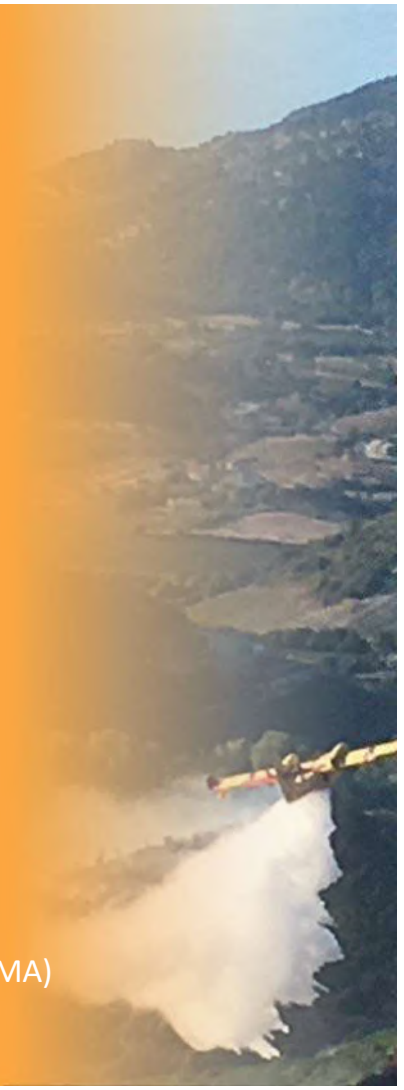


CEMS
Global Flood Monitoring
28.10.2021

Emergency Management

GLOBAL FLOOD MONITORING ALLIANCE:
Earth Observation Data Centre (EODC)
GeoVille Information Systems and Data Processing (GV)
Technische Universität Wien (TUW)
Deutsches Zentrum für Luft- und Raumfahrt EV (DLR)
Luxembourg Institute of Science and Technology (LIST)
Centro Internazionale in Monitoraggio Ambientale – Fondazione (CIMA)

Emergency Management

Methodology

Wolfgang Wagner (TUW)
Sandro Martinis (DLR)
Patrick Matgen (LIST)

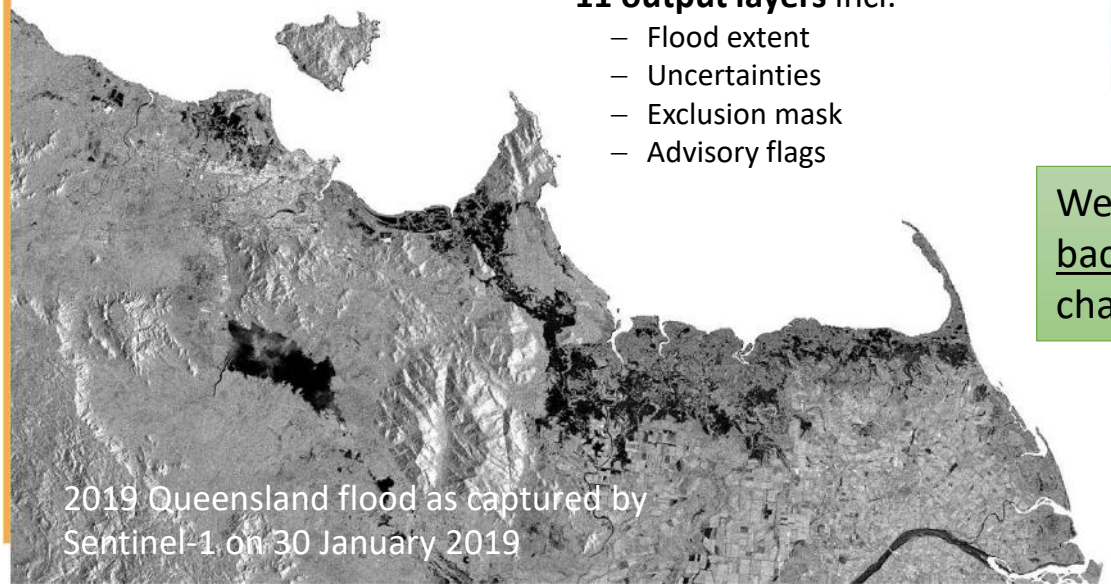
Copernicus Europe's eyes on Earth

European Commission

Emergency Management

Sentinel-1 SAR for flood mapping

- **Sentinel-1** Synthetic Aperture Radar (SAR)
  - 2 satellites with systematic coverage
  - C-band 20m spatial resolution
- **Fully automatic** processing of all incoming Sentinel-1 scenes within 8 hours
- **Ensemble** of 3 flood mapping algorithms
  - **11 output layers** incl.
    - Flood extent
    - Uncertainties
    - Exclusion mask
    - Advisory flags



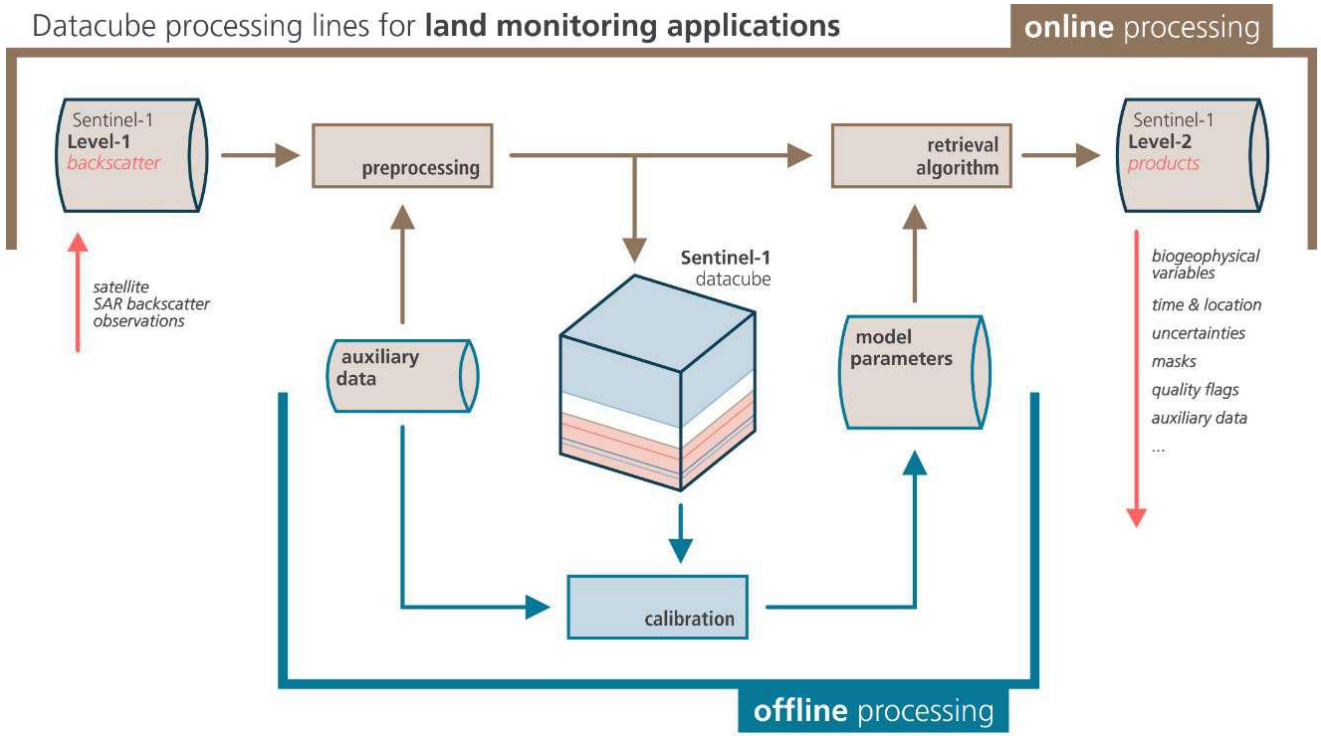
2019 Queensland flood as captured by Sentinel-1 on 30 January 2019

We look for a change to very low backscatter (in the order of -18 dB) as characteristic for open inland waters

Emergency Management

Datacube Processing Architecture

- From offline model calibration and masking to online operations



Wagner et al. (2021) A Sentinel-1 Backscatter Datacube for Global Land Monitoring Applications, *Remote Sensing*, submitted.

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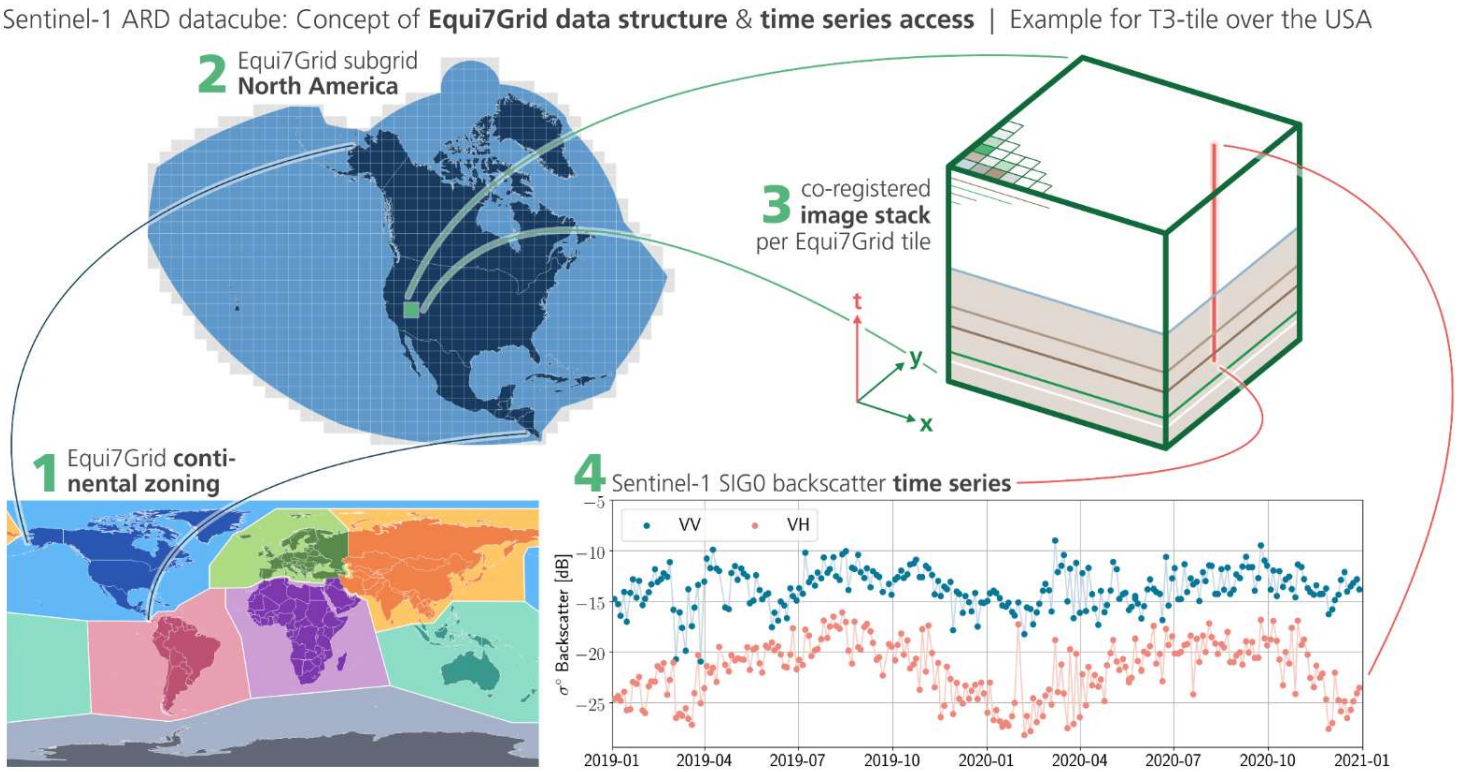
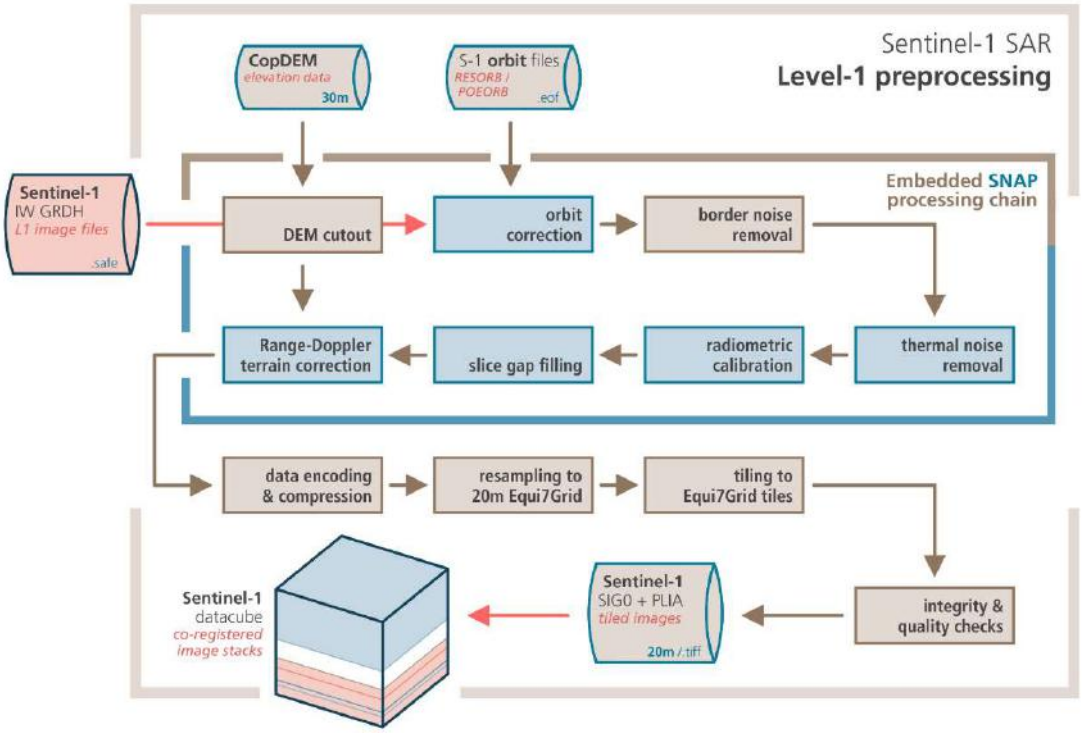
Datacube System based upon the Equi7Grid



Bauer-Marschallinger et al. (2014) Optimisation of global grids for high-resolution remote sensing data, Computers & Geosciences, 72, 84-93. Figure from Wagner et al. (2021) A Sentinel-1 Backscatter Datacube for Global Land Monitoring Applications, *Remote Sensing*, submitted.

Sentinel-1 Preprocessing

Emergency Management



Data Volume in TB

Level-1 Sentinel-1 IW GRD data

Year	Africa	Asia	Europe	NA	Oceania	SA	Total
2015	12.7	15.1	22.0	6.2	4.9	5.3	66.2
2016	20.6	19.2	31.9	11.5	6.6	9.0	98.8
2017	45.0	53.9	71.8	31.4	18.4	23.1	243.6
2018	48.0	58.1	70.3	35.3	20.2	24.7	256.6
2019	94.4	61.1	119.9	38.5	21.1	26.9	361.9
2020	97.3	63.3	130.7	41.4	21.3	28.6	382.6
Total	318.0	270.7	446.6	164.3	92.5	117.6	1409.7

20 m Sentinel-1 datacube

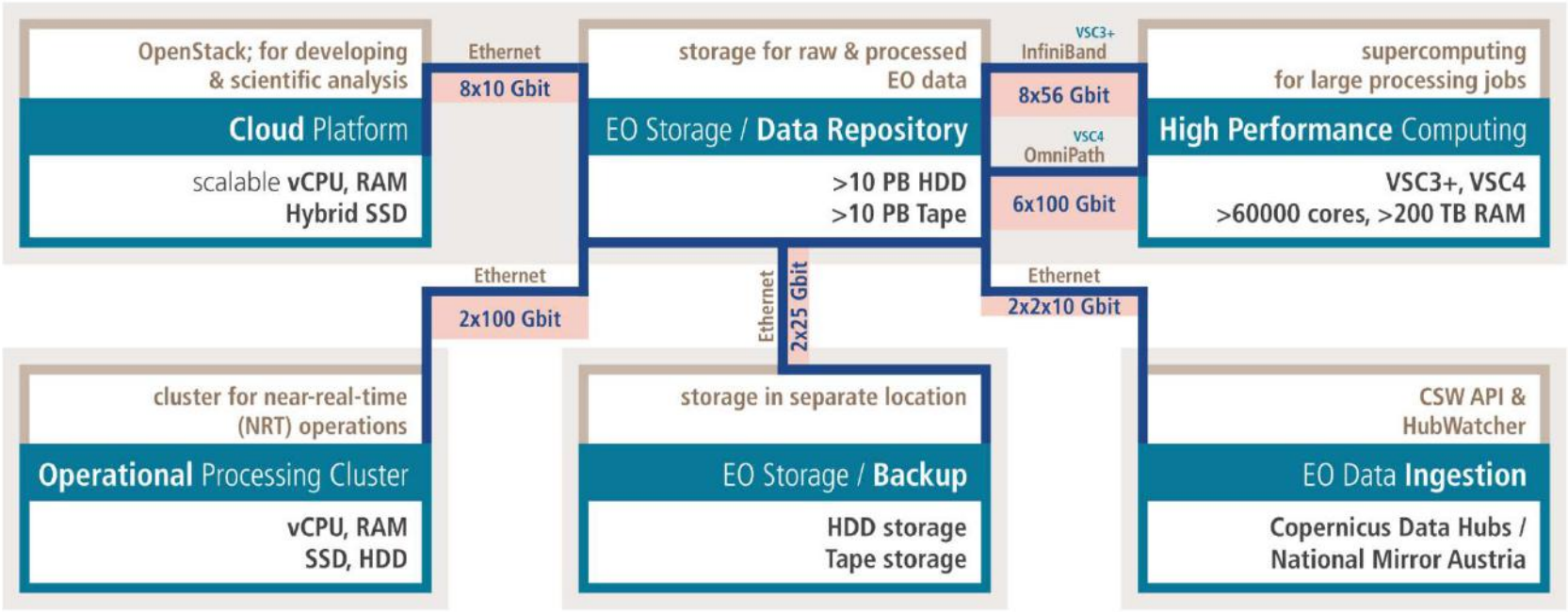
Year	Africa	Asia	Europe	NA	Oceania	SA	Total
2015	2.5	2.9	4.3	1.2	1.1	1.0	13.0
2016	4.4	4.0	6.4	2.5	1.5	1.9	20.7
2017	9.8	11.9	14.6	6.9	4.3	4.9	52.4
2018	10.3	12.8	12.8	7.6	4.7	5.2	53.4
2019	16.9	19.4	23.5	13.4	7.6	8.6	89.4
2020	17.3	20.1	25.0	14.6	7.7	9.4	94.1
Total	61.2	71.1	86.6	46.1	26.9	31.0	323.0

Wagner et al. (2021) A Sentinel-1 Backscatter Datacube for Global Land Monitoring Applications, *Remote Sensing*, submitted.

