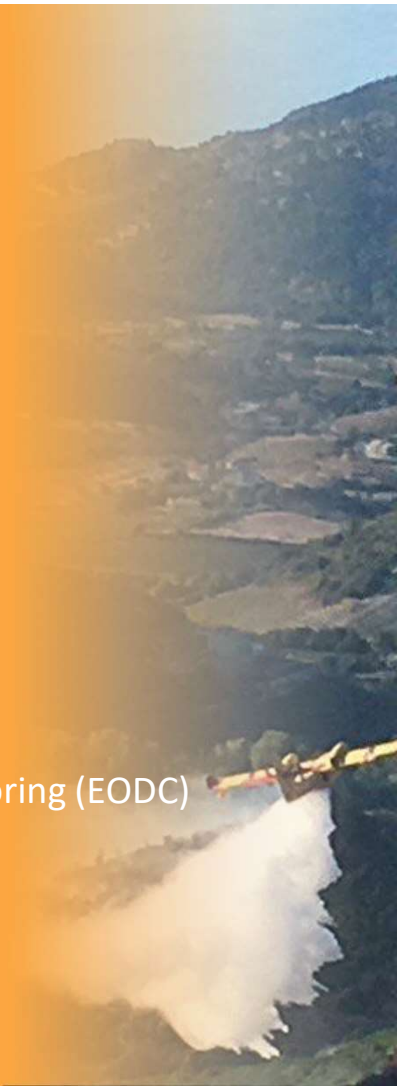


CEMS Global Flood Monitoring Service GFM

Emergency Management

Wolfgang Wagner
Earth Observation Data Centre for Water Resources Monitoring (EODC)
Technische Universität Wien (TU Wien)

28th October 2021

Emergency Management

GFM Team

Christoph Reimer, Senmao Cao, Stefan Reimond, Tom Clark, Dragana Milinkovic, Richard Kidd, Christian Briese

Michél Schwandner, Patrick Wolf, Michaela Seewald, Stefan Ralser, Johannes Schmid, Michael Riffler, Wolfgang Kapferer, Andreas Walli

Bernhard Bauer-Marschallinger, Florian Roth, Claudio Navacchi, Felix Reuß, Alena Dostalova, Mark Edwin Tupas, Wolfgang Wagner

Marco Chini, Yu Li, Renaud Hostache, Patrick Matgen, Ramona Pelich

Christian Krullikowski, Marc Wieland, Candace Chow, Sandro Martinis

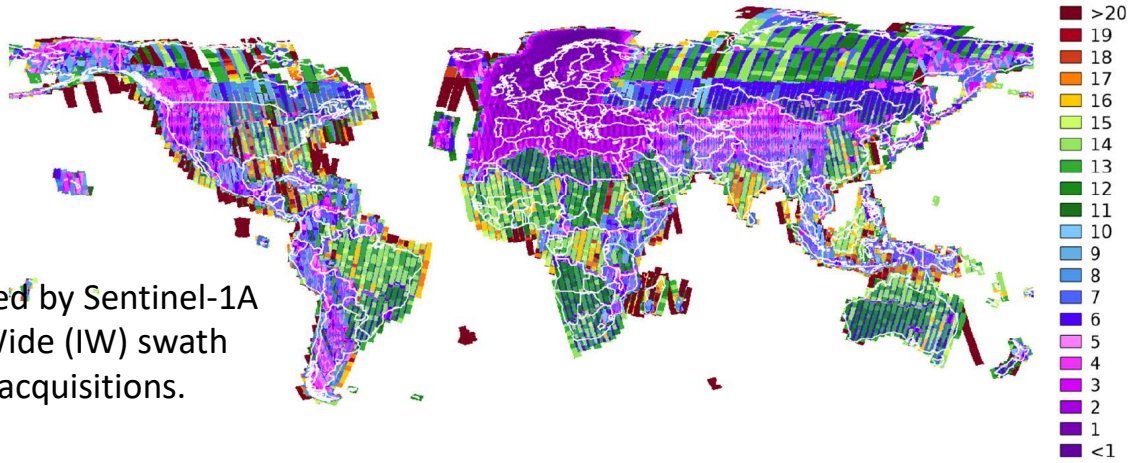
Luca Molini, Roberto Rudari, Elisabetta Fiori, Isabel Gomes

Global Flood Monitoring Service

Emergency Management

Copernicus Emergency Management Service (CEMS) Global Flood Monitoring (GFM) Service:

- **Sentinel-1** Synthetic Aperture Radar (SAR)
  - 2 satellites with systematic coverage
  - Near-real-time monitoring of land surfaces was not a design requirement but nonetheless anticipated
- **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



Average revisit time achieved by Sentinel-1A and 1B in Interferometric Wide (IW) swath mode, based on 2017 data acquisitions.

