



# Copernicus Emergency Management Service



## Global Flood Monitoring (GFM) Product User Manual

Prepared by the EXPERT FLOOD MONITORING ALLIANCE



This publication is a Technical Report on the Global Flood Monitoring (GFM) product of the Copernicus Emergency Management Service, which is operated by an international consortium led by the Earth Observation Data Centre for Water Resources Monitoring GmbH (EODC), under a Framework Contract with the Joint Research Centre (JRC), the European Commission's science and knowledge service. The purpose of the report is to serve as a Product User Manual for the GFM Product to provide a comprehensive overview of the available data and services.

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# 1 Introduction

The Global Flood Monitoring (GFM) Product of the Copernicus Emergency Management Service (CEMS)<sup>1</sup> provides a continuous monitoring of worldwide flood events, by immediately processing and analysing in near real-time (NRT) all incoming Sentinel-1 Synthetic Aperture Radar (SAR) satellite imagery. Key elements of the GFM Product are the use of a historical time-series or “data cube” of SAR backscatter data, enabling high product timeliness, and implementation of an ensemble method comprising three independent, state-of-the-art SAR-based water and flood mapping algorithms, in order to improve the robustness and accuracy of the flood and water extent maps and to build a high degree of redundancy into the service (Salamon et al., 2021; Matgen et al., 2020; Wagner et al., 2020).

The GFM Product is designed to deliver, in NRT, critical information on ongoing floods events to users worldwide, including national authorities, emergency units, research centres, decision-makers and other stakeholders. The GFM Product is specifically designed to address three major user requirements, namely:

- Providing a continuous global, systematic monitoring of flood events.
- Significantly enhancing the timeliness of flood maps for emergency response.
- Improving the effectiveness of activation requests of the CEMS Rapid Mapping component<sup>2</sup>, through a better identification of the areas of interest.

The GFM Product is also designed to provide a long-term archive of global flood monitoring data, making it an ideal source of information for planning specific mitigation and preparedness measures regarding future flood events, e.g. designing flood protection systems or calibrating hydrological models. Finally, combining data from the GFM Product with data from other Copernicus services (e.g. Copernicus Climate Change Service) can deliver useful information for addressing the challenges in climate change response management.

At the core of the GFM Product are three independent, state-of-the-art algorithms (developed by three leading research teams - i.e. LIST, DLR, and TU Wien - who are members of the GFM consortium) for the systematic, automated delineation of flooded areas and water bodies based on all-weather, day-and-night Sentinel-1 SAR satellite images. As is described below (Sections 2 and 3), the three GFM flood mapping algorithms are implemented in an “ensemble” approach, in order to ensure an optimal accuracy of the derived flood and water extent maps, and to build a high degree of redundancy into the production service.

The operational implementation the GFM Product includes the following key elements:

- Downloading the worldwide Sentinel-1 SAR Level-1 Ground Range Detected (GRD) satellite imagery from ESA.
- Pre-processing the downloaded Sentinel-1 data and storing the resulting georeferenced image stacks as a spatio-temporal “**data cube**” (or time-series) of backscatter data.

<sup>1</sup> <https://emergency.copernicus.eu/>

<sup>2</sup> <https://emergency.copernicus.eu/mapping>

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- Operational application, in NRT, of three state-of-the-art, fully automated flood mapping algorithms at a global scale.
- Generation of the required Sentinel-1-based GFM output layers, including Observed flood extent, Observed water extent, Reference water mask, Exclusion mask, and Likelihood values.
- Web service-based access and dissemination of the GFM Product output layers, including an appropriate user support service.
- Regularly performing quality control measures, including assessment of product timeliness and accuracy, and service reliability and accessibility.
- Building up a long-term archive of past observed flood events and water extent.

The purpose of this **Product User Manual (PUM)** is to serve as the reference document for all end-users and stakeholders of the GFM Product. The PUM provides all the basic information to enable the proper and effective use of the GFM Product and associated data output layers, and describes the functions and capabilities of the GFM Product, its applications and alternative modes of operation, and step-by-step guidance on the procedures for accessing and using the GFM Product. Full technical details on the GFM Product are provided on-line in the Product Definition Document (PDD)<sup>3</sup>. A brief technical overview of the GFM Product is provided in Section 2 below.

The GFM Product has been developed and implemented under a Framework Contract with the European Commission’s Joint Research Centre (European Commission, 2020), by an international consortium (the “Expert Flood Monitoring Alliance”) consisting of six partners:

- EODC (Earth Observation Data Centre for Water Resources Monitoring GmbH).
- GeoVille (GeoVille Information Systems and Data Processing GmbH).
- TU Wien (Technische Universität Wien).
- DLR (German Aerospace Centre / Deutsches Zentrum für Luft- und Raumfahrt e.V.).
- LIST (Luxembourg Institute for Science and Technology).
- CIMA (Centro Internazionale in Monitoraggio Ambientale Research Foundation).

The GFM partnership represents Europe’s leading group of scientific experts in the field of satellite-based flood monitoring systems, with a wide-ranging and unique experience in global flood mapping services, and with extensive links with the main information services of Copernicus (the EU’s Earth observation programme), including CEMS and the Copernicus Land Monitoring Service (CLMS). Starting from the earliest days of satellite-based flood mapping and monitoring methods, the individual members of the GFM consortium have built up unprecedented, complementary capabilities for flood mapping, monitoring, and related disaster risk services, and have accumulated a long history of implementing high-quality, successful applications and projects, and developing the related systems for global data processing and access. Further details on the GFM consortium are provided in Annex 1 below.

<sup>3</sup> <https://extwiki.eodc.eu/GFM/PDD>

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## 2 Technical overview of the GFM Product

The Global Flood Monitoring (GFM) Product of the Copernicus Emergency Management Service (CEMS) is an automated, global, flood monitoring system, which complements the existing CEMS components for flood early warning and on-demand mapping, by providing a continuous (i.e. all-weather, day-and-night), systematic monitoring of all major global flood events, in near real-time (NRT), based on the latest Sentinel-1 SAR satellite images.

For each newly acquired Sentinel-1 SAR satellite image, the GFM Product provides 10 output layers of worldwide flood-related information, which are shown in Table 1. Central to the GFM Product are three state-of-the-art algorithms for the SAR-based detection and delineation of flooded areas, which were developed by members of the GFM consortium (i.e. LIST, DLR, TU Wien), which are summarized in Table 2, and are described in more detail in Section 3 below.

In order to ensure optimal accuracy of the derived flood (and water) extent maps, and to build a high degree of redundancy into the production service, the GFM Product deploys the three state-of-the-art flood mapping algorithms in an “ensemble” approach, whereby an area (i.e. grid-cell) is considered to be flooded if (a) it is classified as flooded by **at least two of the three algorithms**, in the normal case when all three algorithms produce a result; (b) it is classified as flooded by **two algorithms**, in the exceptional case when only two of the three algorithms produce a result. (Note that in a pre-operational version of the GFM Product, a slightly different ensemble approach was used: in those exceptional cases when only two of the three algorithms produce a result, the classification result of the algorithm with the **lower classification uncertainty** was selected).

In order to optimize further the quality of the results of the GFM Product, as can be seen in Table 1 an **Exclusion Mask** is used to exclude those areas where SAR-based water (and flood) detection is not technically feasible. The GFM Exclusion Mask is created by combining global information layers delineating the following ground surface characteristics:

- **No sensitivity areas** (e.g. urban areas, dense vegetation), where Sentinel-1 SAR is not sensitive to flooding (or any other type of change) of the ground surface.
- Water look-alikes (e.g. flat impervious areas, sand surfaces), which are indistinguishable from flooded areas due to a **low backscatter** signature.
- Areas with strong topography (and low probability of flood occurrence), where the Sentinel-1 signals are affected by **topographic distortions**.
- **Radar shadows** of mountains, high vegetation canopies or man-made structures.
- Areas with **low coverage** (revisit frequency) of Sentinel-1 observations, where there is an inadequate historical time-series of SAR data available.

As specified in the Technical Specifications for the GFM Product (European Commission, 2020), as well as the 10 output layers of flood-related information, the GFM Product can also

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generate a processed archive of worldwide observed floods and water bodies, from 1 January 2015 until recently.

**Table 1: The GFM Product output layers of global flood-related information, generated in near real-time based on Sentinel-1 SAR satellite imagery.**

#	GFM PRODUCT OUTPUT LAYER	DESCRIPTION AND NOTES
1	Observed flood Extent	Flooded areas mapped by applying the GFM ensemble flood mapping algorithm to the latest Sentinel-1 images of SAR backscatter intensity.
2	Observed water extent	Open and calm water mapped as the union of the observed flood extent and the reference water mask.
3	Reference water mask	Normal (i.e. permanent and seasonal) water mapped by applying the GFM ensemble water mapping algorithm to a historical time-series of Sentinel-1 images of SAR backscatter intensity.
4	Exclusion mask	Areas where SAR-based water mapping is not technically feasible, due to no sensitivity (e.g. urban areas, dense vegetation), low backscatter (e.g. flat impervious areas, sandy surfaces), topographic distortions, radar shadows, or low coverage of Sentinel-1.
5	Likelihood values	Estimated likelihood of flood classification, for all areas outside the exclusion mask.
6	Advisory flags	Flags indicating potential reduced quality of flood mapping, due to prevailing environmental conditions (e.g. wind, ice, snow, dry soil), or degraded input data quality due to signal interference from other SAR missions;
7	Sentinel-1 footprint and metadata	Image boundaries of the Sentinel-1 data used, and in addition information on the “metadata”, i.e. information on the acquisition parameters of the Sentinel-1 data used.
8	Sentinel-1 schedule	Next scheduled Sentinel-1 data acquisition.
9	Affected population	Number of people in flooded areas, mapped by a spatial overlay of observed flood extent and gridded population, from the Copernicus GHSL project.
10	Affected Landcover	Land cover / use (e.g. artificial surfaces, agricultural areas) in flooded areas, mapped by a spatial overlay of observed flood extent and the Copernicus GLS land cover.

**Table 2: Overview of the three state-of-the-art GFM algorithms for SAR-based flood mapping.**

FLOOD MAPPING ALGORITHM	MAIN TECHNICAL FEATURES	SCIENTIFIC REFERENCE
Algorithm 1 (LIST)	<ul style="list-style-type: none"> <li>– Hierarchical split-based approach enabling re-calibration of parameters in NRT based on the most recent pair of S-1 images.</li> <li>– Uses a highly innovative sequence of hierarchical image splitting, statistical modelling and region-growing to delineate and classify areas that changed their flooding-related backscatter response between two image acquisitions from the same orbits.</li> </ul>	Chini et al. (2017)
Algorithm 2 (DLR)	<ul style="list-style-type: none"> <li>– Fuzzy logic-based approach enabling a post-classification and region-growing, taking advantage of topography-derived indices in addition to SAR backscatter.</li> </ul>	Martinis et al. (2015)
Algorithm 3 (TUW)	<ul style="list-style-type: none"> <li>– A fully automatic, pixel-based flood extent mapping workflow which exploits per-pixel full Sentinel-1 signal history in a data cube (time-series) of backscatter measurements;</li> <li>– Enables a very fast, scalable production of flood and water extent maps through pre-computed global parameters at high quality.</li> </ul>	Bauer-Marschallinger et al. (2022)

The performance of the GFM service and product delivery is reported on a quarterly basis, using a minimum set of Key Performance Indicators (KPIs) that monitor the service availability, product timeliness, product quality, unique visitors, total visitors, and total downloads (European Commission, 2020). One of the key user requirement for the GFM Product is the timeliness for generating the GFM output layers of worldwide flood information. The experience of the entire GFM consortium is used to ensure a product timeliness less than or equal to 8 hours, for all Sentinel-1 GRD scenes that become available

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on the ESA data hubs within 5 hours from acquisition. Some of the practical measures that are used to ensure the product timeliness of the GFM Product, are listed in Table 3.

**Table 3: Main practical measures to ensure the product timeliness of the GFM Product.**

#	DESCRIPTION OF MEASURE
1	A redundant Sentinel data access via multi-access point data downloads and parallelization of downloads for an optimised bandwidth utilisation via the hubwatcher software.
2	Automatic retrieval of Sentinel-1 GRD data with the hubwatcher in 96.3 minutes (on average) following ESA publication for general availability.
3	Pre-processing of Sentinel-1 GRD data products and inclusion into the data cube format within 10-20 minutes per scene.
4	Fast data access to the data cube with IO speeds of 15 gibibytes (gib) or 120 gigabytes (GB) per second.
5	Generation of the “ensemble” GFM Product using the three parallel flood mapping algorithms consumes up to 30 minutes, with the final flood extent maps and uncertainty values being calculated within a matter of seconds.
6	Total lead-time of the GFM Product is 60 minutes, to complete the entire operational NRT workflow from image acquisition to delivery.

The guaranteed service availability of the GFM Product is facilitated through EODC’s expertise in Sentinel-1 processing operations (begun in 2014), which are regularly assessed by the ESA mission reports. These *lessons learned* have been used to implement a completely independent IT infrastructure for the CEMS GFM system operations. The operations are also organized through redundant 24/7 production coordinator staff availabilities, such that a 99% service availability is guaranteed.

According to the Technical Specifications (European Commission, 2020), the quality (i.e. thematic accuracy) of the GFM Product’s main output layers Observed flood extent and Observed water extent, should reach a Critical Success Index (CSI) target threshold of **70-80%**. Due to the highly advanced “ensemble” approach integrating the three leading edge GFM flood mapping algorithms, and depending on the quality of input data, a flood and water delineation accuracy which reaches the target threshold is expected. Based on multiple test-cases, the GFM Product usually achieves a satisfactory overall accuracy for both output layers.



### 3 SAR-based flood mapping algorithms used in the GFM Product

A detailed technical description of the three state-of-the-art SAR-based GFM flood mapping algorithms - which were developed by the GFM consortium members LIST, DLR and TU Wien - is provided in the GFM Product Definition Document (PDD)<sup>3</sup>, together with examples of their application in an operational context. In this section, the key technical points of the three **GFM** flood mapping algorithms are summarised, and references are provided to the appropriate sections of the PDD containing more detailed information.

All three of GFM flood mapping algorithms - namely **GFM flood mapping algorithm 1** (developed by LIST), **GFM flood mapping algorithm 2** (developed by DLR) and **GFM flood mapping algorithm 3** (developed by TU Wien) - make use of historical time-series of Sentinel-1 SAR intensity data and use topography-derived indices to refine the initial classification of water bodies. However, differences do appear in how the historical time series of intensity data are used to parameterize the retrieval algorithms, and how ancillary data such as topography are used in the production system. Further differences relate to the inclusion of a region-growing step, the scale at which thresholds are determined and applied to a grid-cell's backscatter value, and other nuances in the way the retrieval algorithms are set up.

Each GFM flood mapping algorithm takes as input Sentinel-1 image data and generates an "Observed Flood Extent" output layer, which is further refined using the "Exclusion Mask" (to mask out areas that cannot be classified, due to local conditions), and the "Reference Water Mask" (showing permanent and seasonal water bodies). As described briefly in Section 2 above, an ensemble-based approach is then used to combine the observed flood extent maps generated by the three GFM flood mapping algorithms, into a "consensus map" representing the final GFM Product output layer "Observed Flood Extent".

Similar to the GFM ensemble flood mapping algorithm, which is used to generate the output layer "Observed Flood Extent", a GFM ensemble water mapping algorithm is used to generate the output layer "Reference Water Mask", based on a "data cube" or time series of Sentinel-1 image data.

The (internal) availability of three separate maps for observed flood extent also provides a convenient means of identifying and addressing any shortcomings affecting a single GFM flood mapping algorithm in specific circumstances or parts of the world, due to many well-known factors such as topography or environmental conditions. Accordingly, the implemented quality assessment procedures can investigate whether classification errors may be attributed to shortcomings of individual algorithms, or limits on the ability of Sentinel-1 SAR data to capture the appearance (or absence) of surface water in particular situations.

The most relevant features of the three GFM flood mapping algorithms are summarised and compared in

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Table 4 below. In the following sub-sections, more details are provided on the three GFM flood mapping algorithms, and on the GFM ensemble flood mapping algorithm and ensemble water mapping algorithm, which are used, respectively, to produce the GFM Product output layers “Observed Flood Extent” and “Reference Water Mask”.

**Table 4: Distinguishing features of the three GFM flood mapping algorithms, which are deployed in an ensemble approach.**

<b>Algorithm (and provider):</b>	<i>GFM FLOOD MAPPING ALGORITHM 1 (LIST)</i>	<i>GFM FLOOD MAPPING ALGORITHM 2 (DLR)</i>	<i>GFM FLOOD MAPPING ALGORITHM 3 (TU Wien)</i>
<b>Main scientific reference:</b>	Chini et al. (2017).	Martinis et al. (2015).	Bauer-Marschallinger et al. (2022).
<b>Application domain:</b>	Automated water and flood extent mapping (pixel-based)	Automated NRT water and flood extent mapping	Automated pixel-based flood extent mapping
<b>Input remote sensing data:</b>	Pair of SAR intensity images acquired from same orbit (any sensor) and model parameters derived from historical time series	Single-temporal SAR intensity data	Single SAR acquisition and model parameters derived from historical time series
<b>Auxiliary data:</b>	HAND index map, exclusion layer, reference water layer, water and flood extent map computed at previous time step	HAND index exclusion map, reference water extent, DEM, optional: low backscatter exclusion mask based on S-1 time-series data	HAND index, exclusion mask, reference water map for generating the fresh flooded areas
<b>Main characteristics:</b>	Scene-specific statistical modelling of backscatter distributions, systematic updating of water bodies maps using combination of change detection and region growing	Hierarchical automatic tile-based thresholding, fuzzy logic-based post classification and region growing	Classification based on backscatter probability distribution by exploiting the historical time series with consideration of backscatter seasonality.
<b>Use of SAR time-series data:</b>	Yes	No. Integration of low backscatter exclusion mask based on S-1 time-series (produced off-line) can be done optionally.	Yes, parametrisation through multi-year time series
<b>Use of contextual information by region-growing:</b>	Yes	Yes	No
<b>Method of initialization:</b>	Statistical modelling of backscatter distributions attributed to water / no water and change / no change classes (per tile)	Hierarchical automatic tile-based thresholding using statistical modelling of class distributions	Generation of backscatter probability distribution from historical time series measurements
<b>Post-classification steps:</b>	Masking of exclusion areas, distinction between water and flood extent using reference water mask.	Masking of exclusion areas, distinction between water and flood extent using reference water mask.	Noise reduction, mask exclusion areas, extraction new flood area compared with reference water mask.
<b>Generation of water likelihood values:</b>	Yes (based on Bayesian inference)	Yes (based on fuzzy logic)	Yes (based on the Bayesian posterior probability)
<b>Main differentiating features:</b>	Hierarchical split-based approach (HSBA) enabling re-calibration of parameters in NRT based on most recent pair of S-1 images	Fuzzy logic-based approach enabling a post classification and region growing taking advantage of topography-derived indices in addition to SAR backscatter	Exploiting per-pixel multi-year Sentinel-1 signal history in data cube, enabling a very fast and scalable production of flood through pre-computed global parameters at high quality

### 3.1 GFM flood mapping algorithm 1 (developed by LIST)

GFM flood mapping algorithm 1, which was developed by LIST, is a hybrid SAR-based flood mapping method that combines parametric thresholding, region-growing, and change detection to detect and map all increases and decreases of floodwater extent in the most recently recorded Sentinel-1 SAR scene with respect to a previously recorded overlapping Sentinel-1 SAR scene from the same orbit (i.e. the reference image).

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The parameters of the two partially overlapping Gaussian probability distribution functions (PDFs) of backscatter values, representing flood and non-flood classes, are estimated using a hierarchical split-based approach (HSBA), which automatically identifies separate sub-regions (i.e. tiles) of variable size in a SAR image (i.e. single-date or change) that are characterized by histograms which are clearly bi-modal, normally distributed and well balanced.

The LIST algorithm takes as input the most recent SAR image and a reference SAR image, and computes a “change image” as the backscatter difference between the two images. Flooded pixels in the change image are expected to be positive because of the reduction of backscatter values caused by flooding. Since the input Sentinel-1 SAR image values (i.e.  $\sigma^0$  backscatter intensities in decibels) are already log-transformed, the change image is in effect a “log-ratio” image<sup>4</sup>. The log ratio method is widely used in change detection of multitemporal SAR amplitude or intensity images, as logarithmic transformation can not only transform the multiplicative noise (speckle) affecting SAR data into additive noise<sup>5</sup>, but also compresses the range of variation of values and better balances these below and above one.

The four PDFs of backscatter values attributed, respectively, to water, no water, change, and no change, which are determined by the HSBA, are used to derive an optimal set of parameters for the subsequent sequence of adaptive thresholding and region growing processes. The region growing approach assumes that grid-cells constituting the target class are clustered rather than randomly spread out over the images. Application of the derived parameters to pairs of SAR images produces one map of floodwater appearing between  $t_{0-1}$  and  $t_0$ , and another map of floodwater receding between  $t_{0-1}$  and  $t_0$ . For the final classification, the flood extent map generated at  $t_{0-1}$  is updated with all appearing and receding floodwater computed at the previous steps, and taking account of the Reference Water Mask, the Exclusion Mask (including the Height Above Nearest Drainage or HAND layer), and the ocean mask from the Copernicus Digital Elevation Model (DEM).

The data processing workflow of the LIST flood mapping algorithm is shown in Figure 1.

***In a nutshell:***

*The LIST flood mapping algorithm of the GFM Product is based on a scientifically validated and patented technology enabling a systematic, automatic, and high-accuracy monitoring of water bodies using Sentinel-1 data. The algorithm uses a highly innovative sequence of hierarchical image splitting, statistical modelling, and region growing to delineate and classify areas that changed their flooding-related backscatter response between two image acquisitions from the same orbits.*

*Further details are provided in the dedicated section of the Product Description Document (PDD):*

<https://extwiki.eodc.eu/GFM/PDD/GFMoutputLayers>

<sup>4</sup> Based on the quotient rule for logarithms, i.e.  $\log[x/y] = \log[x] - \log [y]$

<sup>5</sup> Based on the product rule of logarithms, i.e.  $\log[x.y] = \log[x] + \log[y]$

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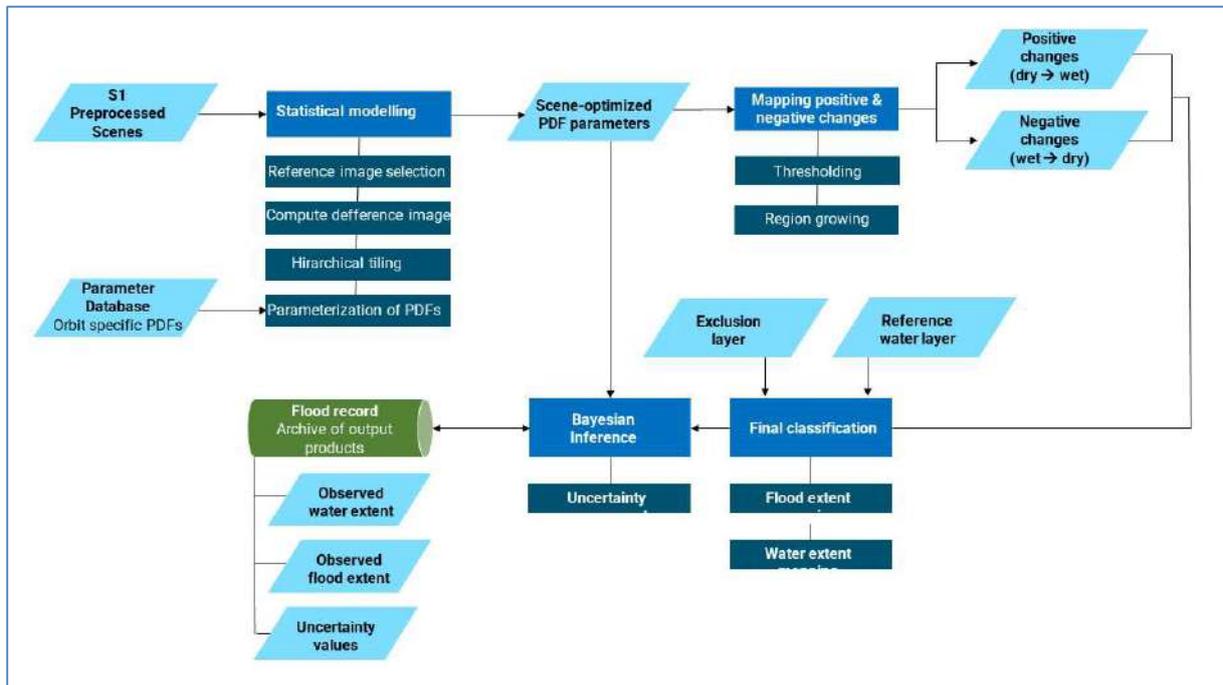


Figure 1. Data processing workflow for the LIST flood mapping algorithm.

### 3.2 GFM flood mapping algorithm 2 (developed by DLR)

GFM flood mapping algorithm 2, which was developed by DLR, is a fuzzy logic-based water class membership assignment, which includes an unsupervised initialization of the classification by tile-based thresholding, and post-classification refinement using a fuzzy logic-based approach (Martinis et al. 2015; Twele et al., 2016). The DLR algorithm requires a full Sentinel-1 scene as the main input and further exploits three ancillary raster datasets: a digital elevation model (DEM), areas not prone to flooding and reference water.

For the unsupervised initialization of the flood and water extent classification, the DLR algorithm applies a parametric hierarchical tile-based thresholding procedure, by labelling all pixels with a backscatter value lower than a threshold to the class “water”. The threshold value is automatically computed for a smaller, limited number of subsets (tiles) of the SAR scene, and applied to the entire scene. The tiles used to define the threshold are selected for based on their backscatter values, based on the assumption that tiles with a low mean backscatter and a high standard deviation show a bi-modal backscatter distribution, and are likely to contain both water and non-water features. Details on the algorithm are provided by Martinis et al. (2015) and Twele et al. (2016).

In order to exclude water look-alikes and to reduce under-estimations from the initial classification, a fuzzy set is constructed consisting of four elements: SAR backscatter coefficient ( $\sigma^0$ ); elevation; slope; and the size of water bodies. The degree of an element’s membership to the class water is determined by the simple Standard S and Z fuzzy membership functions whose values are real numbers in the interval [0, 1] (Pulvirenti et al., 2011).

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The fuzzy logic-based post-classification, which is used for improving the initial classification of the DLR flood mapping algorithm, is illustrated in Figure 2. As can be seen, for each membership function, the membership degree strongly depends on the position of the crossover point  $x_c$  (i.e. half the width of the fuzzy curve), which is defined by the fuzzy thresholds  $x_1$  and  $x_2$ . The fuzzy threshold values for each element are either determined according to statistical computations or are set empirically. As is illustrated in Figure 2, the four elements which comprise the fuzzy set are defined as follows:

- The standard Z function is used for describing the membership degree to open water areas according to the **radar backscatter**.
- Digital elevation data are used to improve the classification through simple hydrological assumptions, i.e., by reducing the membership degree of an image element depending on the **height above the main water area**, by applying the standard Z membership function. Using this fuzzy set (not shown in Figure 2), the number of look-alike areas in regions significantly higher in elevation than the mean of the water areas is reduced, e.g. in mountainous terrain.
- **Topographic slope** information derived from globally available digital elevation data is integrated by using the Z membership function. Using this auxiliary information layer, water look-alikes in areas of steep terrain are removed.
- The S membership function is applied to the **size of the water bodies** to reduce the number of dispersed small areas of low backscatter, which are commonly related to water look-alike areas.

The corresponding fuzzy elements are combined into one composite fuzzy set by computing the average of the membership degrees of each pixel. If one single fuzzy element has a membership of zero, also the membership degree of the composite fuzzy set is set to zero.

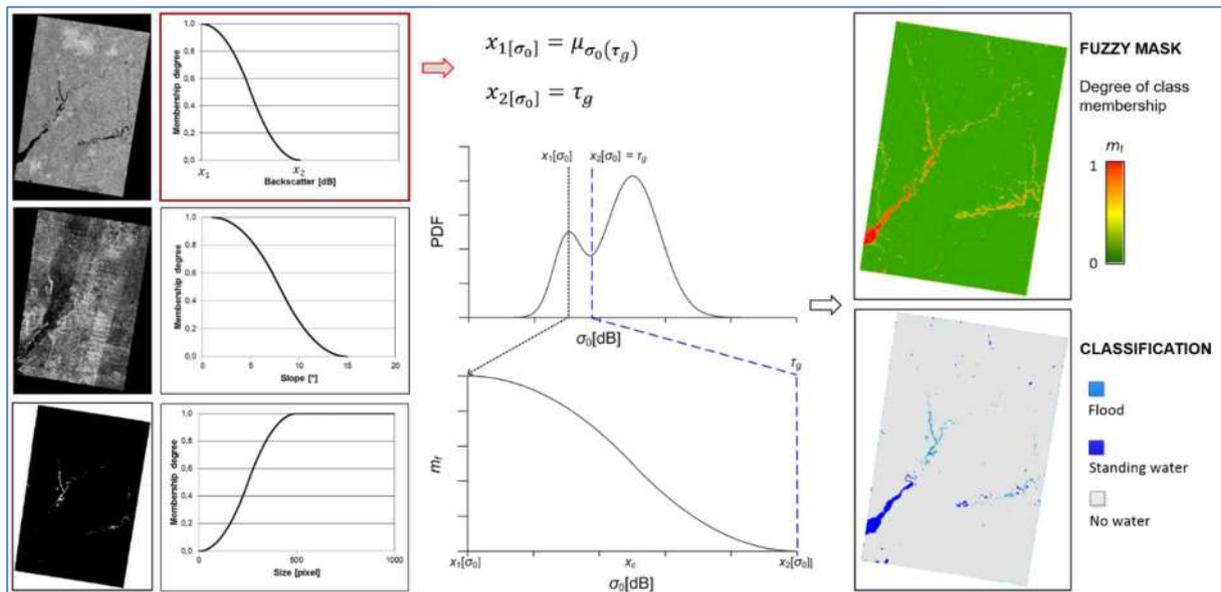


Figure 2. Illustration of the fuzzy logic-based water class membership assignment used in the DLR flood mapping algorithm.

