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End-to-end implementation and operation of the European Ground Motion Service (EGMS)



End User Requirements

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1. INTRODUCTION

1.1. Scope of the Document

The satellite interferometric technique used as a basis for the EGMS has a variety of possible applications. The needs of the end-user community vary in terms of size of the area of interest, frequency of updates and accuracy of measurements. However, two crucial characteristics are ensured by the EGMS:

- The service has been designed to allow unrestricted and timely access to ground motion information for all citizens in the Copernicus Participating States.
- The products delivered by the service are standardised to be useful for as many applications as possible.

This document describes, in a consistent and referenceable way, the end user requirements (URs) relevant for the EGMS products and services. The three product levels of EGMS , Basic, Calibrated and Ortho, were defined to meet such requirements.

The user requirements and the way the EGMS meet them are described in Section 4 Key User requirements.

1.2. References and Related Documents

ID	Reference or Related Document	Date	ID	Source or Link/Location
RD1.	European Ground Motion Service: Service Implementation Plan and Product Specification Document	28/01/2020	Version 1.01	https://land.copernicus.eu/user-corner/technical-library/egms-specification-and-implementation-plan
RD2.	Call for tenders EEA/DIS/R0/20/011 ANNEX I – TENDER SPECIFICATIONS	25/05/2020	Ref. Ares(2020)2691682	https://etendering.ted.europa.eu/document/document-file-download.html?docFileId=85693
RD3.	Report on the user requirements in the Copernicus domain to support Cultural Heritage management, conservation and protection	2020	Copernicus Cultural Heritage Task Force ID unknown	https://ra;brage.unit.no/xmlui/handle/11250/2650038
RD4.	White Paper European Ground Motion Service (EU-GMS) - A proposed Copernicus service element	21-Sep-2017	White Paper Issue 1.0	https://land.copernicus.eu/user-corner/technical-library/egms-white-paper
RD5.	Validation of the EGMS Product Portfolio	05/03/2021	Version 6.0	https://land.copernicus.eu/user-corner/technical-

ID	Reference or Related Document	Date	ID	Source or Link/Location
				library/european-ground-motion-service
RD6.	Interaction and cooperation between the European Ground Motion Service and national/regional Ground Motion Services	22/06/2020	Version 3.0	https://land.copernicus.eu/user-corner/technical-library/egms-specification-and-implementation-plan
RD7.	Algorithm Theoretical Basis Document	20/12/2021	EGMS-D3-ALG-SC1-2.0-006	EGMS ORIGINAL Consortium
RD8.	Product User Manual	10/05/2022	EGMS-D4-PUM-SC1-2.0-007	EGMS ORIGINAL Consortium
RD9.	End User Interface Manual	10/05/2022	EGMS-D5-UIM-SC1-2.0-008	EGMS ORIGINAL Consortium
RD10.	Product Description and Format Specification Document	20/12/2021	EGMS-D6-PDD-SC1-2.0-009	EGMS ORIGINAL Consortium
RD11.	Quality Assurance & Control Report	03/05/2022	EGMS-D10.4-QCR-SC2-042	EGMS ORIGINAL Consortium
RD12.	User Uptake and Communication Plan	15/10/2021	EGMS-D14-UUP-SC1-8.0-016	EGMS ORIGINAL Consortium
RD13.	GNSS calibration Report	20/12/2021	EGMS-D19.2-GCR-SC1-3.0-031	EGMS ORIGINAL Consortium

Table 1 Reference Documents

1.3. Acronyms and Definitions

Acronym	Definition
API	Application programming interfaces
CLMS	Copernicus Land Monitoring Service
DS	Distributed scatterers
EEA	European Environment Agency
EGMS	European Ground Motion Service
EPOS	European Plate Observation System
GeoJSON	Open standard geospatial data interchange format based on JavaScript Object Notation (JSON)
GNSS	Global Navigation Satellite Syst
HLOP	(Sentinel) High-Level Operations Plan
InSAR	Interferometric Synthetic Aperture Radar
IW	Interferometric Wide (swath mode)
KMZ	Keyhole Markup language Zipped
LOS	(satellite) line-of-sight
PS	Point-wise, persistent, scatterers
PSD	Product Specification Document
QC	Quality Control
SAR	Synthetic Aperture Radar
Shapefile	Digital vector storage format for storing geometric location and associated attribute information
WebGIS	Web (technology) Geographical Information System
WebGUI	Web Graphical User Interface