Wagner et al. (2020) Data processing architectures for monitoring floods using Sentinel-1, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., V-3-2020, 641–648.

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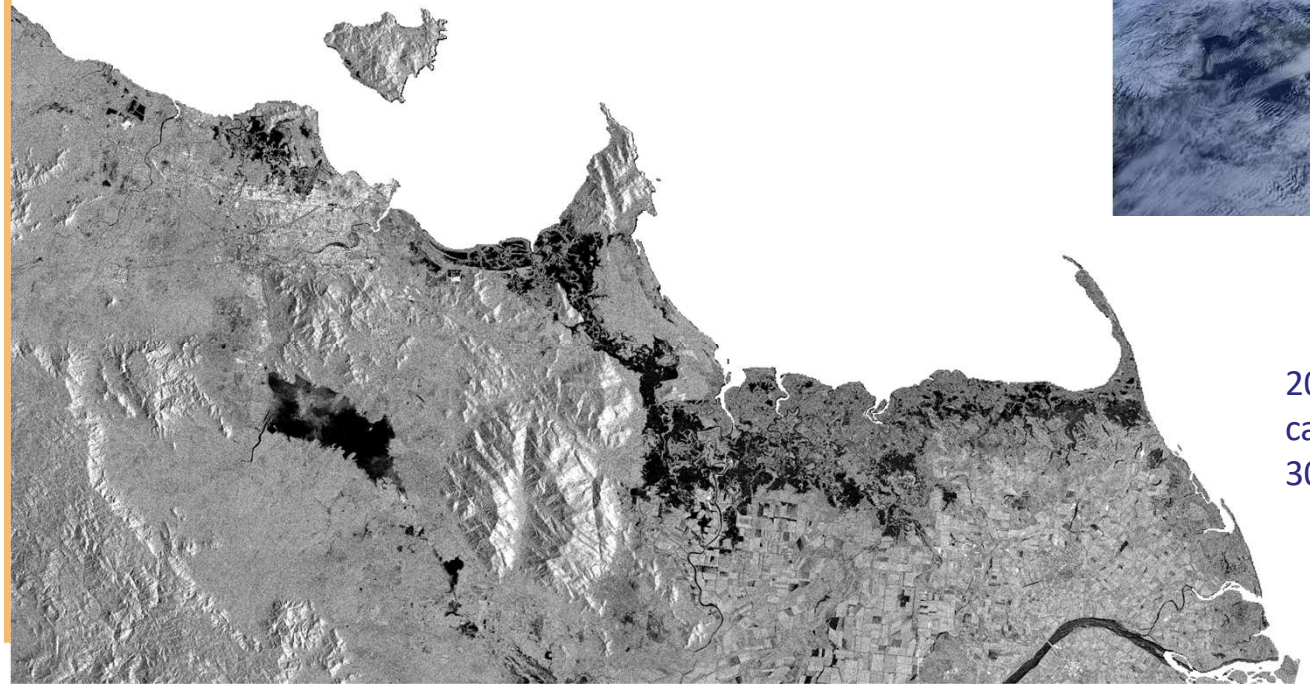
Sentinel-1 SAR for flood mapping

- Day and night measurement capability
- Spatial sampling: 20 m
- Frequency: C-band



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

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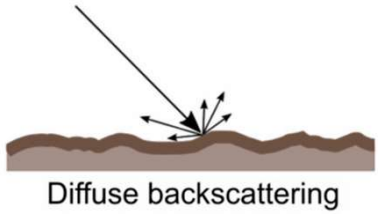
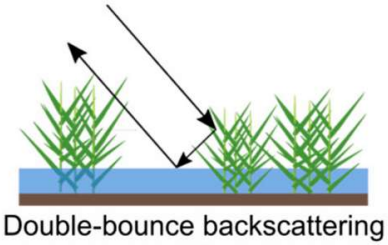
What do we look for?

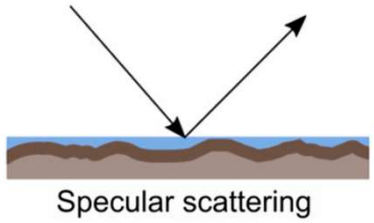
- A change to very low backscatter (in the order of -18 dB) as characteristic for open inland waters

