOB	Sonde	www.raob.com
	Temperature (SURFACE)	ISTI	Surface sensors	www.surfacetemperatures.org
		GSN	Surface sensors	www.wmo.int/pages/themes/climate/climate_data_management_exchange.php
		RBSN	Surface sensors	http://www.wmo.int/pages/prog/www/ois/monitor/agm/AGM2009A/datasets.html
		MESONET	Surface sensors	www.mesonet.org
		AMeDAS	Surface sensors	www.jma.go.jp
		ARM	Thermometer	www.arm.gov
		SKYNET	Thermometer	atmos2.cr.chiba-u.jp
		USCRN	surface weather station	https://www.ncdc.noaa.gov/crn/
		SMEAR	Platinum resistance thermometer	https://www.atm.helsinki.fi/SMEAR/index.php
	Temperature (TOWER)	SMEAR	Platinum resistance thermometer	https://www.atm.helsinki.fi/SMEAR/index.php
	Water vapour (PROFILE)	MWRnet	Microwave radiometer	cetemps.aquila.infn.it/mwrnet/
		NDACC	Lidar (Raman), microwave radiometer	www.ndsc.ncep.noaa.gov/
		EARLINET	Lidar (DIAL, Raman)	www.earlinet.org
		ARM program	Raman lidar	www.arm.gov
		GRUAN	Sonde	www.gruan.org
		GUAN	Sonde	www.wmo.int/pages/themes/climate/climate_data_management_exchange.php
		RAOB	Sonde	www.raob.com
		ESRL GMD	Flask sampling, NOAA Frost Point Hygrometer (FPH)	http://www.esrl.noaa.gov/
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Water vapour (COLUMN)**	IGS	GPS/GNSS	https://igscb.jpl.nasa.gov
		GPSMET	GPS/GNSS	gpsmet.noaa.gov
		SUOMINET	GPS/GNSS	www.suominet.ucar.edu
		MWRnet	Microwave radiometer	cetemps.aquila.infn.it/mwrnet/
		AERONET/PHOTONS	Sun photometer	aeronet.gfsc.nasa.gov / http://loaphotons.univ-lille1.fr/
		SKYNET	Sun photometer	atmos2.cr.chiba-u.jp
		EUROSKYRAD	Sun photometer	http://www.euroskyrad.net/
		SURFRAD	Sun photometer	http://www.esrl.noaa.gov/gmd/grad/surfrad/sitepage.html
		NDACC	FTIR, AERI, microwave radiometer	www.ndsc.ncep.noaa.gov/
		ARM	FTIR, AERI	www.arm.gov
		GRUAN	Sonde	www.gruan.org
		GUAN	Sonde	www.wmo.int/pages/themes/climate/climate_data_management_exchange.php
		RAOB	Sonde	www.raob.com
		CARSNET	Sun photometer	No official link (running in cooperation with AERONET)
		EUREF	GNSS	http://www.epncb.oma.be/
	Water vapour (TOWER)	SMEAR	Infrared gas analyzer	https://www.atm.helsinki.fi/SMEAR/index.php
		FLUXNET	flux tower	http://fluxnet.ornl.gov/
	Water vapor (SURFACE)	ISTI	Surface sensors	www.surfacetemperatures.org
		MESONET	Surface sensors	www.mesonet.org
		SKYNET	Hygrometer	atmos2.cr.chiba-u.jp
		USCRN	Hygrometer	https://www.ncdc.noaa.gov/crn/
		SMEAR	Infrared gas analyzer	https://www.atm.helsinki.fi/SMEAR/index.php

