Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring

WP1: Mapping Geographical Capabilities

D1.8: "Beta version of a 3D tool for the online visualization of existing measurements".

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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.

Within WP1, Task 1.3 has the main objective to map the observing capabilities arising from the discovery metadataset, collected within task 1.2, through the design and implementation of a visualization tool which will provide a 3D description of all identified stations available which are monitoring ECVs worldwide, providing in-situ surface, in-situ sounding, columnar and profiling observations. The visualization tools must be able to filter according to metadata criteria such as spatial and temporal coverage, vertical range, number and type of ECVs, degree of harmonization, variable maturity level, standardization of the monitoring methods etc.

It will be possible to visualize subsets of available measurements according to the filtering criteria. This will enable the selection of the best available ensemble of station records for the validation of a chosen satellite sensor for a selected application. Along with surface based observing capabilities, the 3D tool also allows a user to interrogate and visualize a database containing collocations of EO data. EO sensor characterisation capabilities have been geographically identified according to the EO instrument characterisation requirements of the current and upcoming satellite missions, described by CEOS in The Earth Observation Handbook [http://www.eohandbook.com/]. For each satellite platform, the sensors relevant for GAIA-CLIM are identified and, for each of these sensors, both the nadir footprint and the swath can be interactively over plotted with the surface based measurements stations.

The tools facilitate the analysis of the degree of temporal sampling mismatch for those measurements which are discontinuous in nature, whereby there can exist a range of sampling time offsets to different EO platforms depending upon their orbital configuration. Moreover, it also maximizes the value of existing observations for satellite cal/val, supporting the users in the selection of the most appropriate dataset for their specific studies (network, spatial and temporal domains).

The 3D tool, developed in synergy with partners involved in Work Package 5, will represent the front-end-GUI of GAIA-CLIM 'Virtual Observatory' (VO). The 3D tool is able to work both as a stand-alone software package, and as a module of the VO. it is also designed with the capability to read the database implemented in the VO, check for the data availability for specific measurement station(s), and, if data are available, to enable its interactive visualization through the VO back-end interface. Nevertheless this capability is not yet working given that the VO development is still in progress.

The software responds to the following GAIA-CLIM scientific objectives (S), technological objectives (T) and user outreach objectives (O):

S1. Define and document a tiered system of systems approach to EO measurements characterisation, based upon measurement properties, in order to categorize ground-based and sub-orbital measurement capabilities.

S6. Perform a Cal/Val gap analysis based upon geographical coverage, measurement capabilities / characterisation, user needs, technological impediments and opportunities, and national and international measurement strategies and governance. Produce a set of prioritised recommendations arising.

T1. Development of mapping tools to enable visualization of observing capabilities.

O4. Provision of software tools under a creative common licensing system.

O5. Provision of a graphical interface mapping tool of observing capabilities.

As for Task 1.2, Task 1.3 work is also 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.

In the next section, a summary of the observing capabilities collected in the frame of task 1.2 activity and made available through the 3D tool is reported. This is complemented by the list of satellites available in the 3D tool. Then we provide a tutorial to the use of the 3D tool Beta version: a step-by-step description of the software functionalities as well as of the technical requirements for its operational installation in a data centre are provided (Appendix A).

2. Metadataset

The GAIA-CLIM deliverables D1.6 and D1.7 (GAIA-CLIM 2016a, GAIA-CLIM 2016b) complementarily describe the approach followed within task 1.2 to review the existing observing capabilities. This Task 1.2 activity has provided a discovery metadataset including 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 key information (e.g. measured ECVs, measurement technique, official website) is provided in Table 1 (also reported in D1.6). 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, used to evaluate the network's maturity in the context of the system-of-systems approach and its quantitative assessment, described in the GAIA-CLIM deliverable D1.6, cover about 75% of the surveyed stations (or mobile platforms). The dataset is going to be further updated following the recommendations of the GAIA-CLIM users and, beyond the scope of GAIA-CLIM, but in the frame of the C3S-BARON (C3S-Baseline And Reference Observation Networks) Service project, will be established as a permanent service for the Copernicus program even though only initially for a subset of networks measuring atmospheric thermodynamics and composition.