ICT Infrastructure

Emergency Management

Technical Infrastructure for Sentinel-1 ARD datacube

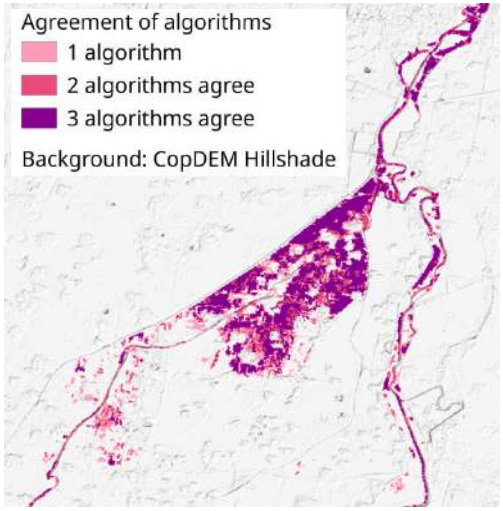


Wagner et al. (2021) A Sentinel-1 Backscatter Datacube for Global Land Monitoring Applications, *Remote Sensing*, submitted.

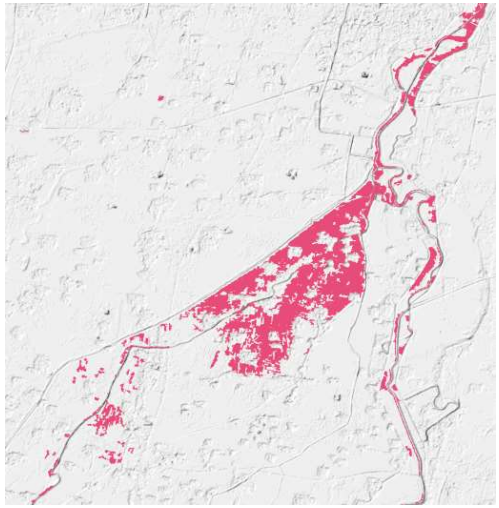
Emergency Management

Ensemble Approach

- 3 Scientific Algorithms
  - DLR: Image classification using fuzzy logic with post classification and region growing
  - LIST: Change-detection using hierarchical split-based approach
  - TUW: Bayesian classifier informed by full per-pixel Sentinel-1 signal history
- Ensemble
  - At least two algorithms must agree
  - Average of single uncertainties



Ensemble

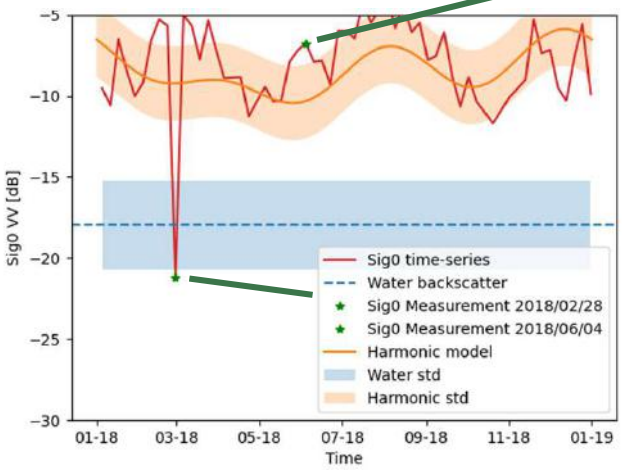


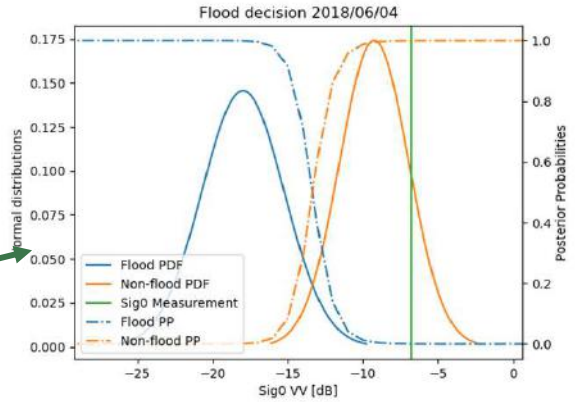
Flooding near Guantao, China
Sentinel-1 scene from 14.10.21

Emergency Management

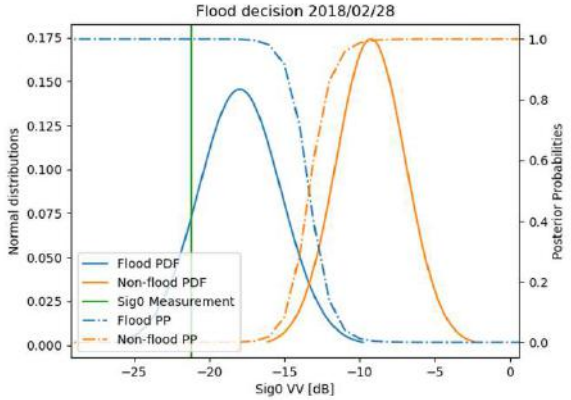
TUW Flood Mapping Algorithm

- Pixel-wise **Bayes decision**
  - non-flood distribution described by a harmonic model (Schlaffer et al. 2015)
  - flood distribution
- Morphological post-processing





No flood



flood

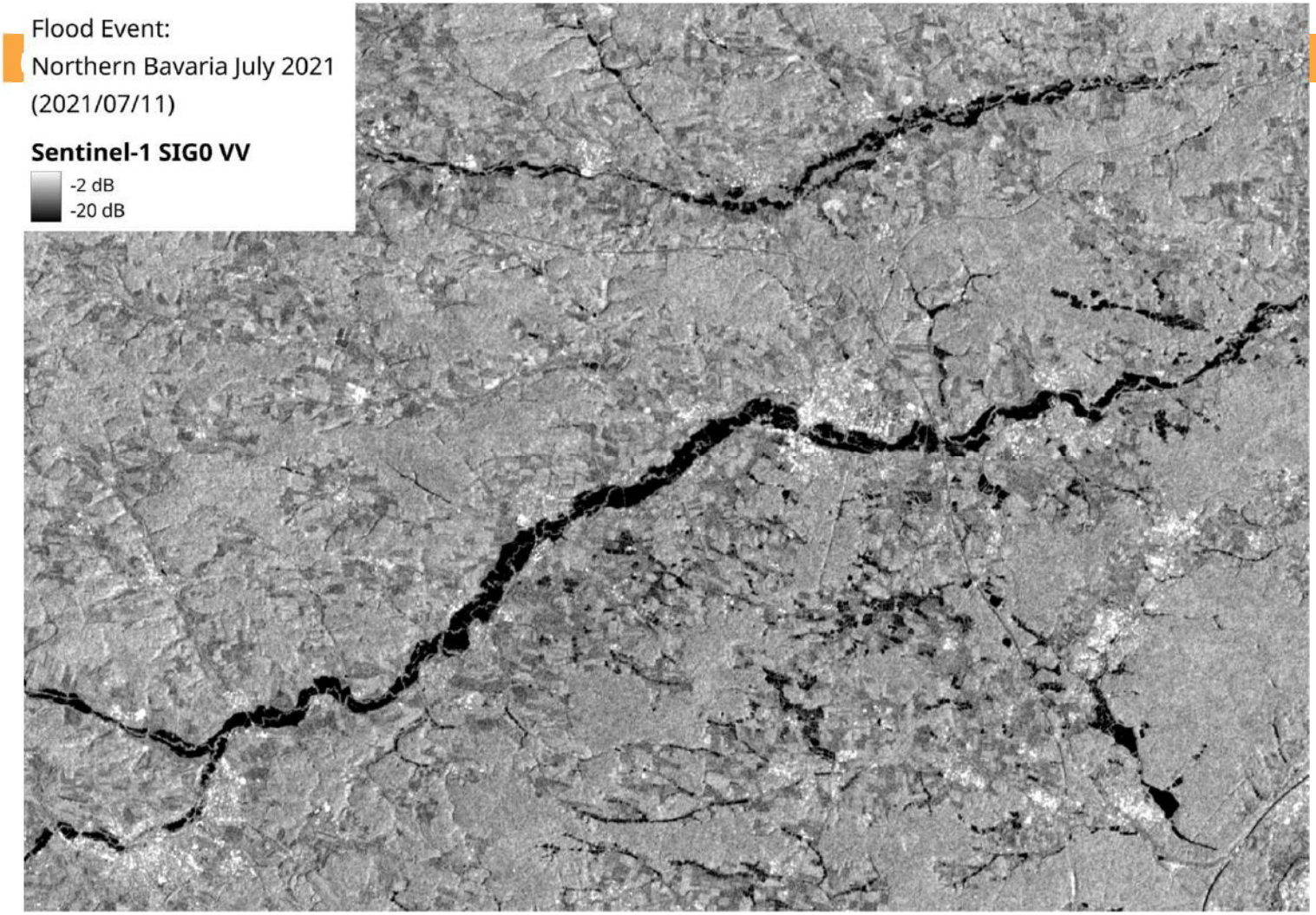
Schlaffer et al. (2015) Flood detection from multi-temporal SAR data using harmonic analysis and change detection, Int. Journal of Applied Earth Observation and Geoinformation, 38, 15 – 24.

Emergency Management

Flood Event:
Northern Bavaria July 2021
(2021/07/11)

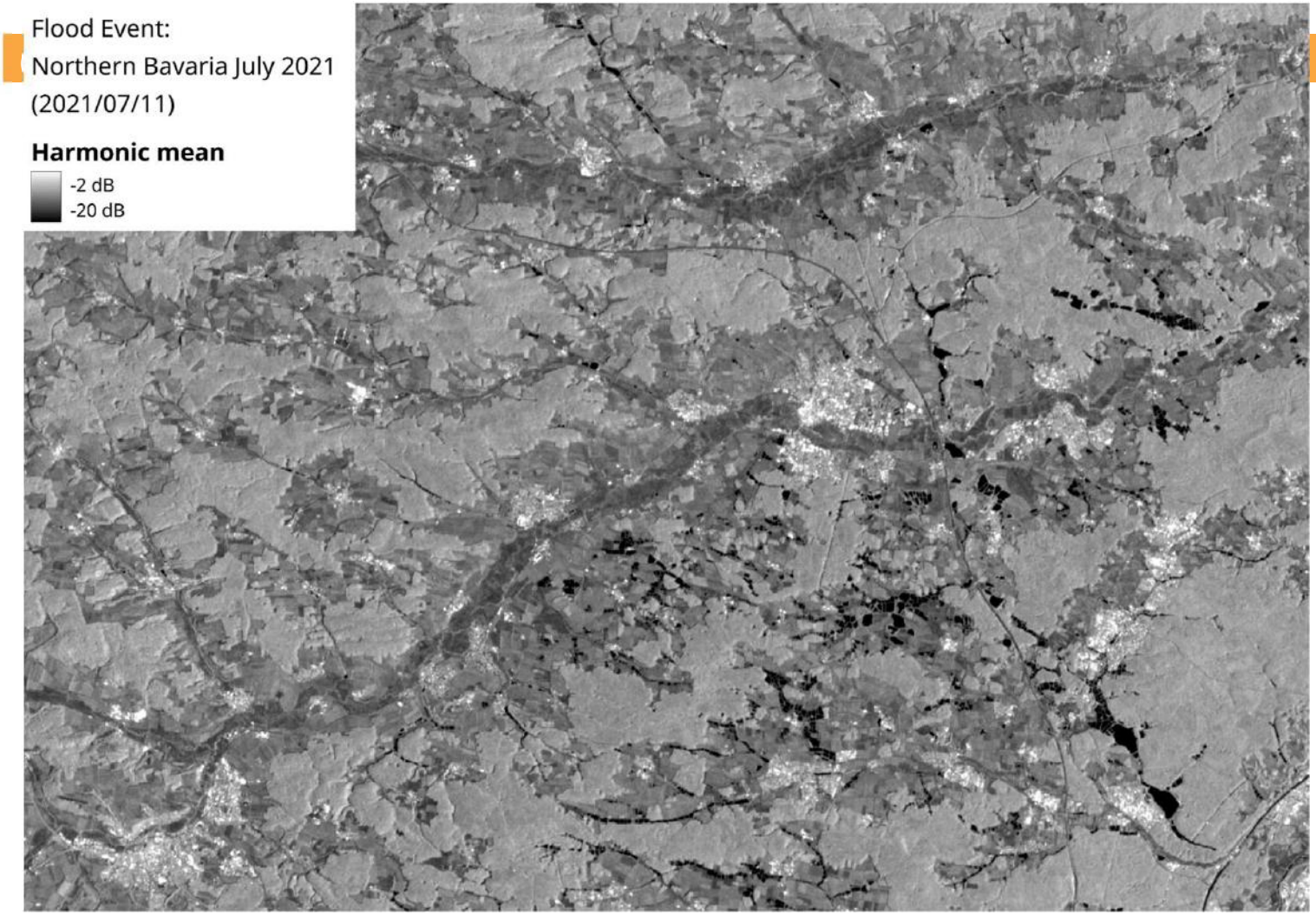
Sentinel-1 SIG0 VV

-2 dB
-20 dB

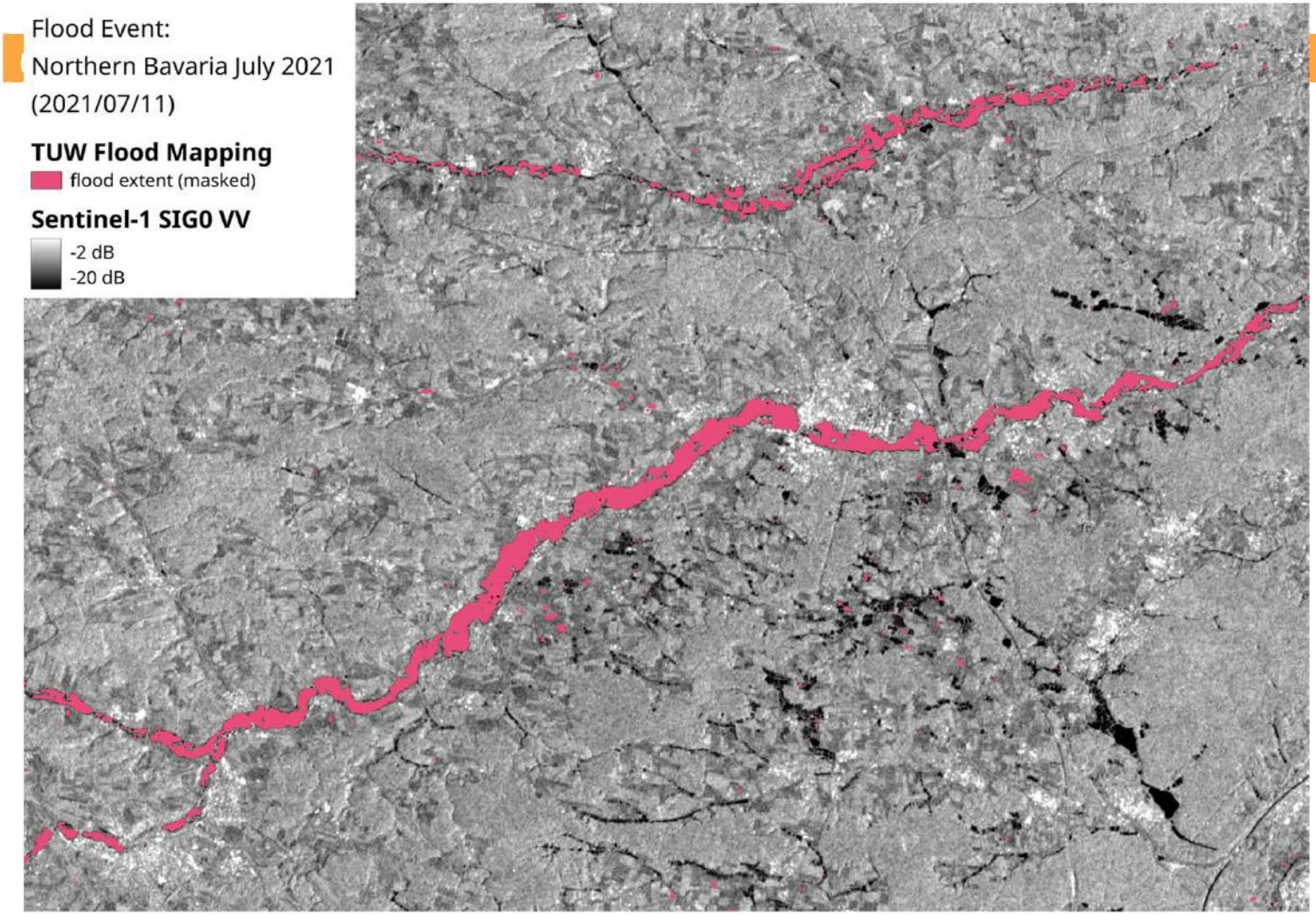


Emergency Management

Flood Event:
Northern Bavaria July 2021
(2021/07/11)