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The flood mask is then created through a threshold defuzzification step, which transforms each image element with a membership degree >0.6 into a “crisp” value (i.e. a discrete thematic class). In order to integrate the transient shallow water zone between open flood water and non-flooded surfaces, and to increase the spatial homogeneity of the detected flood plain, a region-growing step is performed, whereby the preliminary extracted water bodies of the defuzzified classification are progressively enlarged until a tolerance criterion is reached. A relaxed fuzzy threshold with a membership degree of >0.45 is used as a region-growing tolerance criterion, so that only image elements with a fuzzy membership degree between 0.45 and 0.6 neighbouring the class flood are considered. Uncertainty information is contained in the fuzzy mask over classified water pixels, with values ranging from 0 to 1.

The data processing workflow of the DLR flood mapping algorithm is shown in Figure 3.

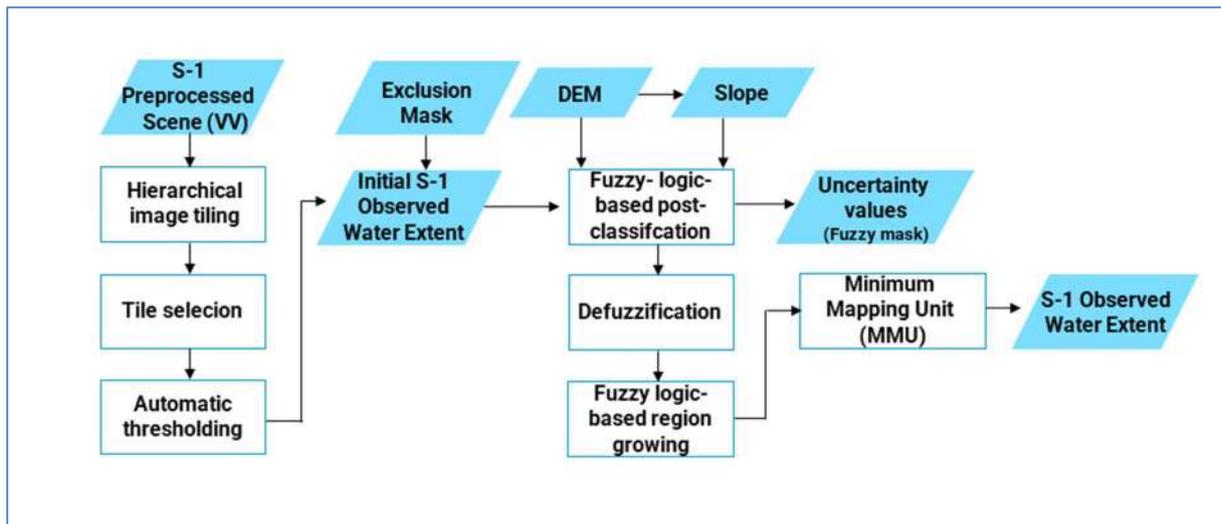


Figure 3. Data processing workflow for the DLR flood mapping algorithm.

**In a nutshell:**

*The key strength of the DLR flood mapping algorithm of the GFM Product is the automatic identification of flooded areas in the SAR data using a hierarchical tile-based thresholding approach and the optimization of the classification by combining various information sources using fuzzy-logic theory and region growing.*

*Further details are provided in the dedicated section of the Product Description Document (PDD):*

<https://extwiki.eodc.eu/GFM/PDD/GFMoutputLayers>

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### 3.3 GFM flood mapping algorithm 3 (developed by TU Wien)

GFM flood mapping algorithm 3, which was developed by TU Wien, is a fully automatic, pixel-based methodology that exploits a multi-year historical time series of Sentinel-1 backscatter measurements over land (for all continents except Antarctica). The SAR observations are organised within the Sentinel-1 “data cube” (i.e. spatio-temporal image stack) managed by the Earth Observation Data Centre for Water Resources Monitoring (EODC) (Wagner et al, 2021; Bauer-Marschallinger et al., 2022). The Sentinel-1 data cube is used to generate dedicated statistical parameters for each individual location on land, comprising the backscatter distributions of each grid-cell for non-flooded conditions, and for water bodies at various incidence angles. Based on these two distributions, the posterior probabilities of the values of an incoming Sentinel-1 image on belonging to the classes “flood” and “non-flood” can be calculated, and used as input to Bayes decision rule to obtain the binary flood map.

The non-flood backscatter probability density function (PDF), which characterizes the normal (i.e. non-flooded) backscatter behaviour for each location, is modelled for each grid-cell as a normal distribution, by analysing the local historical backscatter response under normal conditions, and taking account of the seasonality (i.e. specific periodic, or harmonic, behaviour) exhibited by the local backscatter time series.

The flood backscatter PDF is also assumed to be a normal distribution, which is inferred from a representative collection of SAR measurements over water bodies, taking account of the effect on the backscatter coefficients of the local incidence angle of the radar beam (i.e. considering local slope and terrain). Both the non-flood and the flood PDFs are derived from the data cube separately for each Sentinel-1 orbit, due to the significant impacts on SAR backscatter of the nominal (versus local) incidence angle of the radar beam.

The TU Wien flood mapping algorithm takes as input the incoming Sentinel-1 SAR scene to be processed, a projected local incidence angle (PLIA) layer, and the corresponding parameters of the harmonic model. To classify a Sentinel-1 grid-cell as flooded or not, the posterior probabilities of the backscatter value belonging to “flood” and “non-flood”, is computed.

The maximum posterior probability is used to classify the pixel based on Bayes Decision Rule, where the uncertainty of the class assignment is given by the minimum posterior probability of the other class. With this approach, each pixel is assigned membership in a certain class, along with an uncertainty value ranging between 0 and 1. The uncertainty is minimized with improved separability between the two backscatter signature distributions and is higher where the distributions overlap. Consequently, pixels located along flood boundaries, where class assignment is generally more challenging, are associated with higher degrees of uncertainty. Finally, to convert the uncertainty values to percentages, the uncertainty values are linearly scaled to fall within the range of [0, 100].

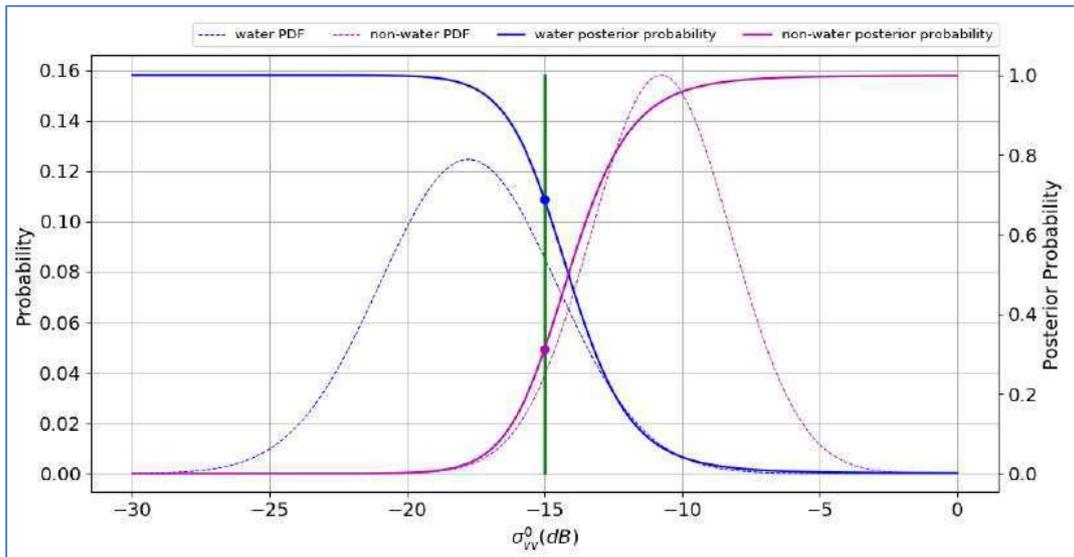
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The classification method used by the TU Wien flood mapping algorithm is illustrated in Figure 4. In this example, the backscatter measurement equals to -15dB, so the pixel is classified as water, since the posterior probability of water is larger than that of non-water. The uncertainty is then the posterior probability of non-water, reflecting the overlap of both PDFs.

The final part of the TU Wien flood-mapping algorithm is to post-process and mask the classification outcome of the Bayes Decision Rule. A small (5x5) spatial majority filter is applied to eliminate single pixels with a lower backscatter due to “noise”. The resulting flood map is masked on a pixel-basis for statistical ill-posed conditions, this includes areas where the two distributions are too close/similar, extreme outliers in the backscatter observations or the radar incidence angle, or when the Bayes Decision is too uncertain (see Bauer-Marschallinger et al, 2022). Additionally, GFM exclusion layers are applied to the observed water map, in order to mask the following areas having an a-priori low or zero probability of being sensed as flooded: radar shadows, no sensitivity, permanent low backscatter, elevated areas that are not prone to flooding (using a HAND index), and permanent and seasonal water bodies. This last step involves subtraction of the GFM Reference Water Mask from the generated and filtered water map to retrieve the final map of flooded areas.

The data processing workflow for the TU Wien flood mapping algorithm is illustrated in Figure 5. Further details on the algorithm are presented by Bauer-Marschallinger et al. (2022), Wagner et al. (2021), and Wagner et al. (2020).



**Figure 4. Illustration of the classification method used by TU Wien’s flood mapping algorithm, based on the water and non-water probability density functions (PDFs), and water and non-water posterior probabilities with equal priors (0.5), for a flooded pixel.**

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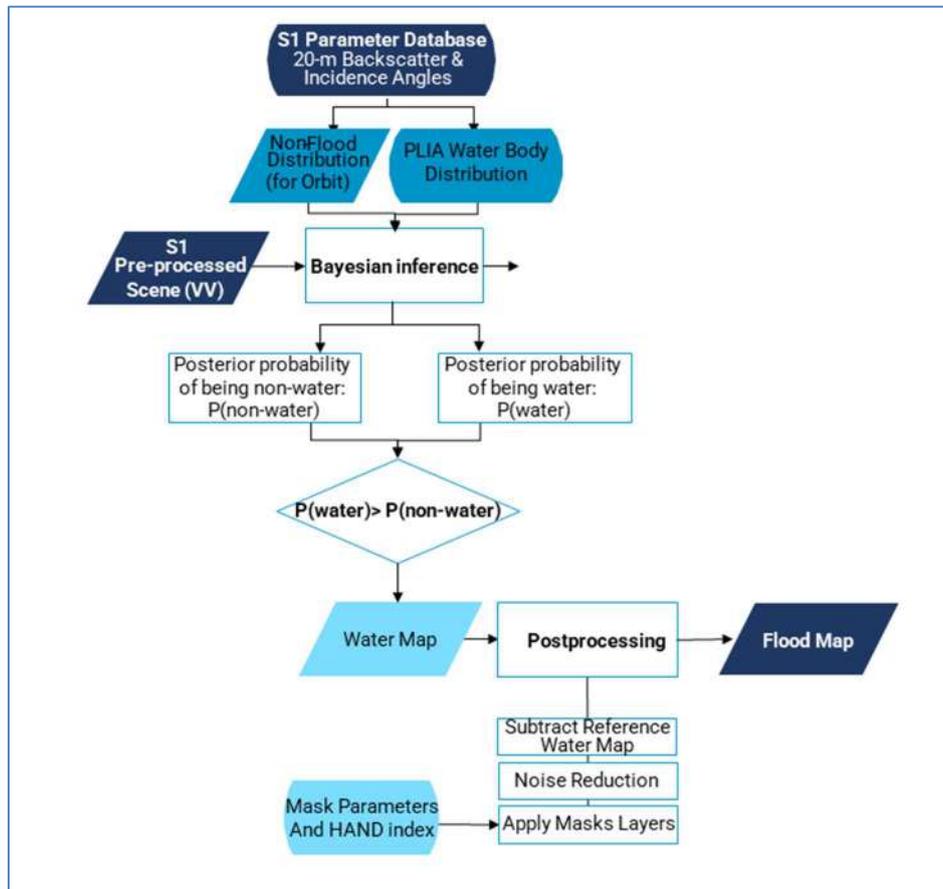


Figure 5. Data processing workflow for GFM flood mapping algorithm 3 (developed by TU Wien).

**In a nutshell:**

*GFM flood mapping algorithm 3 (TU Wien) fully exploits the entire Sentinel-1 signal history within the data cube, realized by a set of a-priori computed statistical parameters layers that provide a highly accurate characterization of Earth’s land surface at pixel level, as well as of the incidence angle dependency in respect to the Sentinel-1 mission.*

*With those parameters as input, and with the mathematical legacy of Bayes, the water delineation procedure can be computationally designed in a relatively efficient manner and is hence most suitable for global operations in near real-time.*

*Further details are provided in the dedicated section of the Product Description Document (PDD):*

<https://extwiki.eodc.eu/GFM/PDD/GFMoutputLayers>

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### 3.4 GFM ensemble flood and water mapping algorithms

The three GFM flood mapping algorithms – i.e. **flood mapping algorithm 1** (developed by LIST), **flood mapping algorithm 2** (developed by DLR), and **flood mapping algorithm 3** (developed by TU Wien) - operate in parallel, and work on the same pre-processed Sentinel-1 input data to generate their own “Observed flood extent” output layers. An ensemble-based approach is then used to combine the three “Observed flood extent” maps generated by the three algorithms, into a single “**consensus map**”. In the ensemble method, each image pixel is first assigned a ratio (0-1) indicating the number of algorithms that classified it as “flooded” (where a ratio of 1 indicates that all three algorithms classified it as “flooded”). The final classification is straightforward and based on a majority decision: a pixel is accepted as “flooded” when at least two of the three algorithms classify it as such. The ensemble flood algorithm applies the reference water and the exclusion mask to harmonize the results of all individual algorithms.

In the unlikely scenario that one of the GFM flood mapping algorithms fail to produce a result, a pixel is classified as flooded only if both the remaining algorithms detect it as flooded. Exceptionally, should only one algorithm's result be available for a pixel, the latter will be automatically classified as “no data”, regardless it is detected as inundated or not.

Similarly, the GFM ensemble water mapping algorithm is used to generate the GFM Product output layer Reference water mask. The LIST and DLR flood mapping algorithms, unlike the TUW algorithm, both produce a water extent map and associated uncertainties, as a by-product of the flood detection. In the GFM ensemble water mapping algorithm, the LIST and DLR algorithms are applied to a “data cube” of Sentinel 1 images for a five-year period (for permanent water) or the mean backscatter value of images over a five-year time period per month (for seasonal water). The resulting single water extent maps are combined into twelve masks, one per month, showing permanent and seasonal reference water extent. The GFM ensemble water mapping algorithm follows the same logic as the GFM ensemble flood mapping algorithm, using a consensus decision of the LIST and DLR algorithms to decide if a pixel is water or no water. Where they disagree, the pixel is considered as not water.

***In a nutshell:***

*The GFM ensemble flood mapping algorithm integrates the results of the three leading-edge GFM flood mapping algorithms into a single product.*

*The GFM ensemble water mapping algorithm integrates the results of two of the GFM flood mapping algorithms to produce a reference water mask, showing permanent and seasonal water bodies.*

*The “consensus maps” that are generated by the ensemble approach substantially improve the robustness and accuracy of the GFM Product output layers “Observed Flood Extent” and “Reference Water Mask”, and add a high degree of redundancy to the data processing workflow.*

*Further details are provided in the dedicated section of the Product Description Document (PDD):*

<https://extwiki.eodc.eu/GFM/PDD/GFMoutputLayers>

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### 3.5 Data cube of historical Sentinel-1 SAR backscatter data used by the GFM Product

As has been mentioned earlier, the data processing architecture underpinning the different GFM flood mapping algorithms is based on the “**data cube**” concept (Wagner et al., 2021; Wagner et al., 2020), whereby all incoming Sentinel-1 SAR satellite images are geocoded, gridded, and stored as analysis ready data (ARD) in an existing space-time SAR data cube. By using a data cube (where the temporal and spatial dimensions are treated in the same way) each Sentinel-1 image can be compared with the entire backscatter history, allowing the implementation of different types of change detection algorithms in a rather straightforward manner. Importantly, the entire backscatter time series for each pixel can be analysed. Therefore, model training and calibration may be carried out systematically for each pixel.

The main advantages of working with data cubes are:

- The flood mapping algorithms are better able to handle land surface heterogeneity.
- Uncertainties can be better specified.
- Regions where open water cannot be detected for physical reasons (e.g., dense vegetation, urban areas, deserts), can be determined a priori.
- Historical water extent maps can be derived, essentially as a by-product of the model calibration, which may serve as a reference for distinguishing between floods and the normal seasonal water extent.

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#### 4 The GFM Product output layers of worldwide flood-related information

Each of the ten GFM Product output layers listed below is briefly described and illustrated in the following sub-sections. A more detailed technical description of the GFM Product output layers is provided in the GFM Product Definition Document (PDD)<sup>3</sup>.

##### 4.1 GFM Product output layer: Observed Flood Extent

The GFM Product output layer Observed Flood Extent identifies the pixels covered by floodwater, mapped using Sentinel-1 (S-1) SAR backscatter intensity. An example of this output layer is shown in Figure 6. Pixels that are normally under water (identified using the monthly Reference Water Mask) are not part of this output layer. Observed Flood Extent is derived using the GFM ensemble flood mapping algorithm, as described in Section 3 above.

To map flood extent pixels for a certain date, the algorithm uses as input the Sentinel-1 (S-1) data overpass plus offline-generated S-1 SAR parameters and auxiliary thematic datasets such as Exclusion Mask and topography (e.g., DEMs and HAND index). The relative orbit path information, to select the corresponding offline-generated S-1 SAR parameters, is extracted from the S-1 Metadata. During the near real-time operation of the GFM Product, the acquisition month of the S-1 scene is retrieved from the S-1 Metadata and the corresponding monthly S-1 Reference Water Mask is cropped to the extent of the processed S-1 scene. All the processing is done at the 20 metres spatial resolution of the S-1 pre-processed data cube.

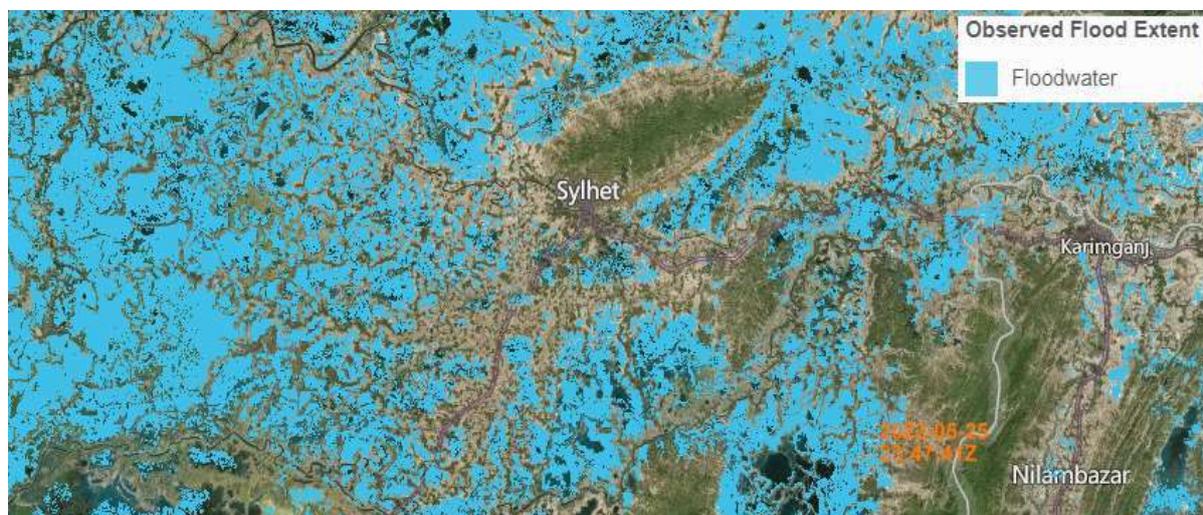


Figure 6. Example of the GFM Product output layer “Observed flood extent”.

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#### 4.2 GFM Product output layer: Observed Water Extent

The GFM Product output layer Observed Water Extent identifies the pixels classified as open and calm water using S-1 SAR backscatter intensity and is derived using the ensemble flood mapping algorithm. An example of this output layer is shown in Figure 7. To map water extent pixels for a certain date, the algorithm uses as input the S-1 data overpass plus offline-generated Sentinel-1 SAR parameters and auxiliary thematic datasets such as Exclusion Mask and topography (e.g., digital elevation models and *HAND index*). The relative orbit path information, to select the corresponding offline-generated S-1 SAR parameters, is extracted from the GFM Product output layer Sentinel-1 Footprint and Metadata. All the processing is done at the 20 metres spatial resolution of the S-1 pre-processed data cube.

In practice, the GFM Product output layer Observed Water Extent is created as a union of the GFM Product output layers Observed Flood Extent (derived by the GFM ensemble flood mapping algorithm) and Reference Water Mask (derived by the GFM ensemble water mapping algorithm), which represents the extent of open water bodies under normal conditions. In the literature, reference masks of permanent water extent are often used for this purpose (Wieland and Martinis, 2019).

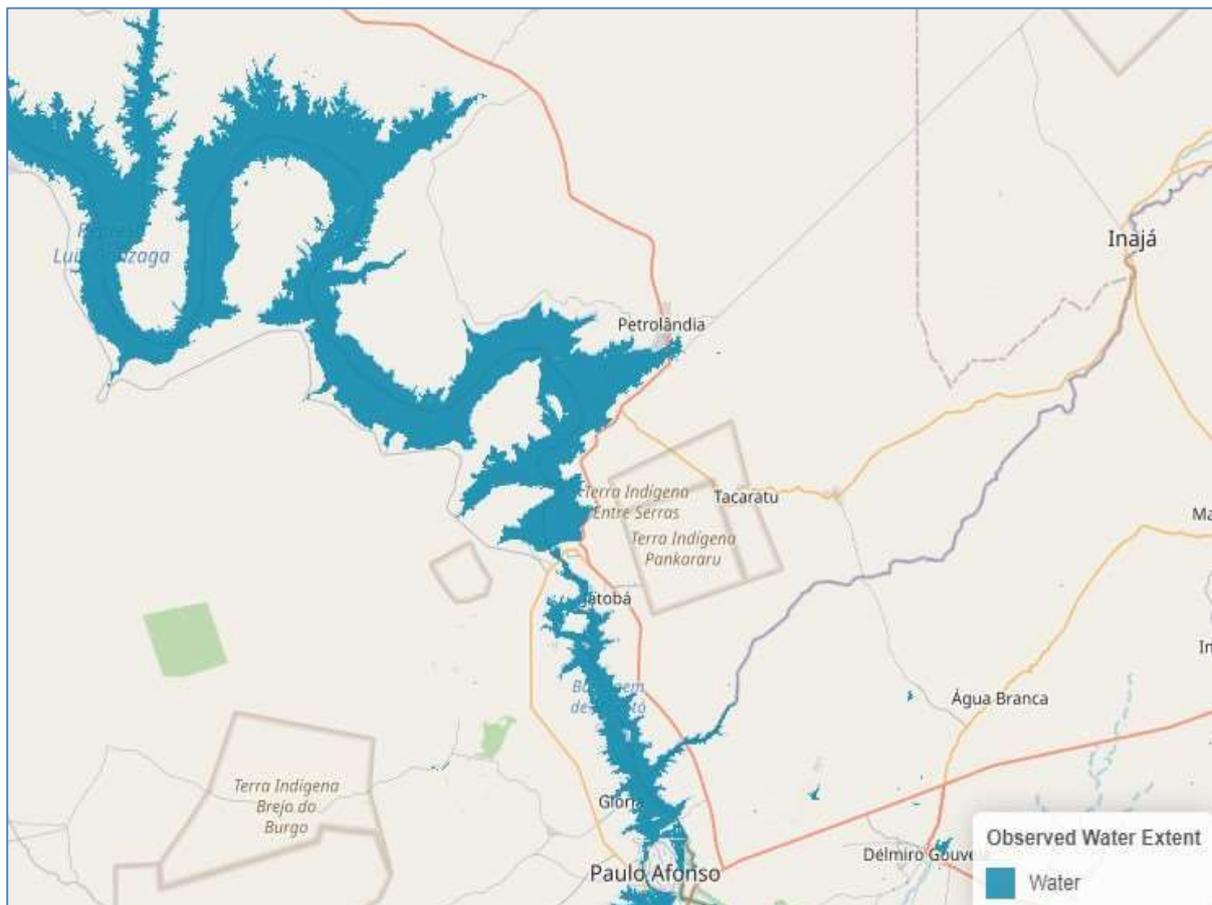


Figure 7. Example of the GFM Product output layer “Observed water extent”.

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### 4.3 GFM Product output layer: Reference Water Mask

The GFM Product output layer Reference Water Mask identifies pixels classified as open and calm water, both permanent and seasonal, by applying the GFM ensemble water mapping algorithm to a two-year “data cube” (time series) of Sentinel-1 SAR backscatter intensity. An example of this output layer is shown in Figure 8.

Whereas the mapping of permanent water extent uses as input the median backscatter of all Sentinel-1 data from a period of five years, the mapping of seasonal water extent uses as input the median backscatter of all S-1 data from a given month over a two-year period. As a result, twelve masks are available, one per month, which includes information on the permanent and seasonal reference water extent. This parameter database is updated once a year. For example, the NRT system running in 2022 relied on the Reference Water Mask extracted from the Sentinel-1 pre-processed data cube from 2020 and 2021.

Radar shadow and low sensitivity exclusion layers, and the *HAND index*, are applied to the reference water mask (and associated uncertainty layer) to correct pixels that were possibly misclassified. Finally, the Copernicus Global Surface Water Maximum Water Extent layer (Pekel et al., 2016) is used to remove possible false positive classifications, while the Copernicus Water Body Mask is used to correct false negatives (e.g. large lakes with roughened surface falsely classified as land) and to enforce a consistent land-sea border.

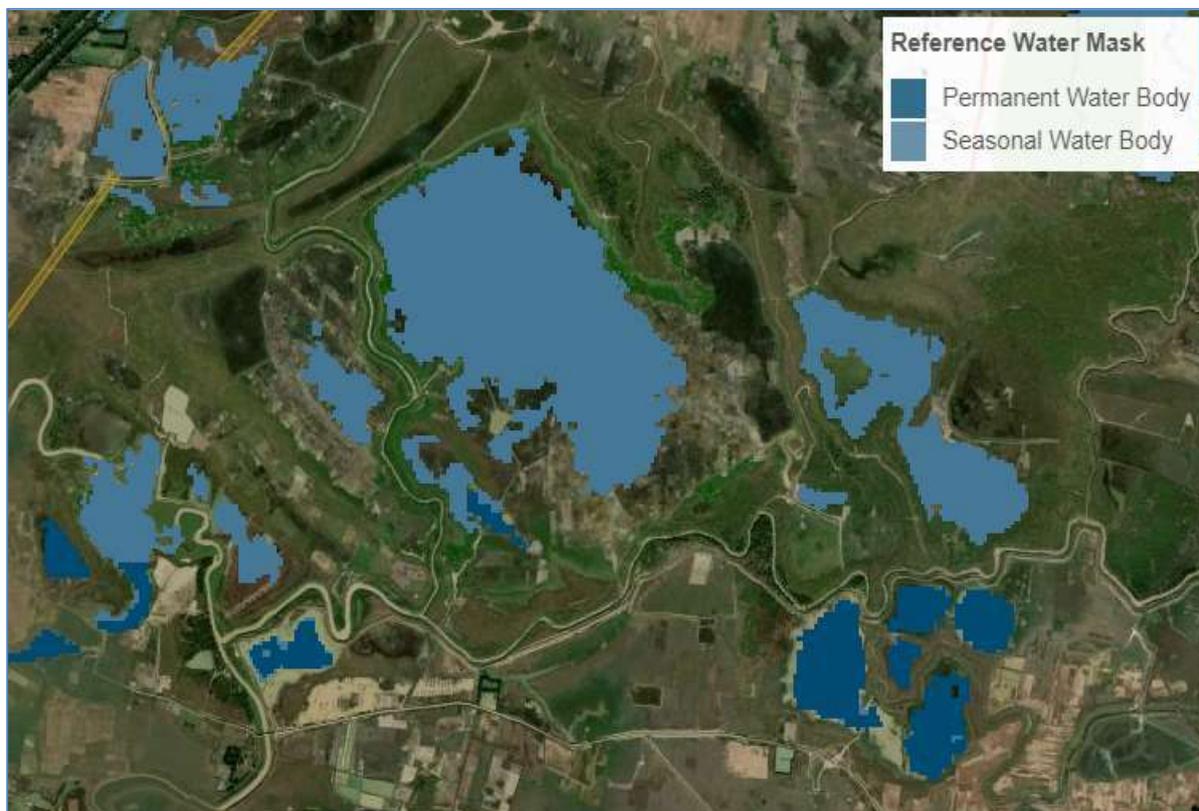


Figure 8. Example of the GFM Product output layer “Reference water mask”.

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A truly permanent water area would mean that there was observed water coverage in every single observation of the considered time-period, i.e., the Water Occurrence (WO), which is the ratio between the number of water detections during a certain time-period and the number of valid observations of the same period, would be 100%. To consider uncertainties in the single water segmentations and the occurrence of hydrological extreme events the WO threshold is usually relaxed to a value of 85-90 % (e.g., *Pekel et al., 2016*).

#### 4.4 GFM Product output layer: Exclusion Mask

The GFM Product output layer Exclusion Mask indicates those locations (grid-cells) where the SAR data does not contain the necessary information for a robust flood delineation, due to the combined deleterious effects of the following main “static” factors:

- No sensitivity to flood mapping, where Sentinel-1 does not receive sufficiently strong signals from the ground surface to distinguish a flooded from a non-flooded surface.
- Water look-alikes, where Sentinel-1 SAR backscatter from the non-flooded ground surface is so low as to be indistinguishable from the backscatter from smooth open water.
- Strong topography, when Sentinel-1 signals are heavily distorted by terrain effects, effectively enhancing the noise and signal disturbances to such a degree to that it becomes larger than the change in backscatter due to potential flooding.
- Radar shadows, when Sentinel-1 receives no signals from certain regions of the land surface because of mountains, high vegetation canopies or anthropogenic structures.