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Water vapour (COLUMN)**	IGS	GPS/GNSS	https://igscb.jpl.nasa.gov
		GPSMET	GPS/GNSS	gpsmet.noaa.gov
		SUOMINET	GPS/GNSS	www.suominet.ucar.edu
		MWRnet	Microwave radiometer	cetemps.aquila.infn.it/mwrnet/
		AERONET /PHOTONS	Sun photometer	aeronet.gfsc.nasa.gov / http://loaphotons.univ-lille1.fr/
		SKYNET	Sun photometer	atmos2.cr.chiba-u.jp
		EUROSKYRAD	Sun photometer	http://www.euroskyrad.net/
		SURFRAD	Sun photometer	http://www.esrl.noaa.gov/gmd/grad/surfrad/sitepage.html
		NDACC	FTIR, AERI, microwave radiometer	www.ndsc.ncep.noaa.gov/
		ARM	FTIR, AERI	www.arm.gov
		GRUAN	Sonde	www.gruan.org
		GUAN	Sonde	www.wmo.int/pages/themes/climate/climate_data_management_exchange.php
		RAOB	Sonde	www.raob.com
		CARSNET	Sun photometer	No official link (running in cooperation with AERONET)
		EUREF	GNSS	http://www.epncb.oma.be/
	Water vapour (TOWER)	SMEAR	Infrared gas analyzer	https://www.atm.helsinki.fi/SMEAR/index.php
		FLUXNET	flux tower	http://fluxnet.ornl.gov/
	Water vapor (SURFACE)	ISTI	Surface sensors	www.surfacetemperatures.org
		MESONET	Surface sensors	www.mesonet.org
		SKYNET	Hygrometer	atmos2.cr.chiba-u.jp
		USCRN	Hygrometer	https://www.ncdc.noaa.gov/crn/
		SMEAR	Infrared gas analyzer	https://www.atm.helsinki.fi/SMEAR/index.php

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Ozone (PROFILE)**	NDACC	DIAL, FTIR, microwave radiometer	www.ndsc.ncep.noaa.gov/
		TOLNET	DIAL	http://www-air.larc.nasa.gov/missions/TOLNet/
		WOUDC	Brewer - Dobson	woudc.org
		SHADOZ	Ozonesondes	croc.gsfc.nasa.gov/shadoz
		ESRL GMD	Flask sampling, Vaisala RS80-A ozone sondes	http://www.esrl.noaa.gov/
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp
	Ozone (COLUMN)	EUBREWNET	Brewer - Dobson	www.eubrewnet.org or http://rbcce.aemet.es/eubrewnet
		WOUDC	Brewer - Dobson	woudc.org
		NDACC	Brewer - Dobson - UV/visible DOAS	www.ndsc.ncep.noaa.gov/
		ARM	Ultraviolet photometry in a dual absorption cell	www.arm.gov
		NOAA ESRL		http://www.esrl.noaa.gov/
		COST Action 726	Multiband Radiometers: Harmonization of Global UVI and	http://www.cost726.org/
		WDCGG	surface (various types)	http://ds.data.jma.go.jp/gmd/wdcgg/
		BSRN	Dobson spectrophotometer	http://www.bsrn.awi.de/
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	***Ozone (SURFACE)***	CAPMoN	Sampling Inlet	http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1
		CASTNET	ozone analyzer	http://epa.gov/castnet/javaweb/index.html
		EANET	Automatic Monitors	http://www.eanet.asia/
		ESRL GMD	Flask sampling, Thermo-Scientific Ozone Monitor, 49c, 3711, UV absorption	http://www.esrl.noaa.gov/
		IDAF	passive filter sampling + ion chromatography	http://idaf.sedoo.fr/spip.php?rubrique3
	Aerosols (PROFILE)	ADNET	variuos type	http://www-lidar.nies.go.jp/AD-Net/
		ALINE/LALINET	Backscatter lidar	http://lalinet.org/index.php/Aline/Commitment
		CISLiNet	Backscatter lidar	http://www.cis-linet.basnet.by/
		CREST	Backscatter lidar	http://crest.ccny.cuny.edu
		EARLINET /ACTRIS	Lidar	www.earlinet.org
		GAW GALION	Various lidar types	http://alg.umbc.edu/galion/
		NDACC	sonde,backscatter lidar	www.ndsc.ncep.noaa.gov/
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp
		MPLnet	MPL backscatter lidar	http://mplnet.gsfc.nasa.gov/