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Domain	Network	Coverage	ECV	Maturity Matrix
Atmosphere	ACTRIS	regional	Aerosol, NOx, VOCs	
Atmosphere	AD-Net	regional	Aerosol	
Atmosphere	AERONET/ PHOTONS	global	Aerosol	
Atmosphere	AGSNET/ CSIRO	global	Aerosol	
Atmosphere	AGAGE	global	Aerosol	
Atmosphere	AMeDAS	regional	Temperature	
Ocean	ARGO	global	Temperature and saliitnity	
Atmosphere	ARM	regional	Various	
Atmosphere	BSRN	global	Aerosol (Radiation)	
Atmosphere	CAPMoN	regional	Aerosol , NOx, O3	
Atmosphere	CARSNET	regional	Aerosol , water vapor	
Atmosphere	CASTNET	regional	Aerosol , O3	
Atmosphere	CAWNET	regional	Aerosol	
Atmosphere	CREST	regional	Aerosol	
Atmosphere	EANET	regional	Aerosol , O3	
Atmosphere	EARLINET	regional	Aerosol	
Atmosphere	EMEP	regional	Aerosol	
Atmosphere	EPA	regional	Aerosol	
Atmosphere	ESRL	global	Aerosol, CO2, CO, CH4, VOCs	
Atmosphere	EUREF	regional	Water vapor	
Atmosphere	EuroSkyRad	regional	Aerosol	
Land	FLUXNET	global	Surface Albedo and fluxes, CO2, water vapour	
Atmosphere	GAW GALION	global	Aerosol	
Atmosphere	GAW PFR	global	Aerosol	
Atmosphere	GPS-Met	global	Water vapor	
Atmosphere	GRUAN	global	Temperature, Water vapor	
Atmosphere	GSN	global	Temperature	
Atmosphere	GUAN	global	Temperature, Water vapor	
Atmosphere	ICOS	regional	CO, CO2, CH4	

Table 1. List of the 49 networks reviewed in the frame of GAIA-CLIM task 1.2 for which complete discovery metadata have been collected. The first column reports the measurement domain, the second the network acronym, the third,

the network coverage, the fourth includes the number of measured ECVs, and the last column reports the availability of one or more maturity matrix for the corresponding network (available if coloured in grey).

Domain	Network	Coverage	ECV	Maturity Matrix
Atmosphere	IDAF	regional	Aerosol, O3, NO2	
Atmosphere	IGS	global	Water vapor	
Atmosphere	IMPROVE	regional	Aerosol	
Atmosphere	LALINET-ALINE	regional	Aerosol	
Atmosphere	MESONET	regional	Temperature, Water vapor	
Atmosphere	MPLNET	global	Aerosol	
Atmosphere	MWRnet	global	Temperature, Water vapor	
Atmosphere	NDACC	global	Various	
Atmosphere	NPS	regional	Aerosol	
Atmosphere	RAOB	global	Temperature, Water vapor	
Atmosphere	RBSN	global	Temperature	
Atmosphere	Scripps CO2	regional	CO2	
Atmosphere	SHADOZ	global	O3	
Atmosphere	SKYNET	regional	Aerosol	
Atmosphere	SMEAR	regional	Temperature, Water vapor	
Atmosphere	SUOMINET	global	Water vapor	
Atmosphere	SURFRAD	regional	Aerosol (Radiation)	
Atmosphere	TCCON	global	CO, CO2, CH4	
Atmosphere	TOLNET	regional	O3	
Atmosphere	USCRN	regional	Temperature, Water vapor	
Atmosphere	WOUDC	global	O3	

Table 1. Continuation.

The metadataset collected within task 1.2 has the final aim to show which and where are the existing observing capabilities at the global scale, for the GAIA-CLIM subset of ECVs, independently of the frequency or the gaps in the data records routinely provided by each station. This is in line with the WP1 scope to identify geographical gaps in the current observing systems: The task 1.2 objective is to show where measurements stations already exist and where not, their density, and to relate the correlated geographical gaps to the ongoing work within Tasks 1.4 and 1.5 which will address the relevance of the geographical gaps on a scientific basis.