An example of this output layer is shown in Figure 9.

For generation of the Exclusion mask, the GFM Product implements various methods that address the identified problems of SAR-based flood mapping. The parameter database stores for all locations, on a pixel basis, the areas excluded by the four groups of factors, with the radar shadow layer per local Sentinel-1 orbit configurations (up to six per location). During NRT operation, the relative orbit is determined from the S-1 metadata, and the respective Exclusion Mask layers are subset to the extent of the processed Sentinel-1 scene and form a single binary mask for exclusion areas.

As no-sensitivity is a problem leading more often to an under-estimation rather than over-estimation of flooding (e.g. in urban areas), the no-sensitivity -masking is only applied to pixels classified as non-flooded. Pixels classified as flooded are kept unmasked. Any no-data areas from the flood mapping algorithm are forwarded to this layer and added as no-data values.

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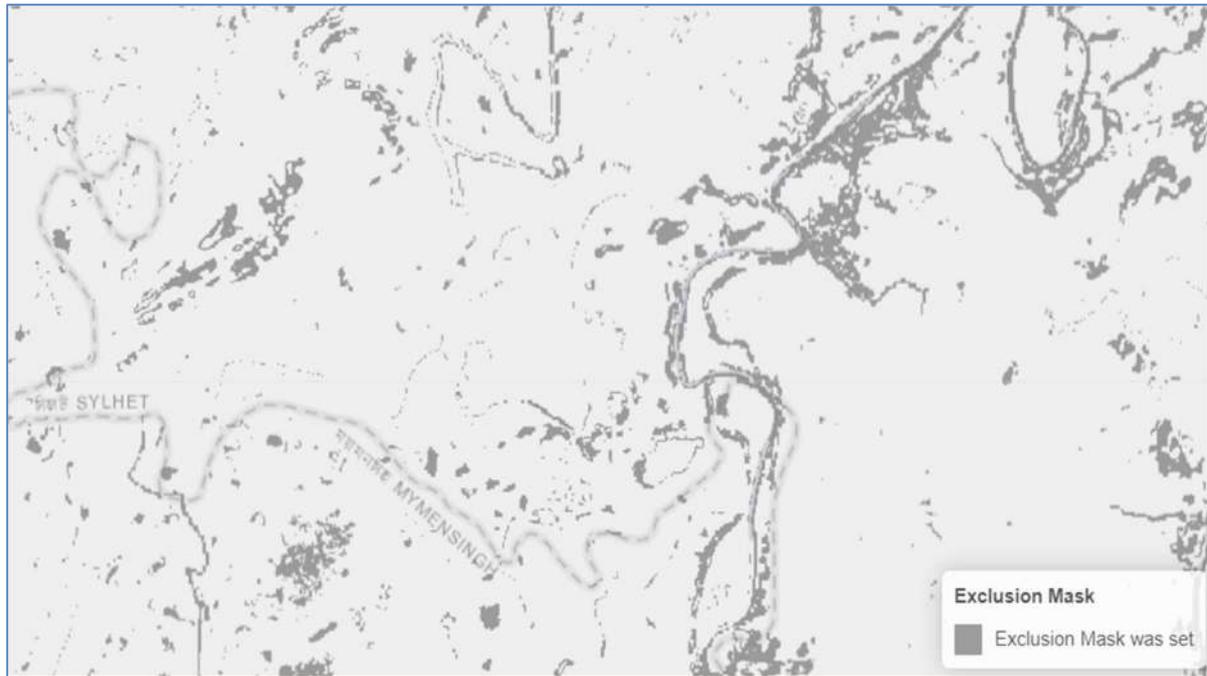


Figure 9: Example of the GFM Product output layer “Exclusion mask”

#### 4.5 GFM Product output layer: Likelihood values

Aggregated likelihood values are generated along with the binary map product as a simplified appraisal of trust in the ensemble flood mapping method. An example of this output layer is shown in Figure 10.

First, the likelihood information from each of the individual algorithms is expressed in the same numerical range [0, 100] to ensure comparability and to facilitate further harmonization. More specifically, probabilistic values from the LIST algorithm and fuzzy membership values from the DLR algorithm are first converted into classification likelihood and next multiplied by a factor of 100. For the DLR algorithm, since fuzzy membership values are only assigned to water pixels, all unflooded pixels are assigned a value of 0. The conversion of these probabilistic (or fuzzy membership) values is carried out as:

$$U = W_i * (100 - P_i) + (1 - W_i) * P_i$$

where:

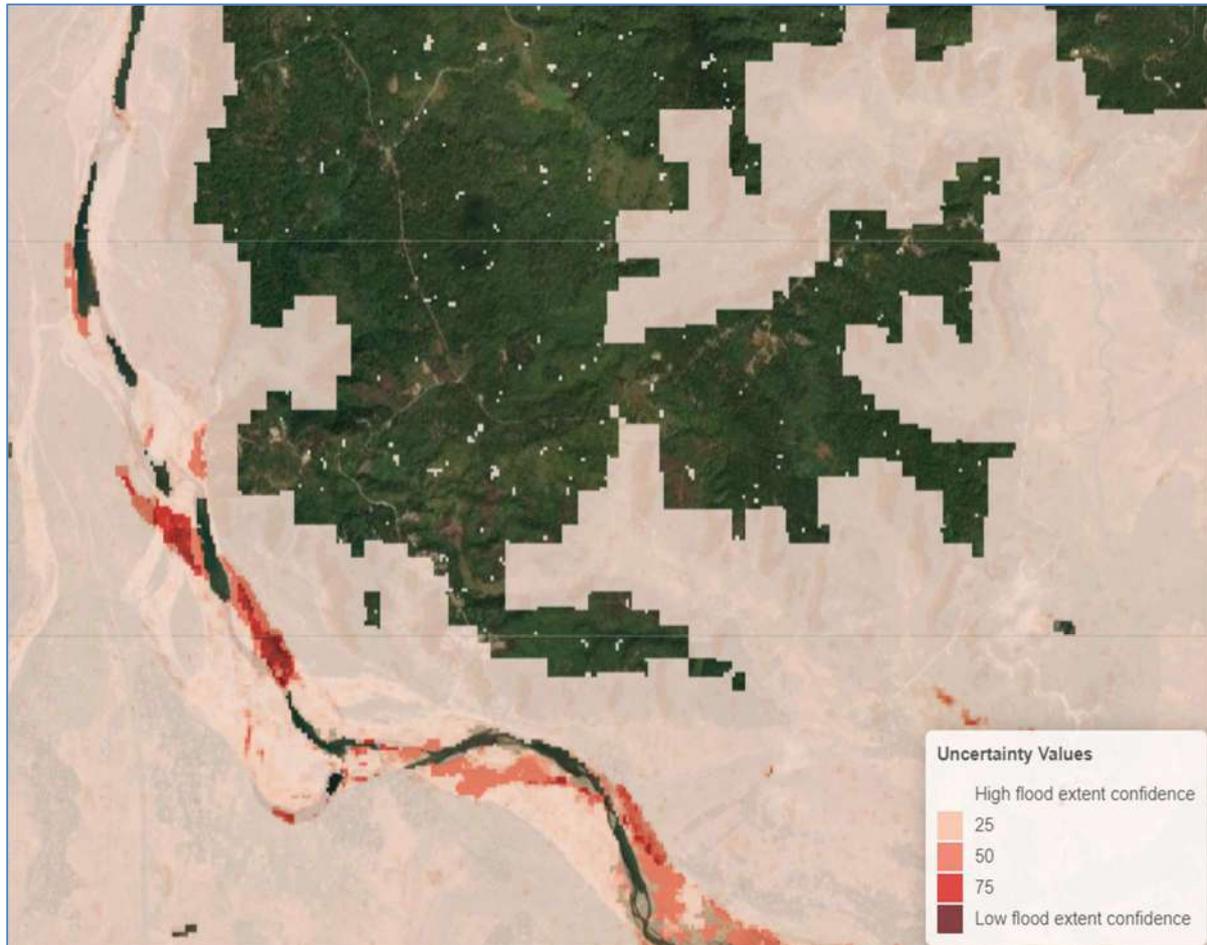
- $W_i$  represents the binary water map classification (0 for dry and 1 for water classes).
- $U$  is the likelihood value.
- $P_i$  is the probabilistic (resp. fuzzy membership) value.

The classification likelihood values resulting from the TU Wien flood mapping algorithm (ranging from 0 to 1000) are divided by 10 to fall with the range [0,100].

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Finally, the average of the likelihoods from the three algorithms is taken. This has a value in the range of [0, 100], where values towards 100 indicate high confidence in the **GFM ensemble flood mapping** approach. Consequently, the likelihood information provided along with the map product communicates how much confidence is associated with the Sentinel-1 classification. End users can then use highly certain flood map products to identify resource requirements over areas of flood exposure to make timely emergency response decisions.



**Figure 10. Example of the GFM Product output layer “Likelihood values”.**

#### **4.6 GFM Product output layer: Advisory Flags**

The GFM Product output layer Advisory Flags indicates pixels that potentially suffer from decreased contrast between water and non-water surfaces due to meteorological factors as wet snow, frost and dry soil, or wind-roughened water. Pixels marked by the Advisory Flags are not excluded by the Exclusion Mask, but users are advised to use with caution the Observed flood and water extent data over flagged areas. An example of this output layer is shown in Figure 11.

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For each incoming Sentinel-1 scene that is input to the flood mapping algorithm, the advisory flag information is generated during NRT runtime. After generating the Observed Water Extent layer, the pre-processed 20m Sentinel-1 backscatter coefficient array is analysed and compared with calm water signature database to find pixels with rough water surface.

After the thresholding and spatial buffering, the obtained intermediate pixel-map indicating regions potentially affected by wind is stored. The 20m-oversampled backscatter data from the temporally corresponding 25km ASCAT observation dataset is compared to the local ASCAT backscatter 20th percentile value, which is pre-computed and accessed from the data cube. All pixels with detected low regional backscatter are forwarded to the intermediate storage and the final Advisory Flag pixel map for the Sentinel-1 scene extent is computed along with a 14 km-radius buffer.

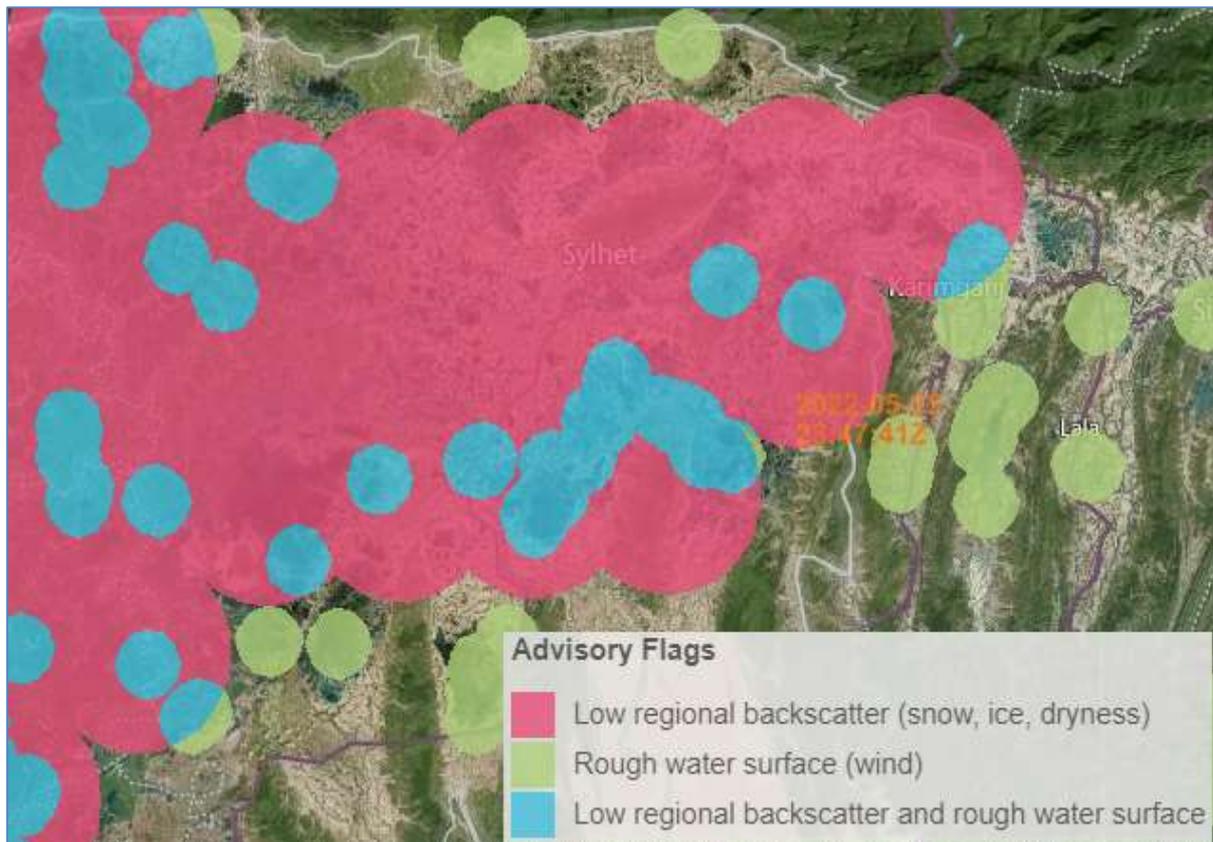


Figure 11. Example of the GFM Product output layer “Advisory flags”.

#### 4.7 GFM Product output layer: Sentinel-1 Footprint and Metadata

The GFM Product output layer “Sentinel-1 Footprint and Metadata” shows all of the metadata attributes provided with each Sentinel-1 GRD data product used to generate the GFM Product main output layers. Metadata of each Sentinel-1 GRD scene are provided in the distributed Sentinel “Standard Archive Format for Europe (SAFE)” format, an XML file containing the mandatory product metadata. An example of this output layer is shown in Figure 11.

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Attributes contained in the manifest file are classified into four categories:

- a. Summary.
- b. Product.
- c. Platform.
- d. Instrument.

Platform- and instrument-related attributes are considered as static for the different Sentinel-1 satellites. A total number of 29 attributes are contained in the manifest file such as information about the absolute orbit number, pass direction, polarisation, sensing start and end date and the product timeliness category. An abstract of the included attributes is given in hereafter as an example.

After successful retrieval of a Sentinel-1 GRD product at EODC the manifest file is parsed and inserted into the operated metadata database. Access to the actively maintained metadata base is given via the well-defined OGC CSW standard referred to as metadata catalogue. The database itself builds upon PostgreSQL following a relational database system.

The requested Sentinel-1 metadata are provided via PostGIS representing a spatial database extender of the PostgreSQL database. The PostGIS layer allows on-demand querying of geographic objects conform to OGC mapping standards such as WMS-T, WCS or WFS.

The footprint of a Sentinel-1 GRD scene as provided in each data product is included in the mentioned manifest file. The footprint is represented as human readable Java Topology Suite (JTS) object named "JTS footprint".

The JTS footprint is converted into Well-known Text (WKT) and Well-known Binary (WKB) in the process of parsing and ingesting the acquired manifest files into the operated metadata database. WKT and WKB are originally defined by the OGC to describe simple features.

Hence, the Sentinel-1 footprint will be available as PostGIS layer accessible via all supported OGC mapping standards. On-the-fly conversion to standalone data formats can be supported via standard GIS tools based on user request.

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Sentinel 1 Metadata	
Mode	IW
Title	S1A_IW_GRDH_1SDV_20220129T143052_20220129T143118_041677_04F566_617D
Format	SAFE
Abstract	-
Mdsources	REMOTE
Platform	SENTINEL-1
Time end	2022-01-29T14:31:18.024000
Publisher	ESA
Identifier	S1A_IW_GRDH_1SDV_20220129T143052_20220129T143118_041677_04F5
Instrument	SAR-C
Time begin	2022-01-29T14:30:52.811000
Insert date	2022-01-29T16:03:13.784000
Total slice	0
Polarisation	VV+VH
Product type	GRD
Slice number	20
Number of lines	0
Orbit direction	ASCENDING
Platform number	A
Processing date	1970-01-01T00:00:00
Processing site	AIRBUS DEFENCE AND SPACE-TOULOUSE
Abs orbit number	41677
Processing level	1
Rel orbit number	130
Resolution class	HIGH
Number of samples	0
Processing country	-
Processing facility	COPERNICUS S1 CORE GROUND SEGMENT - TLS
Processing software	-
Processing organization	ESA
Polarisation combination	DV
Processing software version	-
Product timeliness category	FAST-24H

Figure 12. Example of the GFM Product output layer “Sentinel-1 Footprint and Metadata”, showing the ancillary information for a specific Sentinel-1 overpass.

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Figure 13. Example of the GFM Product output layer “Sentinel-1 Footprint and Metadata”, showing incoming Sentinel-1 overpasses.

#### 4.8 GFM Product output layer: Sentinel-1 schedule

Sentinel-1 observations follow a strict acquisition planning often referred to as acquisition segments. Information on the planned future acquisition is provided by ESA in form of Keyhole Markup Language (KML) files. A single file usually covers an acquisition period of about 12 days, with the start and stop time of the future planned acquisitions already given in the file name. The GFM Product output layer “Sentinel-1 schedule” shows planned Sentinel-1 acquisitions for the next three days. An example of this output layer is shown in Figure 14.

KML files are published regularly by ESA, well before activation, with potential last-minute changes due to requests from the Copernicus Emergency Management Service. Information provided in the KML files is organised based on the planned data takes. Parameters listed in Table 5 are included in the KML. The KML files are regularly checked and downloaded at EODC and ingested into the described metadata database for further analysis. All parameters are exposed as PostGIS layer to extract the requested schedule information indicating the next planned Sentinel-1 GRD acquisition for a given location.

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Figure 14. Example of the GFM Product output layer “Sentinel-1 schedule”.

Table 5. Information provided with the next planned Sentinel-1 GRD acquisition.

PARAMETER	DESCRIPTION
<b>Datatake ID:</b>	Unique product identifier (hexadecimal).
<b>Mode:</b>	Instrument acquisition mode.
<b>Observation (duration):</b>	Duration of the planned data take (in seconds).
<b>Observation (start):</b>	UTC start date and time of the planned data take.
<b>Observation (end):</b>	UTC end date and time of the planned data take.
<b>Orbit (absolute):</b>	Absolute orbit number at the start time of the data take.
<b>Orbit (relative):</b>	Relative orbit number at the start time of the data take.
<b>Polarisation:</b>	Instrument polarisation for the acquired data take.
<b>Satellite ID:</b>	Satellite identifier.
<b>Swath:</b>	Instrument swath (from 1 to 6 for SM, not applicable for IW and EW).

#### 4.9 GFM Product output layer: Affected Population

The GFM Product output layer Affected Population is derived based on data extracted from the Global Human Settlement (GHS) layer and, in particular, from the GHS-POP dataset. This data contains a raster representation of the population's distribution and density as the number of people living within each grid cell. The information is available at various spatial resolutions and for different epochs. An example of this output layer is shown in Figure 15.

For the GFM processing, the dataset at 100m resolution (highest possible resolution) and for the latest available timestep, 2020 are used. Combining this re-projected and re-sampled raster dataset and the flood extent allows to provide the number of affected people for each specific pixel detected as flooded.

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The updated dataset replaces the former GHSL population dataset at 250m resolution with the reference year 2015, which was available at the start of GFM operations and was used for production during October 2021 – March 2023.

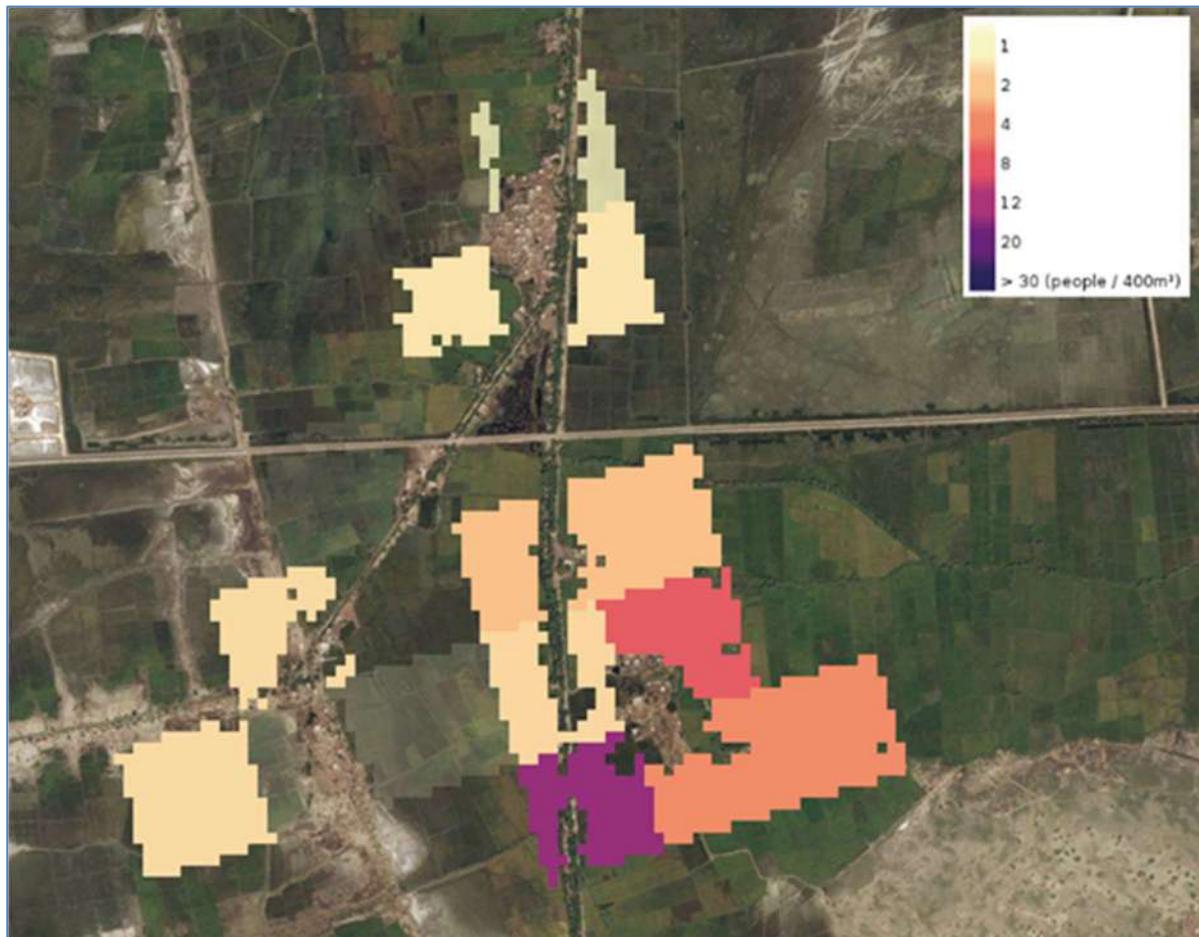


Figure 15. Example of the GFM Product output layer “Affected population”.

#### 4.10 GFM Product output layer: Affected Landcover

The GFM Product also provides, in addition to affected population, an output layer highlighting the Affected landcover for a particular flood case. This information can provide a first assessment of affected land cover or land use types, for example how much agricultural area is affected by the flood extent. An example of this output layer is shown in Figure 17.

Based on the GFM consortium’s production heritage and experience in land cover mapping, this output layer is derived from the 100m-resolution database from the Copernicus Global Land Cover Service enriched with information from the Copernicus Pan-European High-Resolution Layers (i.e., Imperviousness, Forests, Grassland, Water and Wetness) over Europe.

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The Global Land Service includes 23 classes and provides annual updates, with an overall accuracy of 80%. The Copernicus Pan-European High-Resolution Layers have an overall accuracy of 85%+ and are available at 20 m (the 2018 version at 10 m) spatial resolution. In addition to both datasets, GFM also includes the most relevant classes from OpenStreetMap (roads, railways, etc.) to allow a first assessment of affected areas and infrastructure.

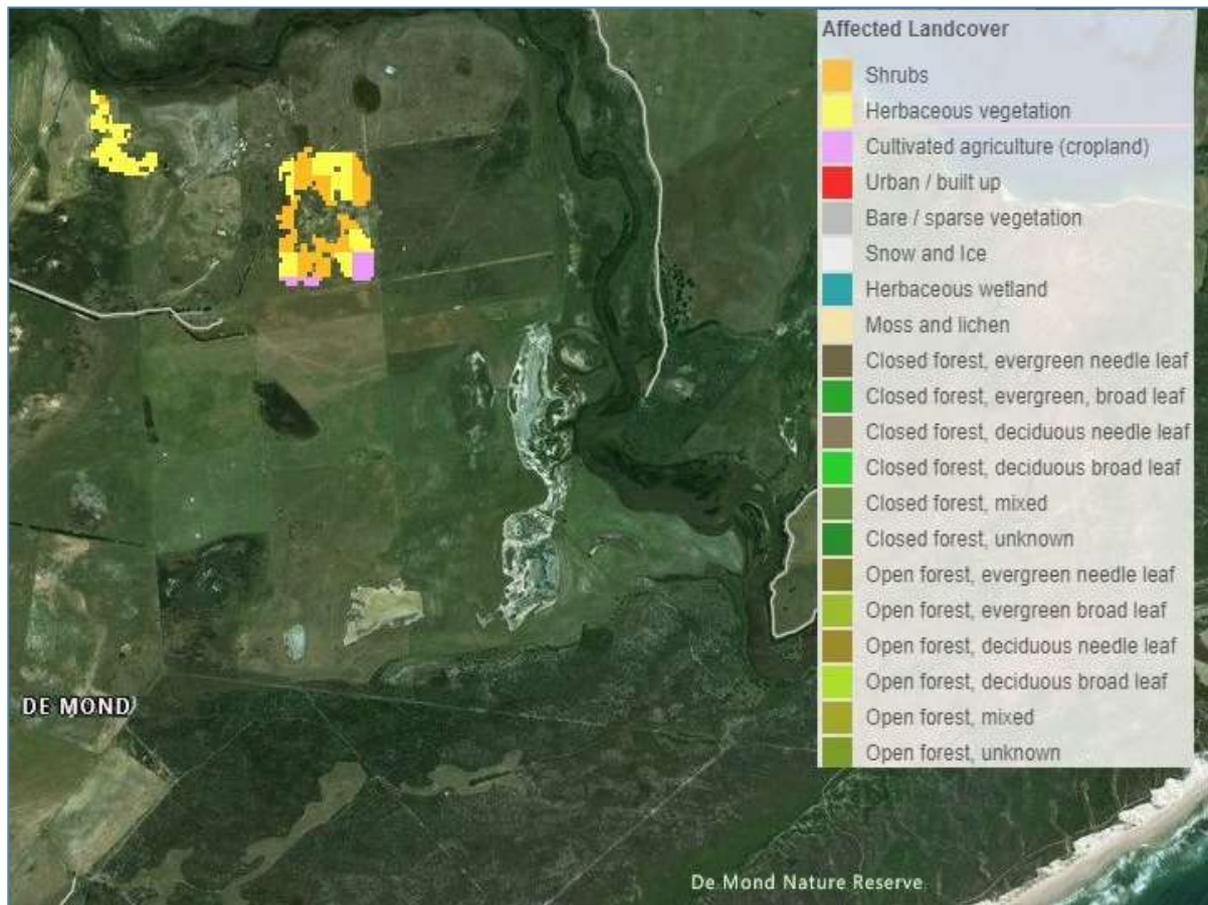


Figure 16. Example of the GFM Product output layer “Affected land cover”.

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## 5 Recommendations and caveats with regard to use of the GFM Product

In general, it is possible to distinguish between both over- and under-detection of observed flood extent (i.e. false alarms and missed alarms, respectively). False alarms unnecessarily draw the attention of users and thus could create frustration and mistrust in the product. Missed alarms on the other hand would lead to situations where a flood event is not detected and leaves the users without notice, possibly losing time for reaction measures.

### 5.1 False alarms

The below-mentioned water-look-alikes can yield **false alarms**:

- Very dry or sandy soils.
- Frozen ground.
- Wet snow.
- Flat impervious areas (e.g. smooth tarmac-covered airfields or roads).

These surfaces and artifacts usually feature very low backscatter signatures and thus appear as water in SAR imagery, rendering the water and flood mapping a difficult task. Another common effect in SAR remote sensing is **radar shadowing**, which appear over strong terrain (especially at the far-range section of the SAR image) as well as in the vicinity of high objects above the ground, like high buildings and along forest borders.

### 5.2 Missed alarms

On the other hand, floods occurring in **urban areas**, **densely vegetated areas**, or under weather conditions featuring **strong winds** or **heavy rainfall** can lead to missed alarms. In particular, wind and heavy rainfall are hard-to-spot dynamic process as they roughen water surfaces and hence undermine the initial assumption of low backscatter due to specular reflection on smooth water surfaces.

### 5.3 How to address false and missed alarms with the GFM Product

A variety of methods can be used to address the abovementioned issues of SAR-based water mapping which potentially cannot be directly solved by the proposed flood detection algorithms using only NRT-available backscatter information and hence indication need on pixel level for potential misclassification due to reduced sensitivity. These challenges are then classified into **Static effects** and **Dynamic effects** with the first bound to the ground surface, land cover or topography, and the latter resulting from meteorological dynamics. This is also done with the perspective on a performant global NRT processing.

Note that “static” is understood here with respect to the GFM reprocessing cycle, i.e., static layers remain unchanged during NRT processing, but they might be updated during the reprocessing after evolution activities.

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Static effects:

- Those that are bound to ground surface characteristics such as land cover (e.g. flat impervious areas, urban areas, densely vegetated areas), and shadowing (radar shadowing), are addressed by the Exclusion Mask. Pixels that could not be classified by the SAR sensor into flood area, permanent / seasonal water body, and non-water area, are highlighted in this product layer as no-data pixels.

