



PROGRAMME OF  
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# Quality Assurance & Control Report: Third Update

## EGMS SERVICE DOCUMENTATION



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# 1 INTRODUCTION

## 1.1 Scope of the Document

This document describes the results of the quality control conducted on the final products and datasets made available within the third update of the European Ground Motion Service (EGMS).

Since 2022, EGMS adds a new and unique European-wide geospatial layer to the Copernicus Land Monitoring Service (CLMS) portfolio, enabling further value-adding through both public and private sector downstream applications.

All Copernicus Participating States and the United Kingdom are covered during the first end-to-end implementation and operation of the service.

This addition to the Copernicus Land Monitoring Service is continental-scale, homogeneous maps of ground motion at mm-per-year precision for measuring ground and infrastructure displacement, e.g., caused by landslides, subsidence, and tectonics.

The products are made by mass-InSAR-processing (Interferometric Synthetic Aperture Radar) of data from Copernicus's Sentinel-1 satellite radar Earth observation mission and provide a unique and new European geospatial dataset, to be used directly or as basis for derived value-added products and services.

The EGMS products and services are freely available to the public, complemented with visualisation and analysis tools via a dedicated webGIS and accessible from the main Copernicus Land Monitoring Services site.

Both from a user perspective and the Pan-European level scale of the service, harmonization of EGMS products is mandatory and indispensable to balance the output of the production entities of the ORIGINAL (OpeRational Ground motion INsar Alliance) consortium.

The ORIGINAL consortium consists of the four companies: e-GEOS, TRE Altamira, NORCE and GAF AG, each of them operating independent processing chains with tailored processing approaches allowing for maximum flexibility, e.g., to address specific natural characteristics (snow coverage) but guaranteeing maximum comparability by using a common methodology.

To provide the user with a product in accordance with the EGMS specifications quality assurance and control activities are performed by the consortium.

All quality criteria and key performance indicators previously used for the baseline product, the first and as well as for the second update assessment hold for the analysis of the third update. Due to the equivalent processing approach, compared to the production of the baseline product, analysing an extended time series and guaranteeing a static distribution of MPs, the quality assurance methodology provides consistent results for the baseline as well as for the updated products. Depending on the specific needs and the update strategy used, the overall quality checks of the different products are specifically adapted in a way that the most meaningful results are obtained.



## 2 QUALITY CHECK STRATEGY

Quality control (QC) within EGMS is critical to service success. In particular, the main scope of the QC protocol is to guarantee reliability, i.e., to provide measurements which fully meet the expected accuracy and can be trusted by the users, consistent in terms of measurement point density, accuracy, precision, and calibration. The foreseen updates of the project shall be consistent with previous deliveries and, to foster adoption and utilization, the data format should be simple, efficient, and constant during the project's activities.

The QC protocol considers and respects the different nature and characteristics of the *Basic*, *Calibrated* and *Ortho* products in order to accurately evaluate the quality and fitness for purpose. The consistency of the products relies on strict control of quality at two levels: within the processing of each individual IPE and within the consistency of processing across all partners. The production of QC test-results is automated as much as possible, and all IPEs were involved to ensure consistency and reproducibility, and to calibrate the quality control procedures both internally and jointly.

## 3 PRODUCT QUALITY CRITERIA

Even if the individual IPEs produce products of the EGMS on separate areas, the QC steps are the same for all IPEs and listed in the following.

QC step	Test Criteria	Product	QC passed conditions
Measurement Point (MP) density	MP density for specific CLC18 ( <a href="#">Corine Land Cover 2018</a> ) classes. The densities will be evaluated on areas sufficiently large in order to guarantee an adequate statistic per each CLC18 class.	Basic	<ul style="list-style-type: none"><li>• class 1.1.1: &gt; 5000 MP/km<sup>2</sup></li><li>• class 1.1.2: &gt; 1000 MP/km<sup>2</sup></li><li>• class 1.2: &gt; 1000 MP/km<sup>2</sup></li></ul> <p>class 3.3: variable depending on the number and correctness of the polygons of these classes</p>
Noise	RMSE with respect to the cubic + sinusoidal model is calculated for each MP.	Basic	Nominally ≤5 mm. An RMSE >5 mm may be required in rare circumstances where the model does not sufficiently represent the actual deformation.
Formatting	Ensure common standards used throughout for e.g., units, scaling, tiling, etc.	Basic Calibrated Ortho	-

Table 3-1 Quality criteria for the overall quality checks



## 4 QUALITY CONTROL RESULTS

### 4.1 Overall quality checks

Compared to the first update, it was permissible for the third update to generate new measurement points and it was indeed acceptable to eliminate measurement points, if they could not be reproduced over the update processing period of 5 years (2019-2023). So, the third update is also comparable to the baseline product and the total number of measurements points for *Calibrated* shows an increase of +55.52%.

