

Gap Analysis for Integrated Atmospheric ECV CLimate Monitoring

WP1: Mapping Geographical Capabilities

**D1.9 Final 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 those 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:

- Aerosol
- Carbon dioxide
- Carbon monoxide
- Methane
- Nitrogen dioxide
- NO_x
- Ozone
- Temperature
- Oceanic temperature and salinity
- Water vapour

Within WP1, Task 1.3 has the objective to map the observing capabilities arising from the discovery metadata set, collected within Task 1.2, through the design and implementation of a visualization tool providing 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 beta version of the 3D visualization tool has been described in the deliverable D1.8 “Beta version of a 3D tool for the online visualization of existing measurements” and has been made available for external use at the link <http://150.145.73.221/Cesium/Apps/GaiaClim/>.

This deliverable follows-up to the deliverable D1.8, by integrating the tool within the Virtual Observatory and completing the documentation. To this purpose, much of the content of D1.8 is repeated again in the current deliverable to enable the use of this document as a user guide for the 3D-visualization tool.

In its final version, the tool is able to visualize all of the surface based observing capabilities described in the deliverables D1.6 and D1.7. Earth Observation (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.

As already state in the deliverable D1.8, 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

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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, represents the front-end Graphical User Interface (GUI) of the GAIA-CLIM 'Virtual Observatory' (VO) for data discovery. The 3D tool can also work as a stand-alone software package and can be easily integrated into a variety of other existing web portals. The 3D tool enables the user to read the measurement 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 and collocations with satellite measurements through the VO back-end interface.

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.

This product provided within the GAIA-CLIM Task 1.3 is also aligned with the objectives of the Copernicus Climate Change Service (C3S), 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. 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 the two user workshops.

A summary of the observing capabilities collected by Task 1.2, and made available through the 3D tool, was reported within the deliverable D1.8 and has not changed since. The reader is referred to this document for further information. The list of satellites available in the 3D tool has been updated and is presented in Section 2. In Section 3, the tutorial on the use of the 3D tool is presented: 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).

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2. Satellite platforms

The 3D tools permit an analysis of the degree of temporal sampling mismatch between selected 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 the platforms reported in Table 1, extended with respect to the previous list reported in deliverable D1.8 describing the beta-version. The satellite platforms and instruments reported in Table 1 have been identified as the most relevant for the GAIA-CLIM project.

Satellite Platform	Instrument name	Instrument type
CALIPSO	CALIOP	Space visible and infrared lidar
FENGYUN 3A FENGYUN 3D FENGYUN 3C	ERM-1	Broadband radiometer
	IRAS	Infrared Sounder
	MERSI-1	Medium Resolution Spectral Imager
	MIRAS (only for 3C)	Microwave Imaging Radiometer with Aperture Synthesis
	MWHS-2	Microwave Humidity Sounder
	MWRI (only for 3C)	Microwave Radiation Imager
	MWTS-2(only for 3C)	Microwave Temperature Sounder
	TOU	UV ozone Spectrometer
VCRR (only for 3C)	Visible and infrared Radiometer	
GCOM W1	AMSR-2	Microwave Scanning Radiometer
GPM-CORE	GMI	Microwave Imager
MEGHA-TROPIQUES	SAPHIR	Microwave sounder for probing vertical profiles of humidity
METEOSAT-7	MVIRI	Visible and infrared Imager
METEOSAT-10 (MSG-3) METEOSAT-9 (MSG-2) METEOSAT-8 (MSG-1)	SEVIRI	Spinning Enhanced Visible and infrared Imager
METEOR-M-2	MTVZA-GY	Imaging/Sounding Microwave Radiometer
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

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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 1. List of the satellite platforms and instrument available for the interactive visualization in the beta version of the 3D tool.

3. 3D visualization tool

In this section, a short tutorial on the use of the 3D tool is provided. The VO front-end GUI allows users to search based upon non-satellite observing capabilities reviewed within Task 1.2, as well as to simultaneously show satellite positions around the Earth. The software architecture and the guidelines for its installation are reported in the Appendices A and B, respectively.