Emergency Management



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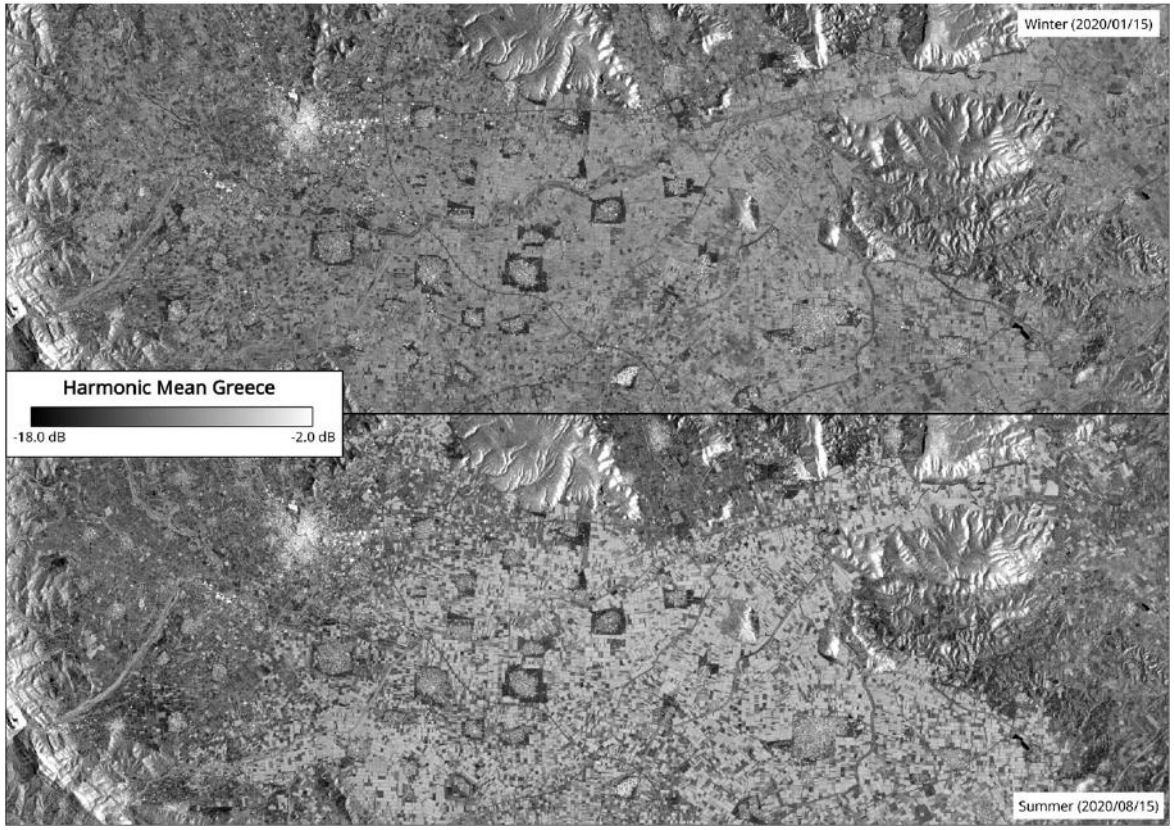
TU Wien Flood Mapping Parameters



Synthetic reference image based on the harmonic model for two different seasons

Winter

Summer

Bauer-Marschallinger et al. (2021) Satellite-based Flood Mapping through Bayesian Inference from Sentinel-1 SAR Datacube, in prep.

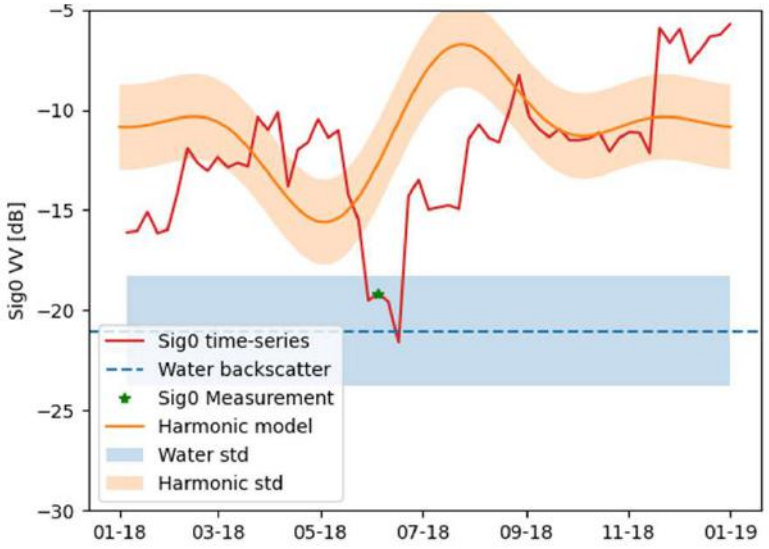
Emergency Management

Known Issues for TUW Flood Algorithm

Divergent seasonality:

- Seasonality is not well predicted by the harmonic model (in some cases)
  → Low backscatter e.g. due to agricultural practices or land cover change is misinterpreted as flood
  → Noisy flood patterns (red dots)

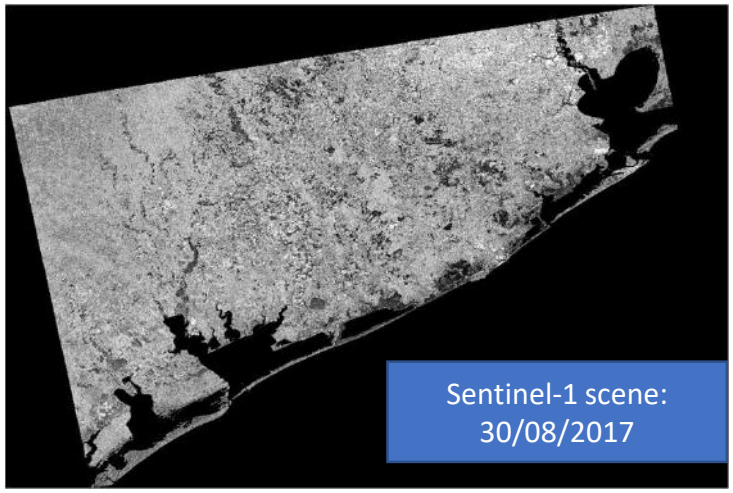
- Mostly affected: Agricultural areas

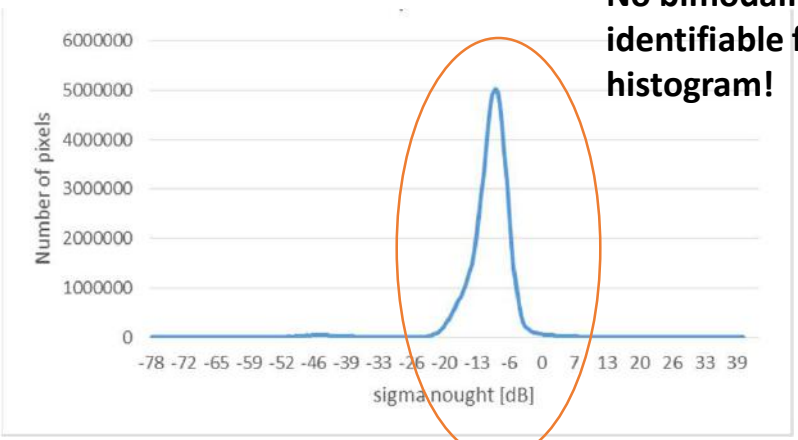


Emergency Management

LIST Flood Mapping Algorithm

- **Statistical modelling– and change detection-based** algorithm that parameterizes two distribution functions to classify pixels into 4 classes of interest: ‘water’ & ‘no-water’ and ‘change’ & ‘no-change’
- Flooded/changed areas often represent only a **small fraction** of an entire SAR scene: difficulty to parameterize distribution functions because the distribution of SAR backscatter values is **not clearly bimodal**





No bimodality identifiable from histogram!

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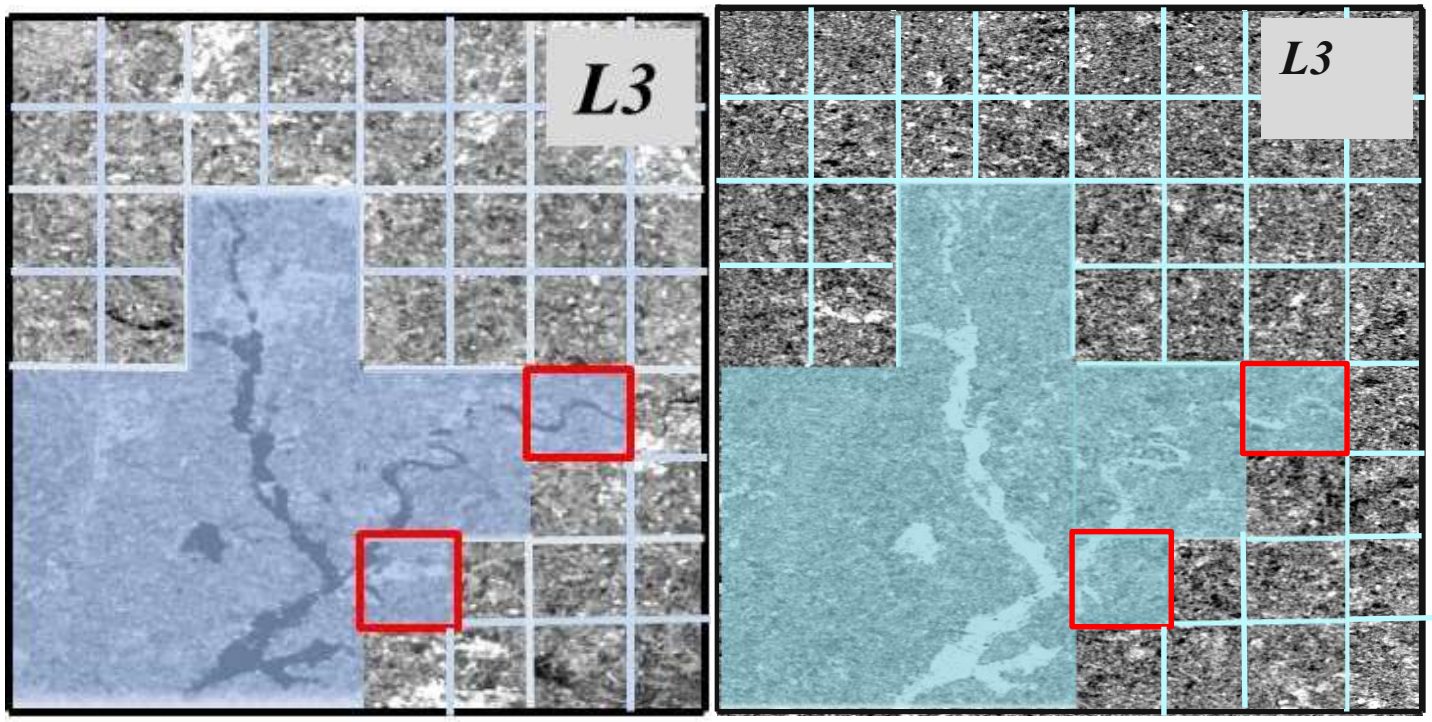
LIST Flood Mapping Algorithm

Flood-IM

Change-IM



Hierarchical split-based approach to select subtiles with identifiably bimodality in histograms

Chini et al., TGRS, 2017

LIST Flood Mapping Algorithm

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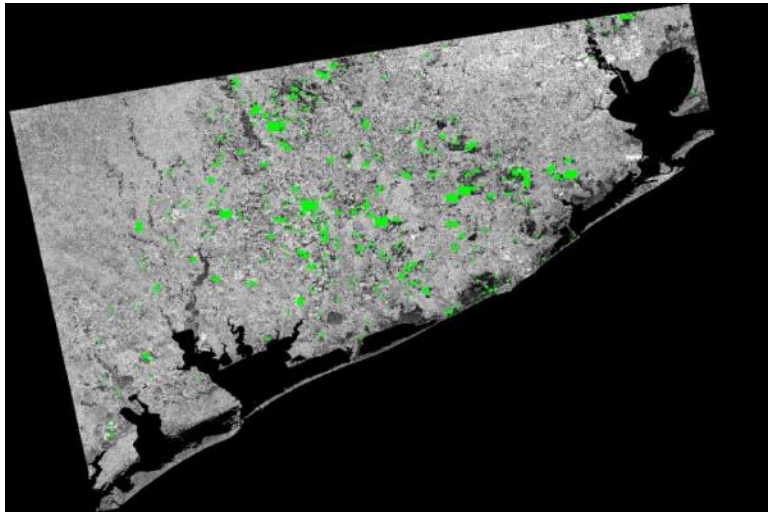
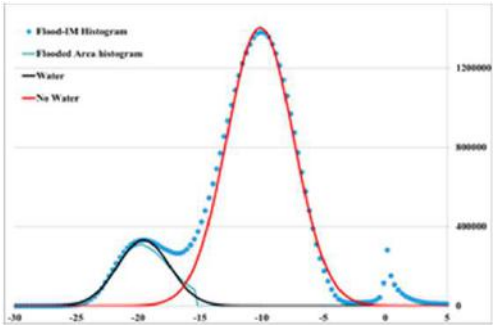
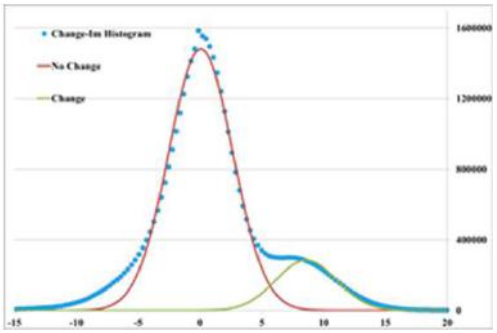


Finally selected tiles enabling parameterization of the algorithm





Parameterization of “water” and “change” classes

Thresholding & region growing

LIST Flood Mapping Algorithm

Emergency Management

LIST WATER/FLOOD DETECTION ALGORITHM

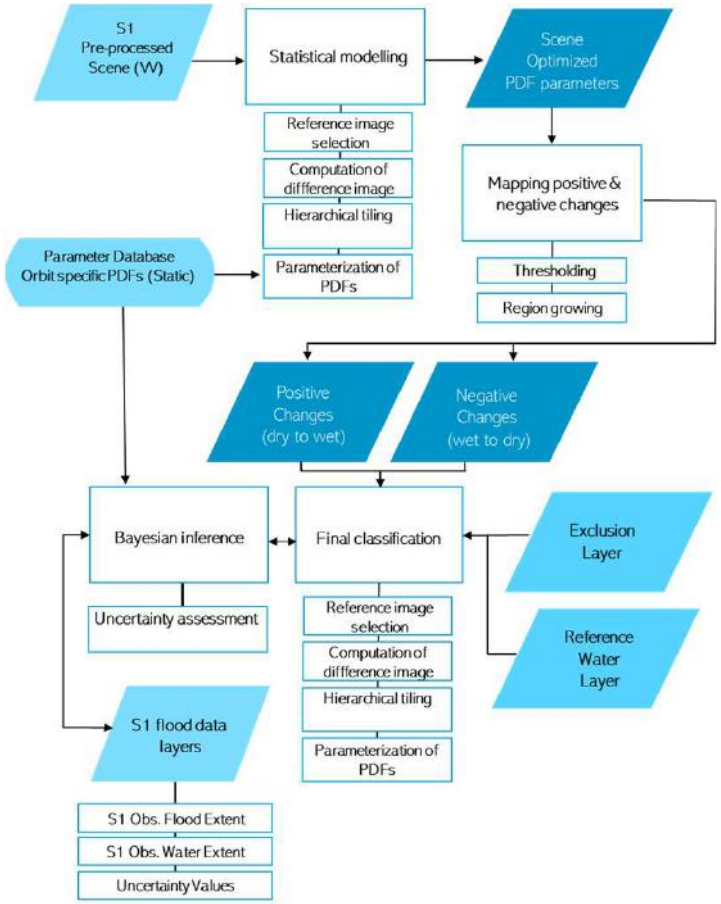
HASARD

Inputs:

- S1 pre-processed scene
- Adequate reference S1 scene acquired from same orbit
- Exclusion layer
- Reference Water Layer
- Flood extent map generated at previous time step
- Parameter database

Outputs:

- Observed Flood extent
- Observed Water extent
- Uncertainty values



LIST Flood Mapping Algorithm

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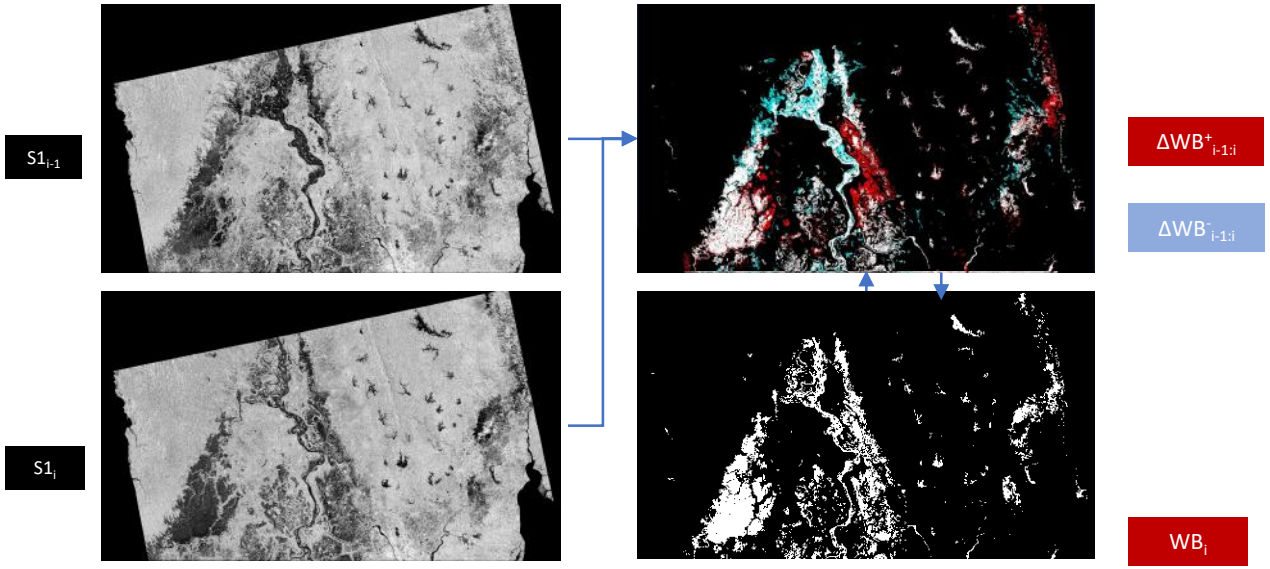
LIST WATER/FLOOD DETECTION ALGORITHM