Product	Period	Total number of deformation points
Baseline	2015-2020	10,013,273,942
First Update	2015-2021	9,482,612,056
Second Update	2018-2022	13,999,128,233
Third Update	2019-2023	15,572,178,690

Table 4-1 Overall total number of *Calibrated* product deformation points

With +24.39%, the comparison of the total number of *Ortho* product points also shows an increase in comparing the baseline with the third update.

Product	Period	Total number of deformation points
Baseline	2015-2020	110,595,427
Second Update	2018-2022	129,811,094
Third Update	2019-2023	137,567,474

Table 4-2 Overall total number of *Ortho* product deformation points

#### 4.1.1 Measurement Point (MP) density

The measurement point density for specific CLC18 classes was determined over the entire area of all the *Basic* products currently available. Separate tests for *Calibrated* products are not required since *Calibrated* is derived from *Basic* without affecting the MP position and therefore the MP density. The checks on the measurement point density in the whole area of EGMS products show that all minimum requirements were met for the third update, and in some classes even considerably outperformed.

The table in the following presents the measurement point densities of the third update in both ascending and descending direction:

CLC18-Class	Threshold	Ascending	Descending
111	>5000	6101	6125
112	>1000	2667	2743
121	>1000	2797	2814
122	>1000	2169	2263
123	>1000	2529	2527
124	>1000	1241	1197
332	>100	2858	3386
333	>100	2518	2977

Table 4-3 Overall measurement point density for specific CLC18 classes based on the *Basic* product

The following table shows the measurement point density comparison between baseline and third update, and reveals a significant increase in total number of points in the urban classes and a major increase is also noted for both orbit directions in the "Open spaces with little or no vegetation" class (332 & 333).

CLC18-Class	Ascending	Descending
111	+5,04%	+3,94%
112	+12,36%	+8,63%
121	+7,45%	+6,89%
122	+11,08%	+10,35%
123	+7,93%	+5,74%
124	+10,15%	+7,61%
332	+19,95%	+34,00%
333	+25,25%	+42,99%

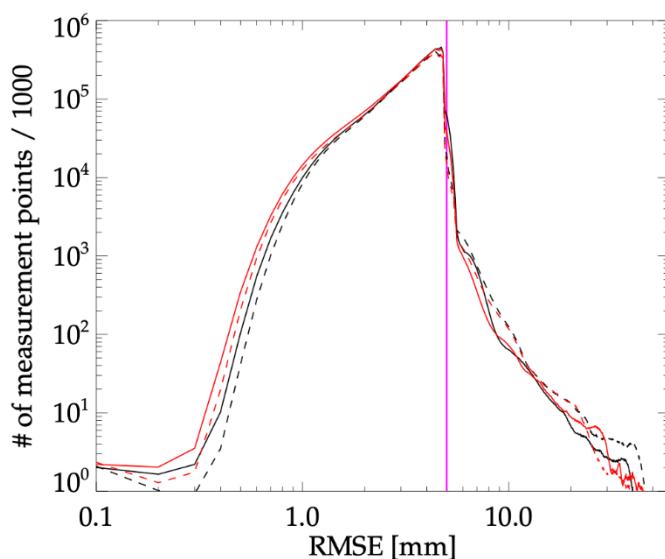
**Table 4-4 Comparison of the point densities in the CLC classes between baseline and third update**

#### 4.1.2 Noise

The required RMSE of nominally  $\leq 5$  mm for the *Basic* product is guaranteed by fixed parameter settings in the processing algorithm. The same threshold was used for the previous production cycles.

The third update is equal to the second update in terms of the length of the time series. However, due to the loss of Sentinel-1B in Dec 2021, there is now a significantly longer period of 12-day sampling in the third compared to the second update.

The following Figure 4-1 shows the histogram of *Calibrated* measurement point quality for the second and the third update in ascending and descending direction.



**Figure 4-1 Histogram of Calibrated measurement point quality (black: ascending, red: descending / solid lines: third update (2019-2023), dashed lines: second update (2018-2022/ magenta vertical line: EGMS specification)**

The figure shows that the third update (solid lines) has a similar and expected difference between the ascending and descending data as in the previous release (dashed lines).