3. Satellite platforms

Satellite Platform	Instrument name	Instrument type
CALIPSO	CALIOP	Space lidar
METOP-A	AMSU-A	Microwave cross-track scanning radiometer
	GOME-2	Cross-nadir scanning SW sounder
	HIRS/4	Cross-nadir infrared sounder
	IASI	Cross-nadir infrared sounder
	MHS	Microwave cross-track scanning radiometer
METOP-B	AMSU-A	Microwave cross-track scanning radiometer
	GOME-2	Cross-nadir scanning SW sounder
	HIRS/4	Cross-nadir infrared sounder
	IASI	Cross-nadir infrared sounder
	MHS	Microwave cross-track scanning radiometer
NOAA 15	AMSU-A	Microwave cross-track scanning radiometer
	AMSU-B	Microwave cross-track scanning radiometer
	HIRS/3	Cross-nadir infrared sounder
NOAA 18	AMSU-A	Microwave cross-track scanning radiometer
	HIRS/4	Cross-nadir infrared sounder
	MHS	Microwave cross-track scanning radiometer
NOAA 19	AMSU-A	Microwave cross-track scanning radiometer
	HIRS/4	Cross-nadir infrared sounder
	MHS	Microwave cross-track scanning radiometer
SENTINEL-3A	OLCI	Moderate-resolution optical imager
	SLSTR	Moderate-resolution optical imager
TERRA	MODIS	Moderate-resolution optical imager

Table 2. List of the satellite platforms and instrument available for the interactive visualization in the Beta version of the 3D tool.

Along with the geographical mapping of the existing observing capabilities, the 3D tools permit an analysis of the degree of temporal sampling mismatch between satellite instruments and surface based stations for a certain number of EO platforms. To this end, the tool allows the users to submit queries to plot at the same time all the available stations measuring one or more ECVs (for a different maturity level) along with the ground track of a selected satellite platform. The swath of each satellite instrument can also be plotted. Real-time animation of satellite performance can be selected, but the user is also allowed to select a specific time interval for the visualization of the satellite orbit. The software can manage a large number of satellite platforms (currently up to 115). However, for the purpose of the VO the list has been restricted

to those platforms, reported in Table 2, which have been identified as the most relevant for the GAIA-CLIM project. The list will be expanded before the release of the final software version expected at month 30 of the project (D1.9: "Final version of a 3D tool for the online visualization of existing measurements", due on 31st August 2017), in agreement with the VO and user requirements.

4. 3D visualization tool

Starting from this section, we provide a short tutorial for the use of the 3D tool developed within GAIA-CLIM task 1.3, which also represents an entry point to the VO and allows users to search in the list of the observing capability reviewed within Task 1.2 as well as to simultaneously show satellite positions around the Earth.

The tool has been implemented on the basis of Cesium, a virtual globe open source written in Javascript that is based on a large community that guarantees its continuous development, improvement and a detailed assistance to any issues.

To implement the 3D tool, along with Cesium, other open source software has been used such Geoserver, Geonetwork, Postgresql, Postgis, Predict4java, Spring and Hibernate.

The Beta version of the 3D visualization tool is able to:

- Explore discovery metadata (including maturity matrix scores) from the Task 1.2 collection.

- Visualize ground-based networks measuring those ECVs listed in GAIA-CLIM grant agreement (Atmosphere and Ocean domains).

- Visualize real-time satellite orbits, footprint and swath for each instrument aboard; the visualization can simultaneously plot two satellite instruments.

- Filter the available discovery metadataset per ECVs, measurement type (column, profile, …), network, measurement maturity level.

The Beta version of the 3D visualization tool is publicly accessible through the CNR geo-webportal at http://150.145.73.221/Cesium/Apps/GaiaClim/.

The implementation of the GUI and key functionalities has also been driven by the needs of the user community as determined in the GAIA-CLIM user survey and by user workshops.

4.1. GUI

The GUI of the 3D tool, as it appears to the user, is shown in Fig.1. In the middle of the screen there is the virtual globe on which the user can perform several standard operations such as zooming or change the map projection, in the manner described later on in this section; at the left side are several menus enabling the filtering of the metadataset and the satellite instrument