2. TARGET USERS OF THE SERVICE

The service is planned to be open and easily accessible by as many users as possible. The most important user's communities identified are [RD1, RD4]:

- Public authorities at European, national, regional and municipal levels
- Citizens of Copernicus participating states
- Oil and Gas Industry Academia
- Natural and man-induced geohazard risk assessment
- Geological and geodetic surveys
- Land management, urban and rural planning
- Climate services
- Infrastructure development and management
- Mining and other natural resources extraction
- Dam and groundwater monitoring
- Insurance topics and litigations
- Structural and civil engineering
- The property market
- Railway and road management

According to the principal user communities identified, it is possible to distinguish among the following thematic areas:

Geohazards	Civil Engineering & Infrastructure	Energy & Natural Resources	Cultural heritage
- Subsidence	- Buildings	- Oil&Gas	- Cultural
- Landslides	- Roads	- Power Plants	heritage
- Earthquakes	- Tunnels	- Wind Farms	conservation
- Volcanoes	- Bridges	- Powerlines	and
	- Railways	- Dams	management
	- Airports	- Mining	
	- Ports		

More details on thematic areas can be found in:
❖ RD8 Product User Manual
❖ RD9 User Uptake and Communication Plan

3. EGMS PRODUCTS

The EGMS portfolio has been defined during the service preparatory phase started in November 2016 and resulted in the “White Paper” [RD4] prepared with the involvement of a group of users including InSAR experts, geodesists and GNSS experts, geologists, geotechnical engineers, surveyors, and experts of infrastructure monitoring.

Sentinel-1 SAR data are delivered by ESA. Raw SAR images are designated Level 0, while single look complex (SLC) are designated Level 1. For this reason, the product level numbering begins at Level 2, which is derived from Level 1 data. In the EGMS service, the products are:

- “Basic” L2a
- “Calibrated” L2b
- “Ortho” L3

More details on EGMS products can be found in:

- ❖ RD8 Product User Manual
- ❖ RD10 Product Description and Format Specification Document

4. KEY USER REQUIREMENTS

An overview of all the Key User Requirements is provided in Table 2.

Paragraph reference	Requirement
4.1	The Product shall be updated annually
4.2	The Product shall cover the Copernicus Participating States
4.3	The Product shall be based on Sentinel 1 full resolution data
4.4	The Product shall contain spatially harmonised and consistent ground displacement information
4.5	The Products shall be produced in accordance with well-defined specifications.
4.6	The Product shall include line of sight velocity values
4.7	The Product shall include absolute ground displacement values
4.8	The Product shall include reprojected ground displacement values
4.9	The Product shall contain time series of deformation
4.10	The Product shall be viewable and hosted on a dissemination platform which is responsive and intuitive
4.11	The Product shall be downloadable
4.12	The Product shall be delivered in standard, open, and documented data and metadata formats
4.13	The Product shall be fully documented to facilitate efficient and correct use
4.14	User manuals and guidelines shall be made available to users
4.15	End users shall be supported via a dedicated help desk
4.16	The Product shall be accurate and quality controlled based on agreed and documented product specifications.
4.17	Quality and validation results shall be available to the end user
4.18	The Product shall be delivered to end users in an operational and continuous manner

Paragraph reference Requirement

- | | |
|------|--|
| 4.19 | The Product shall provide information in support of relevant ground displacement applications defined by end users |
| 4.20 | The Product shall be validated against end user requirements using independent data |
| 4.21 | The evolution of the Product is user driven |
| 4.22 | End users shall regularly be consulted regarding the applicability and quality of the Product |
| 4.23 | The Product shall be promoted via dedicated user uptake and awareness raising activities |

Table 2 A list of the Key User requirements

4.1. The Product shall be updated annually

The EGMS products shall consist of a baseline Basic, Calibrated, and Ortho products spanning from February 2015 till December 2020, and subsequent annual updates.