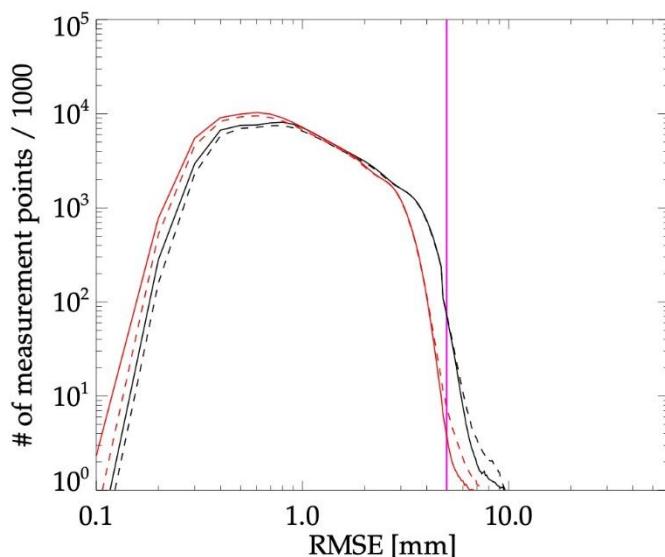
The range of 0.1-0.5 mm is within the inherent noise level and the number of measurement points is very low in this range. Therefore, it is rather difficult to make a conclusion as to the cause of difference between the second and the third updates.

In the range of 0.5-1.5 mm, the results show a slight improvement of the performance compared to the previous release, which is contrary to expectations: A slight decrease in performance was expected due to the increased period of 12-day sampling. This unexpected improvement may be attributed to small improvements in the processing systems. However, the available number of measurement points in this range, corresponding to very high signal-to-noise ratio, remains low.

Between 1.5-4.5 mm, where we find the majority of measurement points, there are minimal differences between the second and the third release, confirming high consistency between the two releases.

The part of the curve >4.5 mm is due to custom processing of some strongly non-linear regions, including earthquakes and volcanic eruptions. For these areas, the RMSE threshold was not used to avoid losing almost all measurement points. Most points in this update end up in the >5mm RMSE interval due to model misfit rather than due to noise or processing errors: a polynomial model does not fit the signal in areas affected by sudden events of large motion.

The discussion for *Calibrated* products above is valid also for the *Ortho* product, as shown in the Figure 4-2.



**Figure 4-2 Histogram of Ortho measurement point quality (black: East-West, red: vertical / solid lines: third update (2019-2023), dashed lines: second update (2018-2022) / magenta vertical line: EGMS specification)**

#### 4.1.3 Formatting

The formatting for *Basic*, *Calibrated* and *Ortho* products were automatically created, checked and spot-checked and complies with the specifications.

## 4.2 Volcanic activity in the area Reykjanes, Iceland

The Reykjanes area has since 2020 experienced a period of volcanic unrest, resulting in several eruptions. The major eruption events in the period 2019-2023 are as follows:

- March 19 - September 18, 2021: Fagradalsfjall
- August 2-21, 2022: Fagradalsfjall
- July 10 - Aug 5, 2023: Litli Hrútur

In addition, many individual lava intrusion events happened that did not result in an eruption, but still caused significant ground motion.

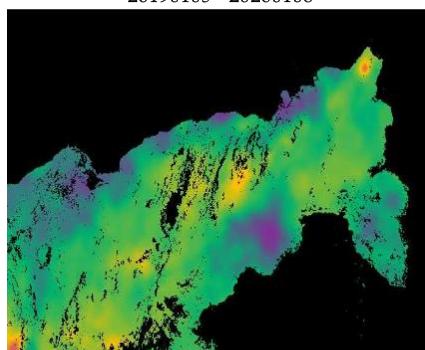
In order to cope with this in the context of EGMS production, custom processing was needed. The major motion was estimated using a traditional approach using multi-looked interferograms at about 100m resolution.

The a-priori estimated large-scale motion was then removed, and the residual signal was analysed with the standard EGMS workflow. Finally, the a-priori estimate was added back. In Figure 4-3, yearly simulated interferograms are shown, demonstrating the temporal evolution of ground motion on Reykjanes.