HASARD

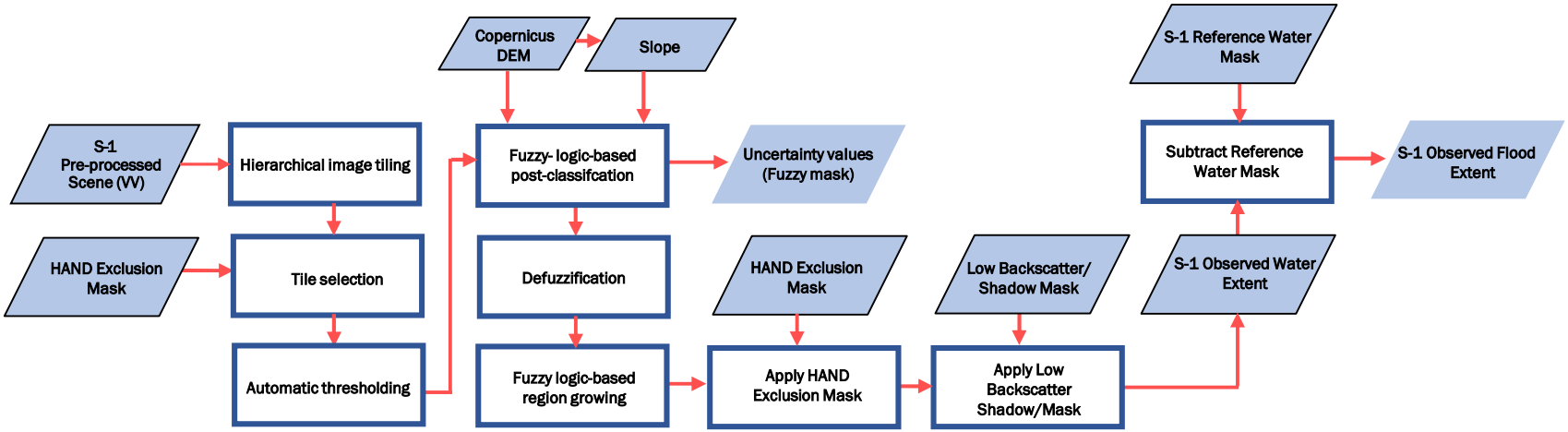


Systematic monitoring of appearing/receding water bodies to update water extent map

DLR Flood Mapping Algorithm

Emergency Management

DLR WATER/FLOOD DETECTION ALGORITHM



Workflow for Sentinel-1 based flood detection using hierarchical tile-based thresholding and fuzzy logic-based post-classification refinement

Martinis et al. 2015: A fully automated TerraSAR-X based flood service, *ISPRS J. of Photogrammetry and Remote Sensing*, 104, 203-212.
Twele et al. 2016: Sentinel-1 based flood mapping: a fully-automated processing chain, *Int. J. of Remote Sensing*, 13, 2990–3004.

DLR Flood Mapping Algorithm

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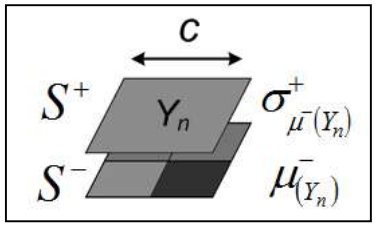
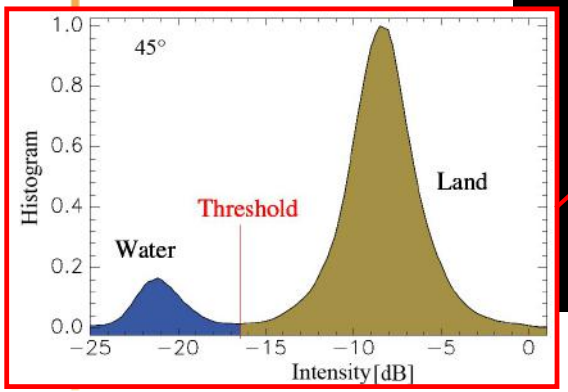
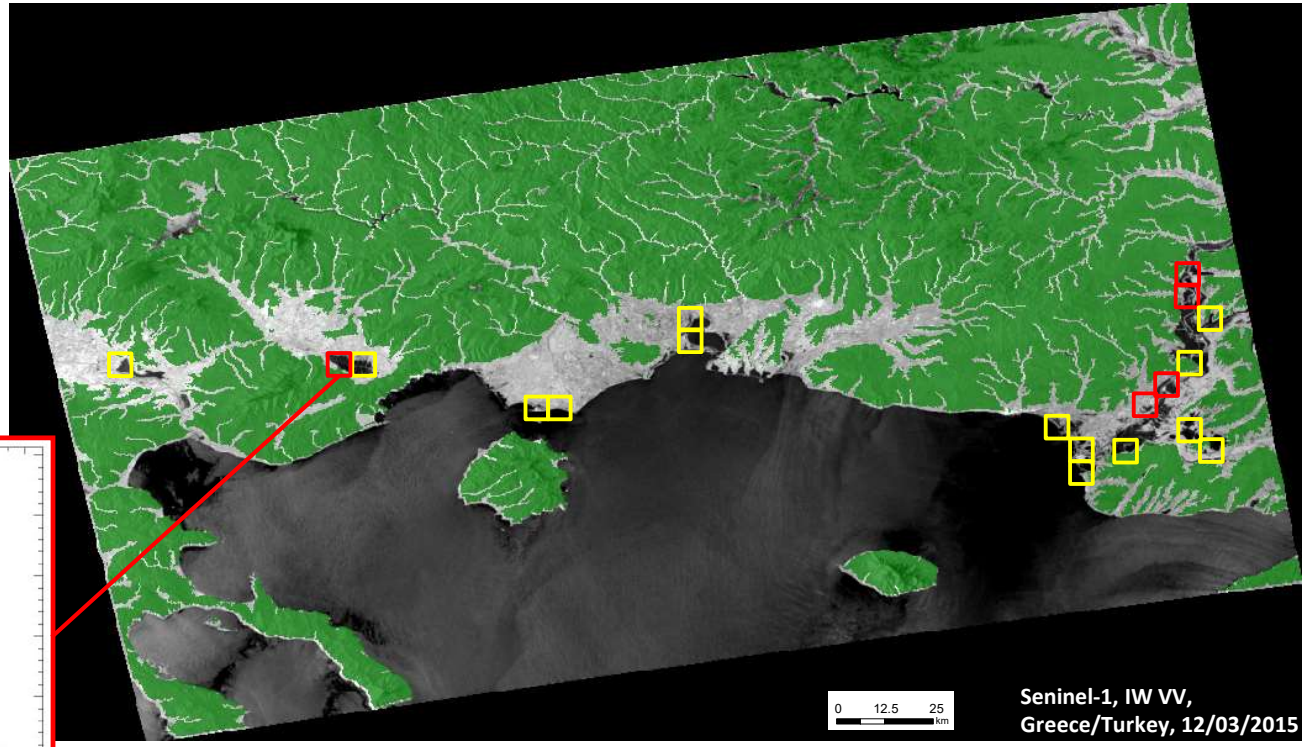
DLR WATER/FLOOD DETECTION ALGORITHM



Bi-level quadtree structure



Separability land/water



Seninel-1, IW VV, Greece/Turkey, 12/03/2015

Candidate tiles for thresholding

Finally selected tiles for thresholding

HAND Exclusion Mask

DLR Flood Mapping Algorithm

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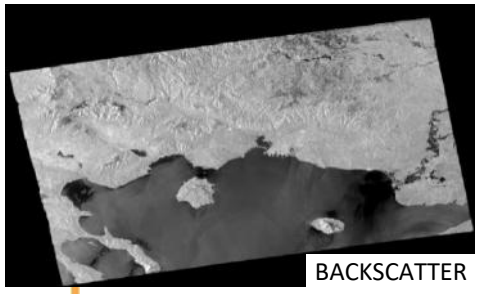
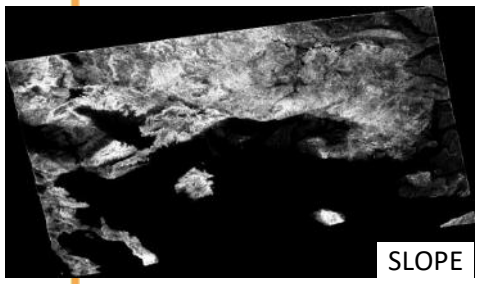
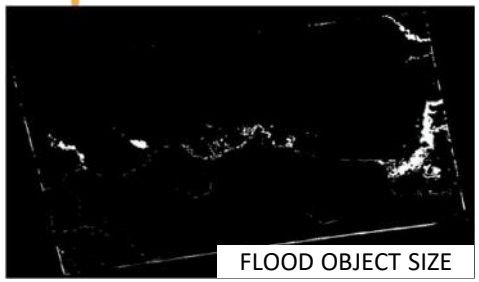
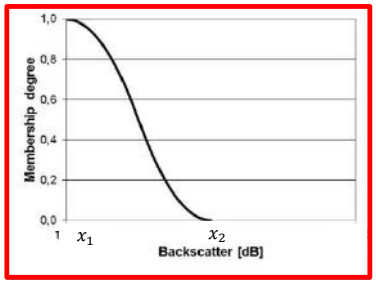
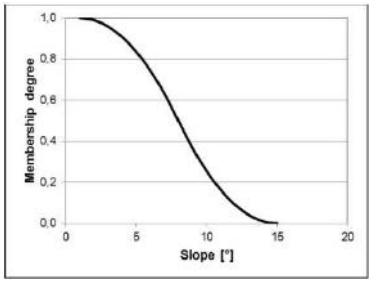
DLR WATER/FLOOD DETECTION ALGORITHM

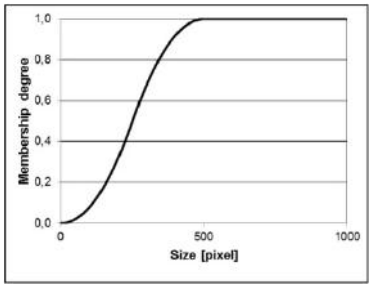




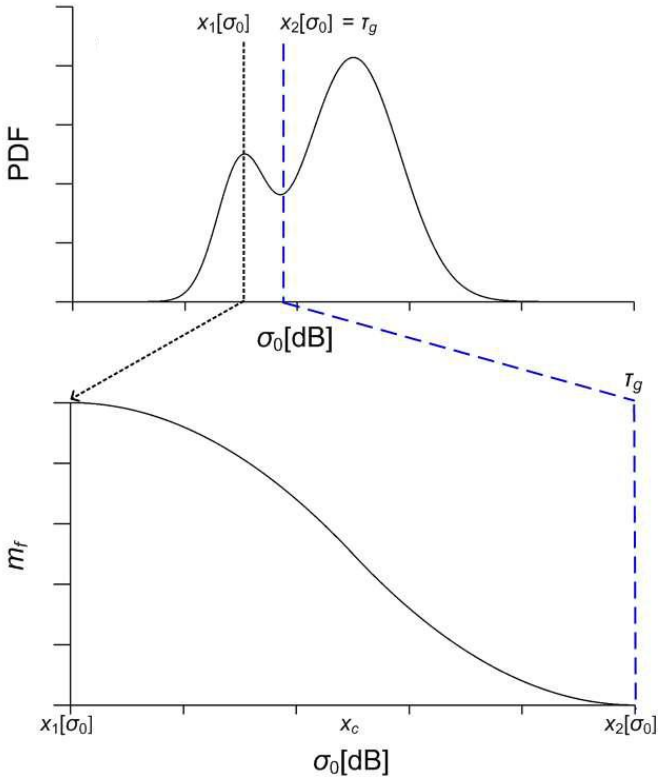








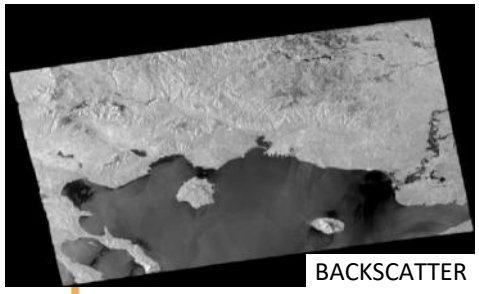
$x_{1[\sigma_0]} = \mu_{\sigma_0(\tau_g)}$ $x_{2[\sigma_0]} = \tau_g$



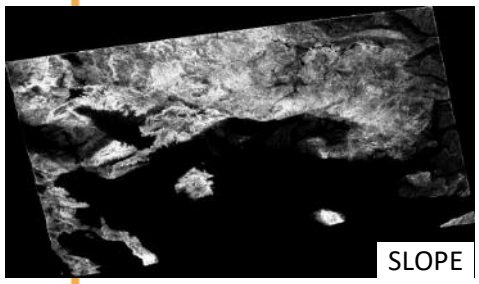
DLR Flood Mapping Algorithm

Emergency Management

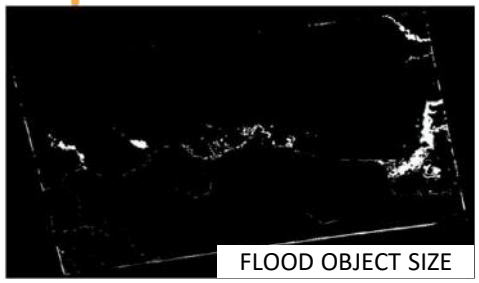
DLR WATER/FLOOD DETECTION ALGORITHM



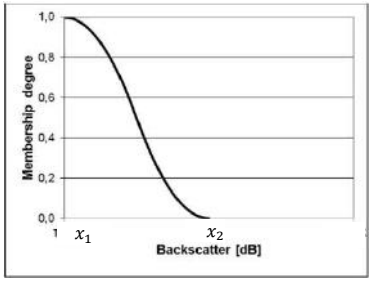
BACKSCATTER

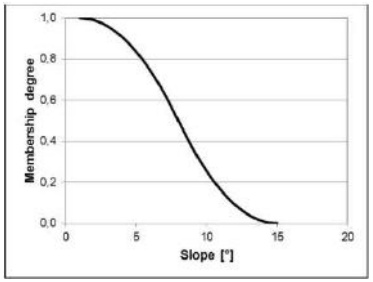


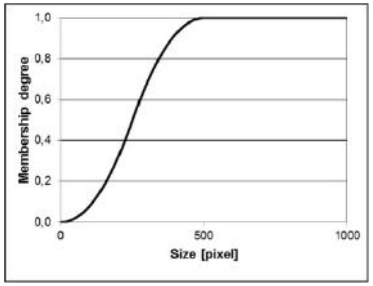
SLOPE

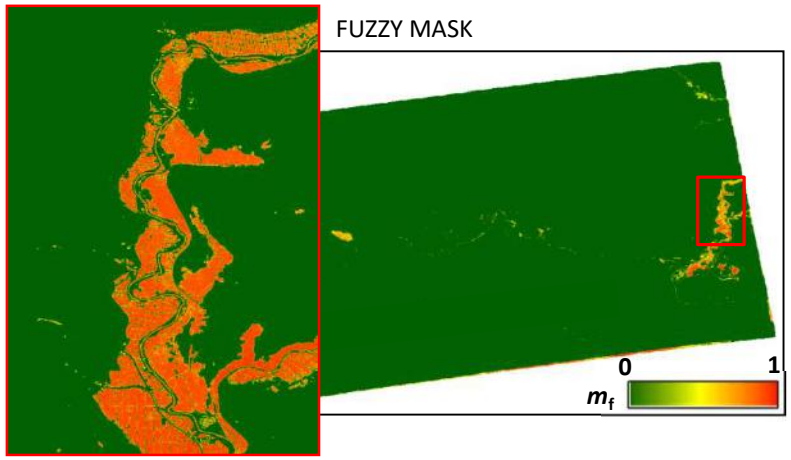


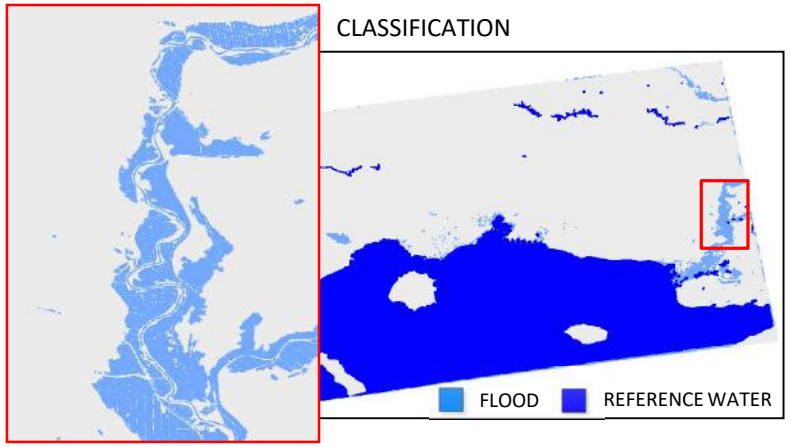
FLOOD OBJECT SIZE











Emergency Management

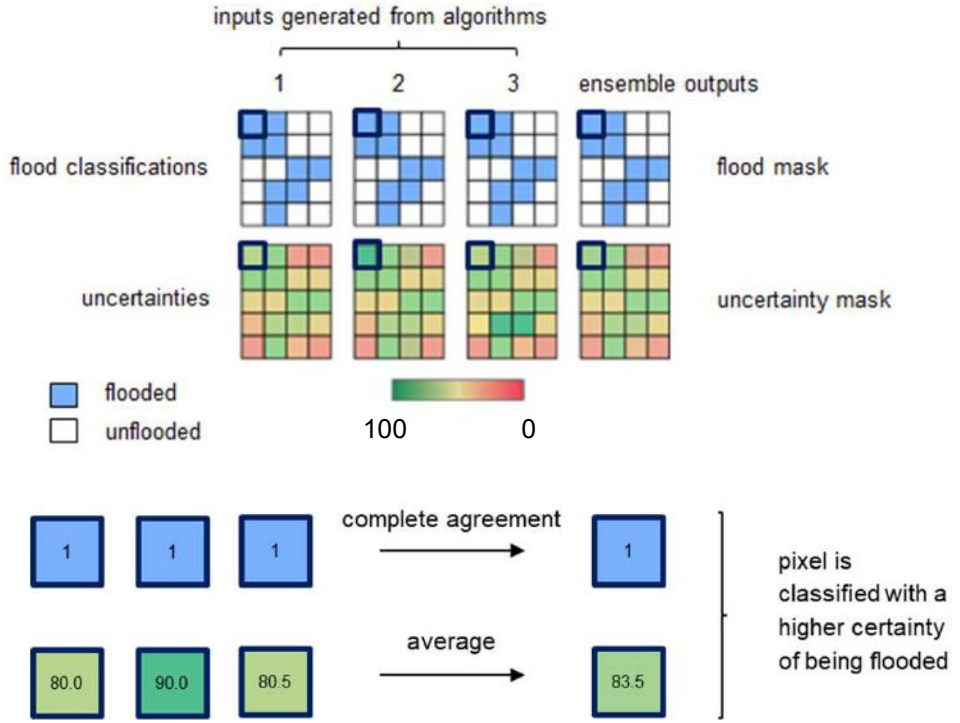
Ensemble Flood Algorithm

ENSEMBLE FLOOD ALGORITHM

- Combines flood and uncertainty results of all three flood algorithms (DLR, LIST, TUW)
- Majority vote decides if a pixel is marked as flood or non-flood
- Final uncertainty layer is the arithmetic mean of all uncertainties provided by individual algorithms