Dynamic effects:

- Those that are triggered by weather conditions – i.e. meteorological features (strong wind, heavy rainfall), meteorological-induced state of the soil (soil dryness, frozen ground, or wet snow) - are flagged by the dynamic Advisory Flags. The Advisory Flags indicate locations where the SAR data might be disturbed by such processes during the acquisition, but leaves the flood and water extent layers unmasked.

Both the Exclusion Mask and the Advisory Flags are delivered together with the other GFM Product output layers and aim at improving the reliability, usefulness and user acceptance of the GFM product. The design of this masking / flagging system recognises also the User perspective: with our approach:

- A simple Exclusion Mask indicates all the pixels that could not be classified by the input Sentinel-1 data, consulting statistical parameters from the data cube as well as auxiliary datasets. The pixels addressed by Exclusion Mask thus can be directly discarded as no-data, leaving the interpretation of the produced flood extent and the (adjacent) no-data-gaps to the users, who commonly know best their area-of-interest.
- The Advisory Flags layer aims to raise awareness that meteorological processes comprising wind or frozen conditions might impair the water body detection. As the Advisory Flags can only be retrieved at a coarser resolution, the information of the flags is not fed into the Exclusion Mask. As coming in the form of the additional layer, it should guide the users when interpreting the product, allowing additional insight on its local reliability at the time of Sentinel-1 acquisition.

**5.4 Other known issues**

Land-sea border:

To assure a globally consistent land-sea border for all GFM flood and water output layers, the CopDEM Water Body Mask (WBM) is integrated into the observed water extent and all pixels are set to “water” where the WBM indicates “sea”. While this static land-sea border provides consistency, it does not take into account daily coastline dynamics caused by tides. It may, therefore, occur in rare cases that the land-sea border shows a low-tide case whereas the Sentinel-1 flood mask covers a high-tide. In such a scenario flood pixels may falsely be identified on near-shore sandbanks that are actually inundated during high-tide.

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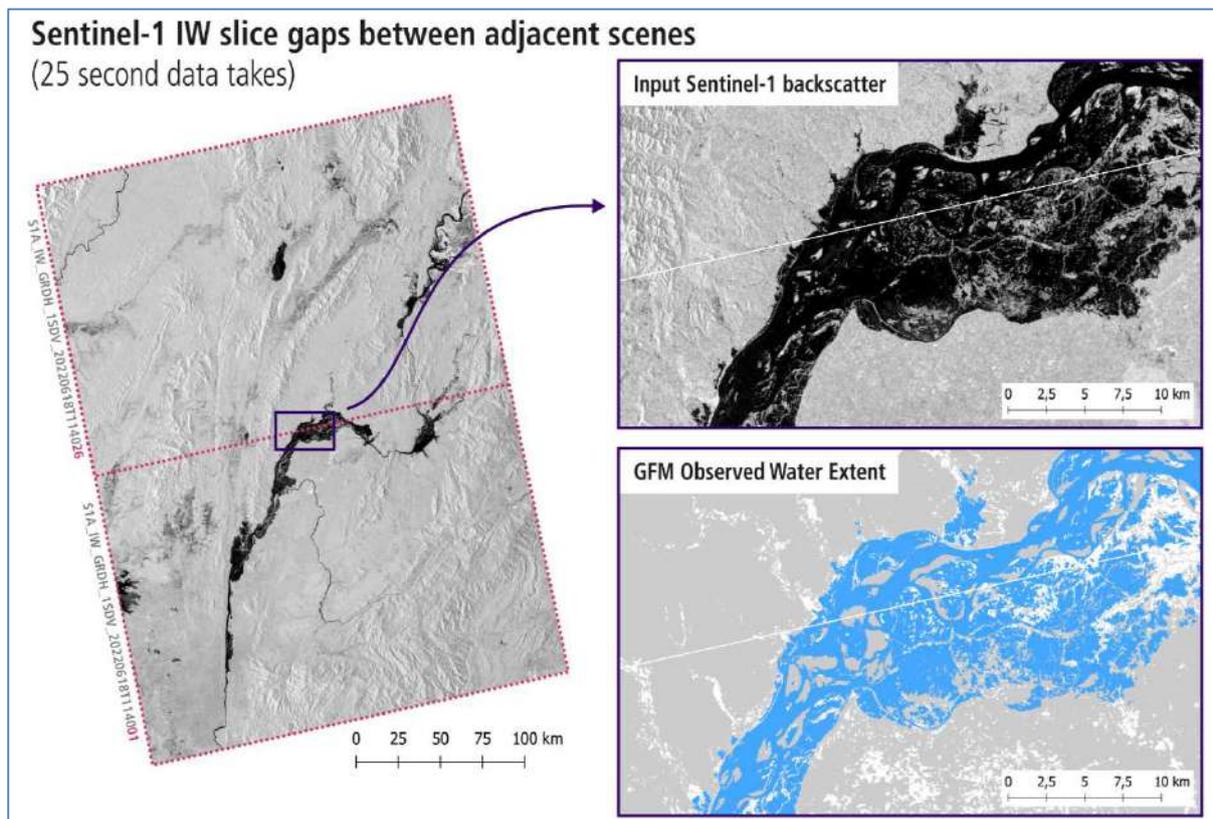


Linear gaps between Sentinel acquisitions:

Sentinel-1 IW CSAR products provided by ESA / Copernicus are the main input to the GFM service. After raw satellite data downlink, ESA as the original data provider, slices the data per 25 seconds sensing time (equivalent to about 170 km in track direction) without leaving any overlap/data duplication.

During the SAR geocoding step, computing the correct backscatter values along the slice edges requires the adjacent measurements. If not available, it generates no-data values, locally. As the GFM service ingest the SAR datasets separately in near-real-time (NRT), neighbouring slices are not available, and narrow stripes of no-data are generated at a dataset's start- and end rows, yielding thin linear gaps. Waiting to have all adjacent files mutually available would decrease the timeliness of the pre-processing, and is not done within the GFM service.

As a consequence, GFM layers remain unclassified over the location of the Sentinel-1 no-data pixels, leaving thin linear gaps. Figure 17 the issue for a flood event in Myanmar in June 2022.



**Figure 17. Example of linear gaps between Sentinel-1 acquisitions in GFM Product results.**

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## 6 Potential user ecosystem for the GFM Product and other relevant services

The identification of the user ecosystem is based on the extended experience of the various partners and a desktop review of relevant European projects in the field of floods, natural hazards and satellite data. Table 6 is intended to point GFM users to the kind of service that could be most suited for their needs.

**Table 6: Overview of potential user ecosystem for the GFM Product and other relevant services.**

FIELD	PURPOSE	SUGGESTED APPROACH	DATA ACCESS
<b>Civil Protection:</b>	NRT situational awareness	<ul style="list-style-type: none"> <li>Automatic feed on flood mapping for specific area. Automatic acquisition of flood mapping products on specific clients.</li> </ul>	<b>Push Notifications</b>
			<b>REST-APIs</b>
<b>Operational Hydrological forecasting:</b>	NRT verification of impact-wise forecasts	<ul style="list-style-type: none"> <li>Automatic acquisition of flood mapping products on <u>EFAS</u> / <u>GloFAS</u>.</li> <li>Automatic acquisition of flood mapping products in other national/regional/global forecast systems (<u>Tethys</u>, <u>WW Hype</u>, <u>FANFAR</u>).</li> </ul>	<b>REST-APIs</b>
			<b>Web Application</b>
<b>DRR-related planning:</b>	Retrieval of historical flood-prone areas	<ul style="list-style-type: none"> <li>Access to the full archive within a specific client application and draft sets of prescriptions to decrease the current risk level or avoid creating new risk.</li> </ul>	<b>Web Map Service</b>
<b>Research:</b>	Calibration/validation of hydrological/hydraulic forecast models	<ul style="list-style-type: none"> <li>Download the entire archive of the global flood monitoring product output layers in raster format to calibrate / validate hydrological/hydraulic forecast models.</li> </ul>	<b>REST-APIs</b>
	Test flood mapping alternative algorithms	<ul style="list-style-type: none"> <li>Access and download the <u>Sentinel-1</u> data used to derive the flood maps over a certain region for specific events and compare them to <b>GFM</b> outcomes.</li> </ul>	<i>UNDER DEVELOPMENT</i>
	Flood mapping algorithms calibration	<ul style="list-style-type: none"> <li>Upload a proprietary algorithm on the Cloud and run it on the full archive of the <b>GFM</b> maps or on a temporal/spatial subset.</li> </ul>	<i>UNDER DEVELOPMENT</i>
	Flood models calibration	<ul style="list-style-type: none"> <li>Access the full archive the flood maps in raster or vector format and calibrate the model on the basis of the historical flood maps.</li> </ul>	<b>REST-APIs</b>
<b>Insurance:</b>	NRT Disaster loss estimate	<ul style="list-style-type: none"> <li>Access in NRT the flood maps in raster or vector format to outline a footprint-based estimate of disaster loss.</li> </ul>	<b>GloFAS/ EFAS</b>
			<b>Web application</b>
<b>Non-expert end users:</b>	NRT actionable information	<ul style="list-style-type: none"> <li>To receive a ready-to-print map in NRT for a certain event in a selected region.</li> <li>To receive short feeds depicting in NRT the flood status over a certain region.</li> <li>To receive notifications on relevant floods in NRT.</li> </ul>	<b>GloFAS/ EFAS</b>
			<b>Web application</b>

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## 7 The GFM Product Access and Dissemination System

GFM Product output layers are freely available through many dissemination systems, each designed for flexible and easy access. Users may access GFM Product output layers through:

- **GloFAS and EFAS.**
- A full set of tailored **REST-APIs.**
- A **Web Map Service.**
- A **Web Push Notification Service.**
- A **Web Map Service.**
- A dedicated **Web Application.**

As is illustrated in Figure 1, all access methods are routed to a central storage via a central access layer. The storage-access layer is capable to serve products in the desired format by drilling down into the data-cubes, querying databases for meta-data or user-management, and receiving data for the WMS-T service.

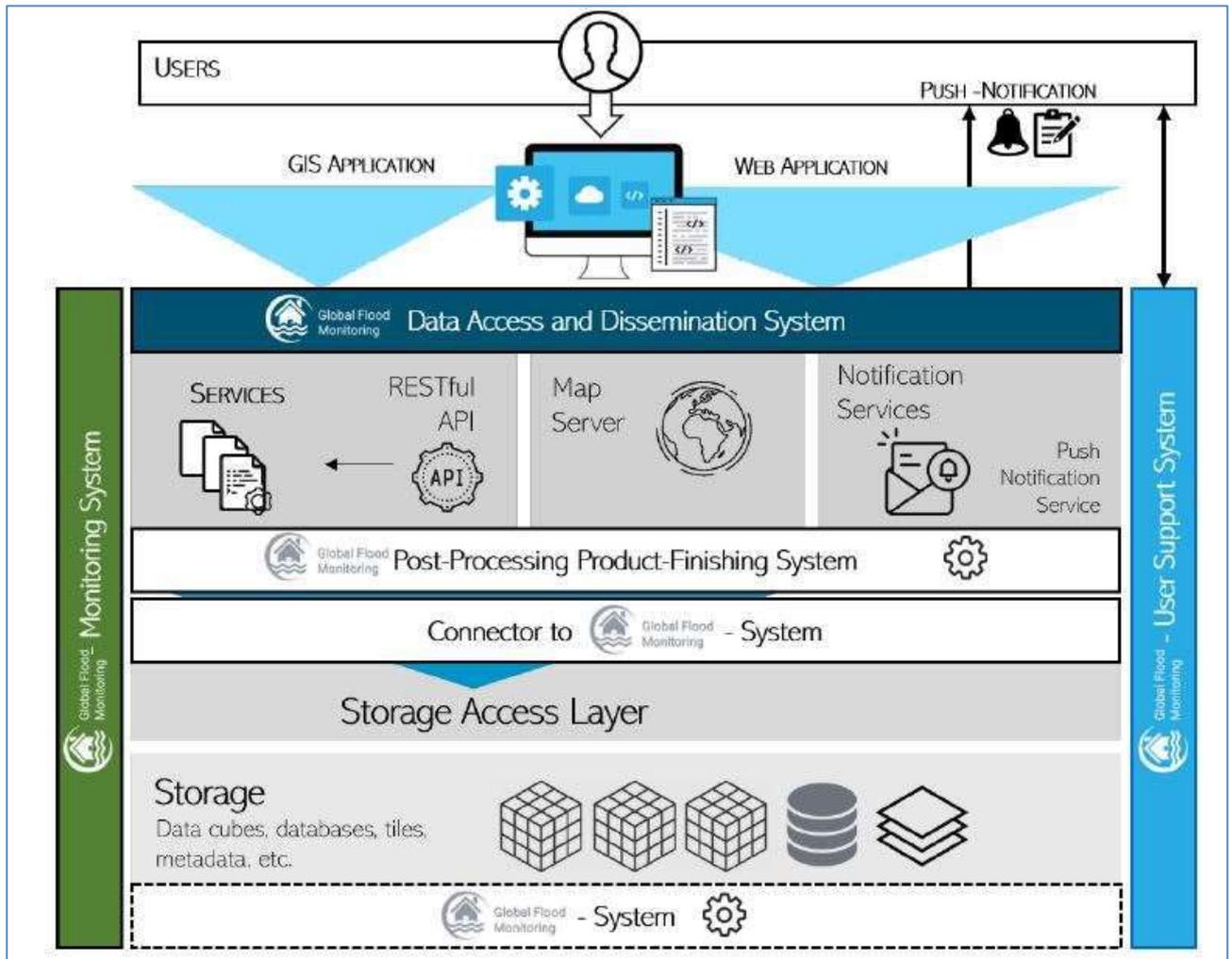


Figure 18: Illustration of the GFM Product Access and Dissemination System.

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## 7.1 The Global Flood Awareness System (GloFAS)

The Global Flood Awareness System (GloFAS) is the global flood service of the European Commission Copernicus Emergency Management Service (CEMS), an operational system monitoring and forecasting floods across the world. GFM's products are made available within the GloFAS Map Viewer<sup>6</sup>. To be allowed to the Map Viewer, users are requested to register to the service by clicking on the following graphic:

Once registered, the MapViewer can be accessed by typing the account details in the following form:

Sign in manually

**Username**

**Password**

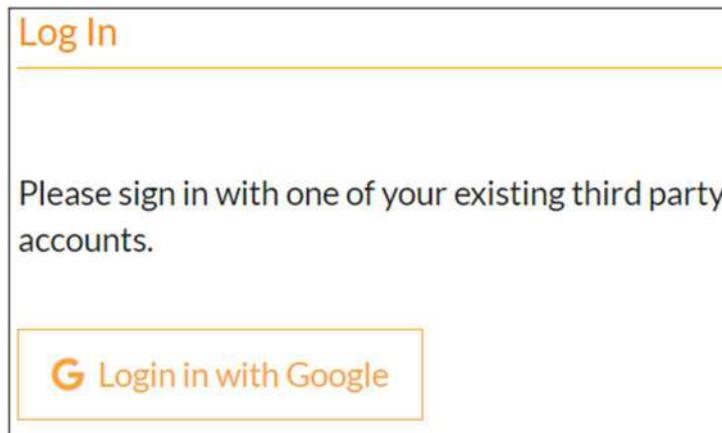
[Forgot your password?](#)

**Keep me logged in**

Users are also offered the chance to sign in to the MapViewer by means of their Google accounts:

<sup>6</sup> <https://www.globalfloods.eu/accounts/login/?next=/glofas-forecasting/>

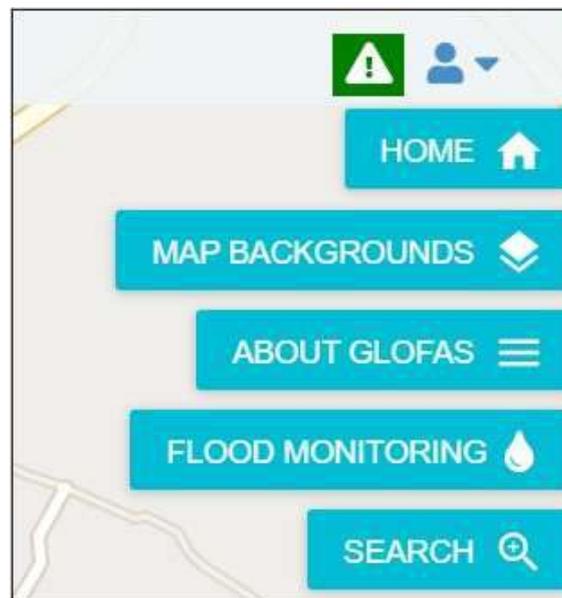
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### 7.1.1 Monitoring the Health Status of the GFM Product

Information about the overall health state of the GFM service is presented to the user within GloFAS Map Viewer. An “alert sign” in the top menu, positioned on the right, next to the user profile, indicates the health state of the service. The alert sign is colour-coded as follows:

- “Green”: Service Up And Running.
- “Amber”: Service Degraded.
- “Red”: Service Not Available.



Detailed information about the health state of the various components of the service can be retrieved by clicking on the “alert sign”. This will open a pop-up window onto the map viewer presenting the latest registered alert notifications as shown below. The different alert notifications are organised by **Group** providing details about the current **Status**, a **Message** describing the alert notification, and a **Date** indicating when the alert was raised. The column

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**Group** in the window refers to the individual components of the service. Four service components/groups are defined which will be outlined hereafter.

Status of GFM system components			
Group	Status	Message	Date
Sentinel1 Datastream	✔	Sentinel-1 pre-processing data registration is up and running.	10/08/2023
GFM Production	✔	Flood data production is up and running.	10/08/2023
GFM Dissemination	✔	No alert registered for this group. Seems as everything is working smoothly.	11/08/2023
API Health	✔	No alert registered for this group. Seems as everything is working smoothly.	11/08/2023

*Note: As a result of the end of the mission of the Copernicus Sentinel-1B satellite (announced by ESA on 3 August 2022), due to the technical anomaly that occurred on 23 December 2021, the current global coverage of the GFM Product, as indicated by the latest Sentinel-1 satellite image tiles which are displayed in the GloFAS Map Viewer, is based on image acquisitions performed by the Sentinel-1A satellite only. It is expected that the full global coverage of the GFM Product (i.e. based on the two-satellite Sentinel-1 configuration) will be restored following the fast-tracked launch of Sentinel-1C, which is currently planned for the second quarter of 2023.*

The group **Sentinel1 Datastream** comprises alerts in respect to any required Sentinel-1 data used to deduce the various layers provided by the service. One major alert event in this group is the Copernicus Services Data Hub<sup>7</sup> acting as reference for all the Sentinel-1 input data used in the service. Downtimes of the Copernicus Services Data Hub as well as issues in receiving the required data will be notified within this group. Furthermore, observed issues in respect to the performed pre-processing of Sentinel-1 data will be alerted, because the pre-processed data is the main input data stream to deduce flood information.

Alert notifications in respect to the production of the individual GFM layers is provided within the group GFM Production. Any observed issues within the actual production system of GFM are forwarded within this group. Anomalies detected in the processing workflow of the flood layers as well as non-availabilities of components of the production system are covered in this notification group as well as the monitoring of the interface towards to the GFM dissemination system.

The GFM dissemination system is responsible to provide access to produced GFM layers. End user entry points the GFM layers are provided by a WMS-T server as well as a dedicated Web Application (portal). Degradations or the unavailability of those will be reported within this group.

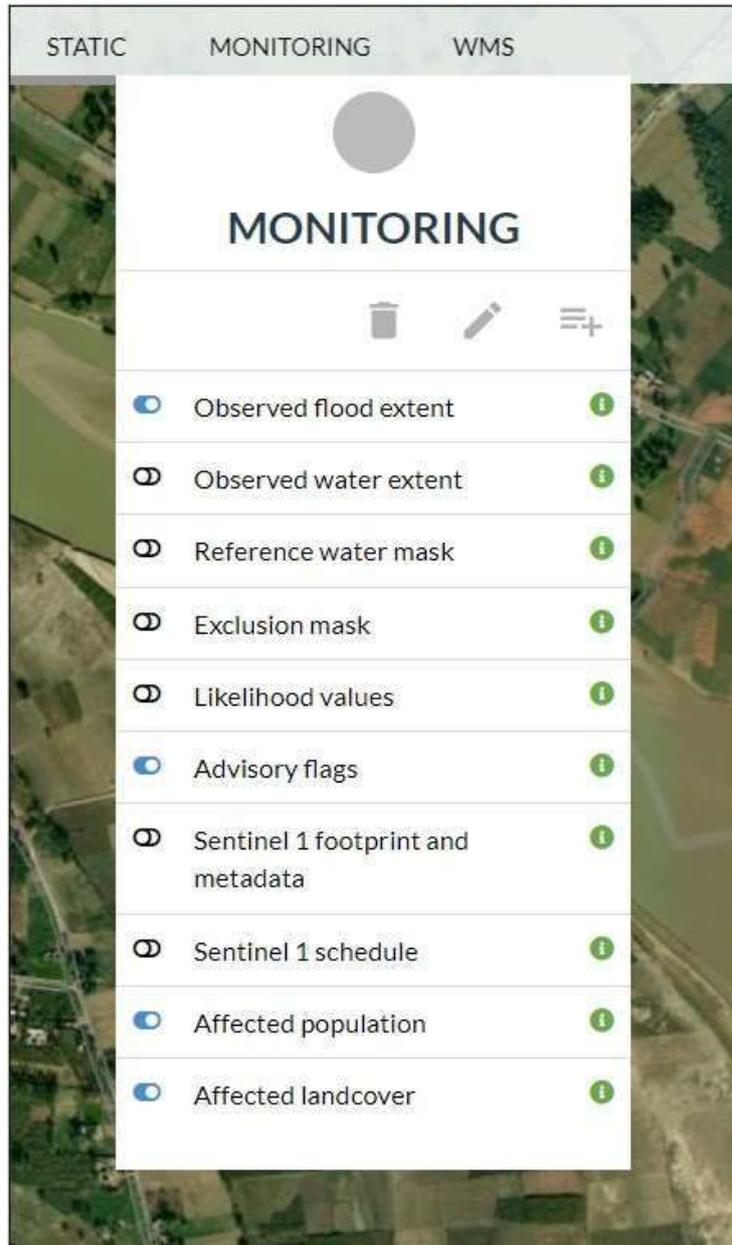
Finally, the API Health group depicts alerts in respect to the developed RESTful APIs. The RESTful APIs are a backend system of high importance connecting the GFM Production and dissemination system. In addition, the APIs allow for machine-to-machine communication to enable push notifications via Twitter.

### 7.1.2 How to browse GFM Products in GloFAS Map Viewer

Once logged in, GFM's products are listed in the top bar under the **“Monitoring”** menu, as shown below:

<sup>7</sup> <https://cophub.copernicus.eu/>

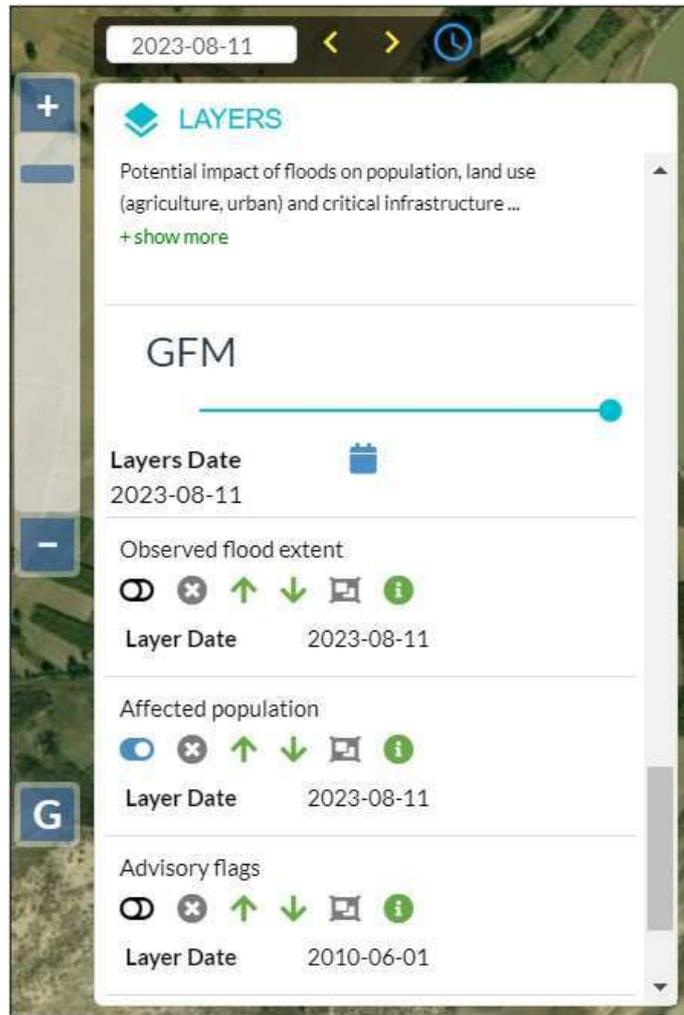
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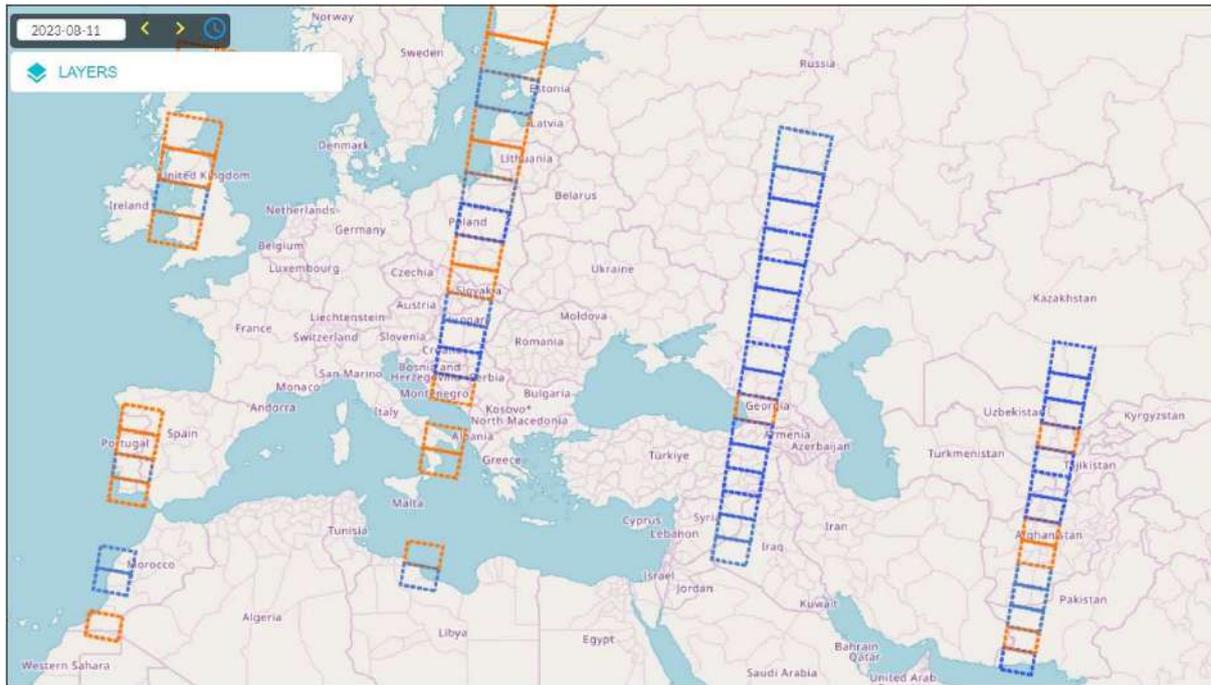


Each layer can be visualized by moving the toggle to the “on” position once done the selected layer will be added to the dynamic layer list on the left side on the screen

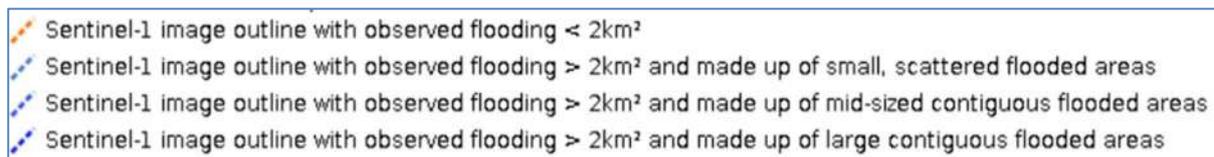


In the following example, the Observed Flood Extent layer is switched on: GloFAS Map Viewer will then display the Sentinel-1 tiles for which GFM\_ has detected flood-covered areas.

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The dashed edge of each S-1 overpass tile is coloured as a function of the size and the pattern of the detected flooded, as shown in the legend below:



### 7.1.3 Areas of interest

GFM-registered users are also offered the possibility to draw their own areas of interest (AOIs). By clicking on **“Flood Monitoring”**, the system will display a first sub-menu offering the user the possibility of selecting:

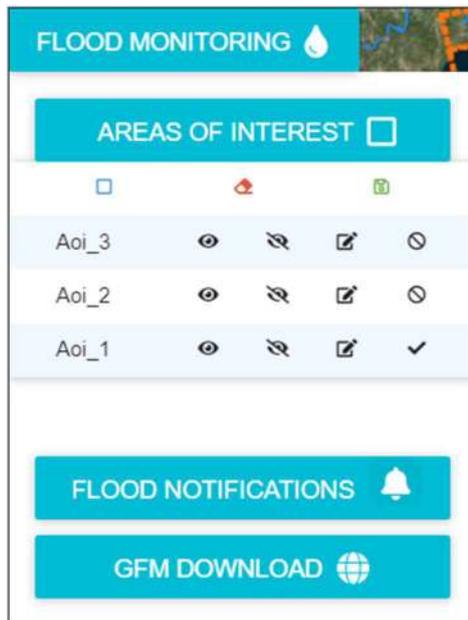
- The list of the designed AOIs.
- The list of the notification for the AOIs as set in the GFM web-app.