Update frequency refers to the frequency with which the displacement data is updated, although the full deformation history is recorded for each data point.

For applications that require a higher update frequency, the yearly provision of the EGMS products constitutes a valuable and validated reference at pan-European level that can be further exploited by specific downstream services.

4.2. The Product shall cover the Copernicus Participating States

Coverage refers to both the locality and the spatial extents of the measurement. Many user groups' applications focus on urban or built environments, the rural-urban interface, or other anthropogenic activities, while other applications are related to natural or geologic processes. In the case of urban infrastructure monitoring, targeted coverage with limited spatial extent is required. In another case of monitoring regional subsidence, wider coverage across urban and natural terrains is required to provide continuous results.

The first production cycle of EGMS will be covering the following land areas:

- Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Iceland, and Norway.
- France: The French Overseas Departments and Regions (DROMs) are included (French Guyana, Guadeloupe, Martinique, Mayotte and Réunion), whereas the French Overseas Territories (TOM) are excluded.
- Portugal: The Azores and Madeira archipelagos are included.
- Spain: The Canary and Baleares islands are included.
- United Kingdom: The Channel Islands Jersey and Guernsey, and the Isle of Man are excluded.
- Norway: The Svalbard archipelago and Jan Mayen are excluded.

More details on the definition of the current EGMS coverage can be found in:

- ❖ *RD1 European Ground Motion Service: Service Implementation Plan and Product Specification Document*
- ❖ *RD2 Call for tenders EEA/DIS/R0/20/011 ANNEX I – TENDER SPECIFICATIONS*

4.3. The Product shall be based on Sentinel 1 full resolution data

EGMS will provide ground motion time-series information with full spatial and temporal resolution using Copernicus Sentinel-1 data from descending and ascending orbits [RD4].

Temporal resolution refers to the acquisition frequency, i.e., the revisit period by the satellite for the same orbit configuration. The temporal resolution affects the maximum displacement velocity that can be observed. Low temporal resolution refers to a revisit period of 30 days or more; medium temporal resolution refers to a revisit period between 10 and 30 days, while high resolution means a revisit period of less than 10 days.

Basic, Calibrated and Ortho will be produced with the highest possible temporal resolution, i.e., in Europe 6 days revisit time (12 days revisit time until October 2016).

4.4. The Product shall contain spatially harmonised and consistent ground displacement information

Spatial resolution is a measure of the ground area imaged for the instantaneous field of view. EGMS will deliver data to be produced at the highest possible spatial resolution, i.e., Basic and Calibrated will have 5m x 20 m pixels size, while Ortho will be produced at 100m x 100m pixels

The large number of Basic products generated from the same radar geometry will be harmonised in the same product referenced to well-defined datum.

The activity will deal with data driven (relative) tile harmonisation approaches and Datum connection [RD1].

<i>More details on products format can be found in:</i>
<ul style="list-style-type: none">❖ RD1 European Ground Motion Service: Service Implementation Plan and Product Specification Document❖ RD10 Product Description and Format Specification Document

4.5. The Products shall be produced in accordance with well-defined specifications.

Products are produced according to the Product Specification Document (PSD) in [RD1]. The EGMS production workflow is designed according to the EGMS technical Specifications [RD2] and fully documented both in terms of product specifications than for the quality and validation protocols implemented.

<i>More details on production workflow can be found in:</i>
<ul style="list-style-type: none">❖ RD7 Algorithm Theoretical Basis Document❖ RD10 Product Description and Format Specification Document❖ RD11 Quality Assurance & Control Report❖ RD13 GNSS calibration ReportQuality Assurance & Control Report

4.6. The Product shall include line of sight velocity values

Basic displacement information will be provided through in the satellite line-of-sight (LOS). This is valid for EGMS Basic and Calibrated.

<i>More details on products format can be found in:</i>

❖ *RD10 Product Description and Format Specification Document*

4.7. The Product shall include absolute ground displacement values

Satellite InSAR allows to derive very accurate information about relative ground motion between two points during the analysed period, but it cannot directly measure absolute displacements.