  0: lower certainty (higher uncertainty) of correct water detection

  100: higher certainty (lower uncertainty)



Emergency Management

Copernicus Europe's eyes on Earth

European Commission

Products Outline

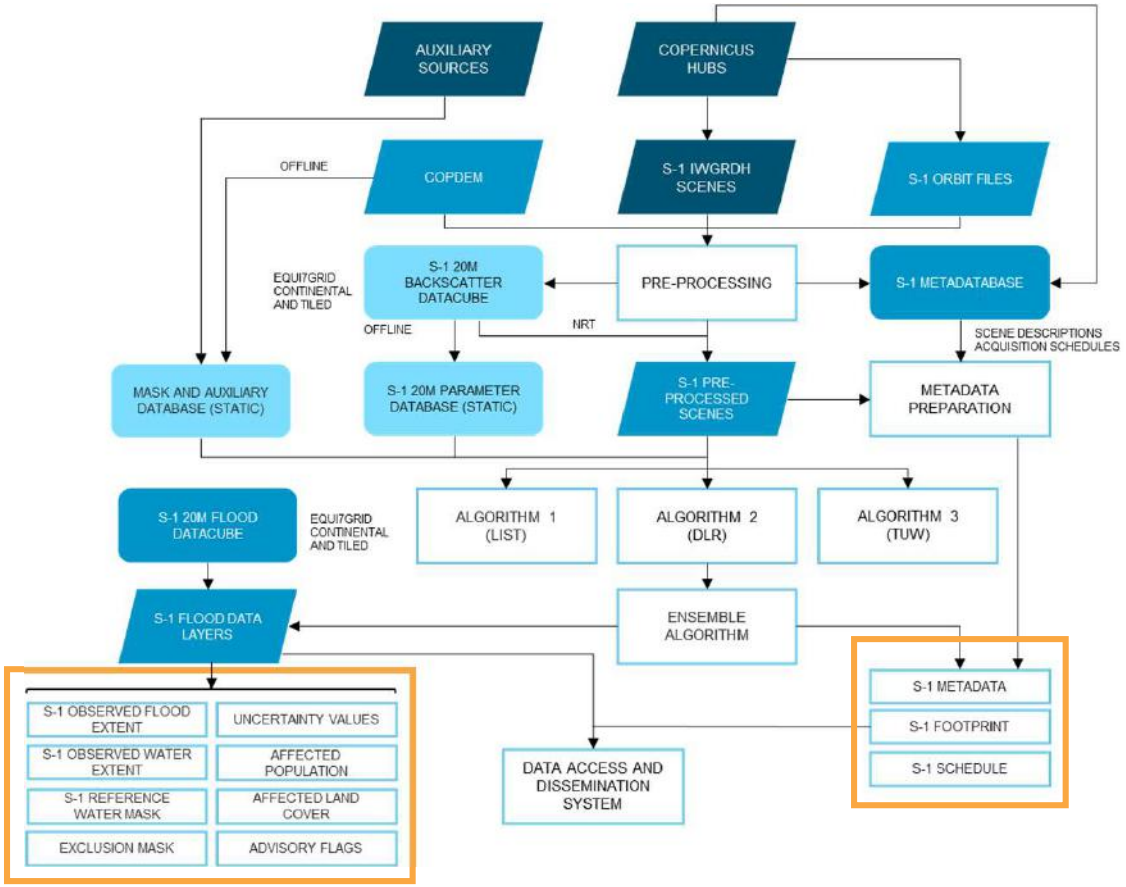
Emergency Management

OBJECTIVES

Continuous global-scale flood monitoring and accurate detection in the case of events

ENSEMBLE APPROACH

- observed flood extents generated with inputs from at least 2 algorithms, based on majority vote
- average of pixelwise uncertainty values
- contextual information to minimize false positives and false negatives



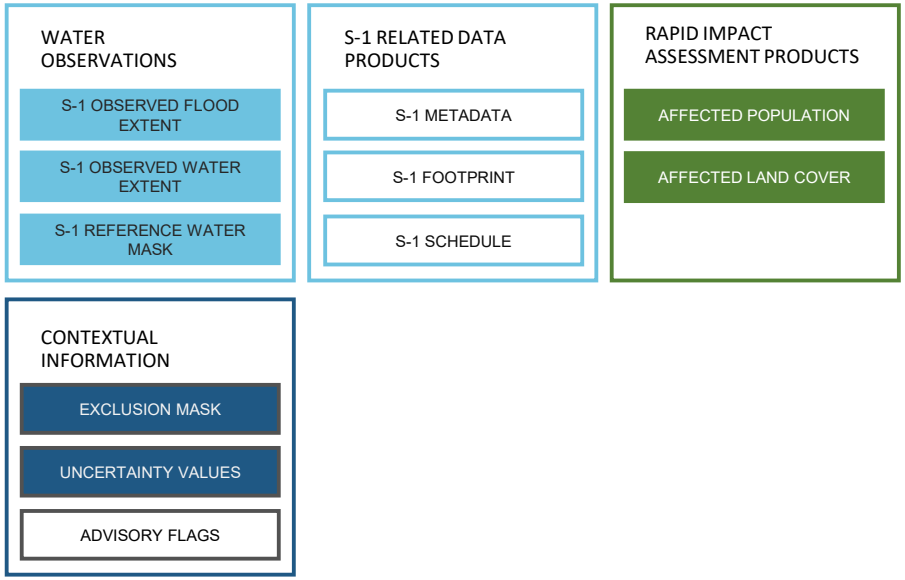
Products Outline

Emergency Management

GENERAL PRODUCT SPECIFICATIONS

- global geographic coverage
- 20 m spatial resolution
- < 8 hours following S-1 image acquisition
- target threshold > 70-80% thematic accuracy, based on Critical Success Index
- 4 categories: 11 products

in this presentation



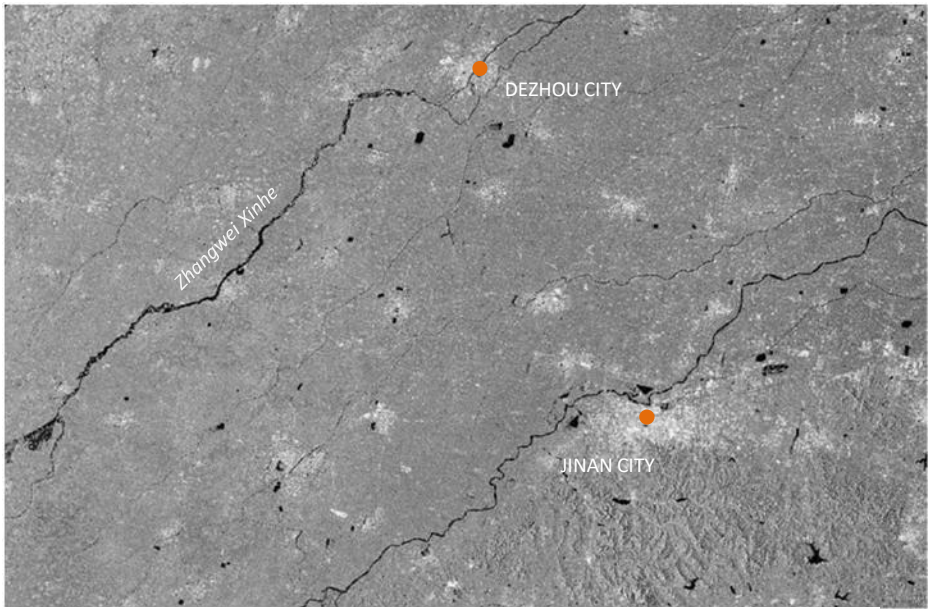
Products Outline

Emergency Management

USE CASE:

FLOOD MONITORING OVER CHINA

- flooding observed along Zhangwei Xinhe (new river) in northeastern China after intense rainfall
- event onset: 12.10.2021
- Sentinel-1 acquisition: 14.10.2021

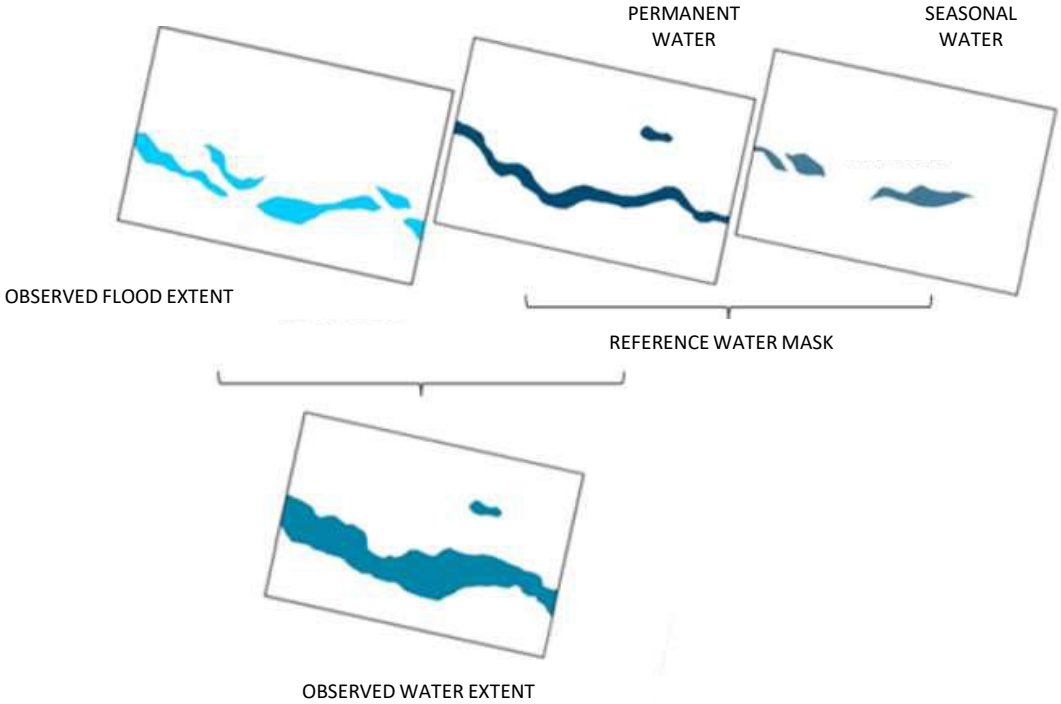


SCENE ID: S1A_IW_GRDH_1SDV_20211014T101311_20211014T101336_040114_04BFFD_8B09

Products Outline

Emergency Management

WATER OBSERVATIONS:
OVERVIEW



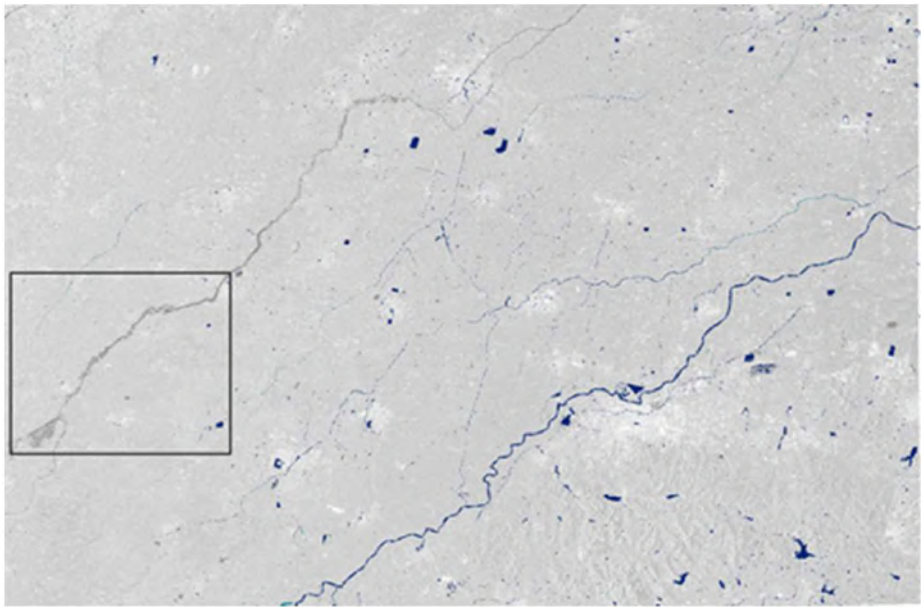
Emergency Management

Products Outline

WATER OBSERVATIONS:

SENTINEL-1 REFERENCE WATER MASK

- combination of two water extents calculated with 2-years of images (2019 and 2020)
  - permanent water (annual mean)
  - seasonal water (monthly median)
- mapped with Sentinel-1 SAR backscatter intensity
  - CopDEM WBM: ensure consistency along land-sea border and within larger inland waterbodies
  - Global Surface Water Maximum Water Extent: minimize false positives



PERMANENT WATER

SEASONAL WATER (OCTOBER)

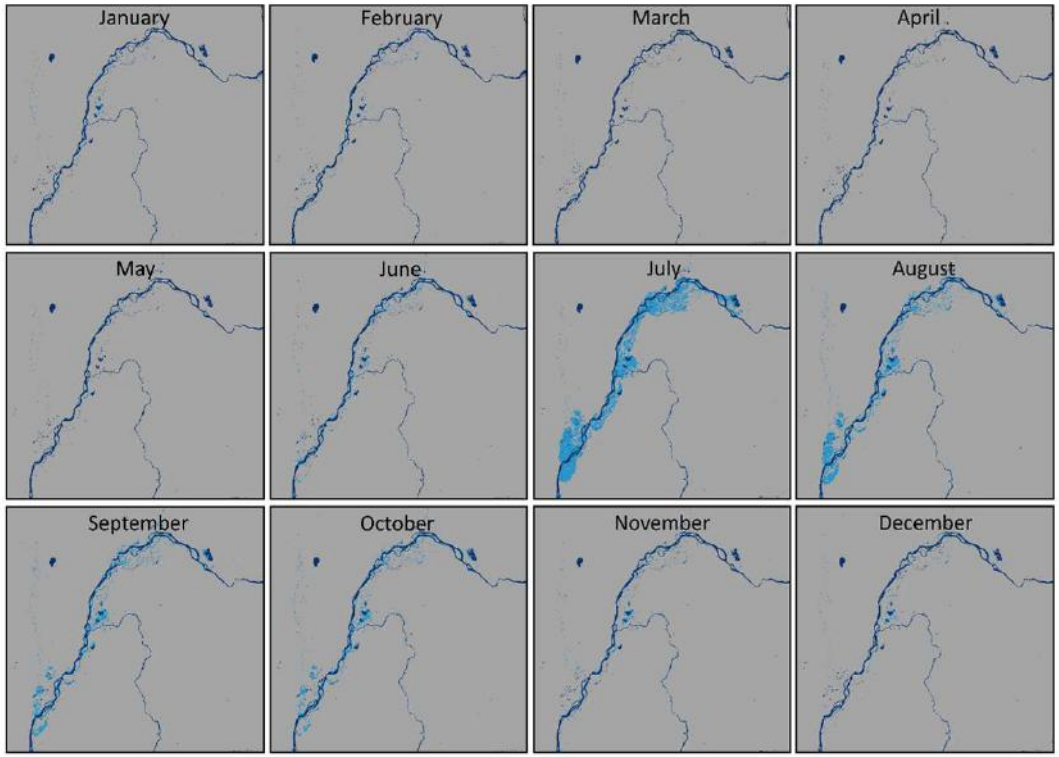
Products Outline

Emergency Management

WATER OBSERVATIONS:

SENTINEL-1 REFERENCE WATER MASK

- combination of two water extents calculated with 2-years of images
  - permanent water
  - seasonal water