to be visualized. Below, all the functionalities of the 3D software are described: the different menus of the GUI are numbered (in yellow) in Fig. 1 and each of these numbered sections are described in details step-by-step.
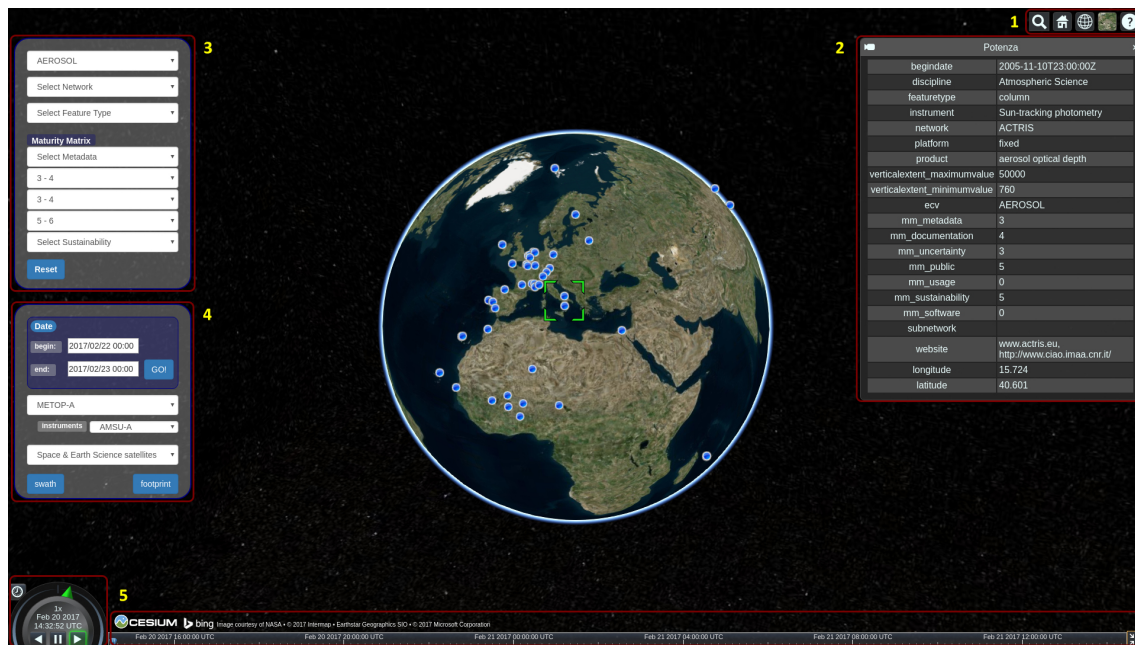

Figure 1. Snapshot of the GUI for the 3D tool. All the menus available in the GUI are numbered (in yellow) and linked to the next Figures where they are described in detail.
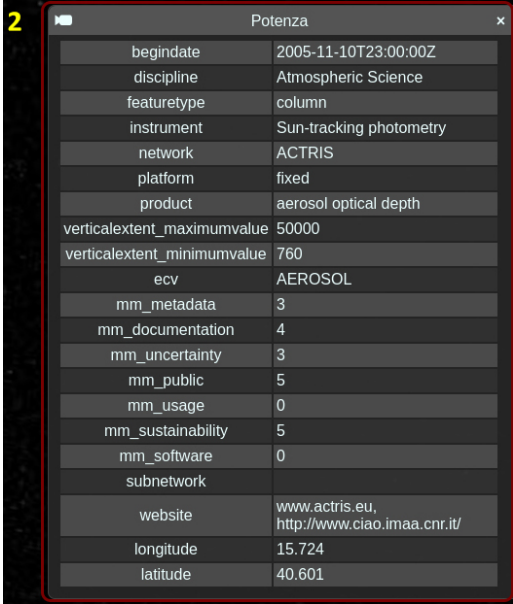
4.1.1. Cesium basic commands

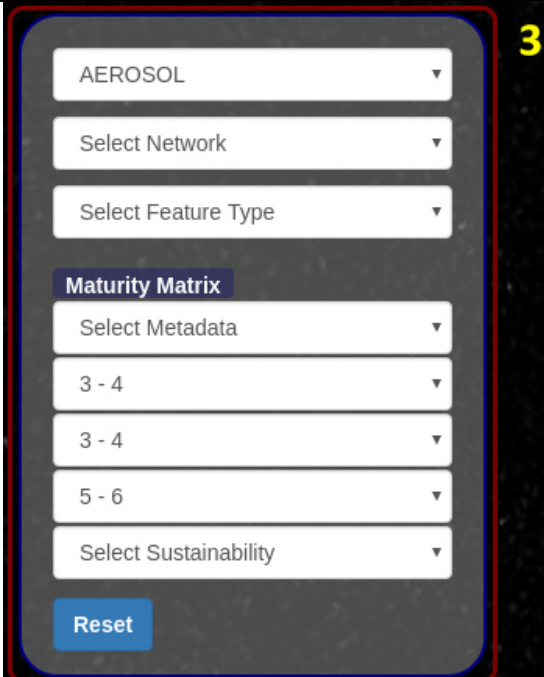|	
	The user can type the name of the location to be searched for; tooltips are provided based on the typed entry.
	Clicking on the 'Home' button you will be redirected to the default display (by default Europe is shown).
	Clicking here the user can change the visualization mode. The default is 3D view, but also 2D and Columbus view are available.
	In this section, you can choose some imagery to show on the surface of the globe; Bing services are available, but also Mapbox, ESRI, OpenStreet and others. In addition to the imagery you can also view the Earth's terrain through the Analytical Graphics Service Inc., STK World Terrain.