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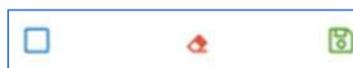
This menu allows the users to visualize the list of the user-defined AOIs:



To the right of each AOI's name, the system allows:

- To display the boundaries of the AOI (eye-shaped icon).
- To hide the boundaries of the AOI (barred eye-shaped icon).
- To modify the boundaries of the AOI (pencil&sheet, this function will redirect the user to the GFM webapp).

Above the list of the available AOIs, users are offered the chance to design the AOIs of their choice directly through GloFAS (see figure below):



- Blue square: design an AOI.
- Red rubber: delete the AOI.
- Green floppy disc: save the AOI.

When the latter icon is pressed, the system will display a form users must fill out to save the AOI and display the available GFM's products.

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### Save Area Of Interest

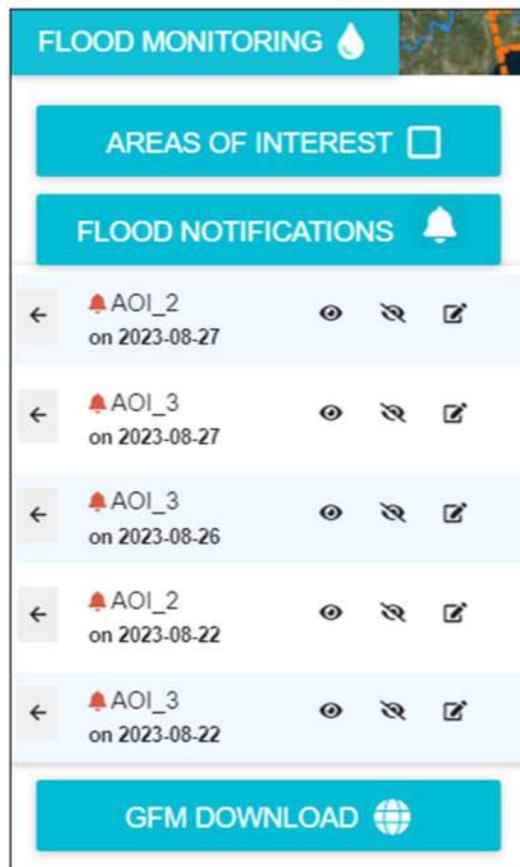
Name:

Description:

save reset

#### 7.1.4 Floods notification

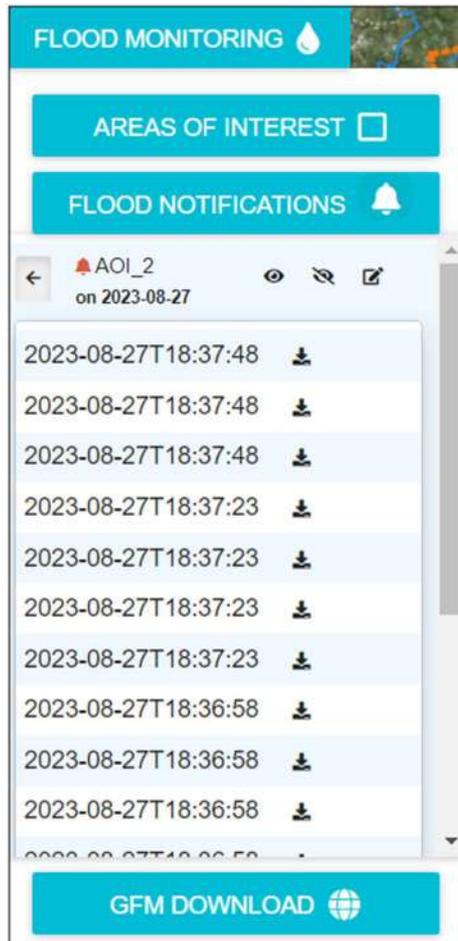
Users have the chance to be notified any time a new GFM's product is available for a specific AOI upon proper configuration of the notification setup through the WebApp. Once done, flood notifications are displayed on GloFAS as well through the menu shown below:



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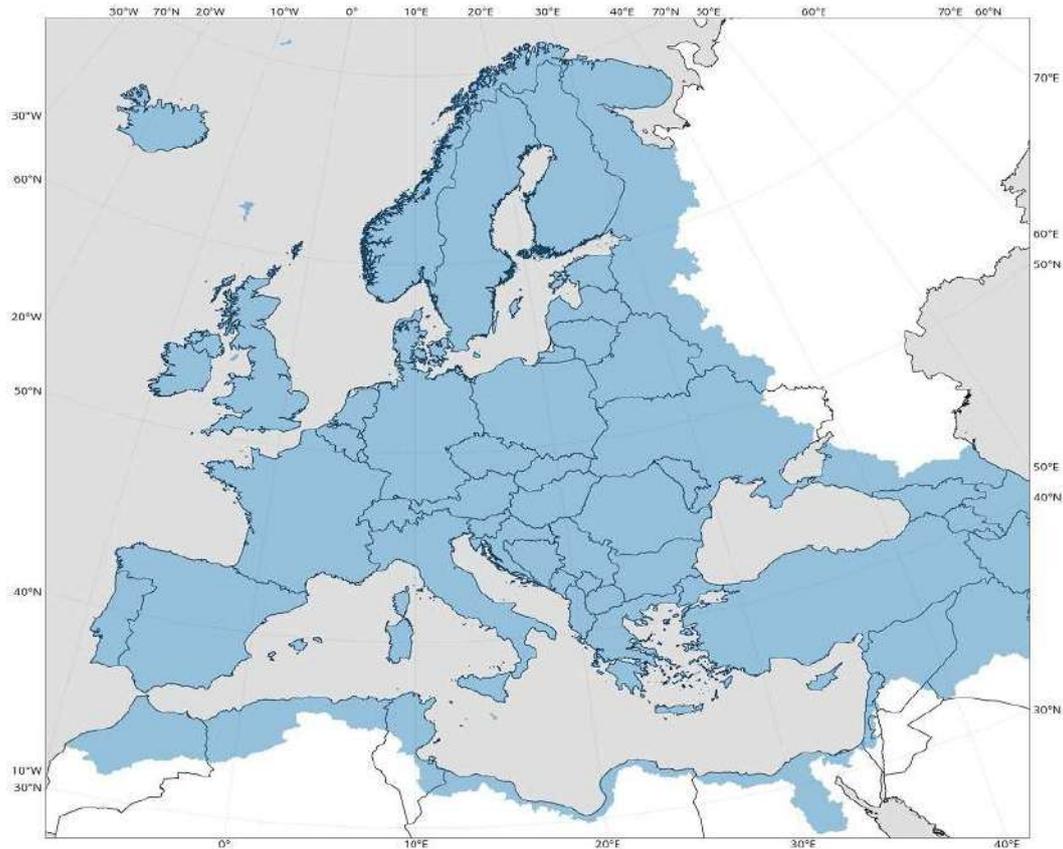
When users click on a notification, the system will display every newly available product. GFM's products can then be downloaded in a bundle (.zip file) in TIFF format by pressing the downward arrow icon, as shown below:



## 7.2 The European Flood Awareness System (EFAS)

The European Flood Awareness System (EFAS) is the flood service of the European Commission’s Copernicus Emergency Management Service (CEMS), and is an operational system monitoring and forecasting floods across the pan-European domain (see below).

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GFM's products are made available within the EFAS Map Viewer<sup>8</sup>. To access the Map Viewer and be allowed to visualise the products in real time, users are requested to become EFAS partners. Please see the terms and conditions of the association agreement<sup>9</sup>. Once registered, the MapViewer can be accessed by typing the account details in the following form:

### LOG IN

Username or email

Password

[Forgot Password?](#)

**Log In**

## 7.2.1 GFM Health Status

<sup>8</sup> [https://www.efas.eu/efas\\_frontend/#/home](https://www.efas.eu/efas_frontend/#/home)

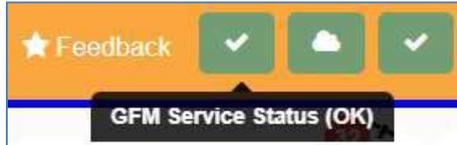
<sup>9</sup> <https://www.efas.eu/en/become-efas-partner>

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Information about the overall health state of the GFM service is also presented to the user within EFAS Map Viewer. An “alert sign” in the top menu, positioned on the right, next to the user profile indicates the health state of the service. The alert sign is colour coded:

- “Green”: Service up and running.
- “Amber”: Service degraded.
- “Red”: Service not available.



Detailed information about the health state of the various components of the service can be retrieved by clicking on the “alert sign”. This will open a pop-up window onto the map viewer presenting the latest registered alert notifications as shown below. The different alert notifications are organised by **Group** providing details about the current **Status**, a **Message** describing the alert notification and a **Date** indicating when the alert was raised. The column **Group** in the window refers to the individual components of the service. Four service components / groups are defined (see below), which will be outlined hereafter:

Date	Title	Type
2022-11-02T15:44:14.391940	Sentinel1 Datastream	Copernicus Data Hub is up and running.
2022-11-06T03:45:40.559730	GFM Production	Flood data production is up and running.
2022-11-07T09:26:56.581337	GFM Dissemination	No alert registered for this group. Seems as everything is working smoothly.
2022-11-07T09:26:56.584229	API Health	No alert registered for this group. Seems as everything is working smoothly.

The group Sentinel-1 Datastream comprises alerts in respect to any required Sentinel-1 data used to deduce the various layers provided by the service. One major alert event in this group is the Copernicus Services Data Hub<sup>7</sup> acting as reference for all the Sentinel-1 input data used in the service. Downtimes of the Copernicus Services Data Hub as well as issues in receiving the required data will be notified within this group. Furthermore, observed issues in respect to the performed pre-processing of Sentinel-1 data will be alerted, because the pre-processed data is the main input data stream to deduce flood information.

Alert notifications in respect to the production of the individual GFM layers is provided within the group GFM Production. Any observed issues within the actual production system of GFM are forwarded within this group. Anomalies detected in the processing workflow of the flood layers as well as non-availabilities of components of the production system are covered in this notification group as well as the monitoring of the interface towards to the GFM dissemination system.

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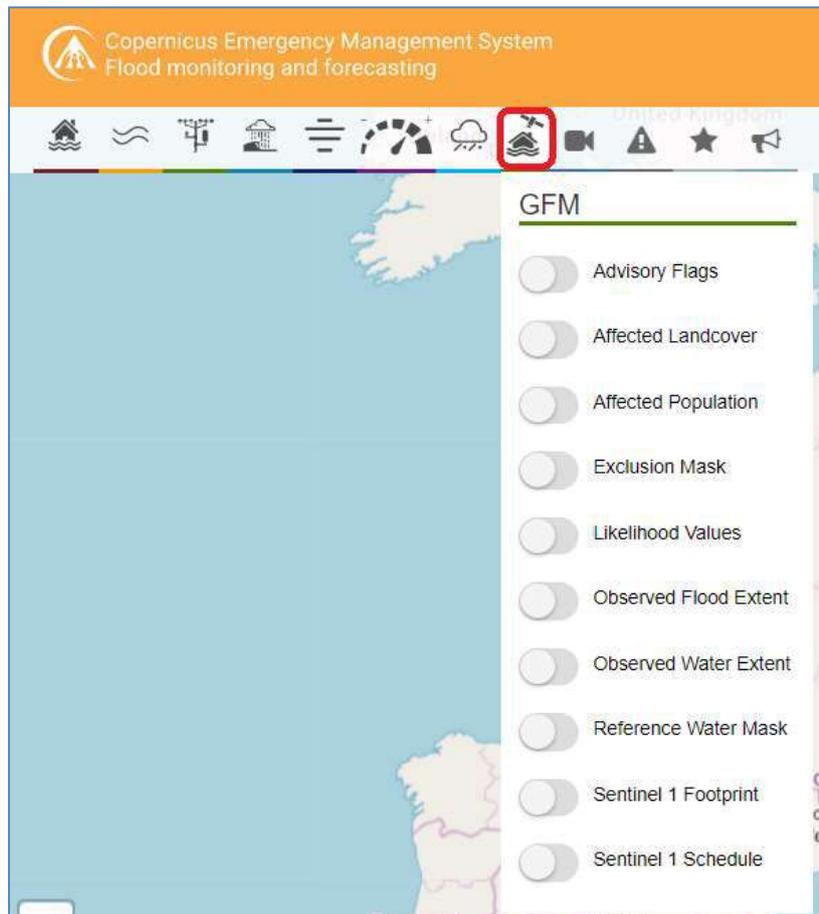


The GFM dissemination system is responsible to provide access to produced GFM layers. End user entry points the GFM layers are provided by a WMS-T server as well as a dedicated Web Application (portal). Degradaations or the unavailability of those will be reported within this group.

Finally, the API Health group depicts alerts in respect to the developed RESTful APIs. The RESTful APIs are a backend system of high importance connecting the GFM Production and dissemination system. In addition, the APIs allow for machine-to-machine communication to enable push notifications via Twitter.

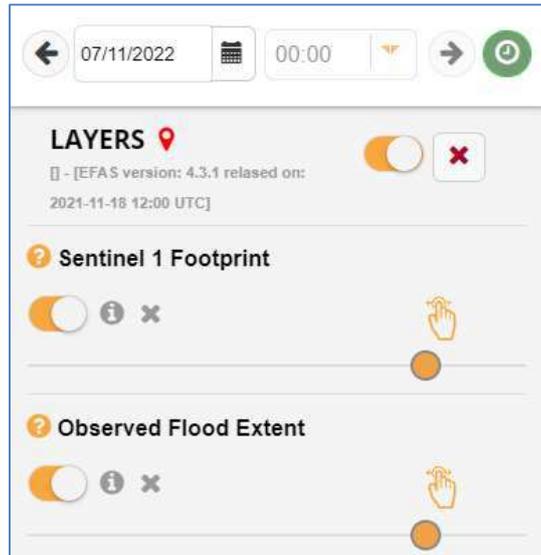
### 7.2.2 How to browse GFM Products in EFAS Map Viewer

Once logged in, GFM's products are listed in the top bar under the “GFM” menu (red rectangle), as shown below:

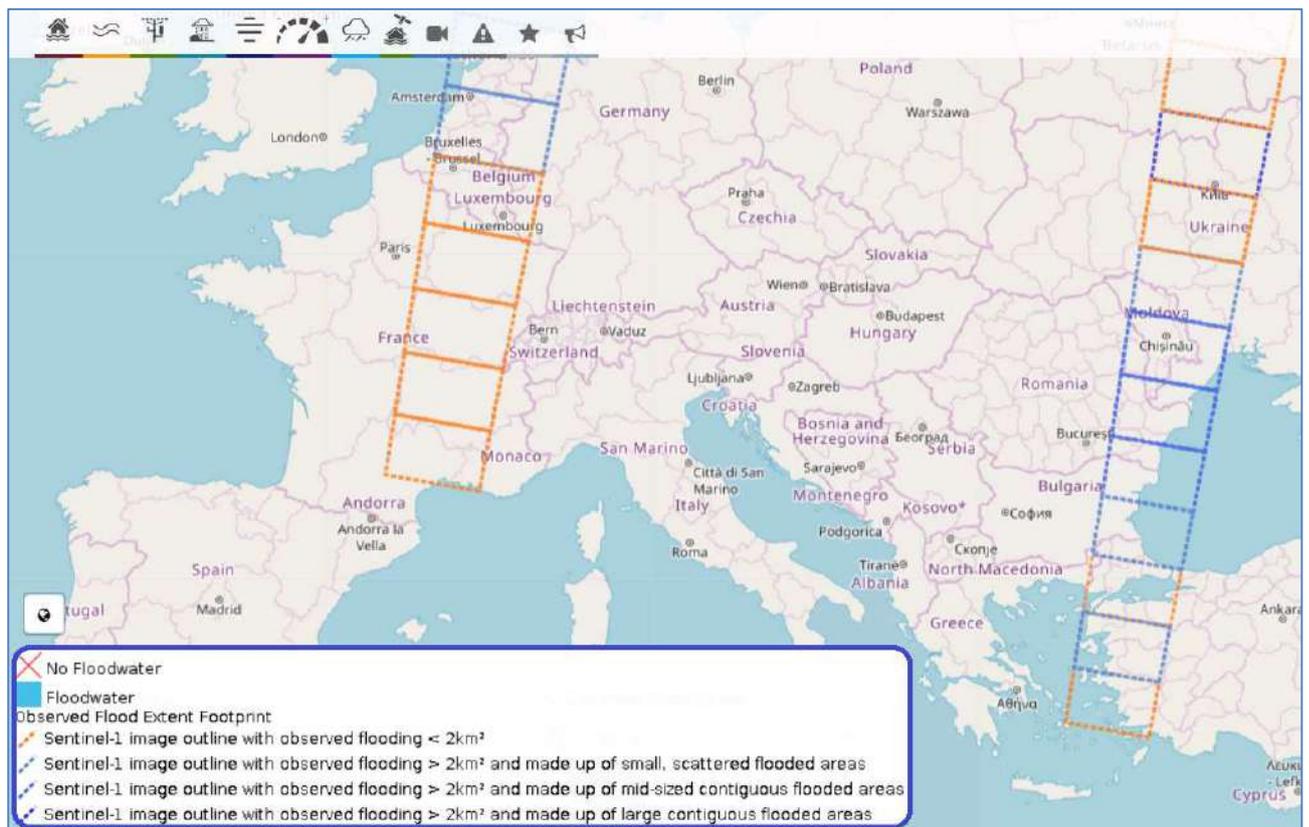


Each layer can be visualized by moving the toggle to the “on” position once done the selected layer will be added to the dynamic layer list on the right side on the screen, as shown below:

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In the following example, the Observed Flood Extent layer is switched on, and the EFAS Map Viewer will then display the S-1 tiles for which GFM has detected flood-covered areas:



### 7.2.3 Areas of interest

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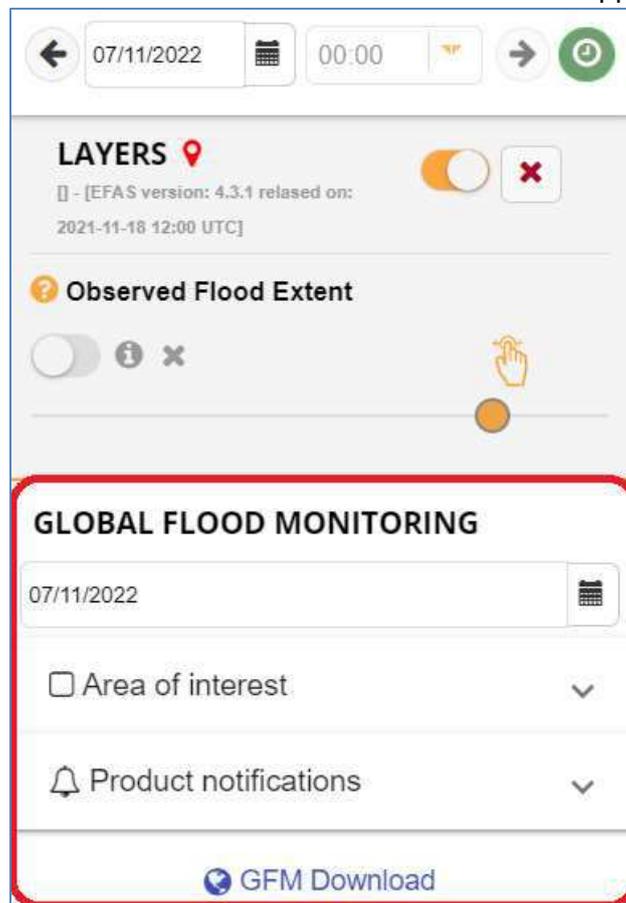


GFM-registered users are also offered the possibility to draw their own areas of interest (AOIs): upon clicking on the “GFM” icon, as shown below:



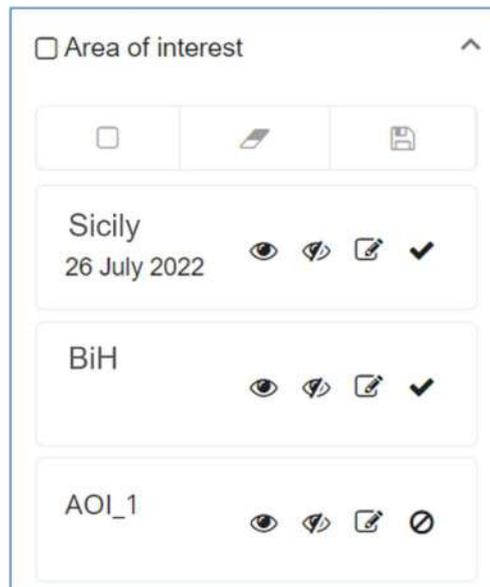
The system will display a first sub-menu (see graphic below) offering the user the possibility of selecting:

- The list of the designed AOIs.
- The list of the notification for the AOIs as set in the GFM WebApp.



This “Area of Interest” menu allows the users to visualize the list of the user-defined AOIs, as shown below:

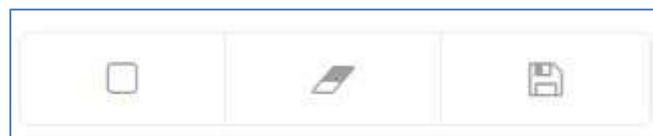
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To the right of each AOI's name, the system allows users to:

- To display the boundaries of the AOI (eye-shaped icon).
- To hide the boundaries of the AOI (barred eye-shaped icon).
- To modify the boundaries of the AOI (pencil&sheet, this function will redirect the user to the GFM webapp).

Above the list of the available AOIs, users are offered the chance to design the AOIs of their choice directly through GloFAS, as shown below:



- Blue square: Design an AOI.
- Red eraser: Delete the AOI.
- Green floppy disc: Save the AOI.

When the latter icon is pressed, the system will display a form users must fill out to save the AOI and display the available GFM Products output layers, as shown below:

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### Save Area of interest

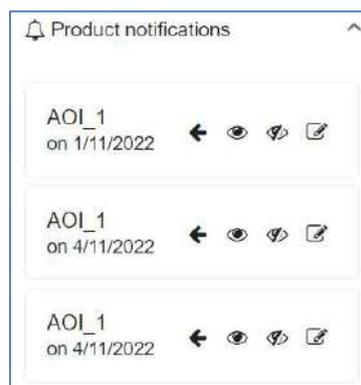
Name  
AOI\_efas1

Description  
AOI\_efas1\_description

Save Close

### 7.2.4 Floods notifications

Users have the chance to be notified any time a new GFM's product is available for a specific AOI upon proper configuration of the notification setup through the WebApp. Once done, flood notifications are displayed on EFAS as well through the menu shown below:



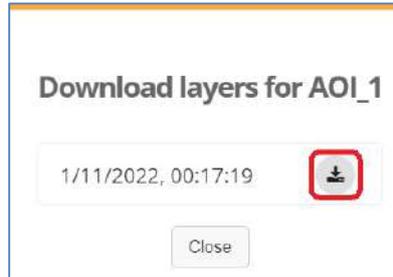
When users click on a notification, the system will display all newly available GFM Product output layers. These can then be downloaded in a bundle by pressing the leftward arrow icon (red rectangle), as shown below:



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The system will then open a pop-up window allowing the users to download the aggregate .zip file (containing all the product output layer, in TIFF format), by pressing the downward arrow in the red rectangle, as shown below:



### 7.3 REST-APIs

RESTful API endpoints are one of the channels to the GFM data access and dissemination system, regardless configuration services, product order or product serving services.

All GFM-related RESTful APIs are written in Python with the Flask framework for web application. Flask is a lightweight Web Server Gateway Interface (WSGI) web application framework written in Python. The API gateway is exposed to the web by NGINX web servers which handle all requests from the internet and route them to WSGI HTTP servers, in our case Gunicorn. Gunicorn translates the requests in WSGI compliant calls and moves the proper request to the pool of workers, which are executing the request. After successful executing the result is converted by Gunicorn to the HTTP request and handed over to NGINX, which takes care of the final delivery. Load-balancing is handled by NGINX to serve the appropriate amounts of HTTP servers for the GFM data access and dissemination system.

Note that all components for the RESTful API access are distributed as open and free licenses.

#### 7.3.1 GFM API documentation

The documentation about how to configure GFM-related RESTful APIs is made available through the popular Swagger UI allowing end-users and/or development teams to visualize and interact with the APIs resources without having any of the implementation logic in place. All the API functions are listed below, the online guide and tutorial are available on-line<sup>10</sup> and in the Quick Start Guide<sup>11</sup>.

#### 7.3.2 How to get a token

To use the set of APIs, users need to get an access token. Information on how the access token could be retrieved are given in the dedicated section of the GFM Web App.

<sup>10</sup> <https://api.gfm.eodc.eu/v1/>

<sup>11</sup> <https://360.articulate.com/review/content/5ff335b6-3d21-4df0-9adb-510d011793b1>

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### 7.3.3 APIs

#### 7.3.3.1 Auth (endpoint specification related to authentication operations)

<b>POST</b>	<code>/auth/email_confirmation</code>	POST definition for activating a user by confirmation mail
<b>POST</b>	<code>/auth/get_bearer_token</code>	POST definition for retrieving an OAuth2 Bearer token
<b>GET</b>	<code>/auth/glofas_authorize</code>	POST definition for generating the Glofas OAuth2 authorize URL
<b>POST</b>	<code>/auth/glofas_callback</code>	POST definition for handling the Glofas OAuth2 callback
<b>PATCH</b>	<code>/auth/glofas_registration</code>	PATCH definition for completing the Glofas registration
<b>POST</b>	<code>/auth/login</code>	POST definition for the login definition
<b>POST</b>	<code>/auth/login/su</code>	POST definition for retrieving an OAuth2 Bearer token for a user ID
<b>POST</b>	<code>/auth/password_change</code>	POST definition for requesting a password reset
<b>POST</b>	<code>/auth/password_forget</code>	POST definition for requesting a password reset
<b>POST</b>	<code>/auth/password_reset</code>	POST definition for resetting the users password
<b>POST</b>	<code>/auth/register</code>	POST definition for the registration process
<b>PATCH</b>	<code>/auth/scopes/update</code>	PATCH definition for setting the OAuth2 scope by ID
<b>GET</b>	<code>/auth/scopes/{user_id}</code>	GET definition for retrieving the OAuth2 scope by ID



### 7.3.3.2 *Users (endpoint specification related to users operations)*

<b>GET</b>	<code>/users/</code>	GET definition for retrieving all users
<b>POST</b>	<code>/users/create</code>	POST definition for creating a new user
<b>DELETE</b>	<code>/users/delete</code>	DELETE definition for removing all customers
<b>DELETE</b>	<code>/users/delete/filter</code>	DELETE definition for removing customers by filter
<b>DELETE</b>	<code>/users/delete/{user_id}</code>	DELETE definition for removing a user by ID
<b>GET</b>	<code>/users/filter</code>	GET definition for retrieving a user by a filter
<b>PATCH</b>	<code>/users/update</code>	PATCH definition for updating the information of a user
<b>GET</b>	<code>/users/{user_id}</code>	GET definition for retrieving a user by a ID

### 7.3.3.3 *Download (endpoint specification related to the GFM Product download)*

<b>GET</b>	<code>/download/all_products/{aoi_id}</code>	GET definition for an asynchronous call to receive an e-mail notification
<b>GET</b>	<code>/download/file/{filter_id}</code>	GET definition for retrieving a single file as download
<b>GET</b>	<code>/download/product/{product_id}</code>	GET definition for retrieving a single product ensemble per as download

### 7.3.3.4 *Legend (endpoint specification related to product legends)*

<b>GET</b>	<code>/legends</code>	GET definition for retrieving legend information
------------	-----------------------	--



### 7.3.3.5 Notifications (endpoint specification related to the notification service)

GET	/notifications/notification_settings	GET definition for retrieving the notification settings
PUT	/notifications/notification_settings/update	PUT definition for updating the notification settings
GET	/notifications/notification_settings/{user_id}	GET definition for retrieving the notification settings by user ID
PATCH	/notifications/notification_status	Patch definition for updating the notification status
PATCH	/notifications/notification_status/product_id	Patch definition for updating the notification status by ID
GET	/notifications/push_notification_history/{user_id}	GET definition for retrieving the push notifications by user ID
GET	/notifications/push_notifications	GET definition for retrieving all push notifications
GET	/notifications/twitter_history	GET definition for retrieving the complete twitter history
GET	/notifications/twitter_history/{user_id}	GET definition for retrieving the Twitter history by user ID
GET	/notifications/twitter_message_config	GET definition for retrieving the complete twitter message configuration
PATCH	/notifications/twitter_message_config/admin	PUT definition for updating the general footer of a Twitter message
PATCH	/notifications/twitter_message_config/user	PUT definition for updating the user parts of a Twitter message
GET	/notifications/twitter_message_config/{user_id}	GET definition for retrieving the Twitter message configuration by user ID
GET	/notifications/twitter_settings	GET definition for retrieving the complete twitter settings
POST	/notifications/twitter_settings/create	POST definition for creating new twitter settings
DELETE	/notifications/twitter_settings/delete/{user_id}	DELETE definition for removing Twitter settings by user ID
PUT	/notifications/twitter_settings/update	PUT definition for updating the twitter settings
GET	/notifications/twitter_settings/{user_id}	GET definition for retrieving a Twitter settings by user ID



### 7.3.3.6 *Products (endpoint specification related to the GFM Products)*

GET	/products/sentinel-1/{product_id}	GET definition for retrieving a single product
GET	/products/{product_id}	GET definition for retrieving a single product

### 7.3.3.7 *Reporting (endpoint specification related to the GFM report generation)*

GET	/reporting/report_statistics/{product_id}	GET definition for retrieving report statistics for a single product
-----	---	--

### 7.3.3.8 *AOI (endpoint specification related to the area of interest)*

GET	/aoi/	GET definition for retrieving all areas of interest
POST	/aoi/create	POST definition for creating a new area of interest
DELETE	/aoi/delete	DELETE definition for removing all regions of interest
DELETE	/aoi/delete/id/{aoi_id}	DELETE definition for removing an area of interest by ID
DELETE	/aoi/delete/user/{user_id}	DELETE definition for removing an area of interest by a customer ID
GET	/aoi/filter	GET definition for retrieving an AOI by a filter argument
POST	/aoi/polygon_size	GET definition for calculating the area of a polygon
PATCH	/aoi/update/filter	PATCH definition for updating particular attributes of an area of interest
GET	/aoi/user/{user_id}	GET definition for retrieving a region of interest by user ID
GET	/aoi/{aoi_id}	GET definition for retrieving an area of interest by ID
GET	/aoi/{aoi_id}/products	GET definition for retrieving the products for an AOI by ID (and time)



### 7.3.3.9 *Support (endpoint specification related to support requests)*

**POST** /support/archive\_download POST definition for triggering an archive download request

### 7.3.3.10 *Utils (endpoint specification for general operations)*

**GET** /utils/countries GET definition for retrieving a list of all available countries

**GET** /utils/organization\_types GET definition for retrieving all company types

## 7.4 WMS-T

GFM Products are fully accessible via GIS environment or web browser. It is possible to access the WMS layers using any WMS client viewer, such as Quantum GIS (QGIS) or ESRI ArcMap. GFM offers WMS that supports temporal requests (WMS-T).