REFERENCE WATER MASK CAPTURES EVOLUTION OF MONTHLY WATER IN MYANMAR 2019/ 2020

PERMANENT WATER
SEASONAL WATER
NON-WATER

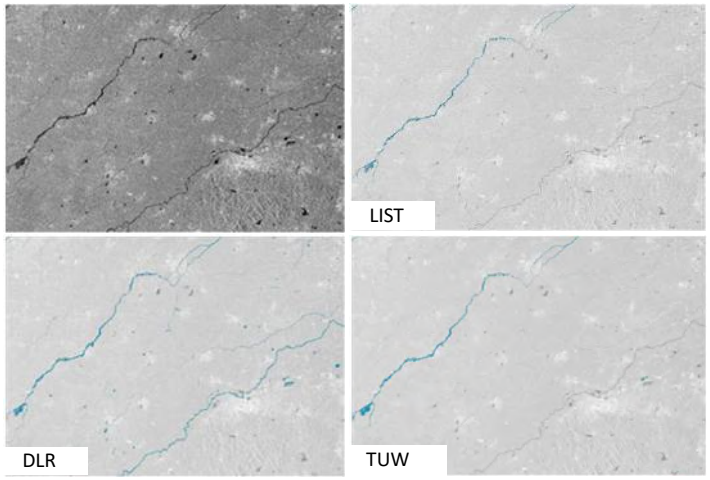
Products Outline

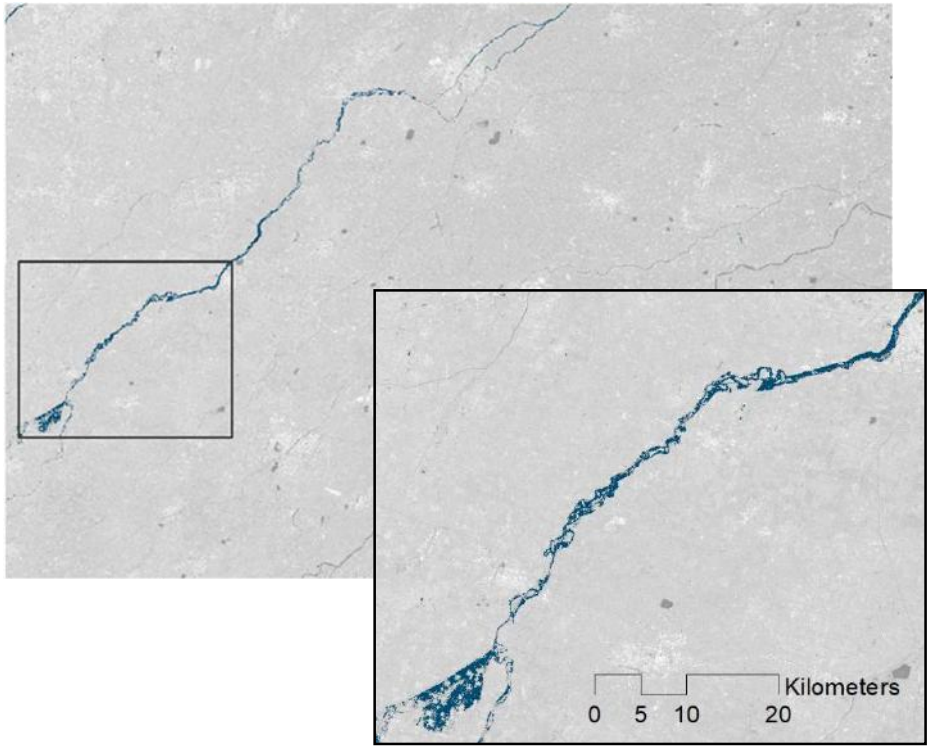
Emergency Management

WATER OBSERVATIONS:

SENTINEL-1 OBSERVED FLOOD EXTENT

- flooded areas detected based on ensemble approach
  - inputs from at least 2 algorithms
  - majority voting





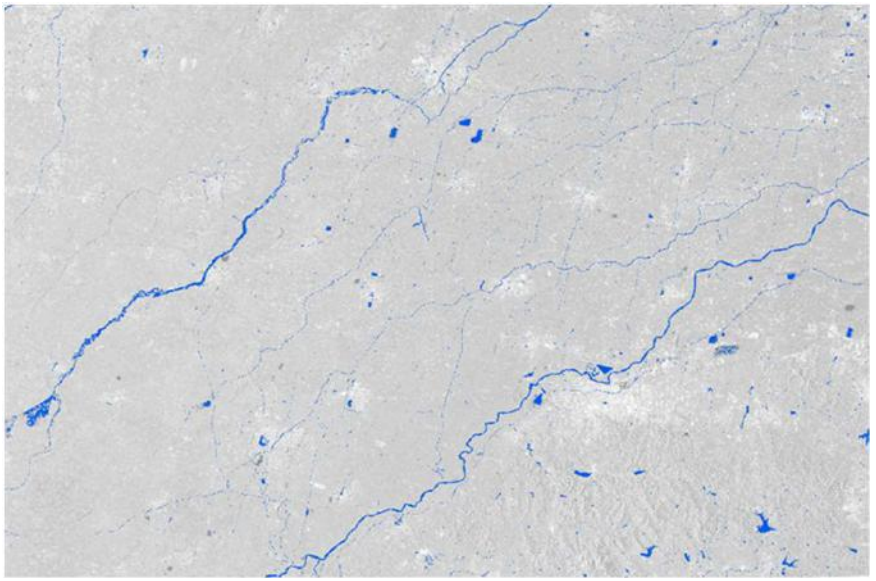
Products Outline

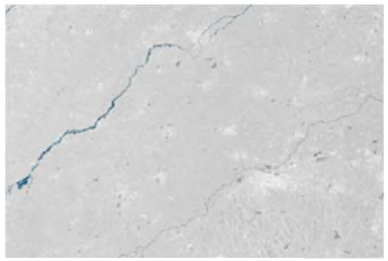
Emergency Management

WATER OBSERVATIONS:

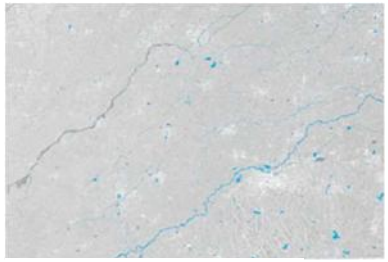
SENTINEL-1 OBSERVED WATER EXTENT

- combination of observed flood extent and reference water mask





S-1 OBSERVED FLOOD EXTENT

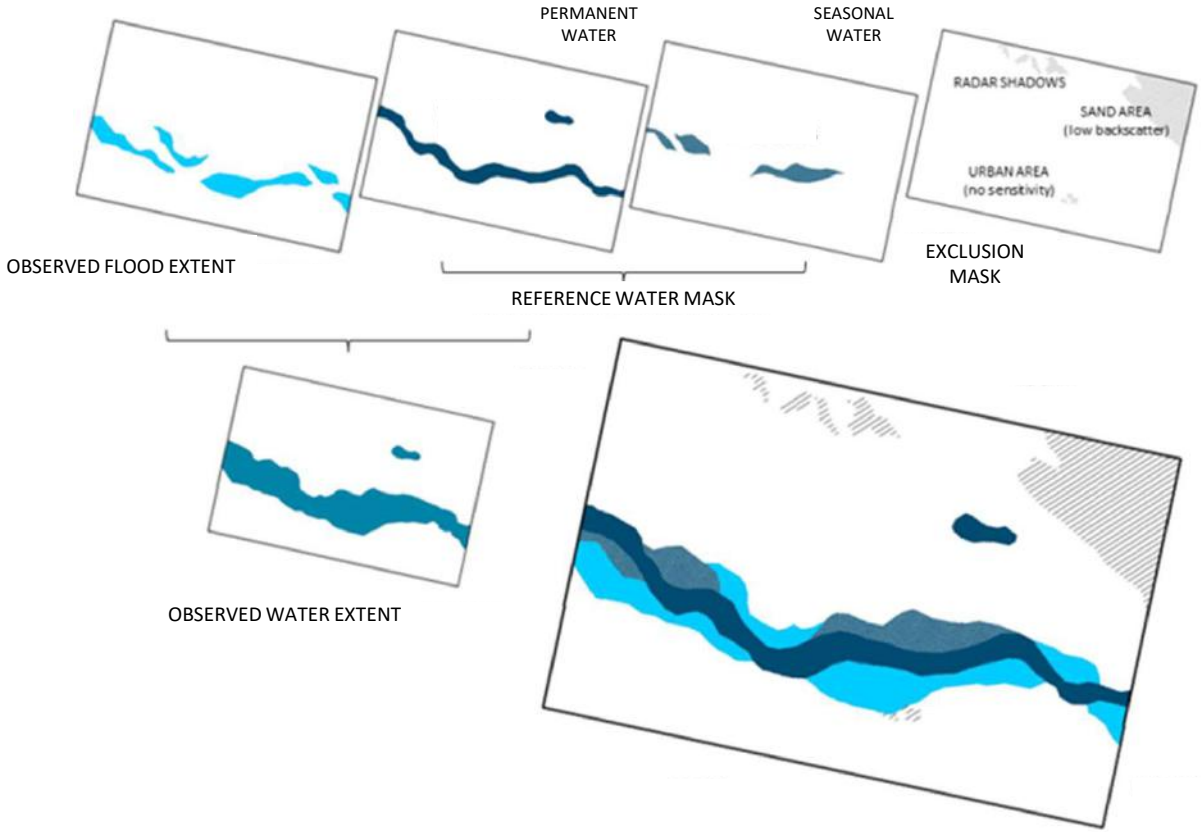


S-1 REFERENCE WATER MASK

Products Outline

Emergency Management

WATER OBSERVATIONS & CONTEXTUAL INFORMATION:
OVERVIEW



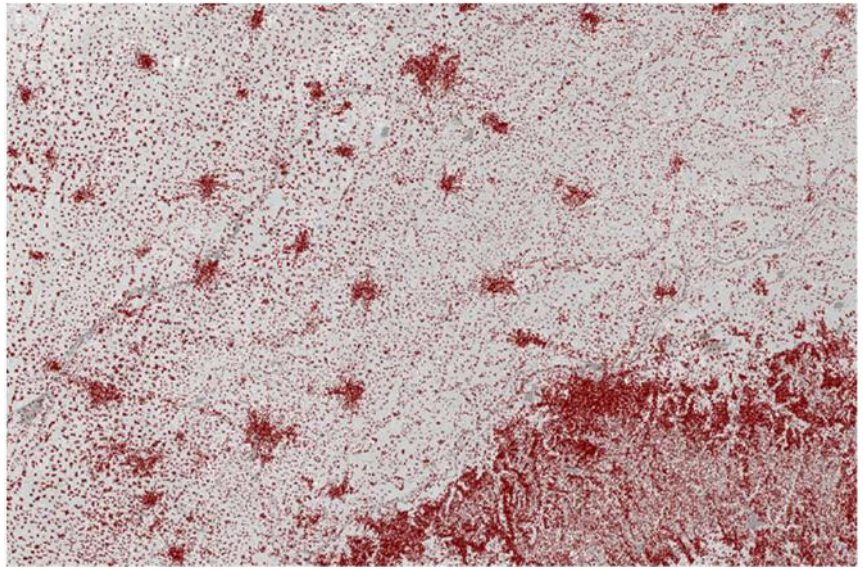
Products Outline

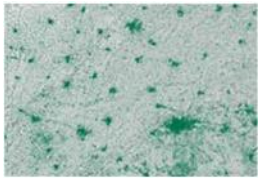
Emergency Management

CONTEXTUAL INFORMATION:

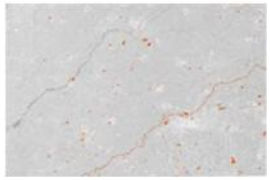
EXCLUSION MASK

- unclassified areas (no data) where robust flood delineation based on SAR data is not possible
- combines static effects of 5 layers
  - no sensitivity
  - water-look-alikes
  - radar shadows
  - topographic distortion
  - poor Sentinel-1 coverage (unhealthy datacube areas)

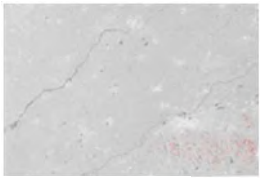




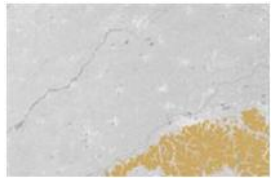
NO SENSITIVITY



LOW BACKSCATTER



RADAR SHADOW



TOPOGRAPHIC DISTORTION

POOR SENTINEL-1 COVERAGE

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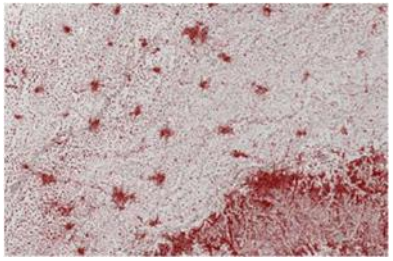
Products Outline

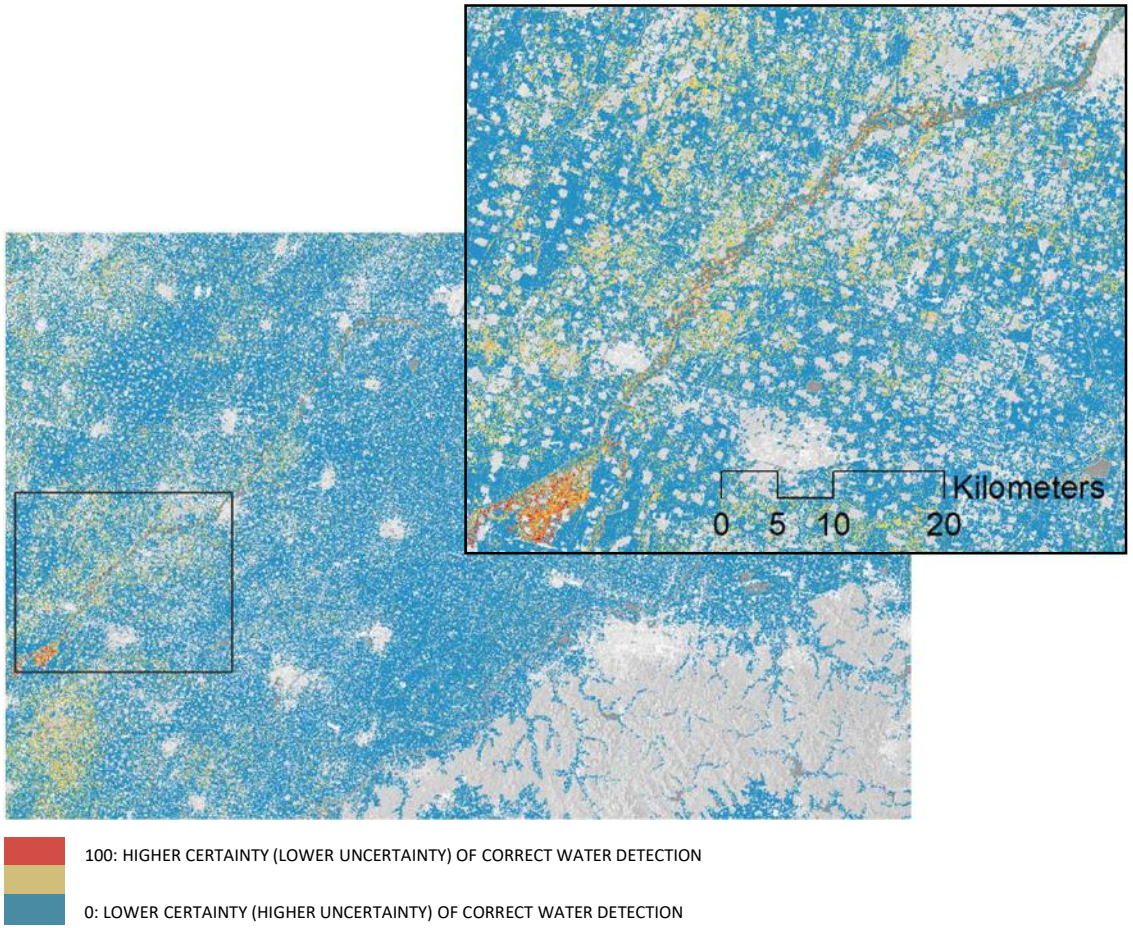
CONTEXTUAL INFORMATION:

UNCERTAINTY VALUES

- classification uncertainty [0, 100] based on ensemble approach for all areas outside of the exclusion mask
  - a quality measure
  - average of pixelwise uncertainty values



EXCLUSION MASK



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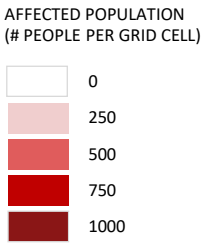
Products Outline

RAPID IMPACT ASSESSMENT PRODUCTS:

AFFECTED POPULATION

- estimated number of people impacted by flooded areas
- mapped by a spatial overlay of the observed flood extent and gridded population data
    - Global Human Settlement (GHS) layer: GHS-POP dataset (2015, at 250 m spatial resolution)



Products Outline

Emergency Management

RAPID IMPACT ASSESSMENT PRODUCTS:

AFFECTED LANDCOVER

- rapid first assessment of landcovers or uses affected by flooded areas
- mapped by a spatial overlay of the observed flood extent and gridded land cover data
  - Copernicus Global Land Cover Service
  - Copernicus Pan-European High-Resolution layers
  - OpenStreetMap

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FURTHER TRAINING/ USER SUPPORT:

RECOGNIZING COMMON SCENARIOS IN FLOOD MONITORING

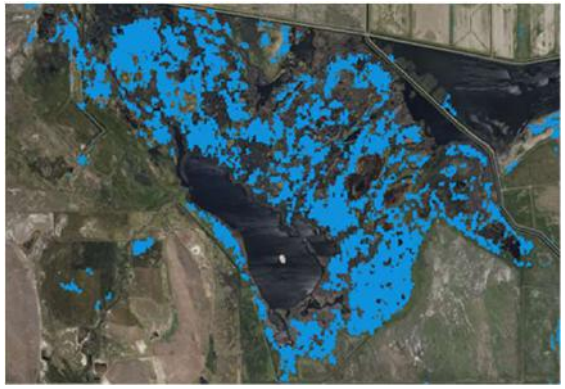
- floods as relatively rare occurrences
- algorithms initially developed for flood detection form the basis of the ensemble approach, further customized for continuous global-scale monitoring
- differentiate between floods and false positives
  - inclusion of contextual information
  - local knowledge
  - experience

Products Outline

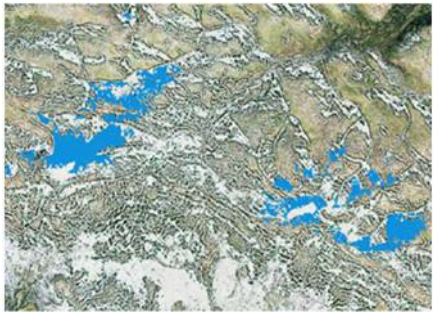
Emergency Management

17.10.2021 CAMBODIA:
CROPLAND WITH HIGH WATER CONTENT

15.10.2021 PAPUA NEW GUINEA:
RIVER MEANDER DYNAMICS



19.10.2021 USA:
WETLANDS IN NATIONAL WILDLIFE REFUGE



16.10.2021 RUSSIA:
WET SNOW AND ICE IN MURMANSK

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Data access & demonstration

Wolfgang Kapferer (GV)