The tool has been implemented on the basis of Cesium, a virtual globe open source written in Javascript that is supported by 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, including Geoserver, Geonetwork, Postgresql, Postgis, Predict4java, Spring and Hibernate.

The 3D visualization tool is publicly available at the web portal <http://150.145.73.221/Cesium/Apps/GaiaClim/> powered by CNR and it is linked to the VO hosted at EUMETSAT. By M35, with the final version of the GAIA-CLIM VO, the link between the two web portals will become transparent to end-users.

3.1. 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 changing the map projection in the manner described later on in this section. On the left side are several menus enabling the filtering of the metadata set and the satellite instrument to be visualized.

In the following, all the relevant 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.

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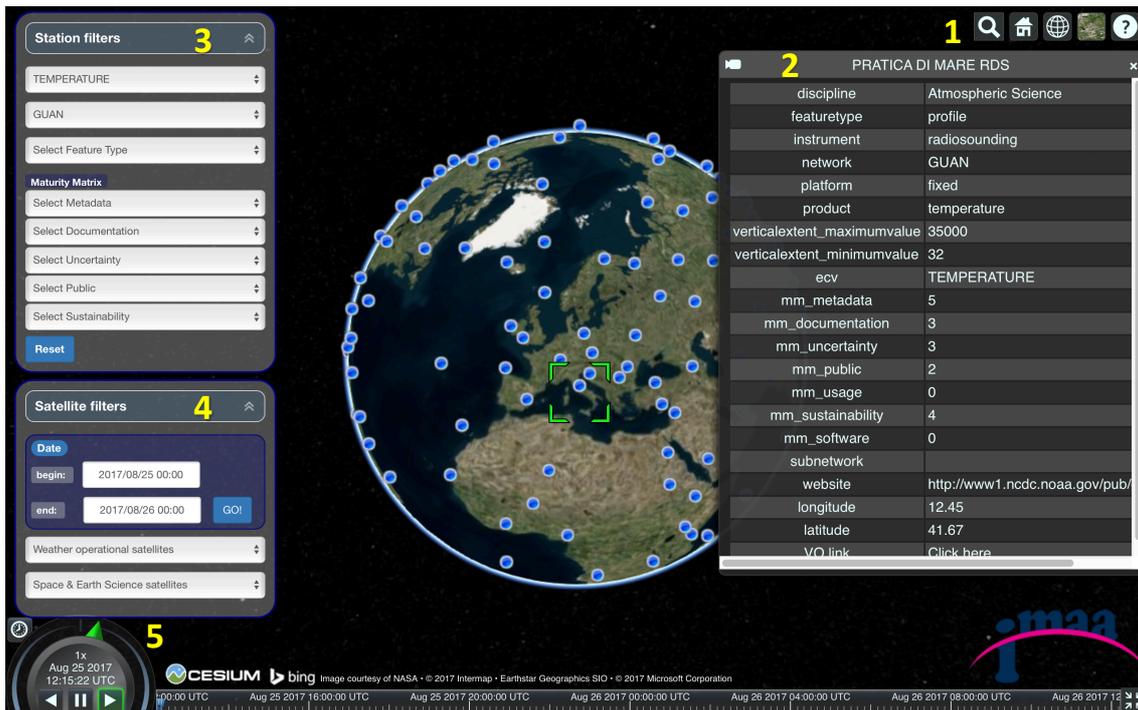


Figure 1. Snapshot of the GUI for the 3D tool. All the menus available in the GUI are numbered (in yellow) and linked to the next figures where they are described in detail.

3.1.1. 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

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devices.