GFM relies on GeoServer as technology to provide a WMS-T service for the global flood monitoring product. GeoServer allows users to display the needed spatial information making maps available in a variety of output formats. OpenLayers, a free mapping library, is integrated into GeoServer, making map generation quick and easy. GeoServer is built on GeoTools, an open-source Java GIS toolkit. The GFM WMS-T is freely accessible, at the indicated URL<sup>12</sup>. The service is designed to display one single global layer per day.

### 7.4.1 QGIS

Steps:

1. Launch QGIS.
2. To avoid timeout errors, set the timeout for network requests to 14,400,000 ms
3. In the browser panel right-click on the *WMS/WMTS* icon.
4. In the *Create a New WMS/WMTS Connection* window insert a title for your WMS connection in the *Name* section and paste the GloFAS WMS URL<sup>12</sup> and then click OK.
5. At this point in the browser panel under the *WMS/WMTS* icon you should see the title for the WMS connection that you have entered. Click on the arrow near the WMS connection to open it.
6. To view the layers simply drag and drop the layer icon into the Layers panel underneath the *Browser* panel, the layer will be displayed in the *Map Panel*.
7. In the *Layer* panel you can see the legend associated to each layer underneath the name of the layer.

<sup>12</sup> <https://geoserver.gfm.eodc.eu/geoserver/gfm/wms>

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8. Some of the layers are queryable. To retrieve the info for the layer:

- Select the layer from the *Layers* tab (the layer name needs to be highlighted)
- In the main toolbar locate the *info* button
- Click on any feature of the layer in the *Map Panel* and the *Identify* result window will open with the information for the layer.

Further documentation on how to use WMS-T in QGIS can be found in the on-line training manual<sup>13</sup>, specific instructions on the use of GFM data in QGIS are also provided in the Quick Start Guide<sup>14</sup>.

### 7.4.2 ArcGIS / ArcMap

Using ESRI ArcGis / ArcMap, you can load a WMS-T directly into your existing map. A quick-start guide (using ArcMap v.10.0.2) is provided below:

1. Launch ArcMap
2. In the *Catalog* panel (on the right-hand side of the screen) click on the *Add WMS Server* icon
3. In the *Add WMS Server* window insert the GFM WMS URL<sup>12</sup>. In the URL section then click on the *Get Layers* button to retrieve the WMS layers. After the retrieving of the layers click on the OK button to close the window:
4. At this point in the *Catalog* panel, you should see all the available GFM layers. To view the layers simply drag and drop the layer icon into the *Table of Contents* panel on the left of the screen. In the *Table of Contents*, you can see the legend associated with each layer by right clicking the name of the layer and then select the legend from the context menu.
5. Some of the layers are queryable, to retrieve the info for the layer:
  - Select the layer from the *Table of Contents* (the layer name needs to be highlighted) In the main toolbar locate the *info* button.
  - Click on *any feature of the layer* in the *Map Panel* and the *Identify* result window will open with the information for the lay
6. To request different forecast time, use the time slider button. This will open a time slider window, moving the cursor will call different forecast times for the selected layer:
  - Open the Time Slider Window and a popup will appear
  - Go to Options (in the popup) and modify the following inputs: display date format = yyyy-mm-dd, display time format = none
  - Using the Time slider you can load GFM WMS layers specified in the available range.

Further documentation on how to use WMS with ESRI ArcGIS/ArcMap can be found on-line, at the indicated web-link<sup>15</sup>.

<sup>13</sup> <https://docs.qgis.org/3.16/en/docs/>

<sup>14</sup> <https://360.articulate.com/review/content/5ff335b6-3d21-4df0-9adb-510d011793b1>

<sup>15</sup> <https://resources.arcgis.com/en/help/main/10.2/>

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## 7.5 WebApp

Users can access this application through EFAS, GloFAS or directly through the GFM URL<sup>16</sup>. This single-page application enables users to:

- Define AOIs.
- Display the available products for a user-defined AOI.
- Download the GFM Products.
- Configure notifications via the app and / or Twitter.

### 7.5.1 Login

GloFAS- or EFAS-registered users can access the system by typing their account details in the displayed form (see below) and then pressing “Submit”. If not registered, users are required to press the “Register” button and to fill in the registration form.

The screenshot shows a login form for the Copernicus Emergency Management Service. At the top left is the logo. Below it is the title "Login" and the instruction "Enter your GFM credentials to login". There are two input fields: "E-mail" with the placeholder "Enter e-mail address" and "Password" with the placeholder "Enter password". A blue "Login" button is positioned below the password field. Below the button is a link: "Forgot Password? or Register". A horizontal line with the word "or" in the center separates this from two dark grey buttons: "Sign in with GloFAS" and "Sign in with EFAS".

<sup>16</sup> <https://portal.gfm.eodc.eu/>

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### 7.5.2 Create an AOI

The AOI dashboard displays a set of buttons and menus allowing the user to create and manage his/her Areas of Interest (AOIs). To create an AOI, first insert “Name” and “Description” of the AOI in the provided form (see below), then click “Next Step”:

The screenshot shows a web form titled "Create new AOI". It has two text input fields: "Name" and "Description", both containing the text "TestAOI". Below the fields is a prominent blue button labeled "Next step". At the bottom center, there are two small grey circles, likely for a progress indicator.

An AOI can be defined in three optional ways:

- Enter the lat / long coordinates of the AOI’s upper-left and lower-right corners.
- Draw the AOI on a map.
- Select a specific administrative region.

#### **Option 1 - Enter AOI coordinates (default):**

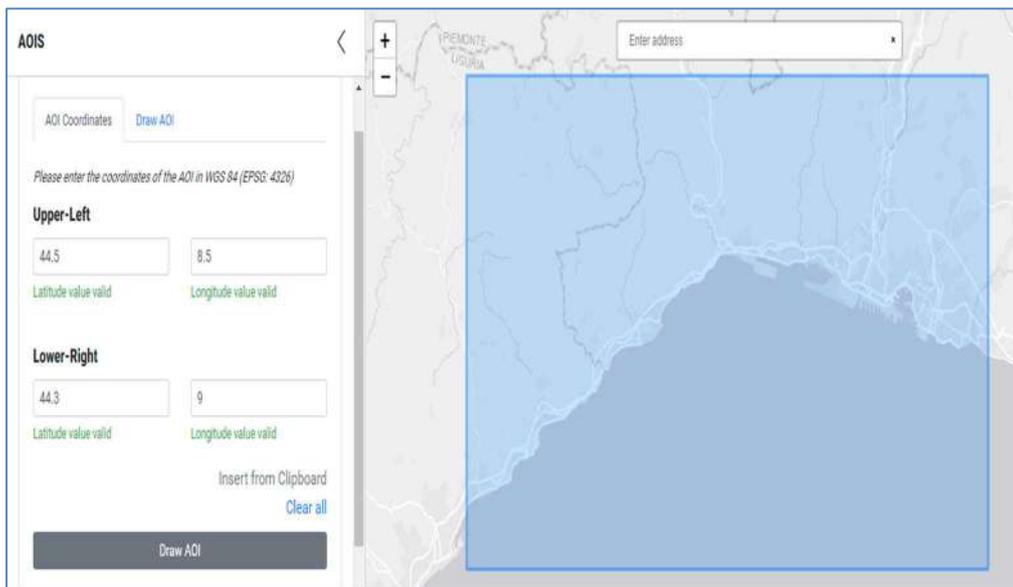
Enter the latitude and longitude coordinates of the AOIs upper-left and lower-right corners, and then click the “Draw AOI” button in the form (see below).

The screenshot shows the "Create new AOI" form with the "AOI Coordinates" tab selected and highlighted with a red box. Other tabs are "Draw AOI" and "Regions". Below the tabs, there is a instruction: "Please enter the coordinates of the AOI in WGS 84 (EPSG: 4326)". Under "Upper-Left", there are two input fields for "Latitude ..." and "Longitude ...". Under "Lower-Right", there are also two input fields for "Latitude ..." and "Longitude ...".

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The system will display the selection on the map on the right-hand side, as shown below:

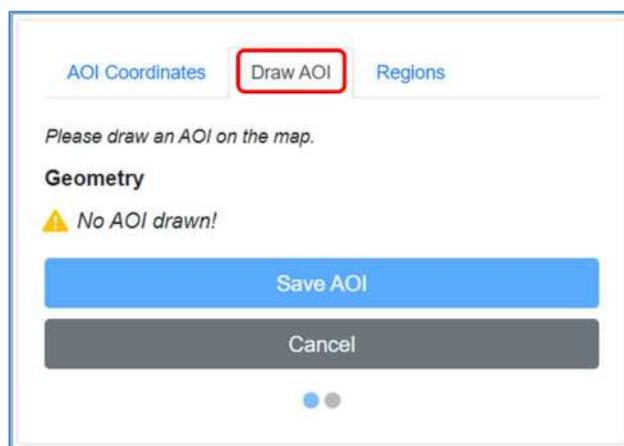


Save the AOI pressing the button "Save AOI" (see below). The AOI will be then added to the list of AOIs.



**Option 2 - Draw an AOI:**

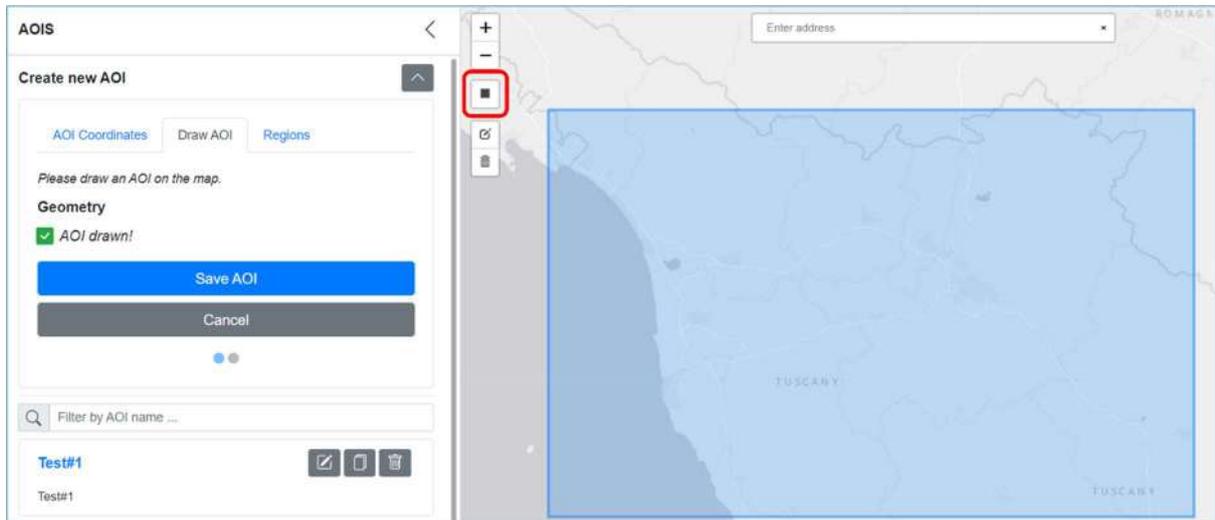
Select the button "**Draw an AOI**", as shown below:



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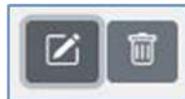
Then click on the dark grey square on the map (see below) and draw a rectangle over the area for which you wish to retrieve flood information:



Once done, the system will update showing the following message



Through the buttons shown below, users can further edit (pencil icon) or delete (bin icon) each AOI of the list:



When editing, users may change the rectangle dimensions or to drag it rigidly (i.e., not changing its shape) across the map. Once the user is satisfied with the defined area, the button **“Save AOI”** will add the AOI to the list.



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### Option 3 – Select an administrative region:

Select the “Regions” button (see below), and then through the dedicated drop-down menus choose the Country and the Region of interest:

Create new AOI

AOI Coordinates Draw AOI **Regions**

Please select an administrative region from the list.

Select country ...

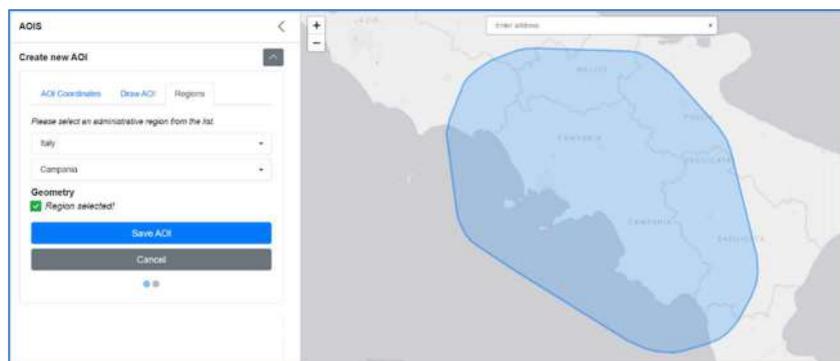
Select region ...

**Geometry**  
⚠ No region selected!

Save AOI

Cancel

In this case the system will automatically draw a polygon fully encompassing the Region of interest, as shown in the example below:



If the user is satisfied with the AOI, the button “**Save AOI**” will add the AOI to the list:



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### 7.5.3 Product download

To download the GFM Product output layers, the user clicks on “Product” in the top bar, as shown below:



Selecting the “Products” button brings up the form shown below:

**Area of Interest (AOI)**

Select AOI ▼

---

**Filter options**

**Start**  No date selected

**End**  No date selected

**Latest**  Retrieve latest product

[Clear filter](#)

**Load products**

The GFM Product output layers for a specific AOI are first retrieved as follows:

1. Select an AOI through the drop-down menu “Select an AOI”.
2. Choose a reference period, using one of the following options:
  - Select its Start and End date through the calendar-shaped icons.
  - Tick the “Latest” box to retrieve the latest GFM Product output layers.
3. Click on “Load products”.

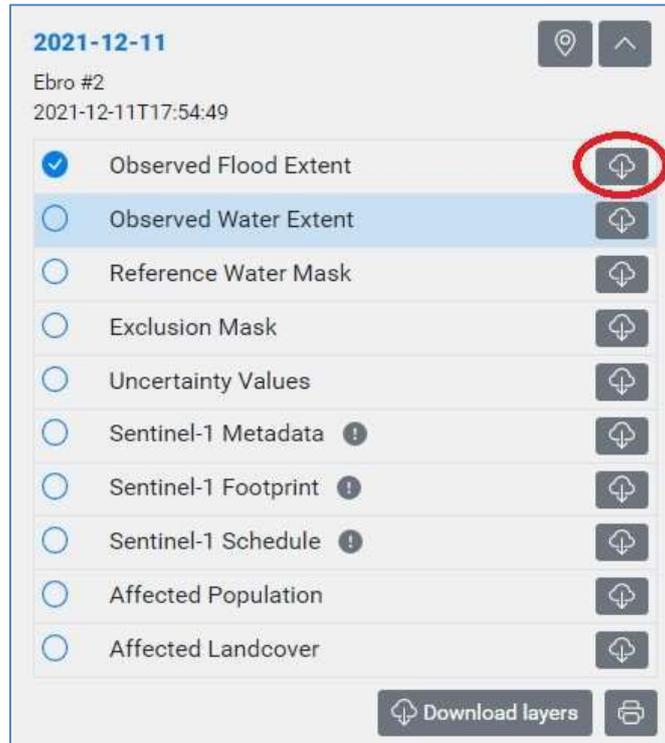
There are five options for specifying which GFM Product output layers to download:

- i. Download a single GFM Product output layer for a specific date.
- ii. Download selected GFM Product output layers for a whole time-series.
- iii. Download selected GFM Product output layers for a specific date.
- iv. Download all GFM Product output layers for multiple dates.
- v. Download the maximum flood extent.

#### **Option 1 - Download a single GFM Product output layer for a specific date:**

To download a single GFM Product output layer, as shown below, the user must click on a specific product (red arrow), tick the appropriate check-box on the side, and then click on the download button on the right (red circle):

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**Option 2 - Download selected GFM Product output layers for a whole time-series:**

To download one or more GFM Product output layers for a defined period:

- a. Choose the AOI and the reference period (as shown above).
- b. Click on “Download all products (for user-selected layers)”, as shown below.
- c. In the pop-up window (shown below):
  - Check / uncheck the GFM Product output layers of interest.
  - Check that the timeframe is correct.
  - Press “Start download”.
- d. As soon as the bundle of the requested product output layers will be ready, an email (see example below), including the URL to download the bundle, will be sent out.

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**Area of Interest (AOI)**

Test#1

**Filter options**

**Load products**

Number of products: 16

Sort products: Sort products by date descending (default)

**Download all products (for user-selected layers) ...**

Download all products

Please select the layers you wish to download.

- Observed Flood Extent (raster)
- Observed Water Extent
- Reference Water Mask
- Exclusion Mask
- Likelihood Values
- Advisory Flags
- Sentinel-1 Metadata
- Sentinel-1 Footprint
- Sentinel-1 Schedule
- Affected Population
- Affected Landcover

[Select all layers](#)  
[Remove all layers](#)

As soon as the files have been prepared, you will be informed by mail. This process may take some time.

Start date: 2023-01-10  
End date: 2023-01-24

**Cancel** **Start download**

**Hi John Smith,**

You started off the download process in the Global Flood Monitoring Portal (<https://gfm.portal.geoville.com>) for all products belonging to the following AOI: **voltumo**

The download includes all registered floods from the 2023-01-17T05:12:22 to the 2023-01-18T16:57:45.

You can download ZIP file from the following link:

**<https://owncloud.gfm.eodc.eu/index.php/s/xYpShtinBjtAdcB/download>**

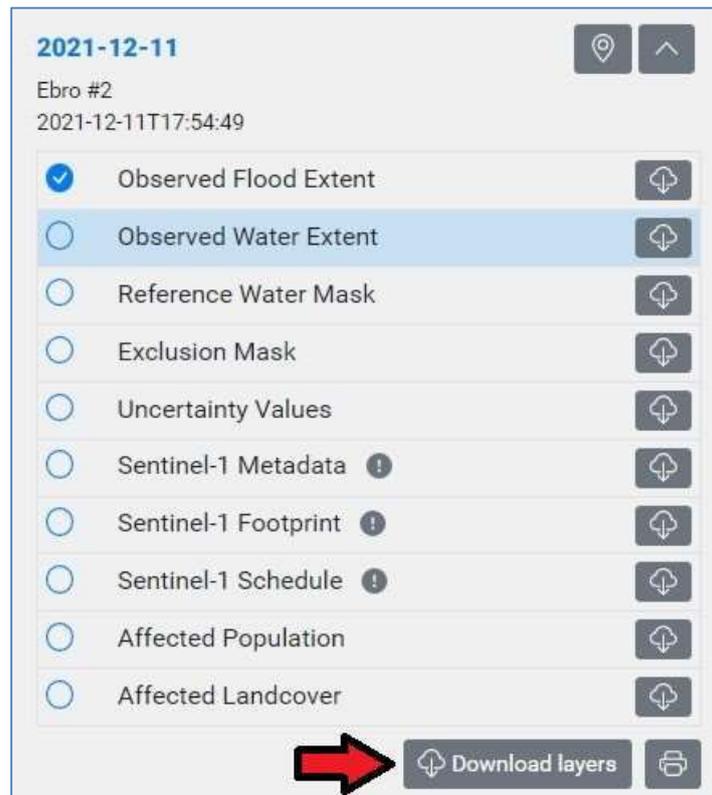
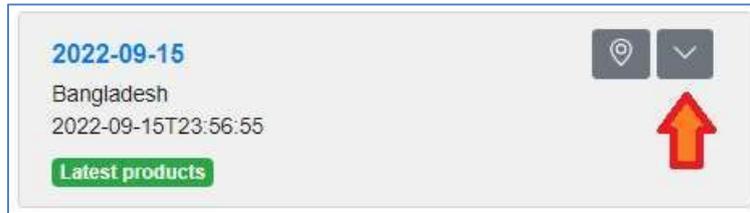
Thanks,  
The Global Flood Monitoring Portal Team

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**Option 3 - Download selected GFM Product output layers for a specific date:**

To download selected GFM Product output layers for a specific date, as shown below, first select the output layers (red arrow), and then press the Download layers button (red circle):

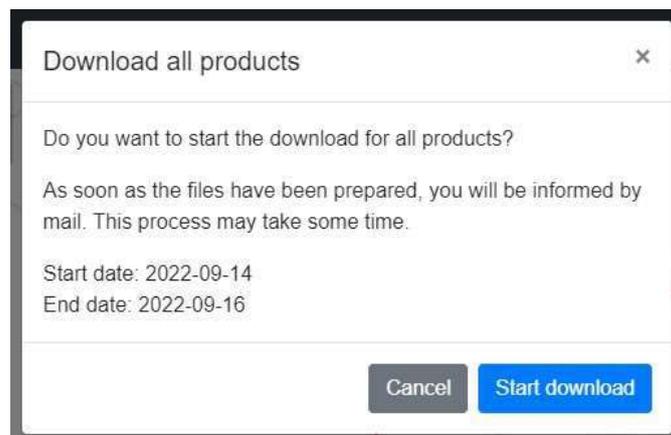


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**Option 4 - Download all GFM Product output layers for multiple dates:**

- If multiple dates are available, users can download all GFM Product output layers for all dates, by clicking on the button Download all products (see red circle below).
- The system will then display a message (shown below) asking the user to confirm the submission of the query. The query is confirmed by pressing “Start download”.
- The system will start assembling the data package. Once completed, an e-mail (example shown below) is sent out providing the link to download the requested dataset.



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### Option #5 - Download the maximum flood extent

The maximum flood extent is the composite of all the Observed Flood Extent layers available in a specific, user-defined period.

Please bear in mind that:

- the length of the selected timeframe cannot be longer than 2 months
- this feature is not available if the "Latest - Retrieve latest product" filter option has been ticked

If the above-mentioned conditions are met, the user will be enabled to submit to the system the query for the maximum flood extent for the requested AOI by clicking on the Download maximum flood extent button

The screenshot shows a web interface for downloading flood extent data. It features a dropdown menu for 'Area of Interest (AOI)' with 'EMR' selected. Below this is a 'Filter options' link with an information icon. A prominent blue 'Load products' button is present. Underneath, it indicates 'Number of products: 7' and a 'Sort products' dropdown set to 'Sort products by date descending (default)'. At the bottom, there are two buttons: 'Download all products (for user-selected layers) ...' and 'Download maximum flood extent', with the latter being highlighted by a red rectangular border.

A pop-up window will then display:

- the details of the query (AOI name, start date, end date)
- a checkbox to set the format of the output (raster [tiff], vector [geojson], or both)

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**Generate maximum flood extent** ✕

---

Please choose the output type for the maximum flood extend product.

Raster

Vector

**Order summary**

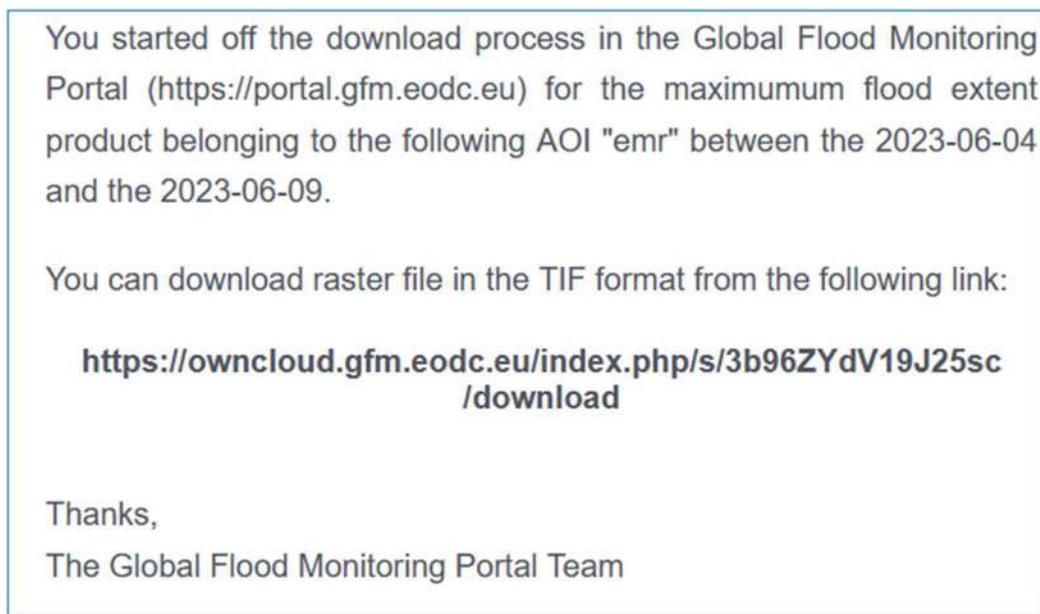
- AOI name: EMR
- Start date: 2023-06-04
- End date: 2023-06-09

As soon as the maximum flood extent product has been prepared, you will be informed by mail. This process may take sometime.

Cancel
Generate extent

By clicking on Generate extent, the system will automatically submit the query to the GFM production servers and a confirmation e-mail will be sent to the user.

As soon as the computational process will be completed, the system will send a second mail, containing the url the data can be downloaded from as in the following figure.



#### 7.5.4 Generate a summary report for selected GFM Product output layers

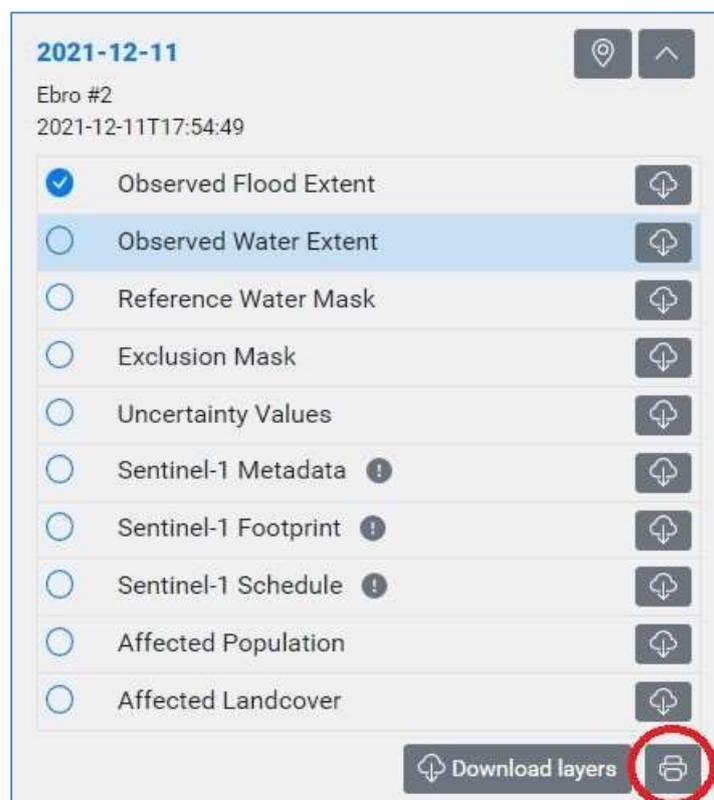
Users can generate a short report for a selected GFM Product output layer.

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To do this, the user opens the list of GFM Product output layers (red arrow below), selects an output layer, and clicks the “printer” button (red circle below).

A PDF document (example shown below) is automatically downloaded to the local drive with all the basic information on the output layer.



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GFM Report

The Global Flood Monitoring (GFM) product is a component of the EU's Copernicus Emergency Management Service (CEMS) that provides continuous monitoring of floods worldwide by processing and analysing in near real-time all incoming Synthetic Aperture Radar (SAR) imagery acquired by the Sentinel-1 satellites.

### PRODUCT DETAILS

Product: 2021-12-11  
 AOI Name: Ebro #2  
 Timestamp: 2021-12-11T17:54:49  
 Layer: Sentinel-1 Metadata

### STATISTICS

Affected Population: 0  
 Affected Landcover:

Landcover Type	Area (m <sup>2</sup> )
Shrubs	2 000
Open forest	1 200
Closed forest	800
Herbaceous wetland	1 600
Herbaceous vegetation	800

Landcover Type	Area
Agriculture / Cropland	154 800

### PRODUCT MAP

### 7.5.5 Activation of push notifications for AOIs

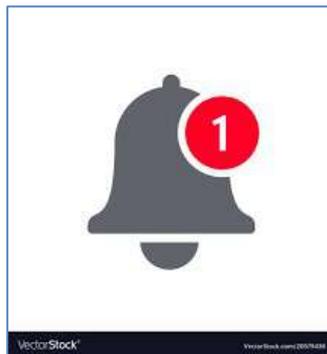
For each AOI, GFM users can activate push notifications for their Area of Interests, as follows:

- Click on the AOI / AOIs for which notifications are required.
- The system opens a dialogue window (see example below) where users can choose to be notified by email or through their Twitter account.
- Every time users will access the application, the bell-shaped icon in the top right corner (see below) will show the number of new / unread notifications.