In order to reference the ground motion estimates to an absolute frame of reference, auxiliary information must be considered such as GNSS network measurements and models. The Calibrated product does actually provide absolute ground displacement values (with reference to an Earth centred reference frame), anchored to a model derived from GNSS time-series data.

More details on the GNSS network used for EGMS can be found in:

❖ *RD13 GNSS calibration Report*

4.8. The Product shall include reprojected ground displacement values

Basic and Calibrated products are point databases (vectorial). As such, the choice of projection and datum do not affect the products themselves. They can be reprojected on-the-fly without any geometric distortion of the data.

Data will be delivered using the European Grid (ETRS89-LAEA), a standard based upon the ETRS89 Lambert Azimuthal Equal-Area projection coordinate reference system, with the centre of the projection at the point 52° N, 10° E. In addition, non-projected (geographic) coordinates using WGS-84 datum shall be annotated for each point in the Basic L2a/ Calibrated L2b products.

Ortho products are based upon a 100 m grid (raster), where each cell is dependent on the chosen projection and datum. When such data are reprojected, they must be resampled, and thus are susceptible to geometric distortions.

More details on products format can be found in:

❖ *RD10 Product Description and Format Specification Document*

4.9. The Product shall contain time series of deformation

The EGMS will provide time series of deformation with full spatial and temporal resolution Sentinel-1 images based on Persistent Scatterers and Distributed Scatterers interferometric analysis.

Over Europe, the current Sentinel High-Level Operations Plan (HLOP) ensures a revisit time for each observation geometry of 6 days in IW mode. The service will provide time series products using all the reliable samples temporally. In general, all images can be used in urban areas while, in natural terrain the influence of vegetation and weather (such as snow and rain) can limit the number of suitable images/samples.

More details on products format can be found in:

❖ *RD10 Product Description and Format Specification Document*

4.10. The Product shall be viewable and hosted on a dissemination platform which is responsive and intuitive

EGMS will provide ground motion data for tens of billions of locations, each with hundreds of individual measurement values (summary values, quality parameters and full deformation time series). Users need a web-based interface (WebGUI) for easy interaction with the data.

The dissemination and visualisation system will be intuitive to use, providing sufficient visualisation and data exploration capabilities such that the need to download data is avoided for most of the user needs.

More details for products visualisation can be found in:

- ❖ RD9 End User Interface Manual

4.11. The Product shall be downloadable

Search and download functionality will be available through the Product Archive and will require the user registration. The authorisation system will be based on the EU Login, while registration will occur on the main CLMS website.

More details for products download can be found in:

- ❖ RD9 End User Interface Manual

4.12. The Product shall be delivered in standard, open, and documented data and metadata formats

Ground motion metadata standards will be developed by the European Plate Observation System (EPOS) satellite data thematic core service. The metadata schema follows the ISO 19115 standard as reported in RD1 Table 4-1.

Ground motion data does not require a complicated file format. Each measurement point has a set of coordinates, a number of attributes summarising the average displacement and quality measures, as well as a set of cumulative displacement measurements, each with a specified date and time. All of this can be represented in a simple, two-dimensional table, with metadata attached. The simplest format is an ASCII text file, with delimiters, such as a csv file, along with a file containing metadata.

More details on products format can be found in:

- ❖ RD10 Product Description and Format Specification Document

4.13. The Product shall be fully documented to facilitate efficient and correct use

The technical and system documentation will facilitate the system maintenance, recovery, and migration operations and the user uptake of the EGMS and products.