3.1.2. Panel of the details

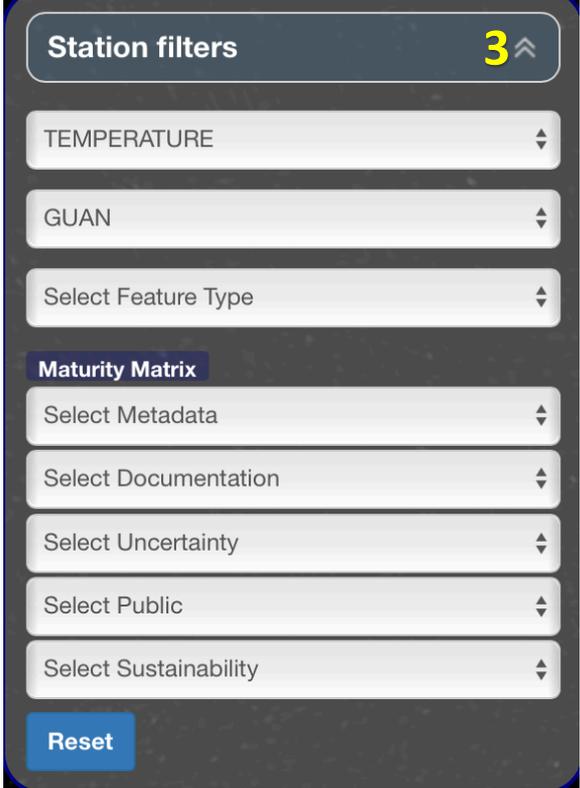
PRATICA DI MARE RDS	
discipline	Atmospheric Science
featuretype	profile
instrument	radiosounding
network	GUAN
platform	fixed
product	temperature
verticalexent_maximumvalue	35000
verticalexent_minimumvalue	32
ecv	TEMPERATURE
mm_metadata	5
mm_documentation	3
mm_uncertainty	3
mm_public	2
mm_usage	0
mm_sustainability	4
mm_software	0
subnetwork	
website	http://www1.ndbc.noaa.gov/pub/
longitude	12.45
latitude	41.67
VO link	Click here

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.

In the last row of the panel, the link for the connection with the VO back-end GUI ("VO link) permits the user to submit a query to the VO database and to check whether measurements are available and to collocate them with the GAIA-CLIM selected list of satellites.

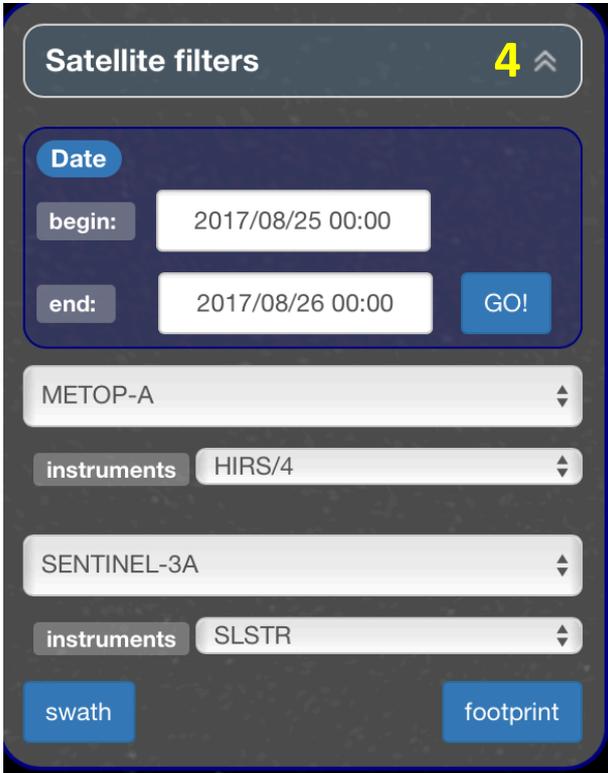
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3.1.3. Discovery Metadata filtering