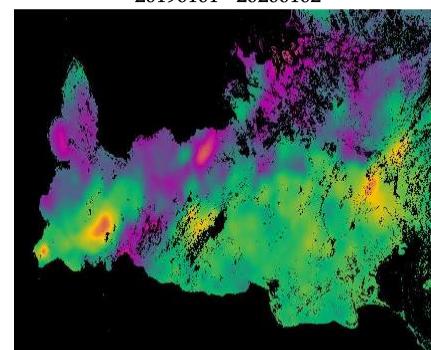
Note that there was limited activity in 2019, while each of the subsequent years show the cumulated effect of all events within each calendar year. Note that the motion differs a lot from year to year, both geographically, and in magnitude.

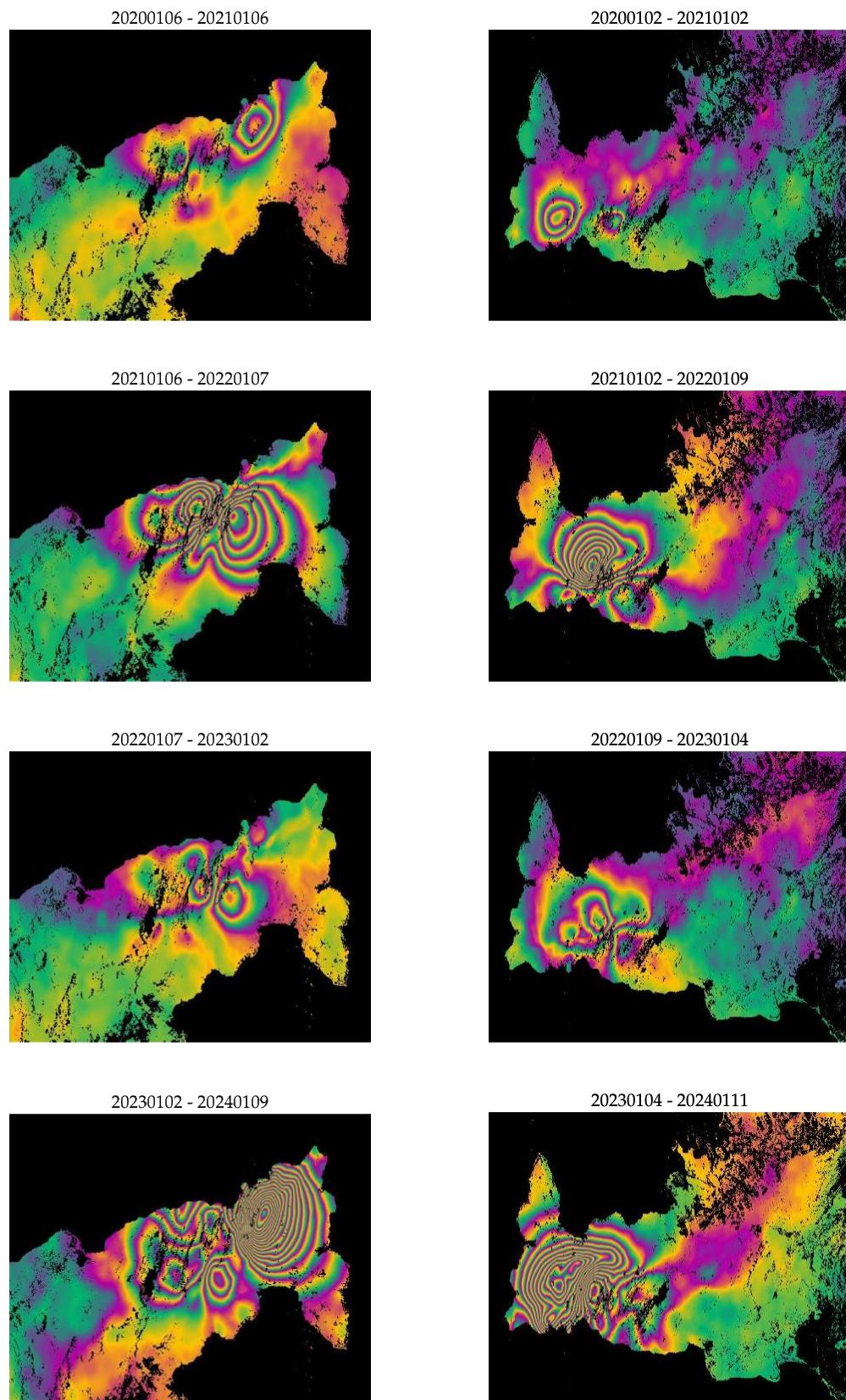
Descending track D03-155	Ascending track A10-016
<ul style="list-style-type: none"><li>• EGMS_L2[ab]_155_0691_IW1</li><li>• EGMS_L2[ab]_155_0691_IW2</li><li>• EGMS_L2[ab]_155_0692_IW1</li><li>• EGMS_L2[ab]_155_0692_IW2</li><li>• EGMS_L2[ab]_155_0693_IW1</li><li>• EGMS_L2[ab]_155_0693_IW2</li></ul>	<ul style="list-style-type: none"><li>• EGMS_L2[ab]_016_0379_IW2</li><li>• EGMS_L2[ab]_016_0380_IW1</li><li>• EGMS_L2[ab]_016_0380_IW2</li><li>• EGMS_L2[ab]_016_0381_IW1</li><li>• EGMS_L2[ab]_016_0381_IW2</li><li>• EGMS_L2[ab]_016_0382_IW1</li></ul>
<b>ORTHO products</b>	
<ul style="list-style-type: none"><li>• EGMS_L3_E27N48_100km_[EU]</li><li>• EGMS_L3_E27N49_100km_[EU]</li><li>• EGMS_L3_E28N48_100km_[EU]</li><li>• EGMS_L3_E28N49_100km_[EU]</li></ul>	