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Aerosols (COLUMN)**	ACTRIS/AERONET/ PHOTONS	Sun photometer	www.actris.org
		SKYNET	Sun photometer	http://atmos2.cr.chiba-u.jp/skynet/
		EUROSKYRAD	Sun photometer	atmos2.cr.chiba-u.jp
		GAWPFR	Precision Filter Radiometers	http://www.pmodwrc.ch/worcc/
		SURFRAD	Sun photometer	http://www.esrl.noaa.gov/gmd/grad/surfrad/
		AEROCAN	Sun photometer	http://www.aerocanonline.com/
		AGSNET	Sun photometer	http://www.csiro.au/en/Research/OandA/Areas/Assessing-our-climate/Aerospan-aerosol-characterisation
		CARSNET	Sun photometer	No official link (running in cooperation with AERONET)
		GAW AOD	Sun photometer	http://www.wmo.int/pages/prog/arep/gaw/aerosol.html
		ESRL GMD	Sun photometer	http://www.esrl.noaa.gov/gmd/
		BSRN	Radiometers	http://www.bsrn.awi.de/
	Aerosols (IN-SITU)	ACTRIS	in-situ aerosol pollutants	www.actris.org
		GAW-insitu	aerosol scattering/absorption	
		EMEP	PM2.5 PM10	www.emep.org
		CAPMoN	in-situ aerosol pollutants	http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1
		CASTNET	in-situ aerosol pollutants	http://epa.gov/castnet/javaweb/index.html

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Aerosols (IN-SITU)**	CAWNET	PM10 (some sites include PM2.5, PM1), visibility, aerosol light absorption and aerosol light scattering.	https://www.cma.gov.cn/english/
		EANET	Acid Deposition and Oxidant Research	http://www.eanet.asia/
		IDAF	in-situ aerosol pollutants	http://idaf.sedoo.fr/spip.php?rubrique3
		IMPROVE	in-situ aerosol pollutants	http://vista.cira.colostate.edu/improve/
		NIES-AGAGE-SOGE	in-situ aerosol pollutants	https://www.nies.go.jp/index-e.html
		ESRL GMD	in-situ aerosol pollutants	http://www.esrl.noaa.gov/gmd/
		IDAF (Africa)	in-situ aerosol pollutants	http://idaf.sedoo.fr/spip.php?rubrique3
		NADP	in-situ aerosol pollutants	http://nadp.sws.uiuc.edu/
	Aerosols (TOWER)	CAWNET	filter sampling and analysis with different methods (X-Ray Fluorescence, ion chromatography, Thermal Optical Reflectance combustion)	https://www.cma.gov.cn/english/
	Carbon Monoxide (COLUMN)	NDACC	FTIR	www.ndsc.ncep.noaa.gov/
		TCCON	FTIR	https://tccon-wiki.caltech.edu/Sites
		ESRL GMD	surface (various types)	http://www.esrl.noaa.gov/gmd/
		WDCGG	surface (various types)	http://ds.data.jma.go.jp/gmd/wdcgg/
	Carbon Monoxide (PROFILE)	ESRL GMD	Flask sampling, until 2000 via gas chromatography with mercuric oxide detection (GC-HgO), from 2000 via fluorescence of CO in the VUV	http://www.esrl.noaa.gov/
		NDACC	FTIR	www.ndsc.ncep.noaa.gov/

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	***Carbon Monoxide (SURFACE)***	NIES-AGAGE-SOGE	Gas chromatograph with mercuric oxide reduction detection (GC-MRD), Cavity ring-down spectroscopy (CRDS),Gas Chromatography with Flame-Ionization Detection	https://www.nies.go.jp/index-e.html
		ESRL GMD	Dobson spectrophotometer, From 1988-2000, gas chromatography followed by HgO reduction detection (GC-HgO), from 2000 using fluorescence of CO in the VUV	http://www.esrl.noaa.gov/
		ICOS	cavity ringdown spectroscopy	www.icos-ri.eu
	Carbon Monoxide (TOWER)	ESRL GMD	Flask sampling, Thermo Electron Corporation carbon monoxide (CO) analyzer	http://www.esrl.noaa.gov/
		ICOS	cavity ringdown spectroscopy	www.icos-ri.eu
	Carbon dioxide (COLUMN)	SCRIPPS C02 program	in-situ	http://scrippsco2.ucsd.edu/
		TCCON	FTIR	https://tccon-wiki.caltech.edu/Sites
		ICOS	laser absorption based analyzers	www.icos-ri.eu
		InGOS	Various types	www.ingos-infrastructure.eu
		RAMCES	surface (various types)	www.andra.fr
		ESRL GMD	surface (various types)	http://www.esrl.noaa.gov/gmd/
		WDCGG	surface (various types)	http://ds.data.jma.go.jp/gmd/wdcgg/
	Carbon dioxide (PROFILE)	ESRL GMD	flask samples analyzed by a nondispersive infrared absorption technique	http://www.esrl.noaa.gov/