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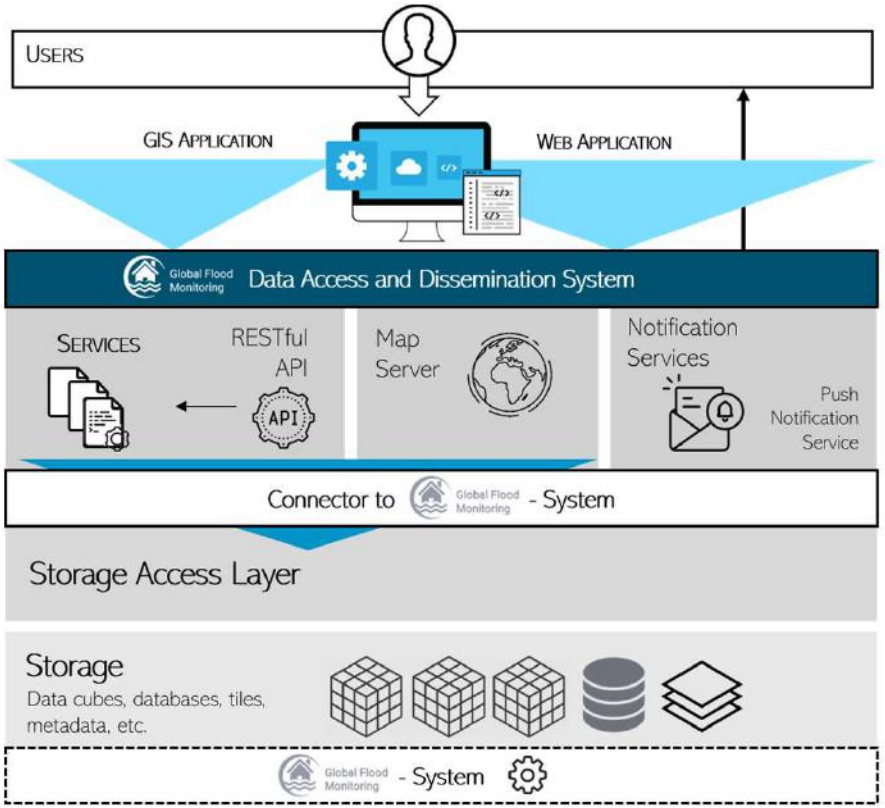
Data Access & Demonstration

The User entry points to the Global Flood Monitoring Service are:

- RESTful API Endpoints
- Web Map Service with Temporal layers (WMS-T)
- Configurable Notification Service
- Web-Application for Product Downloads and configuration



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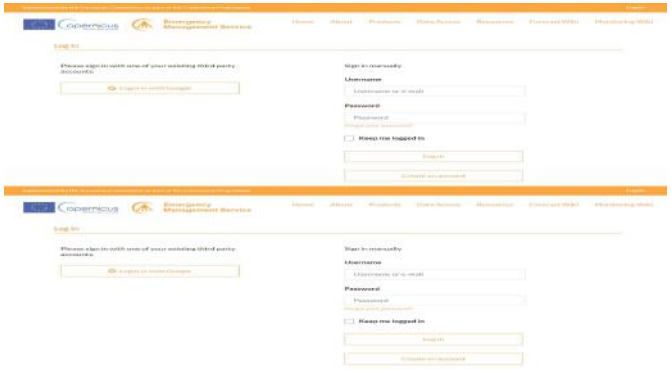
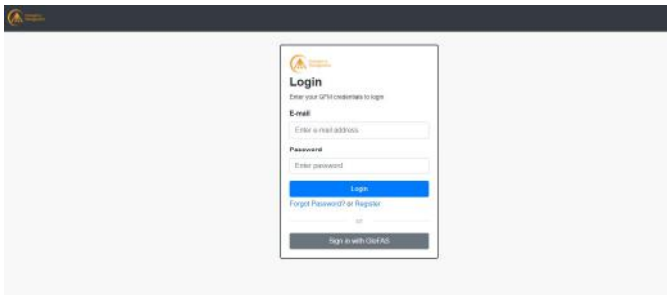
Data Access & Demonstration

The Authentication-Process

- https://www.globalfloods.eu/
- For Product Download and configuration log in at https://gfm.portal.geoville.com/
- One login for all components and functionalities
  (synchronised in the backends)





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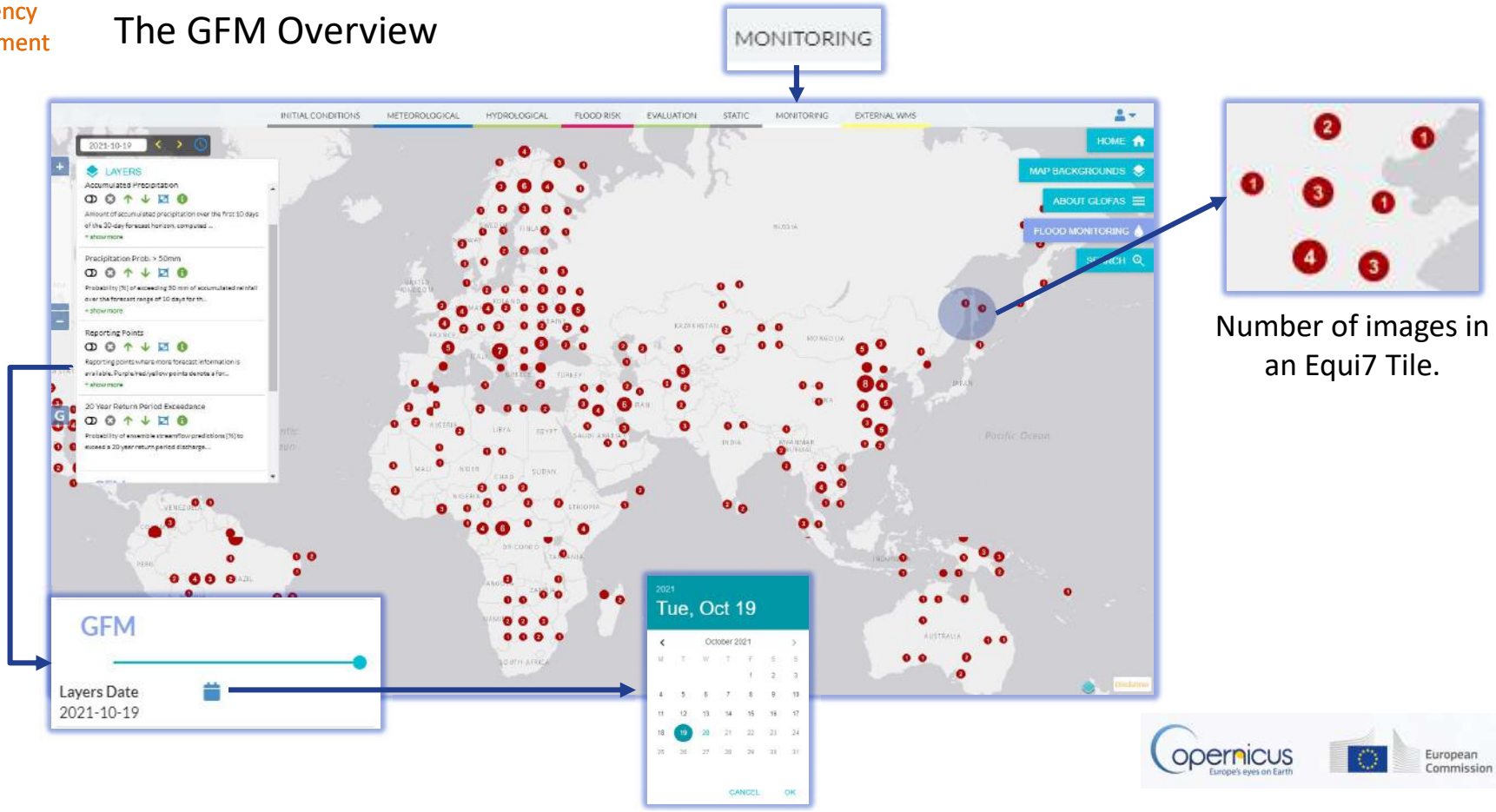
Data Access & Demonstration

The GFM Overview



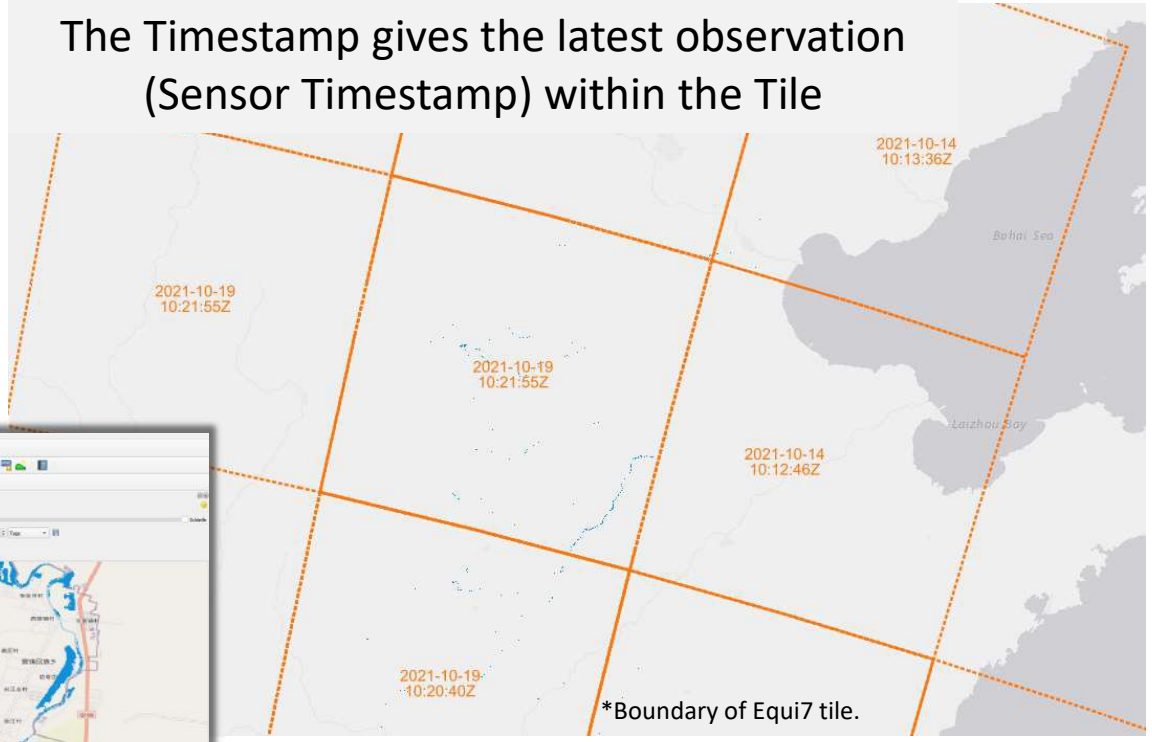
Data Access & Demonstration

Emergency Management

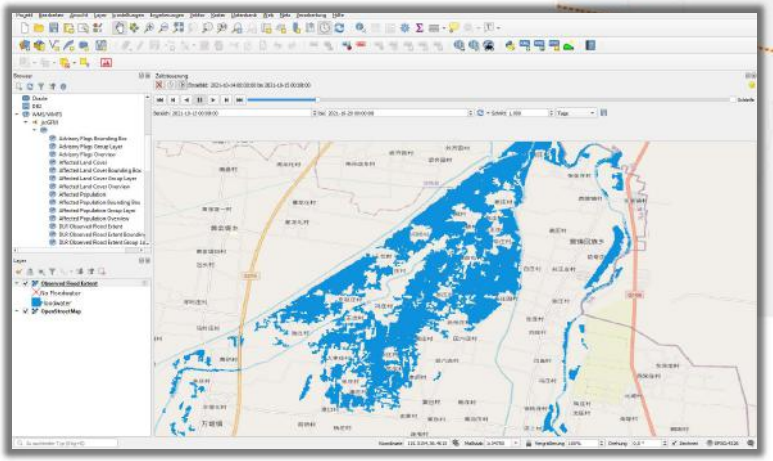
The Web Map Server

Number of images in an Equi7 Tile.

The Timestamp gives the latest observation (Sensor Timestamp) within the Tile



*Boundary of Equi7 tile.



The WMST Service

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Data Access & Demonstration

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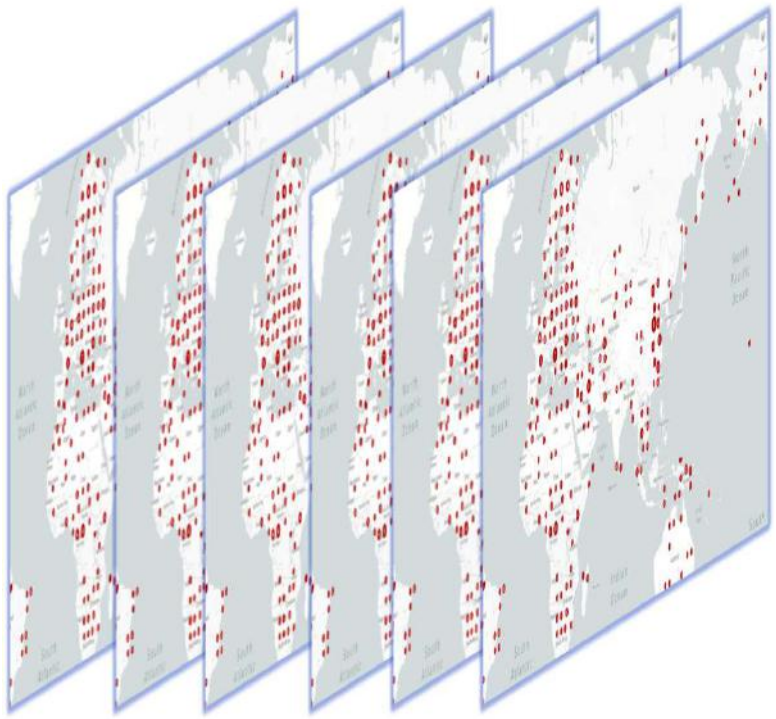
The temporal Aspect

Latest date is special: „The Integral view“
-> all S-1 flood products



Time

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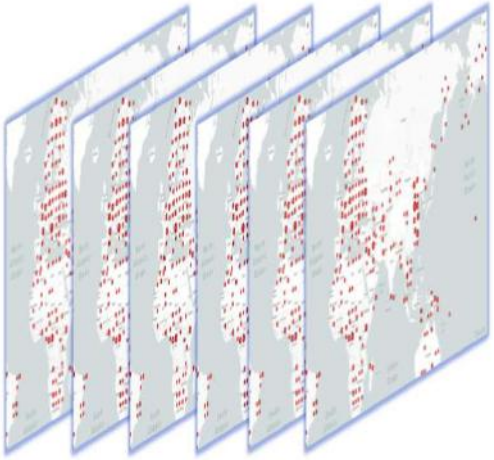
Data Access & Demonstration

The temporal Aspect

Update-Cycle



Each one to three hours we add all new data and adapt the global layers

Time (daily Scale)

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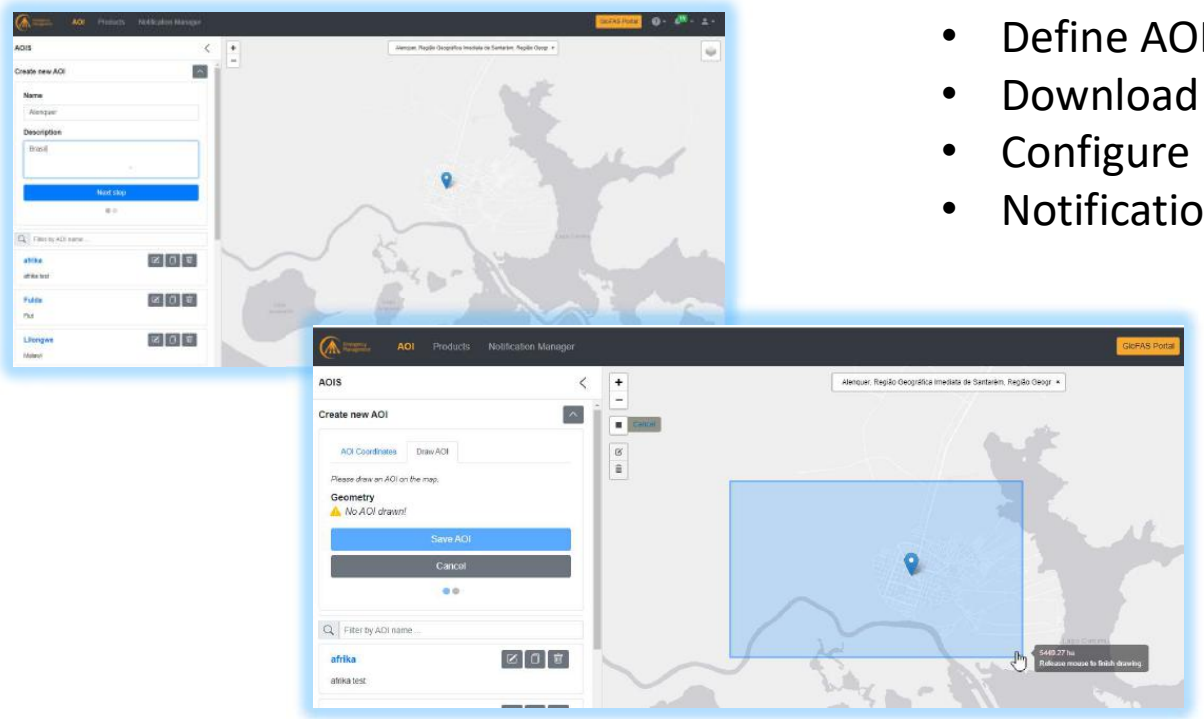
Data Access & Demonstration

Product download and configuration Web-Application

https://gfm.portal.geoville.com/



- Define AOIs
- Download products
- Configure notifications
- Notification histories