	Clicking on this button you will get the basic information on how to change the view of the globe; this also includes all the available explanations of the controls for touch devices.

4.1.2. Panel of the details

	This menu can be activated by clicking on the blue icons visualized on the globe and representing the measurement station reviewed within Task 1.2. This panel summarizes all the information contained in the discovery metadata for the selected station. On the top left side, there is an icon with the symbol of a camera; clicking on it, the view remains anchored to the selected station.
Potenza	
begindate	2005-11-10T23:00:00Z
discipline	Atmospheric Science
featuretype	column
instrument	Sun-tracking photometry
network	ACTRIS
platform	fixed
product	aerosol optical depth
verticalextent_maximumvalue	50000
verticalextent_minimumvalue	760
ecv	AEROSOL
mm_metadata	3
mm_documentation	4
mm_uncertainty	3
mm_public	5
mm_usage	0
mm_sustainability	5
mm_software	0
subnetwork	
website	www.actris.eu, http://www.ciao.imaa.cnr.it/
longitude	15.724
latitude	40.601

In the lower part of the panel, the link for the connection with the VO back-end GUI will be provided before the final software release.
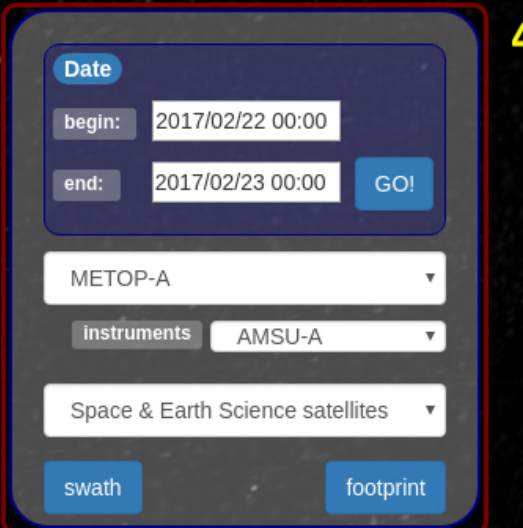
4.1.3. Discovery Metadata filtering

This section contains all the filters which can be applied on the global discovery metadataset; the available options allow the user to filter the data per ECV, Network and Feature Type. The selected values are applied as a logical 'AND' and the activation of a filter automatically enables only those observations which are pertinent to that filter option (e.g., if the user selects water vapor, in the network filter menu there will be only those networks measuring water vapor).

Networks (and stations) can also be filtered according to the measurement level of maturity assessed using the most relevant

	categories defined in the measurement system maturity matrix (MSMM): the categories are Metadata, Documentation, Uncertainty, Public and Sustainability. For each category Comprehensive, Baseline and Reference can also be selected. Finally, the user can reset the filters by clicking on the 'Reset' button.

4.1.4. Satellite platforms

This section is dedicated to filters enabling the visualization of the satellite orbits.