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Carbon dioxide (SURFACE)**	ESRL GMD	nondispersive infrared absorption technique	http://www.esrl.noaa.gov/
		ICOS	nondispersive infrared absorption technique and cavity ringdown spectroscopy	www.icos-ri.eu
		SCRIPPS C02	flask samples analyzed by a nondispersive infrared absorption technique	http://scrippsco2.ucsd.edu/
	Carbon dioxide (TOWER)	ESRL GMD	analyzed by a nondispersive infrared absorption technique	http://www.esrl.noaa.gov/
		FLUXNET	flux tower	http://fluxnet.ornl.gov/
		ICOS	nondispersive infrared absorption technique and cavity ringdown spectroscopy	www.icos-ri.eu
	Methane (COLUMN)	NDACC	FTIR	www.ndsc.ncep.noaa.gov/
		TCCON	FTIR	https://tccon-wiki.caltech.edu/Sites
		ICOS	laser absorption based analyzers	www.icos-ri.eu
		InGOS	Various types	www.ingos-infrastructure.eu
		RAMCES	surface (various types)	www.andra.fr
		ESRL GMD	surface (various types)	http://www.esrl.noaa.gov/gmd/
		WDCGG	surface (various types)	http://ds.data.jma.go.jp/gmd/wdcgg/

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	ECV & Feature Type	Networks	Techniques or measurement type	Website
Atmospheric (surface-based)	**Methane (PROFILE)**	ESRL GMD	Dobson spectrophotometer, flask samples analyzed by gas chromatography with flame ionization detection, radiosounding	http://www.esrl.noaa.gov/
		NDACC	FTIR	www.ndsc.ncep.noaa.gov/
	Methane (SURFACE)	NIES-AGAGE-SOGE	Gas Chromatography with Flame-Ionization Detection(GC-FID), Cavity ring-down spectroscopy (CRDS)	https://www.nies.go.jp/index-e.html
		ESRL GMD	flask samples analyzed by gas chromatography with flame ionization detection, gas chromatography with flame ionization detection	http://www.esrl.noaa.gov/
		ICOS	cavity ringdown spectroscopy	www.icos-ri.eu
	Methane (TOWER)	ICOS	cavity ringdown spectroscopy	www.icos-ri.eu
	Formaldehyde	NDACC	MAX-DOAS, FTIR	www.ndsc.ncep.noaa.gov/
	Nitrogen Dioxide (COLUMN)	NDACC	FTIR, MAX-DOAS	www.ndsc.ncep.noaa.gov/
		RAMCES	surface (various types)	www.andra.fr
		CAPMoN	in-situ	http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1
		WDCGG	surface (various types)	http://ds.data.jma.go.jp/gmd/wdcgg/
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp

Atmospheric (surface-based)	**Nitrogen Dioxide (PROFILE)**	NDACC	UV/Visible Spectrometers	www.ndsc.ncep.noaa.gov/
		SKYNET	Multi Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)	atmos2.cr.chiba-u.jp
	Nitrogen Dioxide (SURFACE)	ACTRIS	Chemiluminescence (CL),Colorimetry, Sepctrophotometry (visible), UV/vis spectrometry/radiometry	www.actris.org
		EANET	Automatic Monitors, Passive sampler	http://www.eanet.asia/
		IDAF	passive filter sampling + ion chromatography	http://idaf.sedoo.fr/spip.php?rubrique3
	NOx (surface)	CAPMoN	sampling inlet +Chemiluminescence (CL)	http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1
	VOCs (COLUMN)	NDACC	FTIR (several VOC including HCHO), MAX-DOAS (onlyHCHO and glyoxal)	www.ndsc.ncep.noaa.gov/
		ACTRIS		
		WDCGG	surface (various types)	http://ds.data.jma.go.jp/gmd/wdcgg/
Atmospheric (airborne)	**Temperature, Water vapor, aerosol, ozone, other trace gases**	E-AMDAR	in-situ	www.eumetnet.eu/e-amdar
	Temperature, Water vapor, aerosol, ozone, other trace gases	IAGOS	in-situ	www.iagos.org

	ECV & Feature Type	Networks	Techniques or measurement type	Website
Ocean	**Temperature and salinity**	ARGO	Floats	www.argo.org
Land	**Surface Albedo and fluxes**	FLUXNET	in-situ	http://fluxnet.ornl.gov/