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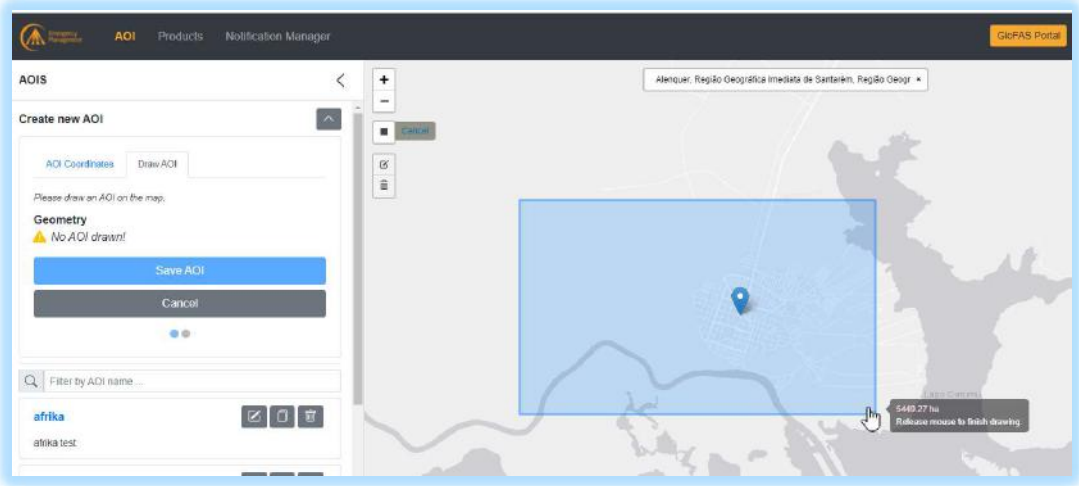
Data Access & Demonstration

Product download and configuration WebApplication

https://gfm.portal.geoville.com/

- Define AOIs for downloading Products and configuring the Notifitcation Service



- Either by Coordiantes or Drawing on a the map
- The Notification- and Download-Service of Products is active for all Equi7 tiles the boundary intersects with

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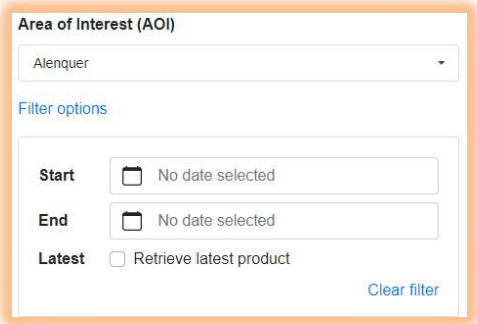
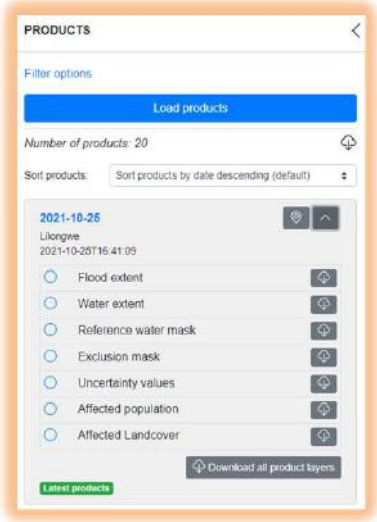
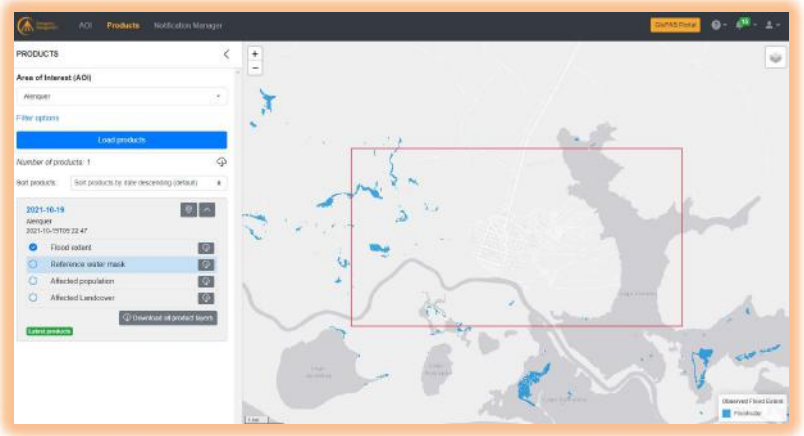
The Product Download Page



- Select your defined AOI and optional Timerange



- Select your Product and visualise it



- Download individual Layers
- Donwload bundled Timeseries

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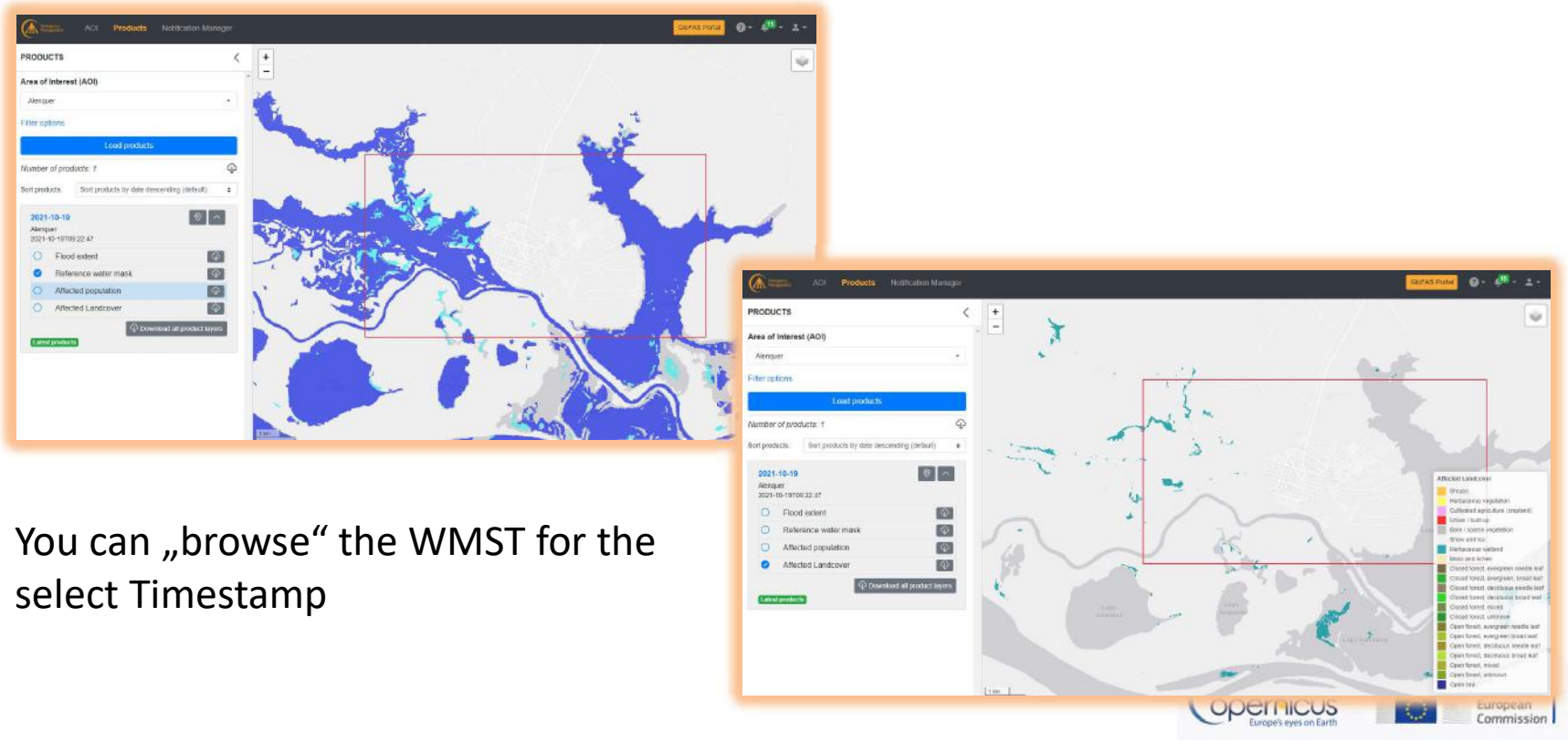
The Product Download Page



You can „browse“ the WMST for the select Timestamp

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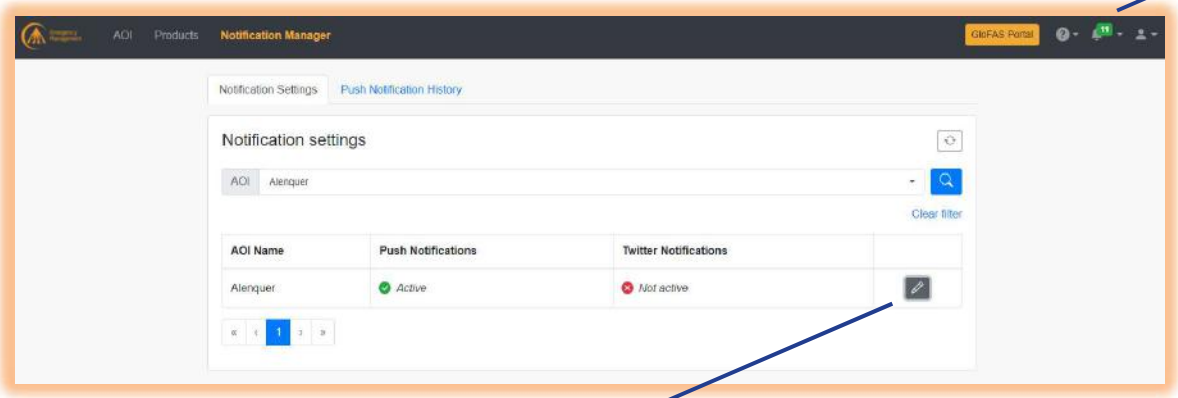
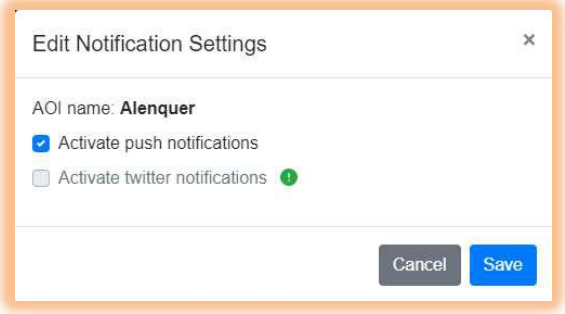
The Notification Configuration

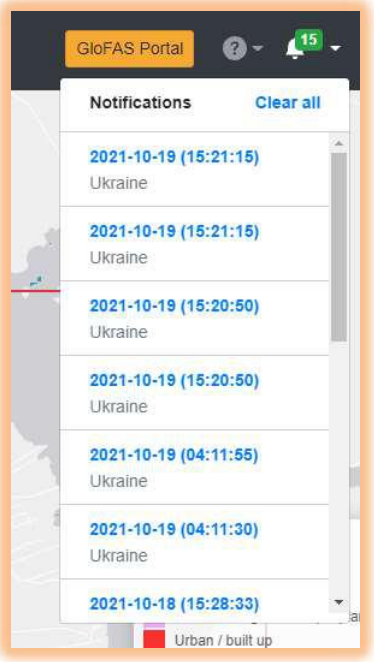
Select your AOI





Activate the Notification

Twitter Configuraion coming soon



The list of all active - not seen - Notifications

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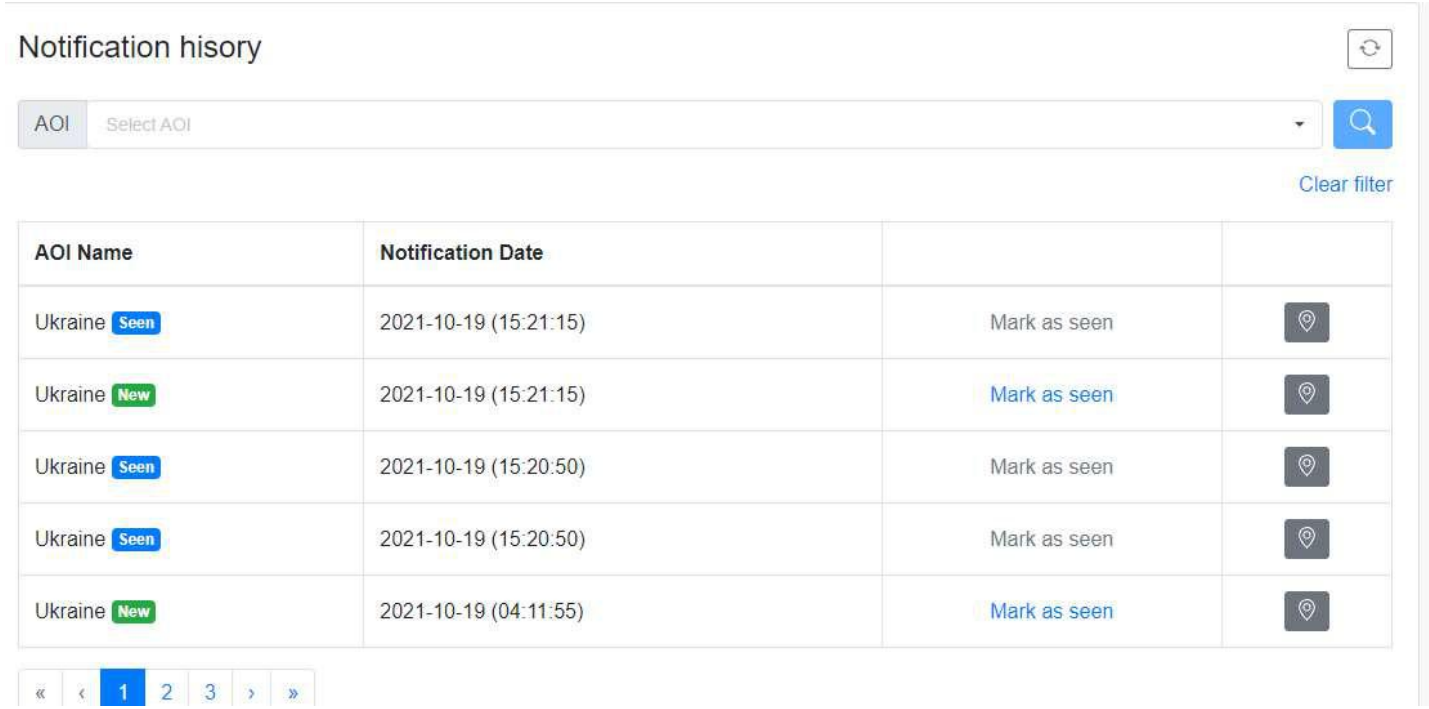
The Notification History for your AOI



Summary

- The products with all layers can be accesed via
  - A WMST Service
  - the Glofas Portal
  - a Product Download and Configuration Web-Application
- Notifications can be configured for AOIs

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User support service

Luca Molini (CIMA)

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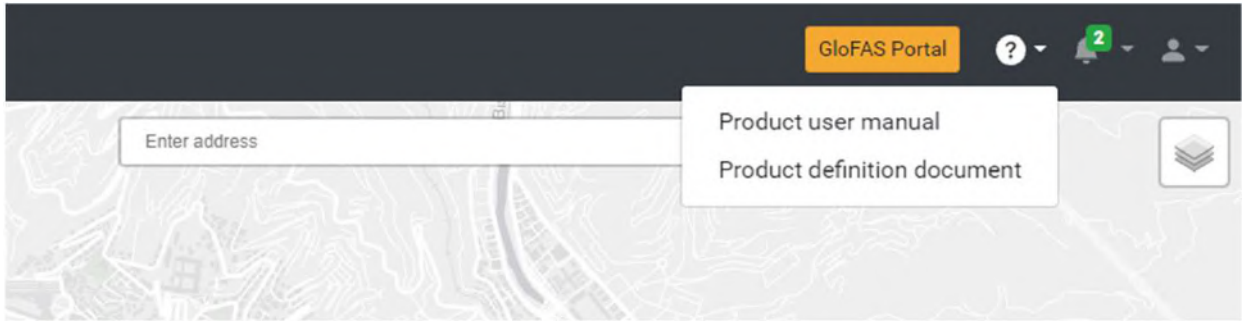
Product User Manual (PUM)

- Provides practical guidance on how to connect to the service or download of the products.
- A description of the algorithms.
- A description of the products characteristics
- A summary of the validation procedure and the results.
- A review of the user requirements.
- Recommendations regarding application-specific information and aspects to consider when using the product.
- A set of Frequently Asked Questions (FAQ).

- Detailed technical specification can be found in the **GFM Product Description Document (PDD)**

Product User Manual (PUM)

- ✓ publicly available at https://extwiki.eodc.eu/GFM/PUM
- ✓ …or via GFM's WebApp
- ✓ … or via www.globalfloods.eu



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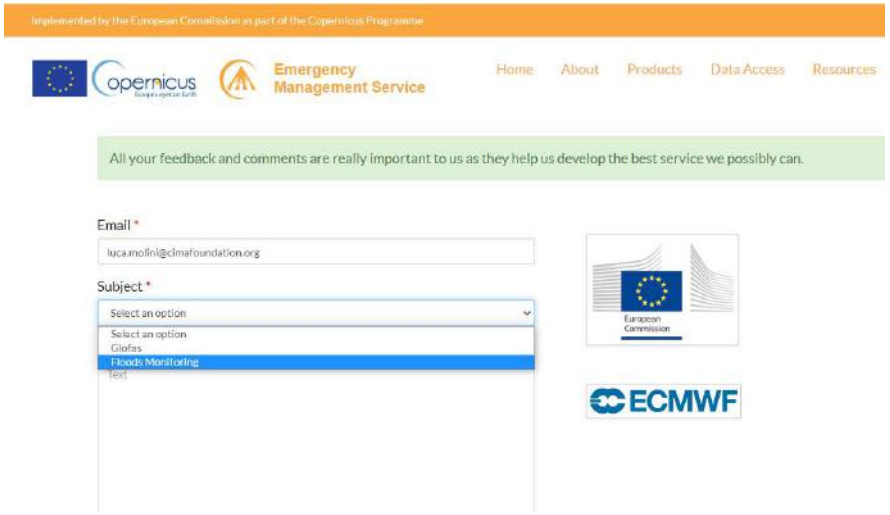
User Support Service

- **User Support service**

✓ 9-17 CET on working days, in English

✓ gfm-support@eodc.eu

✓ …or via GloFAS Contact us



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