	<p>This section contains all the filters, which can be applied on the global discovery metadata set; 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 vapour in the network filter menu, only those networks measuring water vapour are shown).</p> <p>Networks (and stations) can also be filtered according to the assessed level of measurement maturity using the most relevant categories defined in the measurement system maturity matrix (MSMM). These categories are metadata, documentation, uncertainty, public and sustainability. For each category comprehensive, baseline and reference observations can also be selected.</p> <p>Finally, the user can reset the filters by clicking on the 'Reset' button.</p> <p>To match with the different screen resolutions and avoid overlaps between the different menus and the main frame of the GUI, the menu can be dropped up and down using the arrows on the top-right. A few issues may still be observed with laptop screens smaller than 10 inches caused by specific constraints of Cesium minimum image resolution; nevertheless, the GUI usage is still fully functional for the user. . Therefore, use on mobile devices is discouraged at this time.</p>
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3.1.4. Satellite platforms

	<p>This section is dedicated to filters enabling the visualization of the satellite orbits.</p> <p>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.</p> <p>As for the menu #3, to match with the different screen resolutions and avoid overlaps between the different menus and the main frame of the GUI, the menu can be dropped up and down using the arrows on the top-right. Issues with the screen resolution have been described above.</p>
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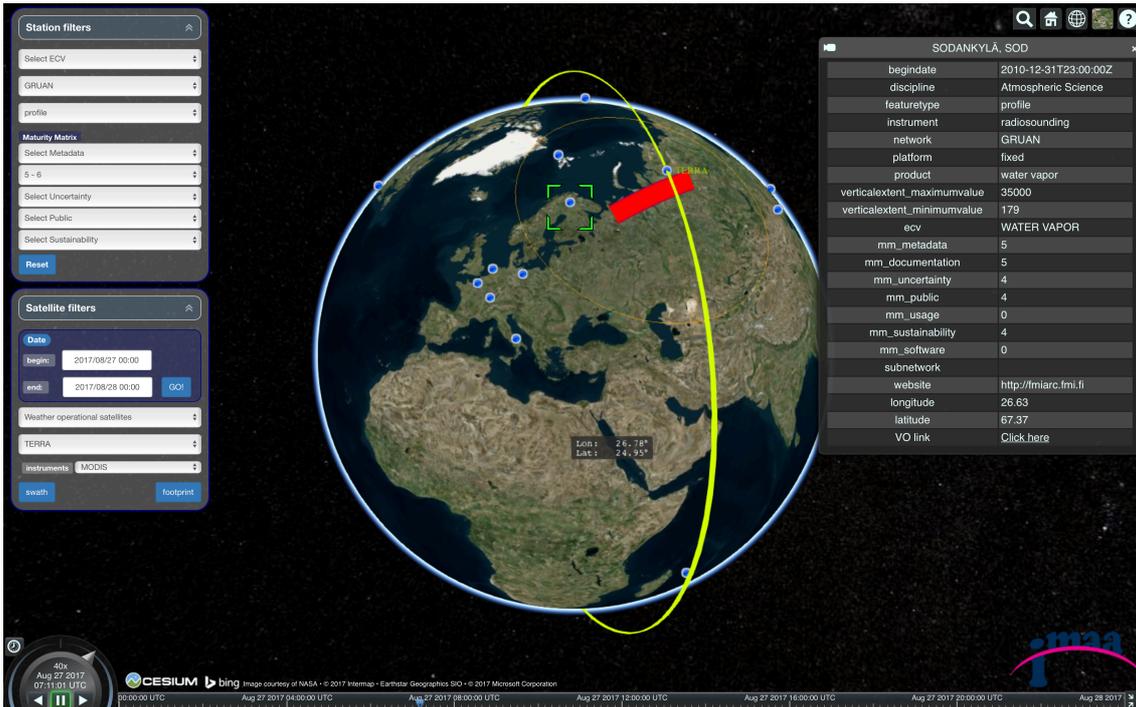


Figure 2: View of the 3D tool including the GRUAN network stations performing columnar aerosol measurements classified as “Reference” for the category “Documentation” of the measurement system maturity matrix (MSMM). The orbit of the satellite TERRA and its position on 27.08.2017 at 07:11:01 UTC is also shown along with the swath of TERRA. In the right part of the image, the information panel reporting the discovery metadata of the Lindenberg station are displayed.