The user sets a time range and by clicking on the "GO!" button, the animation of satellite orbits will be shown. For each satellite the list of instruments operated on-board is provided and can be selected; once the user has selected a specific instrument, clicking on the 'Swath' button, a red rectangle will be drawn onto the Earth surface as wide as the swath of the selected instrument (Fig. 2). Besides the rectangle, an orange circle representative of the maximum field of view of the satellite according to its distance from the Earth surface is also drawn. Finally, by clicking on the 'Footprint' button you can see the satellite's nadir overpass at the ground.
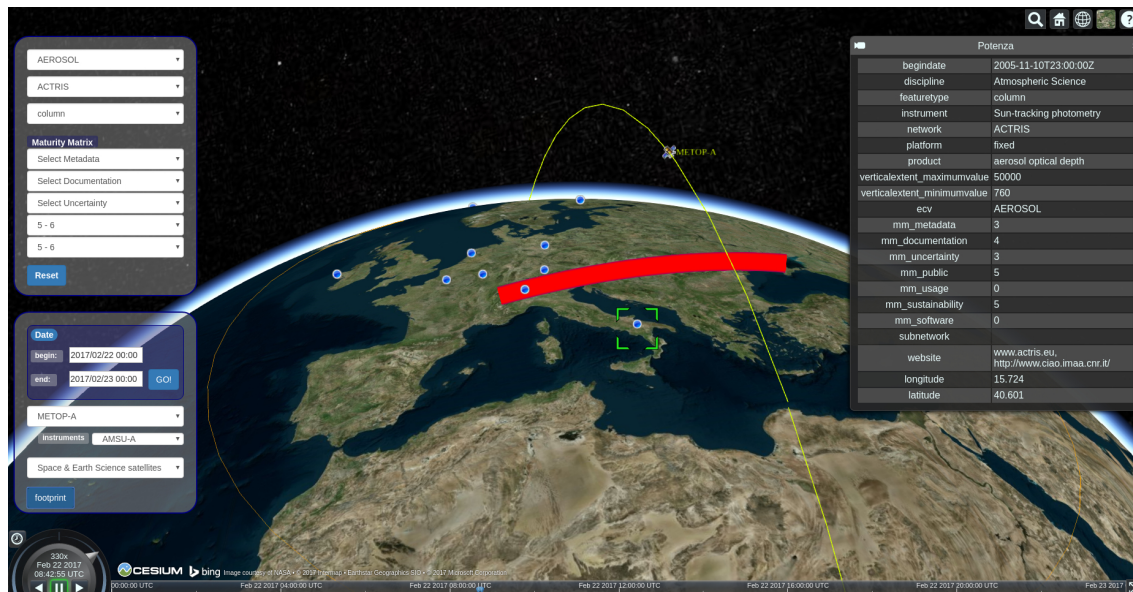
Figure 2: View of the 3D tool including the ACTRIS network stations performing columnar aerosol measurements classified as "Reference" for the category " Public and Sustainability" of the measurement system maturity matrix (MSMM). The orbit of the satellite Metop-A and its position on the date 22.02.2017 08:42:55 UTC is also shown along with the swath of AMSU-A. In the right part of the image, the information panel reporting the discovery metadata of the ACTRIS Potenza station are displayed.

4.1.5. Time bar

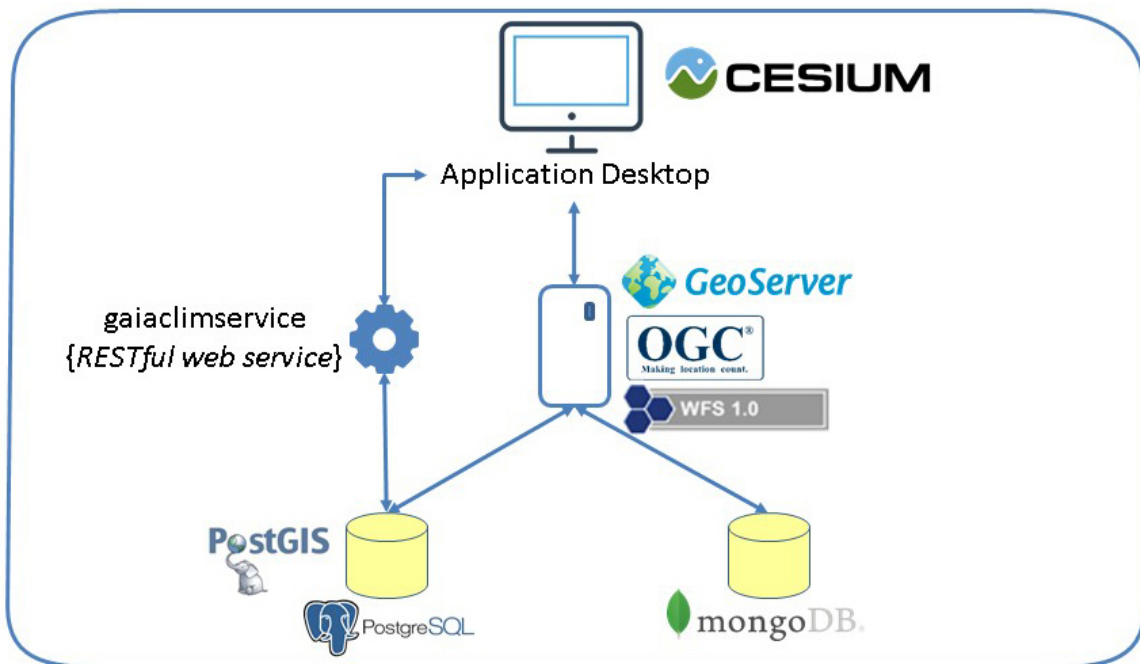|	
	The Cesium clock and the time bar are the tools that allow you to easily select over time the satellite positions along its orbit. The user can increase the speed by dragging the green triangle positioned on the top of the watch or alternatively by clicking anywhere on the time bar in the lower part of the screen.