In particular, the following public documents will facilitate the efficient and correct use of EGMS products:

Ref. ID	EGMS Deliverable ID and title	Description
RD7	Algorithm Theoretical Basis Document	Describe the algorithms and methodologies adopted for the generation of Basic, Calibrated and Ortho .
RD8	Product User Manual	Enable users to understand and efficiently and correctly use the EGMS products.
RD9	End User Interface Manual	Enable the user to efficiently and correctly use the EGMS dissemination platform.
RD10	Product Description and Format Specification Document	Describes the EGMS products, along with details of specifications, formats, attribute tables and metadata, plus other information considered of use to users of the service.
RD11	Quality Assurance & Control Report	Collect the outputs of the QC Protocol and demonstrate that the production of the EGMS' of Basic , Calibrated and Ortho follows the minimum quality requirements set by the Tender Specifications.
RD12	User Uptake and Communication Plan	Describe in detail the user uptake and communication plan and its main components with a focus on the involvement of different user groups.
This document	End User Requirements Document	Describe, in a consistent and referenceable way, all end user requirements relevant for the EGMS products and services
RD13	GNSS calibration Report	Present the results of the calibration based on GNSS data carried out during the EGMS's production. Offer an overview of the A-EPND GNSS model and evaluate the quality/accuracy level reached with the current availability of stations in Europe.

Table 3 EGMS Public documentation

4.14. User manuals and guidelines shall be made available to users

A User manual will explain the EMGS web interface and help the user to navigate and find the desired information.

More details about the Product User Manual and the EMGS web interface can be found in:

- ❖ RD8 Product User Manual
- ❖ RD9 End User Interface Manual

4.15. End users shall be supported via a dedicated help desk

To ensure a prompt assistance to user questions and issues, a Help desk will be accessible through the CLMS website.

The CLMS help desk is accessible here:

- ❖ <https://land.copernicus.eu/contact-form>

4.16. The Product shall be accurate and quality controlled based on agreed and documented product specifications.

Quality requirements have been introduced to ensure a successful service. The quality requirements have been drafted to be conservative enough to minimise mismatch with user quality expectations and be too moderate enough in order not to lose too much information. Recommendations for each product level are reported in RD1 (Table 3-10). It is worth mentioning that the quality requirements are subject to change over time due to availability of more data (RD1 Table G-2).

Basic and Calibrated will be produced at the highest possible spatial resolution (i.e., ~5m x 20 m pixels, in range and azimuth respectively), including the full line-of-sight deformation history of each measurement point

Ortho will be produced at the highest possible spatial resolution with 100 m x 100 m pixels.

- Basic will be produced with less than 5 mm standard deviation for any constant velocity point, with respect to a local reference point (up to 10 km apart) and a temporal reference.
- Calibrated will be produced with a minimum of less than 10 mm accuracy between any two constant velocity points within a single scene up to 50 km apart. Calibrated will be produced with a 3D geolocation accuracy equal to 10 m.
- Ortho will be produced with a minimum of 10 mm accuracy for any points up to 50 km apart. This requirement is valid for 100 m x 100 m resolution cells with space-homogeneous and time-constant velocities, and zero north-south motion.
- Note that the geolocalisation accuracy requirement for Calibrated products will ensure minimal leakage between grid cells of Ortho products. For Calibrated and Ortho products, the listed quality requirement assumes availability of high-quality GNSS data. The accuracy strongly depends on the external calibration data available, in particular the density of GNSS stations, which is different in the different European countries.

More details on quality assurance can be found in:

- ❖ RD11 Quality Assurance & Control Report

4.17. Quality and validation results shall be available to the end user

Reliability of the products is a fundamental priority for the EGMS. The validation activity will be performed by an independent team of experts with respect the production and implementation phase of the EGMS. The validation process evaluates the InSAR products through an independent assessment. Validation is intended to encompass technical validation (e.g. comparison to a reference dataset, inter-comparison between different terrain motion supply chains) and user validation (e.g. fitness for purpose). [RD1, RD4, RD5].

Quality control and validation activities performed during the EGMS production and implementation phase will be made available through number of documentation and quality reports.

<i>More details on quality assurance can be found in:</i> ❖ RD11 Quality Assurance & Control Report
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4.18. The Product shall be delivered to end users in an operational and continuous manner

EGMS is part of the services being offered in the context of the Copernicus programme.

Copernicus is based on a constellation of satellites that makes a huge number of daily observations, also with the support of a global network of thousands of land, air, and marine-based sensors to create the most detailed pictures of Earth. The technological prowess of Copernicus, especially in terms of availability and accessibility, has made Copernicus the largest space data provider in the world, currently delivering 12 terabytes per day.