3.1.5. Time bar

The image shows a close-up of the time bar interface. On the left, there is a watch face displaying '1x', 'Feb 20 2017', and '14:32:52 UTC'. To the right of the watch is a large yellow number '5'. Below the watch and number is a time bar with a green triangle at the top and a red line at the bottom. The time bar is labeled 'CESIUM' and 'bing' and shows the date and time 'Feb 20 2017 16:00:00 UTC'. The interface also includes a 'CESIUM' logo and 'bing' branding.

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.

4. Summary

In this document, the main functionalities of the 3D-visualization tool developed within Task 1.3 as the front-end GUI of the 'Virtual Observatory' (VO) are described. The tool provides a 3D description of all identified stations available that 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 tool permits 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 3D tool is able to work as a stand-alone software application and can also be integrated into other platforms. The Cesium 3D is now integrated in the VO; the final version of the VO will allow to maximize 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) and enabling the retrieval of co-location datasets through the VO back-end interface. The 3D-tool architecture also excludes any future issues related to changes in the implemented technology.

Acknowledgements

The final version of the presented 3D tool uses the JavaScript library of Cesium in the Apache 2.0 license agreement with which it is distributed. Consistent with conditions of use, in our 3D tool, the logo of Cesium and a link to its website are present.

Thanks to Shane Carty (University of Dublin) for his recommendations in the use of Cesium and for the friendly discussions had during the development of the 3D tool.

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/CSMLV3_Lowe.pdf).

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Glossary

CESIUM	Cross-platform virtual globe for dynamic-data visualisation in the space and defence 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 architecture

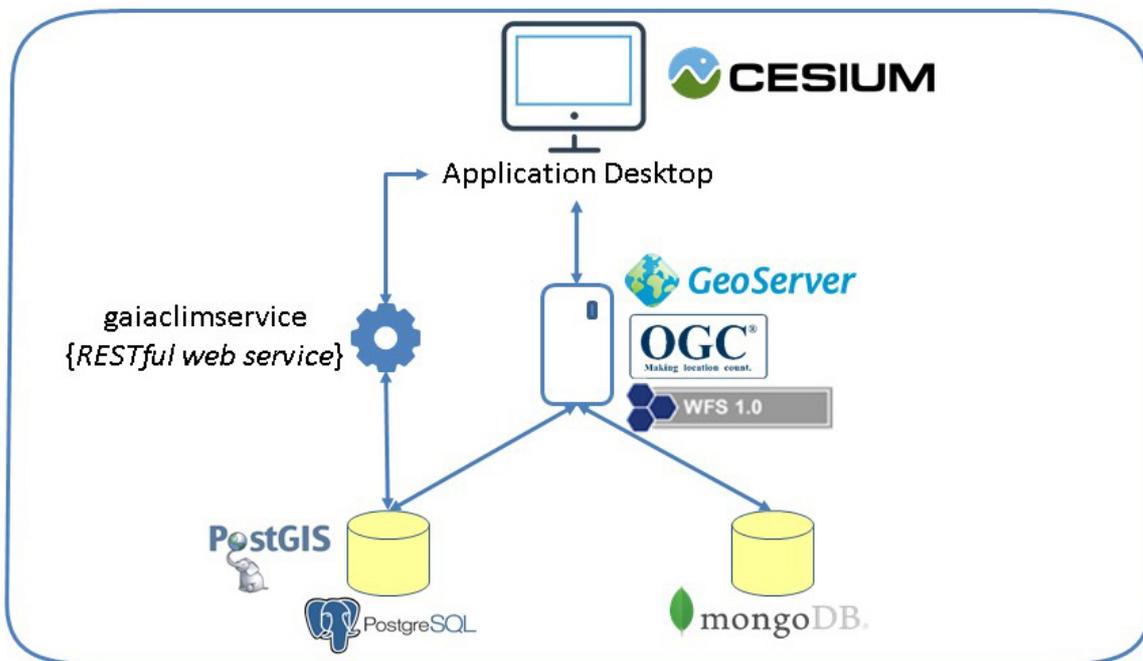


Figure 3: diagram of the 3D tool software architecture.