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4.2. Software architecture

Figure 3: diagram of the 3D tool software architecture.

In this section, a quick description of the architecture of the Cesium 3D tool is provided.

The highest layer of the architecture is represented by Cesium, the virtual globe chosen to become the graphic user interface for the 3D tool; in the lower layer, there is the DB, Postgresql; finally, in the middle we have introduced Geoserver, an open source web application which provides geospatial data, in compliance with the international standards set by OGC (WFS 1.0 [one point zero] in this case, Lowe et al., 2011).

It has been necessary to introduce this intermediate layer to unhook Task 1.3 activity from that of the VO, in order to continue the development of the 3D tool without MongoDB, the DB selected for the implementation of the VO; the future transition of the metadatabase from Postgresql to MongoDB will be facilitated by Geoserver: indeed, changing the configuration of the existing layers in Geoserver the transition will be automatically achieved.

In addition to Geoserver, a RESTful web service was added to the middle layer in order to support Cesium, which includes information on satellite platforms and the sensors operated on-board. This solution completely separates the user interface from the database, excluding any issue related to changes in the implemented technology.

The visualization of the metadatabase collected by Task 1.2 of the GAIA-CLIM project, currently available using the CNR geo-webportal, is going to be transitioned such as to be available through the GUI of the VO.

In Fig.4, a sketch of the VO overall architecture (largely described in D1.7) is reported which shows the role of the Cesium front-end GUI with respect to the rest of the VO and the DB. The

integration of the Cesium 3D tools within the VO is in progress and will be completed by Month 30 of GAIA-CLIM.
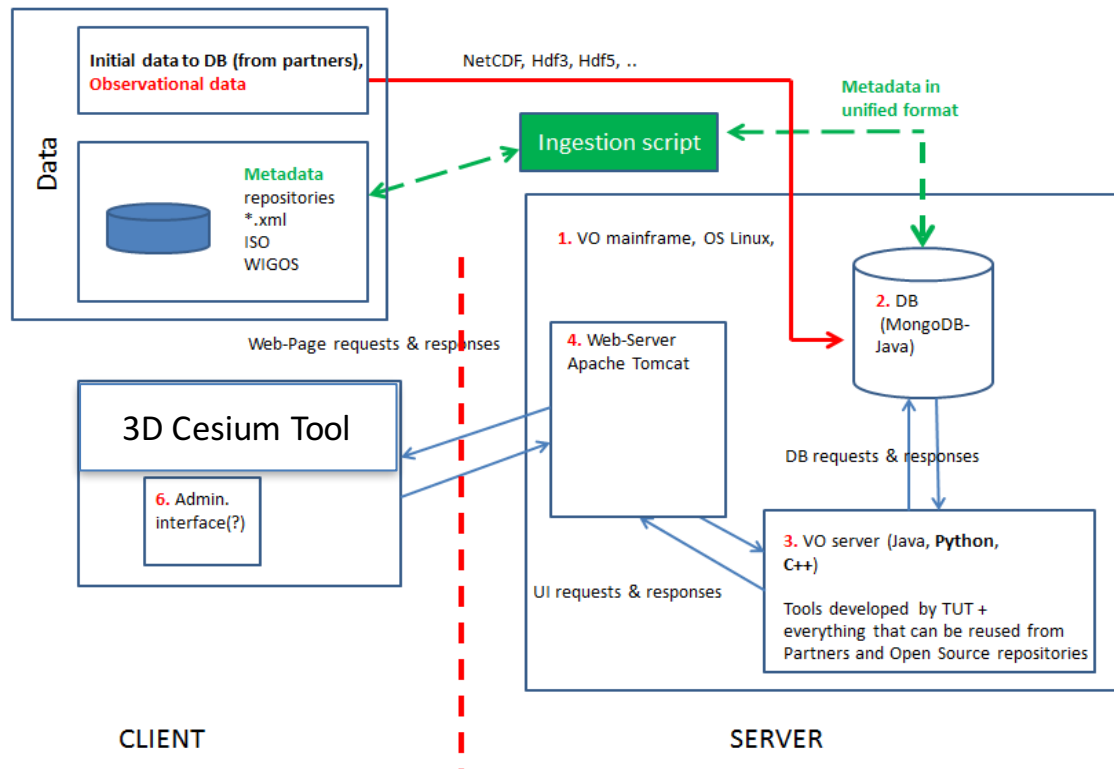

Figure 4: Sketch of the VO architecture – Client (as VO GUI), Server with DB, Web-Server and Server Software supporting the VO and GUI functionalities. The 3D Cesium interface will be the front-end GUI for the VO.