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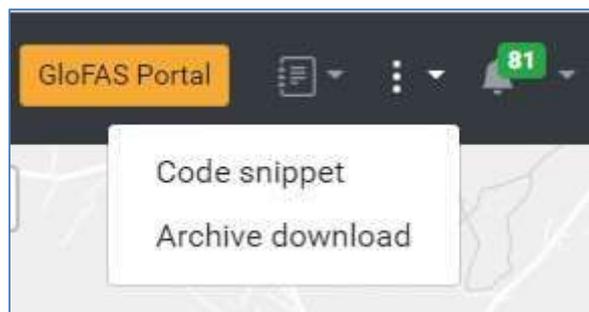


Notifications				
AOI		Select AOI		
AOI Name	AOI Description	Push Notifications	Twitter Notifications	
AOI 1	This is a short Description 1	Active	Active	
AOI 2	This is a short Description 2	Not active	Active	
AOI 3	This is a short Description 3	Active	Not active	
AOI 4	This is a short Description 4	Not active	Active	
AOI 5	This is a short Description 5	Active	Active	



### 7.5.6 Code snippet

The code snippet tool allows the users to generate an inline frame widget which can be integrated into any HTML page. To activate this feature, users must click of the three-point column icon on the top bar and select “**Code snippet**”



Once done, the system will open a form users shall fill in to request the desired product layer, acquisition time, and background for a specific AOI.

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### Code Snippet

The code snippet tool allows you to generate an inline frame widget which can be integrated into any HTML page.

Step 1 - Generate Map    Step 2 - Preview

AOI NAME  
India (N. Tamil Nadu)

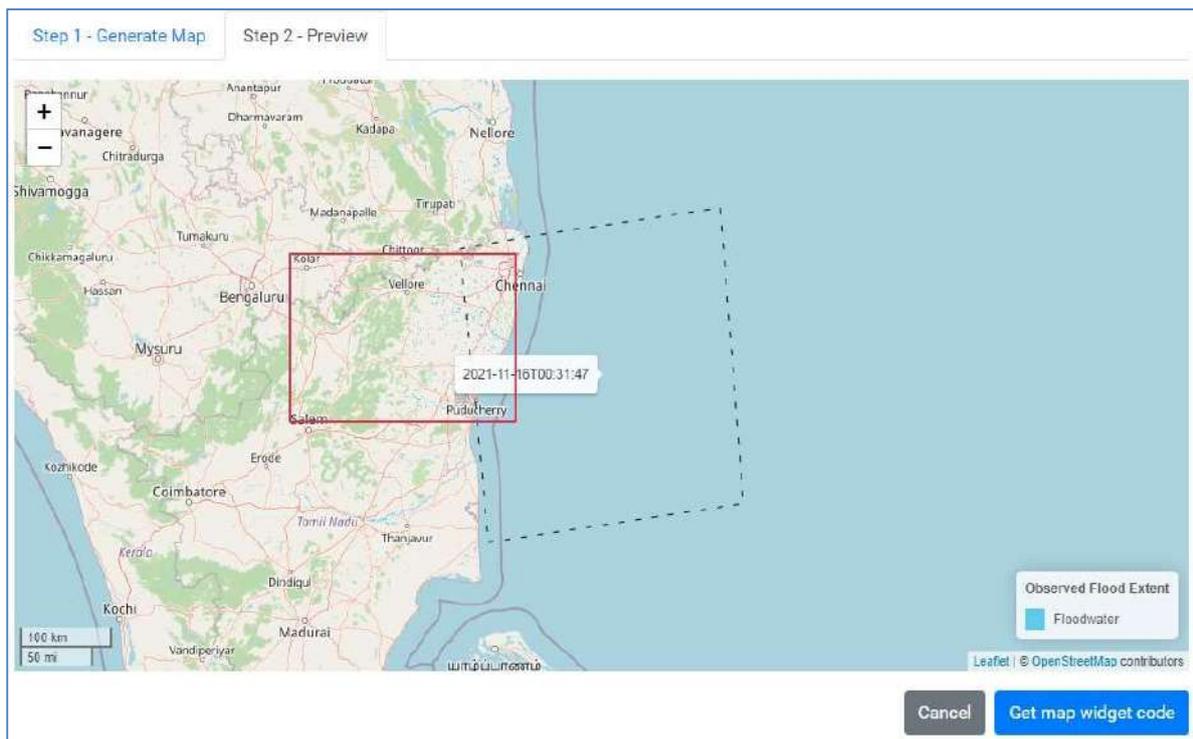
PRODUCT LAYER: Observed Flood Extent    PRODUCT DATE: 2021-11-16T00:31:47    MAP TYPE: Select map type

AOI EXTENT  
 Show AOI extent

SATELLITE EXTENT  
 Show satellite extent

Refresh    Generate map

After all the needed parameters are entered, users must click on the **"Generate map"** button: the system will then display a preview of the map according to user's request.



If the generated map fulfils the requirements, users can ingest it as a widget code by copying it in their html code.

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**Map Widget Code** ✕

Copy snippet code to the clipboard and paste to an empty website.

```

<!DOCTYPE html>
<html>
  <head>
    <title>GFM - Map</title>
    <meta charset="utf-8" />
    <meta name="viewport" content="width=device-width, initial-scale=1.0">

    <link rel="stylesheet" href="https://unpkg.com/leaflet@1.7.1/dist/leaflet.css"/>
    <script src="https://unpkg.com/leaflet@1.7.1/dist/leaflet.js"></script>

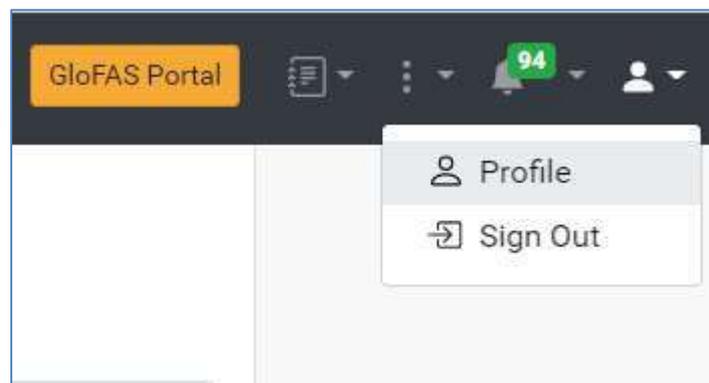
    <style>
      #map {
        width: 800px;
        height: 500px;
      }
    </style>
    <style>
      .info {
        padding: 6px 8px;
      }
    </style>
  </head>
  <body>
    <div id="map">
    </div>
  </body>
</html>

```

Copy snippet code to clipboard

### 7.5.7 Get an access token

GFM offers the possibility to access its products through a set of REST-APIs. To use the APIs, users need to get an access token that can be retrieved in their "Profile" section of the WebApp.



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The token could be then retrieved by clicking on the button "**Retrieve access token**".

### Personal Information

This form allows you to change your personal user data.

E-MAIL ADDRESS  
j.smith@company.org

FIRST NAME: Joan      LAST NAME: Smith

COUNTRY: Italy

ORGANIZATION NAME: Company

ORGANIZATION TYPE: Private Sector

PASSWORD  
[Change password](#)

ACCESS TOKEN  
[Retrieve access token](#)

[Refresh](#) [Update data](#)

The final step is to type the personal password in the text box at the bottom of the pop-up and to press the "**Get Token**" button: the system will then generate a **temporary token** that will be valid for the next 5 hours.

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### Retrieve Access Token

USER-ID

ZK5jBjjw1fyZTQF9BQWkx4vR

GET ACCESS TOKEN (API CALL)

```
curl -X 'POST' 'https://api.gfm.eodc.eu/v1/auth/login' -H 'accept: application/json' -H 'Content-Type: application/json' -d '{"email": "luca.molini@cimafoundation.org", "password": "<MY_PASSWORD>"}'
```

GET ACCESS TOKEN (DIRECTLY)

Password

ACCESS TOKEN

**M1kPitvslA4RzsNY7UTEkmNFoUZald6IERWfrzIG4C**

EXPIRES IN:

**5 hours - Tue Apr 19 2022 15:22:08 GMT+0200 (Ora legale dell'Europa centrale)**

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## 8 Frequently Asked Questions (FAQs)

### 8.1 General Queries

#### 8.1.1 What is GFM?

The GFM is a service of the CEMS ecosystem specifically designed to provide users all around the world with the most timely, updated, and reliable flood mapping products based on Sentinel-1 satellite imagery.

GFM is implemented and operated by a consortium comprising the following organizations: EODC; GeoVille; TU Wien; LIST; CIMA Foundation; DLR.

All the data produced by GFM are freely available through GloFAS and the WebApp.

#### 8.1.2 How can I contact the Users' Support Service?

User Support is coordinated by CIMA Foundation and will be guaranteed through e-mail, during working hours (8:00-17:00), 5-days-a-week in English.

Users shall use, alternatively:

- GloFAS Contact Us form
- EFAS user support

Please remember to file your request for support by selecting **Floods Monitoring** in the *Subject* drop-down menu

The screenshot shows a contact form with two main fields: 'Email \*' and 'Subject \*'. The 'Email' field contains the placeholder text 'Your Email'. The 'Subject' field is a dropdown menu with 'Floods Monitoring' selected and highlighted in blue. Other visible options in the dropdown include 'Select an option', 'Glofas', and 'Text'. To the right of the form is the European Commission logo, which features the flag and the text 'European Commission'.

Duty officer's contact: [gfm-user-support@cimafoundation.com](mailto:gfm-user-support@cimafoundation.com)

#### 8.1.3 How do I get GFM training and/or access educational material?

Most of the information Users may need to help them using properly all the GFM's products is included in the PUM and in the PDD.

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Other material is constantly updated on [GloFAS](#) and EFAS resources page.



For any further information please contact the User Support.

#### 8.1.4 How to credit GFM as data source in publications

GFM is part of CEMS ecosystem and so are all the products provided and made available through GloFAS and EFAS. Therefore, the same rules apply to GFM when credits are to be given: please check the Terms and Conditions sections on the aforementioned webportals.

#### 8.1.5 Where do I find GFM's technical documentation?

GFM's technical documentation is provided as a product user manual (PUM) in wiki format and in a printer-friendly version.

Specific documentation on the algorithm and the products is included in the Product description document (PDD), also available in a printable version in GFM wiki website.

#### 8.1.6 Are there other sources I could consult before taking a decision?

GFM aims to guarantee a high degree of accuracy for all its products, yet users must be aware that a certain degree of uncertainty has to be taken into account.

Therefore, before taking a decision, it is highly recommended to crosscheck GFM's information with other, independent sources such as: VIIRS; MODIS; UNITAR; International Disaster Charter; Dartmouth Flood Observatory. National hydro-meteorological services are usually another valuable and authoritative way of checking current danger levels: please check WMO's full list to find the national body in charge in the territory in your AOI.

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### 8.1.7 Are there any restrictions on using GFM's imagery downloaded from GloFAS?

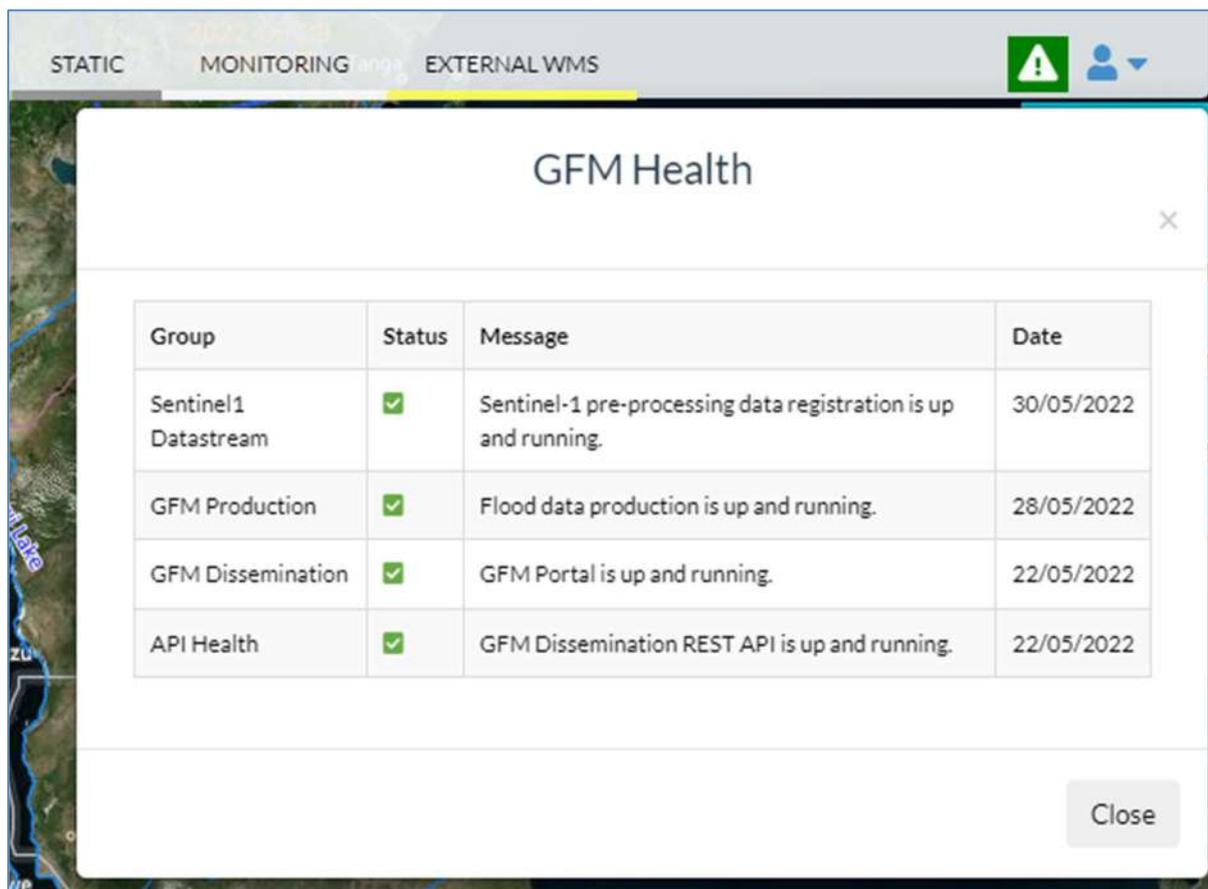
GFM is part of CEMS ecosystem and so are all the products provided and made available through GloFAS and EFAS.

Therefore, the same rules apply to GFM: please check the Terms and Conditions sections on the aforementioned webportal.

### 8.1.8 How can I know whether the system is fully operational or not?

As the GFM Products are made available through GloFAS and EFAS, these systems will inform users on any malfunction affecting this component.

For instance, in GloFAS any failure in the generation of each daily dataset as well as any limitation of the service are shown in the upper right corner with a banner:



In case of a malfunction, the banner turns red: by clicking on it, a pop-up window will open, listing all the missing or delayed outputs of the system.

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### 8.1.9 Is the information I give to GFM Login really safe?

GFM is part of CEMS ecosystem and so are all the products provided and made available through GloFAS and EFAS. Therefore, the same rules apply to GFM when security matters are addressed: please check the privacy sections on the aforementioned webportals. For what concerns external applications as the GFM's web app, GFM guarantees to secure all access by standard encryption, as per project's ToRs.

## 8.2 Data Access

### 8.2.1 How can I request a specific GFM Product?

GFM is part of CEMS ecosystem and so are all the products provided and made available through GloFAS and EFAS.

Regardless which portal will be accessed, all GFM's products will be then available on both.

If a user has the need to download a specific product or a bundle of products related to a specific *AOI* or time span, GFM has set up a web-application by means of which a query (or more) can be refined according to his/her requirements. All the information about how to do it, which formats data are provided and so forth are addressed in the dedicated section of the PUM.

### 8.2.2 Which web services are available?

GFM offers many ways of access the data of its products, and specifically a full set of web-based tools have been designed to meet users' expectations. In particular, users may take advantage of the services listed below:

- A full set of tailored REST - APIs.
- A Web Map Service.
- A dedicated Web application.

For any further information please contact the User Support.

### 8.2.3 Do you have GFM Products for download for individual countries?

Users interested in downloading products on a specific country shall address in the first place the Web application as through that tool they are enabled to configure the system to receive notification on their e-mail or Twitter account on any update regarding floods detected, site-specific.

Moreover, the Web application also offers the capability of downloading the required dataset in bundle or for separate products for a specific region.

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### 8.2.4 How do I subscribe to upcoming products?

Users interested in products on a specific country shall address in the first place the Web application as through that tool they are enabled to configure the system to receive notifications on their e-mail or Twitter account on any update regarding floods detected, site-specific.

Moreover, the Web application also offers the capability of downloading the required dataset in bundle or for separate products.

For any further information please contact the User Support.

## 8.3 Products/Processing

### 8.3.1 How frequently are GFM data updated?

GFM Products rely on Sentinel-1 data, therefore their availability is mostly dependent on the latter. One of the GFM Products is the S-1's schedule by means of which users can retrieve the information on the next data update. Specifically, update and authoritative information on the revisit time are available on S-1 webpage, the figure below is courtesy of ESA:

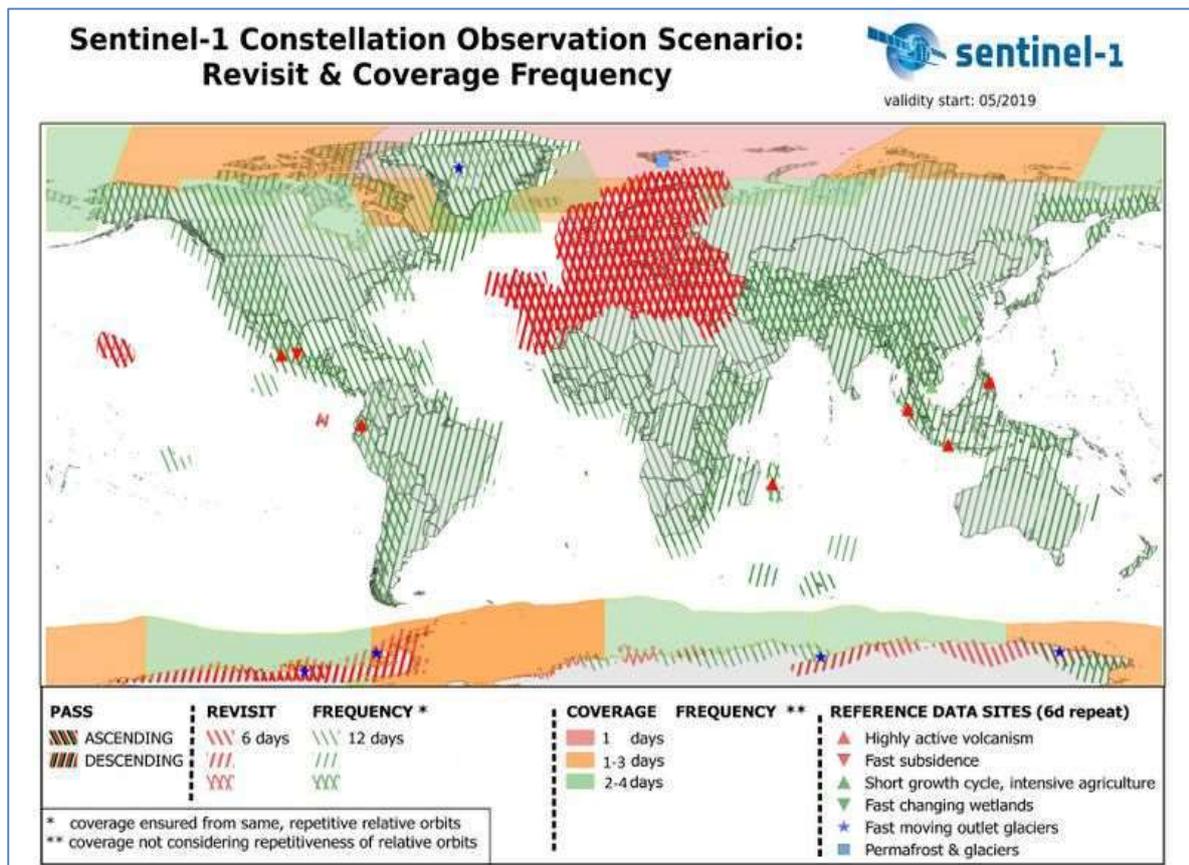


Figure 19. Illustration of the Sentinel-1 satellites revisit and coverage frequency.

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### 8.3.2 What time does the satellite pass over my area?

Information on the next available S-1 pass over a specific area is provided as one of GFM Products, namely the S-1's schedule, available on GloFAS and EFAS. The time of the planned future acquisition is also provided by ESA in form of Keyhole Markup Language (KML):

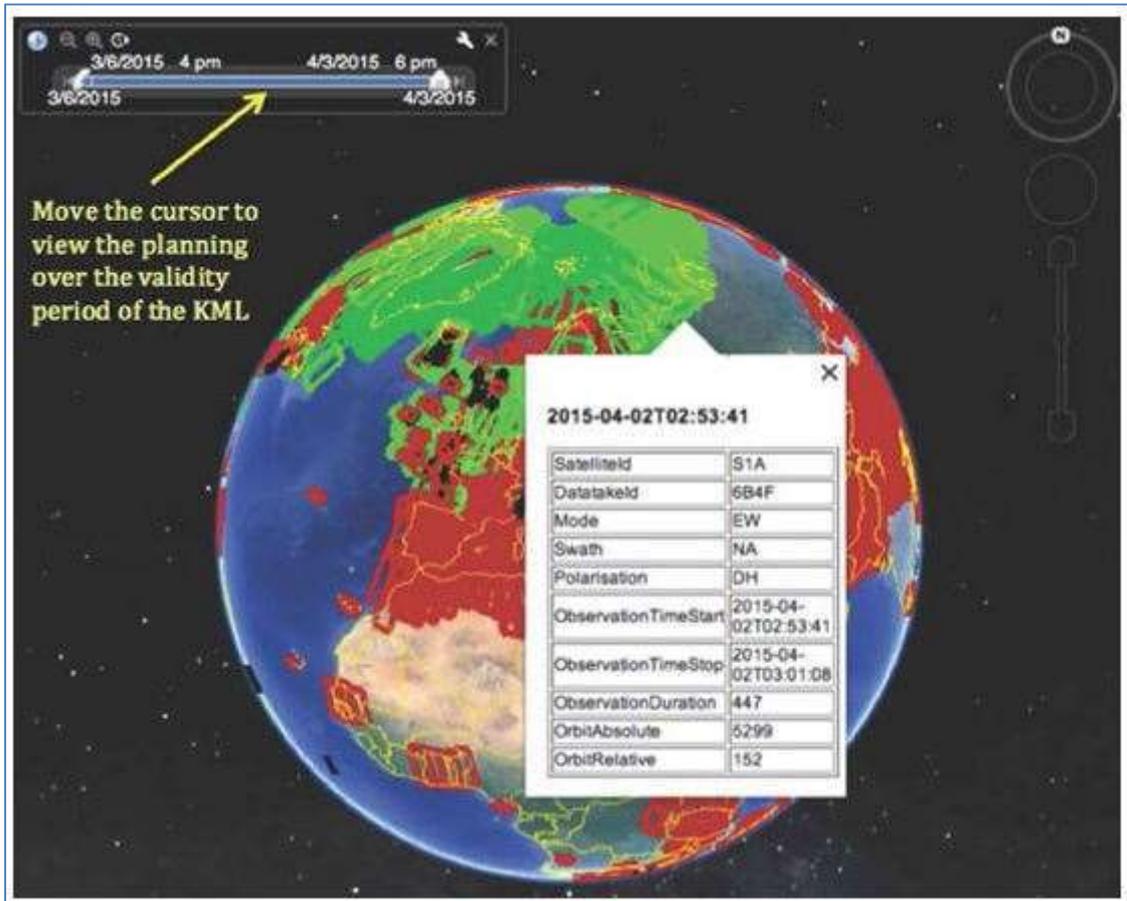


Figure 20. Illustration of the Sentinel-1 satellites schedule.

For any further information please contact the User Support.

### 8.3.3 In which format are GFM output product layers available?

GFM makes available in near real-time a full set of output layers of worldwide flood information, which are listed in Table 5. Further details are provided on the dedicated section of the PUM.

### 8.3.4 Which projection is used for the product output layers?

As per donor's request, the projection used for all the GFM Products in vector/raster format is WGS84 - EPSG:4326.

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More specific on EPSG could be also found here: <https://epsg.org/home.html>

### 8.3.5 How to interpret the Likelihood Values layer

GFM's flood detection estimate is provided through an ensemble algorithm. Based on a "consensus-maps" and an expert-designed threshold of classification, uncertainty is a non-negligible factor to be taken into account prior to any decision-making process. For this very reason, the likelihood output layer is produced and associated to every computed flood detection extent, offering the end user a clear and immediate information on the confidence of the estimate in terms of percentage.

This has a value in the range of [0, 100], where values towards 100 indicate high confidence in the ensemble flood extent detection approach.

Consequently, uncertainty information provided along with the map product communicates how much confidence is associated with the S-1 classification. End users can then use highly certain flood map products to identify resource requirements over areas of flood exposure to make timely emergency response decisions.

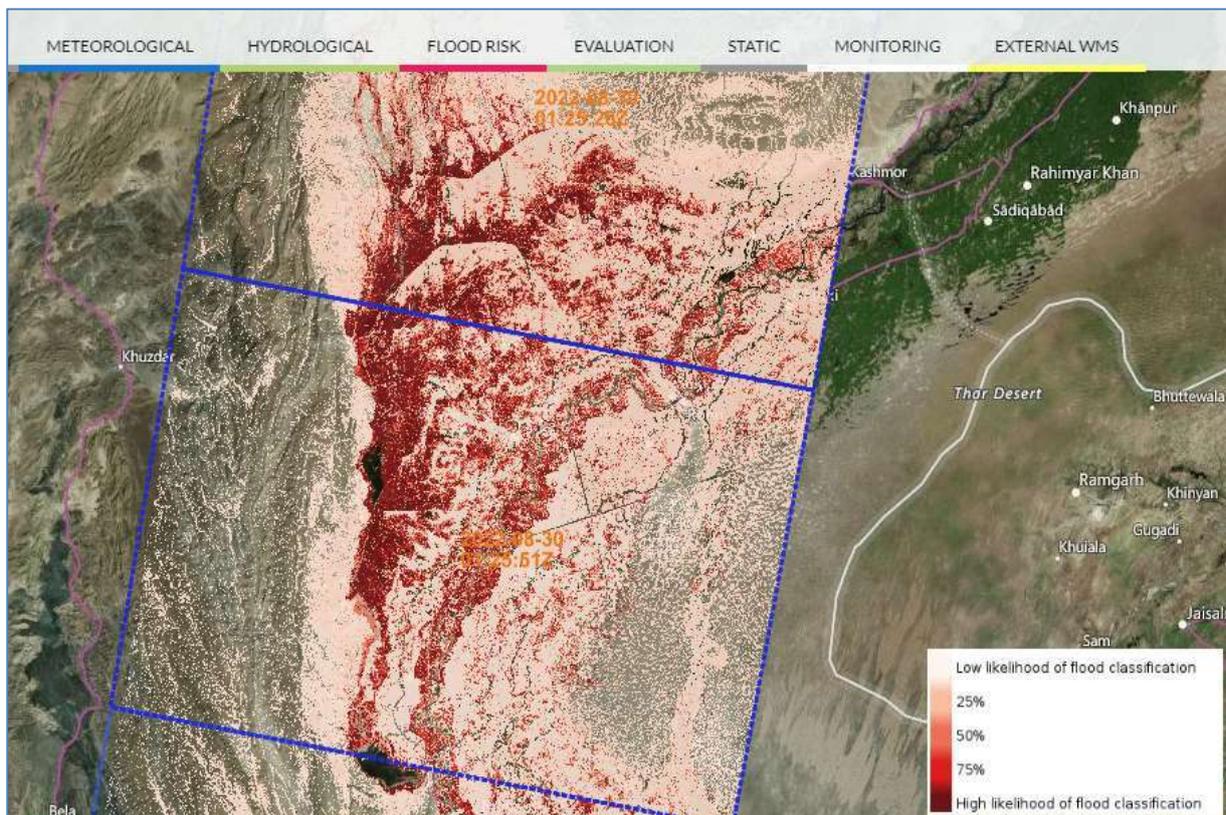


Figure 21. Example of the GFM Product output layer “Uncertainty values”.

More specifics are also available on the dedicated section of the PDD<sup>3</sup>.

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### 8.3.6 I found a mistake in a GFM Product output layer. How can I report it?

Ideally, QA/QC process are operational within GFM's project framework to ensure the highest quality standard together with a minimization of potential systemic errors and mistakes. Nevertheless, users are encouraged to report any inconsistencies they could come across to the User Support, using alternatively:

- GloFAS Contact Us form
- EFAS user support

Remember to file your request for support by selecting Floods Monitoring in the *Subject* drop-down menu:

The image shows a contact form with two main sections: 'Email' and 'Subject'. The 'Email' section has a text input field labeled 'Your Email'. The 'Subject' section has a dropdown menu with 'Floods Monitoring' selected. To the right of the form is the European Commission logo.

Duty officer's contact: [gfm-user-support@cimafoundation.com](mailto:gfm-user-support@cimafoundation.com) (Monday to Friday, 9-17 Brussels Time).

### 8.3.7 How does GFM estimate the impact of an event?

A preliminary assessment of sector-specific impacts of observed flood events, is provided using the GFM Product output layers “Affected population” and “Affected land cover” (see the dedicated section of this PUM).

### 8.3.8 What is the spatial resolution of the data?

The spatial accuracy of the GFM Product is set to conform to the optimal geometric quality of standard products derived from Sentinel-1 20-metre resolution GRD data. A thorough description of the steps leading to the final 20-metre resolution is available here [GFM's products spatial resolution](#)

### 8.3.9 How to ingest GFM'S WMS-Ts in a desktop GIS application

GFM can be displayed through state-of-the art GIS software. Users can find all the information they need on how this is done on the dedicated section of this PUM.