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 GUI 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 the 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 metadata base from Postgresql to MongoDB will be facilitated by Geoserver; in fact, by 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 metadata base collected by Task 1.2 of the GAIA-CLIM project, currently available using the CNR web portal, 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 presented, which

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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 end of GAIA-CLIM.

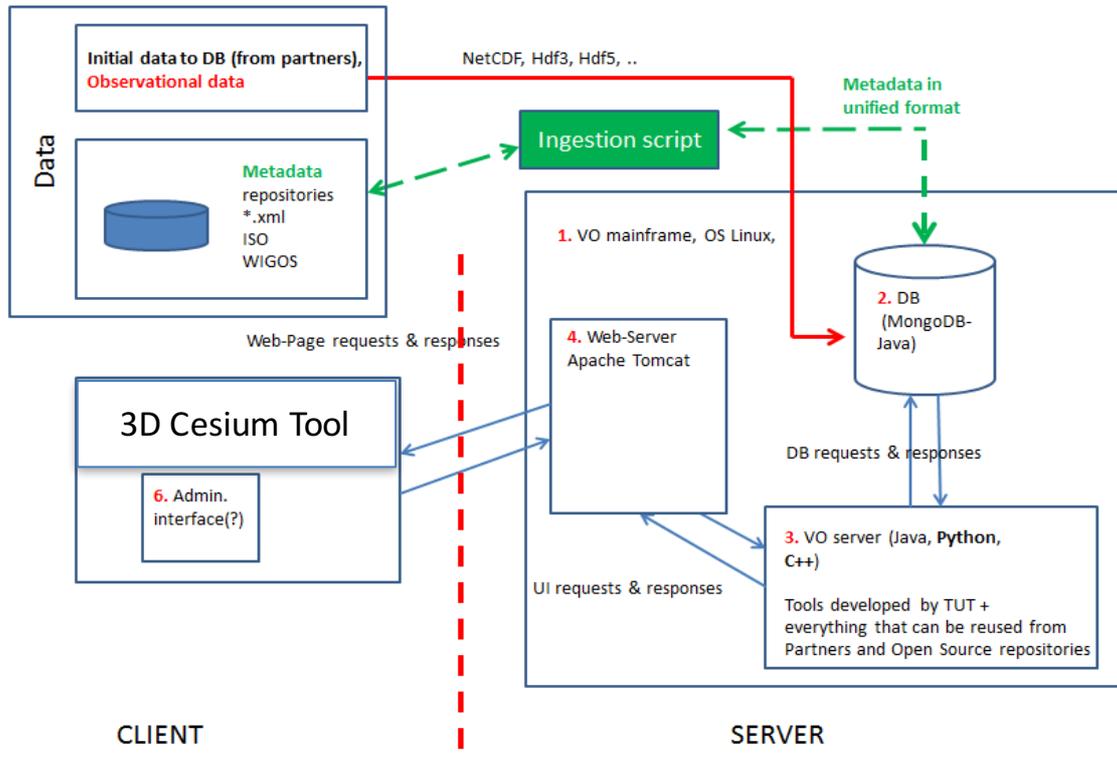


Figure 4: Sketch of the VO architecture – Client (as VO GUI), Server with DB, Web-Server and Server Software supporting the VO and GUI functionalities. The 3D Cesium interface will be the front-end GUI for the VO.

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Appendix B: Software installation

The 3D tool is distributed along with all the components, which are integral to 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; data source 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

A virtual machine is available on which it is possible to install all the components 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 you must load 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 '_$gaiaDbPsW$_';
```

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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
```