The vast majority of data and information delivered by Copernicus is made available and accessible to any citizen, and any organisation around the world on a free, full, and open basis.

The dissemination and visualisation service will be guaranteed during normal working hours (weekdays 09:00-17:00 CET).

It is planned that:

- the maximum downtime of end-user access to the Product Archive shall not exceed 1 % of Service Period on a monthly basis,
- the maximum downtime of access to the products through the Dissemination System shall not exceed 1 % of Service Period on a monthly basis,

4.19. The Product shall provide information in support of relevant ground displacement applications defined by end users

In order to guide the user, when interpreting the data published on the EMGS, and to avoid unrealistic expectations (e.g. regarding accuracy or coverage or most importantly misinterpretation), the documentation will provide guidelines. These guidelines will explain theoretical considerations in a simple manner and further explain their practical meaning using examples generated by the service.

<i>More details for products guidelines can be found in:</i> ❖ RD8 Product User Manual

4.20. The Product shall be validated against end user requirements using independent data

The validation activity will be performed by an independent team of experts with respect the production and implementation phase of the EGMS using external information including [RD5]:

- Topographic measures (e.g. Global Navigation Satellite Systems - GNSS);
- Active and passive corner reflectors;
- Medium to very high-resolution optical images (including multi-temporal products);
- Catalogues of phenomena or damaging events (e.g. landslide inventories);
- Geological, lithological, hydrogeological, geomorphological or geotechnical maps;
- Thematic maps;
- In-situ displacement monitoring data (e.g. inclinometers, tiltmeters);
- Deformation monitoring data referred to single structures or buildings;
- Information about engineering works or tunnelling;
- Inventories of anthropic activities that can trigger surface motion, e.g. mining or tunnelling;
- Other interferometric results obtained over the same area and the same time frames, produced by operational National and Regional Ground Motion Services.

More details on quality assurance can be found in:
❖ RD11 Quality Assurance & Control Report

4.21. The evolution of the Product is user driven

The ability for EGMS to adapt to future changes in need and desire within the scope and spirit of Copernicus services, as well as future evolution with respect to technology, growing Sentinel constellation etc., is a critical aim of the service. The ambition for EGMS is to meet the needs of as many end-users as possible, given reasonable boundary conditions, such as coverage and update frequency while also considering future evolution of the service

The Service Evolution will build on the following Principles [RD1]:

- Users are explicitly and transparently involved: user's needs drive service evolution, with work to translate user requirements into achievable service evolution objectives.
- Scientific (observations, modelling, data assimilation) and technological (e.g. computing capabilities, information systems) advances relevant for EGMS shall be fully taken into account.
- Lessons and knowledge derived during the initial phases of the service are used to drive the service change and/or service upgrade.
- Delineation with downstream activities: the core service focuses on activities best performed at a pan-European scale.
- Transparency about EGMS evolution with respect to downstream sectors in order to foster European industrial growth.

More details on user uptake and awareness raising activities can be found in:
❖ RD12 User Uptake and Communication Plan

4.22. End users shall regularly be consulted regarding the applicability and quality of the Product

A comprehensive communication strategy and plan will be assessed and implemented for assuring the proper awareness of the EGMS to the end users and involve key users in using and evaluating the products through workshops, survey questionnaires, webinars and similar initiatives.

More details on user uptake and awareness raising activities can be found in:

- ❖ [RD12 User Uptake and Communication Plan](#)

4.23. The Product shall be promoted via dedicated user uptake and awareness raising activities

It is important to reach as many end-users as possible. Currently, most ground motion data users tend to be experts. In the future, it is hoped that ground motion data will be findable and understandable by all relevant authorities and citizens. To that end, the data must be well documented and understandable

The European Ground Motion Service will provide user uptake activities to raising awareness of End Users Community, including geological surveys, road, railway and mining administrations, regulators and planners, public authorities at European, national, regional and municipality level, citizens of Copernicus participating states, industry and academia, etc.

More details on user uptake and awareness raising activities can be found in:

- ❖ [RD12 User Uptake and Communication Plan](#)