5. Summary

In this document the main functionalities of the 3D visualization tool developed within Task 1.3 as the front-end-GUI of GAIA-CLIM 'Virtual Observatory' (VO) are described. The tool provides a 3D description of all identified stations available which are monitoring ECVs worldwide, providing in-situ surface, in-situ sounding, columnar and profiling observations. Along with the geographical mapping of the existing observing capabilities, the 3D tools permit an analysis of the degree of temporal sampling mismatch between satellite instruments and surface based stations for a relevant subset of EO platforms. Real-time animation of satellite performance can be selected but the user is also allowed to select a specific time interval for the visualization of the satellite orbit. The software contributes to maximizing the value of existing observations for the satellite cal/val supporting the users in the selection of the most appropriate dataset for their specific studies (network, spatial and temporal domains).

The 3D tool is able both to work as a stand-alone software and as a module of the VO. The integration of the Cesium 3D tools within the VO is in progress and will be completed by Month

30 of GAIA-CLIM. The 3D tool architecture will strongly facilitate the integration in the VO and will exclude any future issue related to changes in the implemented technology.

Acknowledgements

References

Bojinski, S., M. Verstraete, T.C. Peterson, C. Richter, A. Simmons, and M. Zemp. The Concept of Essential Climate Variables in Support of Climate Research, Applications, and Policy. Bull. Amer. Meteor. Soc., 95, 1431–1443 (2014).

Lowe D. and Woolf A. (2011): CSML 3.0 presentation from OGC MetOcean Domain Working group (http://external.opengis.org/twiki_public/pub/MetOceanDWG/MetOceanDWGBonn/CSMLV 3_Lowe.pdf).

Glossary

CESIUM	Cross-platform virtual globe for dynamic-data visualisation in the space and defense industries
DB	DataBase
ECV	Environmental Climate Variable
EO	Earth Observation
GCOS	Global Climate Observing System
GUI	Graphical User Interface
OGC	Open Geospatial Consortium

Appendix A: Software installation

The 3D tool is distributed along with all the components which are integral part of the software architecture; this is the content of the installation package:

1. A virtual machine with OS Lubuntu on which the whole environment is installed;

2. The Cesium folder containing the 3D tool to install in Tomcat;

3. The Geoserver folder containing an instance of the Geoserver; datasource and layers are already configured for their use in Cesium;

4. The gaiaclimservice.war package containing the REST web service that provides satellite information to Cesium

5. gaiaclimDB.sql.zip, the database dump

As indicated at the point 1, a virtual machine is available on which it is installed all the component needed by the user; if you want to perform a new installation on a different server, you can proceed with the following steps:

1. DB Installation and loading data

From the terminal, type the following commands (instead of 'x' write the version available for your distribution):

```
sudo apt-get install postgresql-9.x postgresql-9.x-postgis-2.x
sudo su postgres
createdb gaiaclim
psql -d gaiaclim -f /usr/share/postgresql/9.x/contrib/postgis-
2.x/postgis.sql
psql -d gaiaclim -f /usr/share/postgresql/9.x/contrib/postgis-
2.x/spatial_ref_sys.sql
```

Then it must be loaded the sql script:

```
psql -d gaiaclim -f gaiaclimDB.sql
```

Finally you need to change the password of the user 'postgres' ('_$gaiaDbPsW$_' is the password with which it's configured also geoserver):

```
ALTER USER postgres with encrypted password '_$gaiaDbPsW$_';
```

2. Installing Java

From the terminal, type the following commands:

```
sudo add-apt-repository ppa:webupd8team/java
sudo apt-get update
sudo apt-get install oracle-java8-installer
```

3. Installing Tomcat

Download from the official website the binary distribution and unpack the zip into a folder (eg /home/xxxx/sw).

Go to the 'bin' directory and make executable the 'catalina.sh' file.

```
chmod + x catalina.sh
```

4. Deploy Cesium, Geoserver and gaiaclimservice

Copy the folders 'Cesium' and 'geoserver' and the file 'gaiaclimservice.war' in webapps folder of Tomcat.

In the terminal, go to the 'bin' folder of Tomcat and type:

```
./catalina.sh start
```