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## 8.4 Data Quality of the GFM Product

### 8.4.1 How are GFM data validated?

Implementing and operating the GFM service requires a set of procedures to ensure the technical and scientific quality of the GFM Product’s output layers of flood information, and of the generating service, with the overall aim to deliver the GFM output layers (including observed flood extent, reference water mask, exclusion mask, and other supplementary information) with the best possible quality. Quality Assessment (QA) procedures include both systematic automated and planned offline quality checks considering all aspects of the production, from data ingestion to data processing, data delivery, and thematic accuracy of the main GFM Product output layers. The QA mainly focuses on evaluating:

- a. The thematic accuracy of the main GFM Product output layers (i.e., “Observed Flood Extent” and “Reference Water Mask”).
- b. The product timeliness.
- c. The service availability and user uptake.

The assessment takes place on a regular basis, i.e., a quarterly reporting period. The results from all QA/QC checks are documented in an Annual Report. The assessment of the thematic accuracy follows a qualitative and quantitative approach. A quantitative assessment will be performed on the full Sentinel-1 timeseries covering the period from 2015 to 2021 with a point-based sampling approach. Besides, a use-case-based evaluation for a selected number of cases will be implemented for the near real-time processing, starting in 2022. With this we aim for an exhaustive comparison of specific flood events for which the flood extent is manually derived within a locally confined area allowing to run a pixel-based comparative analysis.

Technical reports about the quality of the GFM Product are available on-line<sup>17</sup>.

### 8.4.2 Are there known GFM Products quality issues?

The overall thematic accuracy shows good results and meets the target values of the assessed quality criteria. The quality assessment was performed based on several defined flood events since the near real-time production is in place and the assessment will continue on a regular basis in the future. Detailed results on the analysis, as well as on the product timeliness, service availability and user uptake can be found in the reports that are available online<sup>18</sup>.

### 8.4.3 Where can I find the latest report(s) on GFM Products quality/reliability?

An initial assessment on the GFM Products quality (thematic accuracy) has been done. The pre-operational product and service quality assessment report is publicly available on-line<sup>17</sup>.

<sup>17</sup> [https://extwiki.eodc.eu/GFM/PUM/Quality\\_Assessment\\_Report](https://extwiki.eodc.eu/GFM/PUM/Quality_Assessment_Report)

<sup>18</sup> [https://extwiki.eodc.eu/GFM/PUM/Quality\\_Assessment\\_Report](https://extwiki.eodc.eu/GFM/PUM/Quality_Assessment_Report)

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In future, the yearly reports will be made available, under the same web-address.

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### Annex 1: Professional profile of the Expert Flood Monitoring Alliance

**GFM** is run by a consortium, called the **Expert Flood Monitoring Alliance**, consisting of:

- 2 companies: the **EODC** (Group Leader) and **GeoVille**
- 3 research institutions: **TU Wien**, **LIST** and **CIMA Foundation**
- the German Aerospace Center **DLR**

The consortium comprises truly the most experienced group of leading experts in Europe for satellite-based flood monitoring systems with a unique CLMS, CEMS and global flood mapping service heritage. From the early days of satellite-based flood mapping and monitoring applications, the individual members of this group have built unprecedented, yet thematically complementary flood mapping, monitoring and related disaster risk service capacities as well as a accumulated a long track record of high-quality implementations and successful projects, related processing and data access systems with applications globally.

#### **EODC:**

The Earth Observation Data Centre for Water Resources Monitoring GmbH (or **EODC**) was established in May 2014 as a visionary concept outlined by Prof. Wolfgang Wagner and a group of public and private actors in the field of Earth Observation. The setup of the EODC was a direct response to the advent of Copernicus (the EU’s Earth observation programme), and the resulting unprecedented amounts of data that would be acquired by Copernicus over the coming decades.

The Sentinel-1 satellites’ projected data volumes and related data transfer requirements, in combination with data-hungry algorithms (e.g., machine learning, time-series analysis), far exceed local storage and bandwidth capacity. The algorithms themselves also demand increased computational power. Therefore, the focus and mission of EODC is to connect in an efficient manner the required storage (data) and computing power (software), thus eliminating data transfer issues. This is achieved through close c-operation with EODC’s partner network, consisting of leaders in Earth observation science (i.e., academic and research institutions), business (SMEs), governmental and inter-governmental institutions, and non-profit organizations (NGOs and foundations).

The **EODC** serves as a platform where customers and long-term partners of EODC can access state-of-the-art cloud-computing, data, and products from a vast long-term repository of EO missions. Moreover, **EODC** offers exclusive access to the Vienna Scientific Cluster (VSC) super-computing infrastructure (VSC-3 and VSC-4, ranked 82 in the top 500 in June 2019).

In terms of related expertise, the **EODC** has been working on an IT infrastructure concept that fully supports storage, processing, and re-distribution of various types of EO data, using most up-to-date ICT solutions. Following changes in technology over time and requirements arising through different types of EO data, this concept is being constantly adapted. Lessons learned and knowledge gained through this process form a solid basis for understanding of the needs and requirements associated with high performance storage and retrieval of large data

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streams, value-added product generation, as well as timely delivery in different manners (e.g., download, web-mapping, and processing services, etc.) and to interdisciplinary interested parties.

The **EODC**'s three broad spheres of service provision include cloud and high-performance computing, data and product provision, and the development of bespoke EO software and services.

Regarding related experience, the **EODC** is active in a number of national and international projects. After the successful implementation and completion of phase 1 and phase 2 of ESA's CCI Essential Climate Variable (ECV) soil moisture project, **EODC** leads the R&D evolution of the soil moisture ECV. Furthermore, EODC provides an operational framework for the production, and scientific advancement, for the soil moisture climate data record derived from passive and active space borne EO data sets. The **EODC** successfully led the Copernicus Climate Change Service (C3S) Soil Moisture Service and currently leads the C3S Land Hydrology and Cryosphere (LHC) Services with an operational Climate Data Production System (CPS) in place, it provides Soil Moisture Climate Data Records (CDR) and coordinates the provision of Lakes, Glaciers, and Ice Sheets and Ice Shelf ECV CDR's to ECMWF and C3S.

Moreover, **EODC** coordinates its partners in the provision of near real-time soil water index (SWI) products, provides a mirrored processing chain, and offers reprocessing service in the C-GLOPS project, which is the first fully operational phase of the Copernicus Global Land segment. Furthermore, **EODC** and its partners are active in projects dealing with the development of scientific algorithms and automatic processing chains for the monitoring of different local, regional, and global parameters from Sentinel 1, Sentinel 2 and other EO data sources. More information is provided on the EODC official website

### GeoVille

Also based in Austria, **GeoVille** is an internationally operating company that provides consultancy, services and products related to Earth observation (EO), geo-information and geographic information systems (GIS). Enabling the geographic inventorying of human and natural dynamics through the eye of satellite sensors, while adding the spatial dimension to information-gathering, analysis and monitoring for policy support and informed decision-making, constitutes **GeoVille's** core mission, together with providing turnkey geospatial intelligence solutions for efficient data access, client operations and management.

In terms of related expertise, since its foundation (in 1998) **GeoVille** has fed the continuous demand for the delivery of satellite-based flood mapping and monitoring services. Hence, very early on, **GeoVille** invested in research and development activities in order to build up the know-how and capacities to delineate floods from normal water extent, in both optical and microwave (radar) satellite data. This started in the 1990s with manual mapping procedures, and over the years has evolved from semi-manual processing procedures to fully automatic identification and mapping services. Integral to this evolution were the build-up of

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associated satellite data access and processing facilities, the product quality assurance procedures and extension of the various product delivery mechanisms.

**GeoVille** was the first European service provider with RADARSAT (2000) and TerraSAR-X (2008) distribution agreements for the sole purpose to be able provide to provide flood monitoring services. Later in 2014, GeoVille invested in a strategic private-public-partnership to found the EODC, which was a blueprint for the Copernicus DIAS, to be able to store and process Sentinel-1 data on a global level, partly to enable fully automatic flood monitoring services and related data access mechanisms.

Today, **GeoVille** operates the first fully automatic Sentinel1- and Sentinel2-based land monitoring system within its LandMonitoring.earth platform, which provides RESTful Web service based 24/7 access to its customers around the globe. **GeoVille** has further significant expertise in operations, quality assurance and data access via cloud-based service solutions within the Copernicus Data and Information Access Services (DIAS) and the Copernicus Land Monitoring Service (CLMS). **GeoVille** currently operates the CLMS processing systems for the “Imperviousnes” and “Water and wetness” products of the Copernicus High Resolution Layers (HRL), and the CLC+ Sentinel-1 and -2 -derived products.

Regarding related experience, some R&D milestones include the Austrian Space Application programme projects NeosQuick (2003), Aid4Floods(2004), NatHaz (2005) and SAR-X(2007), which all contributed to the service application development of SAR-based flood mapping capacities.

The FP-7 project FLOODIS (2010) and InCreo (2011) were a game-changer for the data access as they provided for the first system development with multiple mechanisms to automatic flood monitoring capacities via web pull / push and mobile app technologies, which were further improved in the H2020 projects I-REACT (2015). The latter achieved true fully integrated data approaches providing a fully automatic risk assessment capacity to the end-users at global level.

Regarding product accuracy assessment, GeoVille has developed the open-source, on-line based validation platform LACOVAL / LACO-Wiki for standardizing the validation of land cover and land cover changes by map users and producers alike. GeoVille has ample hands-on validation experience and commits itself to respect best-practice (ISO certified) along established standards (e.g., CEOS Cal/Val, LPV, EARSC, JRC) of the EO sector.

GeoVille has wide-ranging, hands-on validation experience, and commits itself to respect best-practice (ISO certified) along established standards (e.g., CEOS Cal/Val, LPV, EARSC, JRC) of the EO sector. **GeoVille** is currently the product and service quality assurance service provider of the JRC S2 Global Mosaic Service.

Regarding flood monitoring applications, **GeoVille** was first to provide operational TerraSAR-X flood monitoring services to water and disaster risk centres in Europe. On a global level, GeoVille provided its flood mapping expertise as service provider to the JRC EMS Risk &

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Recovery Mapping (2015-2017), the ESA projects (TIGER-NET, GlobWetland, EO4SD Climate Resilience and ESA WorldWater) and the development sector via many International Financial Institutions, such as WB, with focal regions in Africa, Central and South America and South-East Asia.

Within TIGER-NET **GeoVille** processed the first documented S1-flood delineation (in Namibia), which triggered related monitoring services in many other African countries (e.g., Nile Basin, Zambezi Basin, etc.). Since then, hybrid optical (HR and VHR) and SAR based flood mitigation, assessment and monitoring services are provided through an operational system. Today, GeoVille operates with its expert IT department a state-of-the-art multi cloud-based operation, monitoring, and data access system with application programme interfaces (APIs) to feed the entire range of internet-based access mechanisms for its customers worldwide. Please refer to the administrative section of the Cover Letter, for a full company description with related evidence of expertise and experience documentation.

More information is provided on the GeoVille official website

**TU Wien**

**TU Wien** (Technische Universität Wien) was founded in 1815 (as “k.k. Polytechnisches Institut”), making it the first university of technology in today’s German-speaking world.

TU Wien’s microwave remote sensing (MRS) research group, which contributes to the GFM consortium, is part of the Department for Geodesy and Geoinformation (GEO), which conducts research and teaching in observing, modelling, and communicating geo-scientific states and processes, and has about 100 staff. The MRS focuses on the physical modelling of radar backscatter and the retrieval of soil moisture, water bodies, vegetation, and other geophysical variables from scatterometer and Synthetic Aperture Radar (SAR) data. Their scientific work has paved the ground for several operational soil moisture data services for ASCAT and Sentinel-1 in cooperation with national (e.g. ZAMG, EODC) and international (e.g. EUMETSAT, ECMWF) partners. These data services have been developed and operated within the framework of EUMETSAT’s Satellite Application Facility in Support to Operational Hydrology and Water Management (HSAF), the Copernicus Global Land and Climate Change Services (CGLS and C3S), and the ESA Climate Change Initiative (CCI).

In addition to the scientific output in numerous peer-reviewed research articles and conference contributions, most scientific algorithms and satellite data management software developed by the MRS team for scatterometer and SAR data analysis are implemented in various Python libraries, several of which are available as open source on <https://github.com/TUW-GEO>. The software libraries for ASCAT and Sentinel-1 are designed to allow global and operational processing, and have been deployed on desktop computers, operational systems, cloud platforms and high-performance computing environments. The MRS group has led and participated in international research projects funded by ESA and the European Commission.

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**TU Wien** has been one of the initiators and co-founders of the EODC. In addition to being able to use EODC’s Petabyte-scale storage with its stored Sentinel EO data (Sentinel-1: globally all available GRD data; Sentinel-2: globally all available L1C data), its cloud platform, and **TU Wien’s** super-computing facilities (Vienna Scientific Cluster), the **TU Wien** MRS group has powerful in-house processing capabilities: they operate an 800 TB Fileserver with a 1 PB robotic tape library, 12 top end working stations, several terminal servers, approximately 80 workstations and a back-up server. The internal network is based upon a Windows Active Directory Domain.

Owing to an intense collaboration with the IT-departments of EODC and **TU Wien**, the remote sensing research group is experienced in handling large earth observation data volumes and developing software packages for automatic processing.

In terms of related expertise, the experts of **TU Wien** contribute to the consortium an in-depth knowledge of SAR data processing, building upon a long-standing experience with the European Envisat and Sentinel-1 missions.

With its SAR team focusing on Level-1 data ingestion, processing, aggregation, and the retrieval of geophysical variables feeding into Level-2 products, a strong scientific and technical competence on Sentinel-1 IW and EW mode data has been gained. The pre-processing engine of the SAR Geophysical Retrieval Toolbox (SGRT) – which dates to 2007 and has been constantly enhanced and adapted – features a near-real-time-capable (NRT) workflow especially tailored for Sentinel-1 input. It integrates the state-of-the-art geocoding and calibration functionalities of ESA’S SNAP Toolbox, as well as an in-house-developed border-noise-removal algorithm and several automated routines for quality-control, resampling and gridding. With the perspective of Big Data entering remote sensing, the spatiotemporal data-cube for raster data based on the Equi7Grid was created in 2014 and is hosted now by EODC, allowing a geometric accurate and efficient handling and storage of massive satellite data volumes.

In addition to the two other thematic key variables soil moisture and vegetation, the mapping and monitoring of water bodies has been the central topic of several research and operation projects of TU Wien. Thanks to the possibility of directly accessing the Sentinel-1 data-cube and analysing the full time series of SAR backscatter at pixel level, the delineation of permanent and seasonal water body extent can be achieved on a global scale.

Most recent research has been conducted on the analysis of temporal and spatial signatures of water bodies to estimate flood frequencies and to detect flood events.

Regarding related experience, the MRS research group of **TU Wien** has been part of several operational and thematic-related projects:

- Copernicus Global Land Service (GIO-GL, C-GLOPS1, C-GLOPS2; 2013-ongoing): NRT provision of a portfolio of bio-geophysical products on the status and evolution of land surface at global scale, using the most suitable satellite sensors including the Sentinel

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fleet. As project partner, TU Wien is responsible for the soil moisture product and processing chain development, data-cube design, and the continuous scientific quality evaluation.

- HSAF (CDOP 1-3; 2007-ongoing): NRT and CDR (climate data record) provision of operational data on hydrological variables (precipitation, soil moisture, snow parameters) from EUMETSAT satellites. As project partner, **TU Wien** is responsible for the soil moisture product and processing chain development, and the continuous scientific quality evaluation
- EC H2020 I-REACT (2016-19): Project to increase the resilience of European citizens and assets to natural disaster by integrating existing local and European services into a platform that supports the entire emergency management cycle. **TU Wien's** role as project partner was to develop and demonstrate an on-demand NRT Sentinel-1 flood mapping service.
- ESA Globwetland (2015-17): A large Earth Observation application project to develop and demonstrate an open-source software toolbox for the end-to-end processing of a large portfolio of EO products and the subsequent derivation of spatial and temporal indicators on wetland status and trends, from local to basin scales. TU Wien was a sub-contractor to GeoVille, producing Sentinel-1 water body maps for about 20 % of the African land surface area based on Sentinel-1 time service.
- CLMS HRL Water & Wetness (2017-22): This service provided high-resolution water and wetland layers based on multiple input data for Europe. **TU Wien** was a sub-contractor to GeoVille, producing water body maps for Europe based on Sentinel-1 time series.
- ESA Sentinel-1 Global Backscatter Model (2018-19): The development and production of a global 10 m Sentinel-1 backscatter model. This involved pre-processing the entire global Sentinel-1 data record for the years 2016 and 2017, applying strict quality control procedures and the selection of suitable backscatter models.
- FFG Austrian Data Cube (2018-20): This project delivered a data cube system for Austria with the goal to remove technological barriers for the use of Copernicus data in Austria. **TU Wien** was responsible for the definition and production of the Sentinel-1 data cube to the *Acube*.

More information is provided on the TU Wien official website.

## LIST

The Luxembourg Institute of Science and Technology (**LIST**) is a Research and Technology Organization (RTO) active in the fields of materials, environment, and IT, under the trusteeship of the country's Ministry of Higher Education and Research.

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It works across the entire innovation chain: fundamental and applied research, incubation, transfer of technologies. By transforming scientific knowledge into technologies, smart data and tools, **LIST** empowers citizens in their choices, public authorities in their decisions and businesses in their strategies.

**LIST**'s research unit *Environmental Sensing and Modelling*, which is engaged with this proposal, carries out impact-driven research, geared towards monitoring, forecasting and predicting environmental systems in a changing world. Its research and development activities are centred on the combination and exploitation of remote sensing information obtained by multiple and complementary sensors installed on spaceborne and airborne platforms.

The assimilation of remote sensing data with numerical prediction models enables the generation of higher-level information ranging from local or regional to global scales, with unprecedented accuracy and spatio-temporal resolution. This strategy is used to develop innovative applications in precision agriculture, natural resources management, disaster risk reduction and maritime surveillance.

The development of scientific algorithms enabling the systematic, automated, and rapid production of flood extent maps from various satellite Earth Observation data sets counts among the unit's primary research objectives. Moreover, the scientists at **LIST** are renowned for their research leading towards a more efficient assimilation of various EO-derived data sets into hydrologic and hydraulic models, as well as a more comprehensive assessment of flood hazard and risk at large scale through a combination of numerical modelling and remote sensing. Its EO relevant expertise in both fields is demonstrated by a track record of scientific publications and research projects.

Over the last decade the unit's collective knowhow and its technological assets have been applied to develop new products and services supporting flooding-related disaster risk reduction at large scale.

Some examples of such applications are provided in the following:

- ESHAPE (EuroGEO Showcases: Applications Powered by Europe), 2019-2023, European Commission – H2020: LIST is leading the project's flood pilot (as part of the water resources showcase) and is generating a Sentinel-1 and ENVISAT-based record of floods over Europe for the time period 2002 – 2019.
- EDRIFT (Satellite EO based solutions to support disaster risk financing in Southeast Asia), 2018-2020, European Space Agency: The project aims to setup and maintain a fully automated Sentinel-1 based flood mapping processor to systematically monitor water bodies in 3 countries of SE Asia during every year's Monsoon season.

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- SEADRIF (Southeast Asia Disaster Risk Insurance Facility), 2018-2020, World Bank: The project aims to automatically generate flood extent maps and to estimate the number of persons affected by flood events to support the parametric insurance models of the disaster risk financing industry.
- LANDCOVER CCI (Global land cover map development for climate modelling applications), 2013-2015, European Space Agency: The LIST oversaw the quality control and large-scale validation of the permanent water bodies layer derived from the collection of ENVISAT ASAR recordings.
- HTEP (Hydrology Thematic Exploitation Platform), 2013-2015, European Space Agency: Implementation of an ‘on demand’ Sentinel-1 based flood mapping application on the HTEP platform and development of a water extent monitoring system for large lakes in Africa.

Other relevant projects in recent years include HYDRAS+ (Improving drought management by assimilating multi source satellite data into hydrologic models), HASARD (Implementation of new methods for remote sensing-based flood hazard mapping on the ESA’s Grid Processing on Demand environment, and WATCHFUL (Water Cycle Feasibility: characterizing the water cycle at global and basin scales using EO data).

More info on LIST official website.

**CIMA Research Foundation**

CIMA Research Foundation (hereafter called CIMA Foundation) is a scientific organization under the Italian Legal Regulations governed by public law, which is recognized as a centre of excellence for civil protection by the national Italian regulation.

**CIMA Foundation’s** mission is to develop scientific and engineering technologies for application in environmental-related fields with focus on disaster risk reduction, civil protection and preservation of terrestrial and water-related ecosystems, always connecting research, operations, capacity development and assistance to the end users. **CIMA Foundation’s** researchers have a long record in defining procedures and models to assess flood risk. This expertise grew taking advantage of the direct contact with institutions operating on the topic and has been always characterized using the state-of-the-art technologies to improve the detail of flood hazard mapping as well as of flood vulnerability assessment.

Specific GIS and WEB-GIS tools developed by CIMA represent the best of the available information on the territory and provide an added value in all the projects developed in this research area and are taken as current global reference for flood monitoring by international bodies such as WMO.

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In terms of related expertise, **CIMA Foundation** has a diversified expertise that is based on the knowledge expressed by more than 100 researchers, post-docs Ph.D. candidates and collaborators. The core expertise of **CIMA Foundation** aligns along three axes:

- *Early warning system for floods and fires*, including links and preparation of related emergency plans.
- *Multi hazard, Multi risk National and Local Disaster Risk Profiles* definition and connection with national and local strategies, including specific cost benefit analysis for mitigation measure prioritization.
- *Use of Satellite products* in support of the two above mentioned axes

Satellite information is heavily used in support of **CIMA Foundation** modelling approach. **CIMA Foundation** is official validator of rainfall and soil moisture products for the H-SAF. It has been also contributing to the Copernicus Risk & Recovery service where modelling and satellite observations are properly merged to produce more reliable and cost-effective risk maps.

**CIMA Foundation** distinctive expertise is in the constant contact with the end users of such scientific products. This contributed to its capacity in producing actionable research that impacts in the everyday life of users and eventually citizens in line with its mandate. In particular, the Risk Assessment and Loss Data Department is specialized in modelling risk and impacts linked to natural hazards, with a special focus on floods. Statistical approaches are used to combine hazard information with data describing exposure characteristics (i.e., population, built-up, service and productive systems or the environment), as well as vulnerability, the predisposition of exposed elements to be adversely affected by hazards. Common products for such activities are probabilistic risk profiles or impact assessment studies.

Special effort is dedicated to the integration of global (satellites or non-satellite) information with local data to obtain the best representation of exposure and vulnerability fitting to the purposes of the specific study. To this end, specific tools have been developed for use at the national or international level. **CIMA Foundation** has a specialised ICT unit that has developed many applications for Disaster Risk Reduction and specifically in developing space technology application for DRR.

Thanks to a more than a decade’s experience in developing applications for ASI, ESA and Italian Civil Protection department, **CIMA Foundation** can contribute a strong expertise in front-end and back-end design and realisation with specific attention to service delivery through APIs and dedicated web-services. **CIMA Foundation** has an ISO 9001:2008 Quality Assurance Certificate provided by AENOR International. This quality assurance certifies **CIMA Foundation** quality process in conducting scientific research and technological transfer which includes standard procedures and practices assuring the quality of services.

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Regarding related experience, since 2010, under a framework agreement, **CIMA Foundation** provides technical, scientific assistance and technological innovation to the Italian Civil Protection department and the Italian Civil Protection system (including regions) for developing tools and new governance system for the management of climate risk with focus on floods, hydro-meteorological extreme, landslide and forest fires.

**CIMA Foundation** has assisted the Italian Civil Protection department in international cooperation activities for capacity developing on Disaster Risk Reduction with focus on Climate risks. Recently, **CIMA Foundation** is working closely with the World Bank DRFI and ESA (SEADRIF & eDrift projects) on a series of project in support of Risk Financing in Southeast Asia, that merges the early warning system, the impact evaluation and the use of satellite data for parametric insurance activation in Cambodia, Laos PDR and Myanmar. This has resulted in an operational service that will commence by this monsoon season in Myanmar and Laos.

Under the umbrella of the WMO, **CIMA Foundation** implements the Dewetra platform, a system for real time monitoring, prediction and prevention of flood and wildland fire risks. So far, the Dewetra platform has been operationally implemented in: Albania, Italy, Serbia, Croatia, Lebanon, Bolivia, Ecuador, Philippines, Tunisia, Ecuador among others. **CIMA Foundation** assists the end-users of the platform with a 24/7 user support.

**CIMA Foundation** is in the steering committee of the Global Flood Partnership and of the Risk Nexus Initiative. **CIMA Foundation** participated in the Project PREVIEW, Prevention Global Flood Partnership Information and Early Warning (FP6) and led the project RASOR – Rapid Analysis and Spatialisation of Risk ([www.rasor-project.eu](http://www.rasor-project.eu)): A Copernicus downstream project funded under the FP7 that developed an advanced web-based platform for multi hazard and multi-risk assessment assisted by EO Data ([www.rasor.eu](http://www.rasor.eu)).

**CIMA Foundation** is part of the IMPREX - IMproving PRedictions and management of hydrological EXtremes H2020 project ([www.imprex.eu](http://www.imprex.eu)) dealing with real-time impact assessment and its application in EWS and implementing a Pan-European Hydro-meteorological forecasting chain that will be complementing the existing EFAS Copernicus service.

**CIMA Foundation** is also partner in GEO-CRADLE, Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO related initiatives towards GEOSS. **CIMA Foundation** strongly involved in the Heimdall H2020 project led by DLR aiming at developing a platform that exploits modelling and EO data for the management of Emergencies.

**CIMA Foundation** has been in the lead of the Global Flood Hazard Model contributing at the UNISDR Global Assessment Report (<https://www.preventionweb.net>). CIMA coordinates the Global Flood Record within the Global Flood Partnership (<https://portal.gdacs.org>), with the

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aim of combining satellite, model data, and observation to Loss Data to better analyse and predict Flood Impact. CIMA is also Implementer of the DesInventar Loss Data base in many Countries (i.e., Albania, Kosovo, Serbia, Belarus, Caribbean Countries) in collaboration with UNDRR and UNDP.

More information is provided on the CIMA Foundation official website.

**DLR**

As the German Aerospace Research Centre and the national space agency **DLR** is organised as a chartered non-profit organization and has approximately 9,100 employees at 27 locations in Germany. DLR’s work on the GFM Product is conducted by the Georisks and Civil Security department of the German Remote Sensing Data Center (DFD).

Its main focus is to support the entire disaster-management cycle with satellite-based geoinformation products in cases of environmental and natural threats, humanitarian crisis situations and civil security emergencies. The department has strong expertise and longstanding experience in satellite-based flood mapping and monitoring. Its scientific and technical work includes developing new analytical methodologies for working with remote sensing data, using and further developing geoinformation technologies, developing thematic remote sensing processors and monitoring systems, vulnerability and risk modelling, and designing and establishing crisis information and early warning systems.

The department also operates the Centre for Satellite Based Crisis Information (ZKI), whose function is the rapid acquisition, processing and analysis of satellite data and the provision of timely satellite-based information products for rapid decision support in case of disasters and humanitarian crisis and civil security emergencies.

In terms of related expertise, the core expertise of DLR is on research and development as well as the establishment of operational services in the fields of satellite-based emergency mapping (e.g., ZKI, CEMS), flood mapping and monitoring (e.g., InsuResilience flood monitoring India) and early warning systems (e.g., German Indonesian Tsunami Early Warning System).

With its national and international receiving stations **DLR** offers direct access to data from Earth Observation missions, derives information products from the raw data, disseminates these products to users, and safeguards all data in the National Remote Sensing Data Library for long term use. This includes amongst others the Sentinel-1 and 3 (OLCI) Processing and Archiving Centres (PACs). In this context, **DLR** develops, operates and continuously improves fully automated processing chains for flood monitoring from SAR (Sentinel-1 and TerraSAR-X) and optical (Sentinel-2 and Landsat) satellite data.

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Software tools and algorithms are based on sound scientific studies, published in peer-reviewed journal articles and are being extensively tested in numerous national and international projects and services with world-wide coverage.

Regarding related experience, **DLR** has longstanding experience in satellite-based emergency mapping with particular focus on flood mapping and monitoring services throughout numerous projects and services. The most relevant ones are listed below:

- The International Charter "Space and Major Disasters", 2010-present: Association of space agencies and satellite operators to provide a unified system for the rapid acquisition and delivery of satellite data in case of disasters. **DLR** entered the Charter in October 2010 and provides data for the TerraSAR-X satellite mission. In this context also flood products derived fully automatically by **DLR's** Sentinel-1 and TerraSAR-X Flood Services are provided to users.
- ZKI-DE, 2013-present, service contract with Federal Ministry of the Interior – Germany: **DLR** developed the ZKI-DE Service for enabling federal authorities to obtain and analyse current remote sensing data and geoinformation at short notice to support civil and public security.
- Copernicus Emergency Management Service (CEMS – Mapping component), 2015-2018, EU: Copernicus service for satellite-based emergency mapping in case of disasters or humanitarian crisis worldwide. **DLR** was mainly involved in service enhancement and evolution as well as in emergency mapping.
- SAFER (Services and Applications for Emergency Response), 2009-2012, EU FP7: Develop the existing satellite-based emergency response service into an operational service (ERS - Emergency Response Service) with focus on meteorological-driven (e.g. fires, floods) and geophysical hazards (e.g. earthquakes, landslides)

Other relevant projects include DAREnet (Danube river region resilience exchange network), InsuResilience (Flood monitoring for the insurance sector in India), ASAPTERRA (Advancing SAR and optical methods for rapid mapping), CODE-DE (Copernicus data and exploitation platform Deutschland), HEIMDALL (Multi-hazard cooperative management tool for data exchange, response planning and scenario building), DRIVER+ (Driving innovation in crisis management for European resilience), RIESGOS (Multi-risk analysis and information system components for the Andes region) and GITEWS

Together with LIST and TU Wien, **DLR** was part of the core *Expert Group* that was set up by the European Commission's Joint Research Centre (JRC) to assess the feasibility of an automated, global, satellite-based flood monitoring product, to complement and enhance the capabilities of the CEMS for mapping and monitoring floods (Matgen et al., 2020).

More information is provided on the DLR official website.

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