20190105 - 20200106



20190101 - 20200102





**Figure 4-3 Equivalent yearly interferograms for tracks D03-155 (left) and A10-016 (right) for each year 2019-2023.** Note that the images are shown in radar geometry, such that the descending data appears upside down with respect to geographic coordinates. The simulated interferograms are phase wrapped the same way as real interferograms, in intervals of [-14,14] mm, corresponding to half a wavelength per colour cycle.



## Conclusions

The results of the quality checks demonstrate that products generated so far by all individual IPEs agree and match for the third update well in terms of technical specifications and furthermore meet all requirements (see Chapter 3) defined by the EEA for the third update products.

One of the main criteria for the overall product is the measurement point density of the *Basic* product against selected classes from CORINE Land Cover 18. This analysis was performed over the entire EGMS area and CLC18 classes (111, 112, 121, 122, 123, 124, 332 and 333), showing that the product overfulfills specifications and requirements for the products of the first update (see Measurement Point (MP) density).

The same holds for additional main product quality criteria, respective noise and formatting. Both of them completely fulfil the requirements by fixed configurations in the processing chain predominantly by automatic product generation and applied quality procedures.

There are event-related outliers in the third update that required special attention, but overall the product has improved compared to the baseline and the first update. Not only was the number of measurement points increased by almost 56%, but with the exception of two non-urban classes in the descending direction, a significant increase in point density was also achieved.

The presentation of the RMSE for *Calibrated* and *Ortho* product also shows an improvement in the products compared to the baseline. A direct comparison with the first update was omitted because these products are not particularly comparable in terms of procedure and length of the time series.

In summary, it can be stated that the presented checks show an agreement of all products of the EGMS (*Basic*, *Calibrated* & *Ortho*) with all quality requirements of both the IPEs quality standards and the EEA.



# List of Abbreviations

Abbreviation	Name	Reference
AOI	Area of Interest	
APS	Atmospheric Phase Screen	
ATS	Average Time Serie	
ATSD	Detrended Average Time Series	
BPR	Baseline Product Review	
CLC	CORINE Land Cover	
CLMS	Copernicus Land Monitoring Service	
DEM	Digital Elevation Model	
DS	Distributed Scatterer	
EEA	European Environment Agency	<a href="http://www.eea.europa.eu">www.eea.europa.eu</a>
EGMS	European Ground Motion Service	<a href="https://land.copernicus.eu/pan-european/european-ground-motion-service">https://land.copernicus.eu/pan-european/european-ground-motion-service</a>
GNSS	Global Navigation Satellite Systems	
InSAR	Interferometric Synthetic Aperture Radar	
IPE	InSAR Processing Entity	
IPR	Intellectual Properties Rights	
KPI	Key Performance Indicators	
LAEA	Lambert Azimuthal Equal Area	
MP	Measurement Point	
ORIGINAL	OpeRational Ground motion INsar Alliance	
ORR	Operational Readiness Review	
PS	Persistent Scatterer	
QC	Quality control	
RD	Related Documents	
SCR	Signal to Clutter Ratio	
stddev	Standard deviation	
TS	Time Series	



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