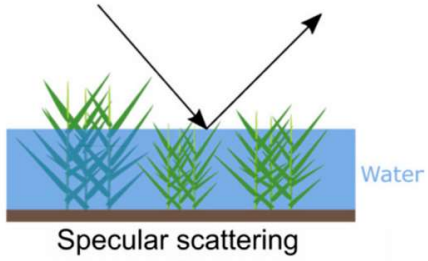
High Backscatter





Low Backscatter





C-band VV Backscatter Signature of Calm Open Water

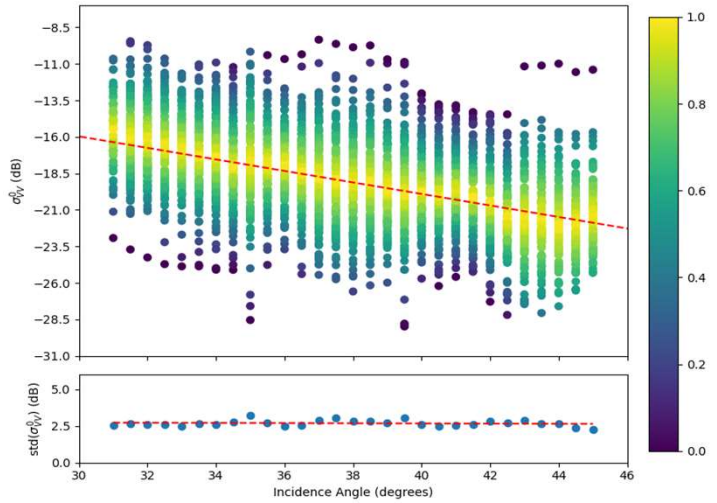


Figure modified from Ottinger and Kuenzer (2020) Spaceborne L-Band Synthetic Aperture Radar Data for Geoscientific Analyses in Coastal Land Applications: A Review, Remote Sensing, 12(14).

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What might go wrong?

- There are many "water-look-alike" surfaces
  - Static: Tarmac, sand deserts, grasslands, shadows, …
  - Dynamic: Agricultural fields, wet snow, frozen soils, …

may cause false positives

may be problematic for no-flood scenes (i.e. in >>99% of all cases)

- There are no-sensitivity areas
  - Dense vegetation, urban areas, etc.

may cause false negatives

may be problematic for flood scenes

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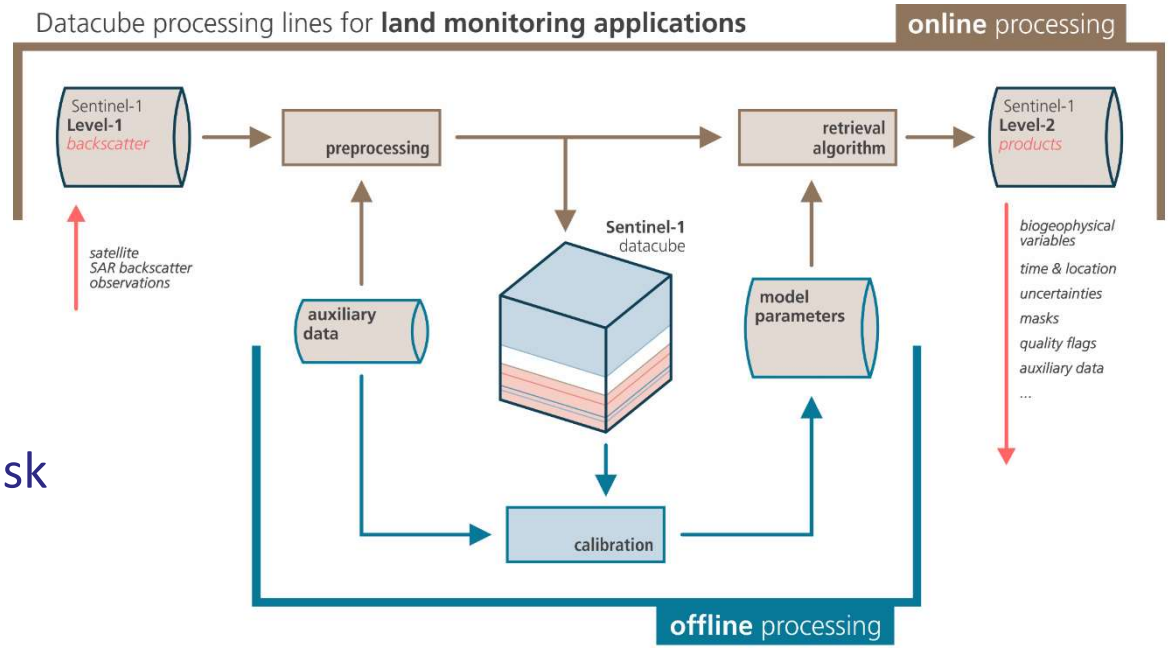
Strategies to deal with challenges

- Off-line calibration of model parameters
- Per-pixel masking
- Advisory flags

- Can be realised using a Data Cube architecture

- Seasonal water mask

Wagner et al. (2021) submitted



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Sentinel-1 Preprocessing

- Sentinel-1 preprocessing starts from IW GRDH images and orbit files
- SRTM was replaced by Copernicus DEM
  - Adoptions needed for SNAP software
  - Reprocessing of complete archive

Level-1 Sentinel-1 IW GRD data

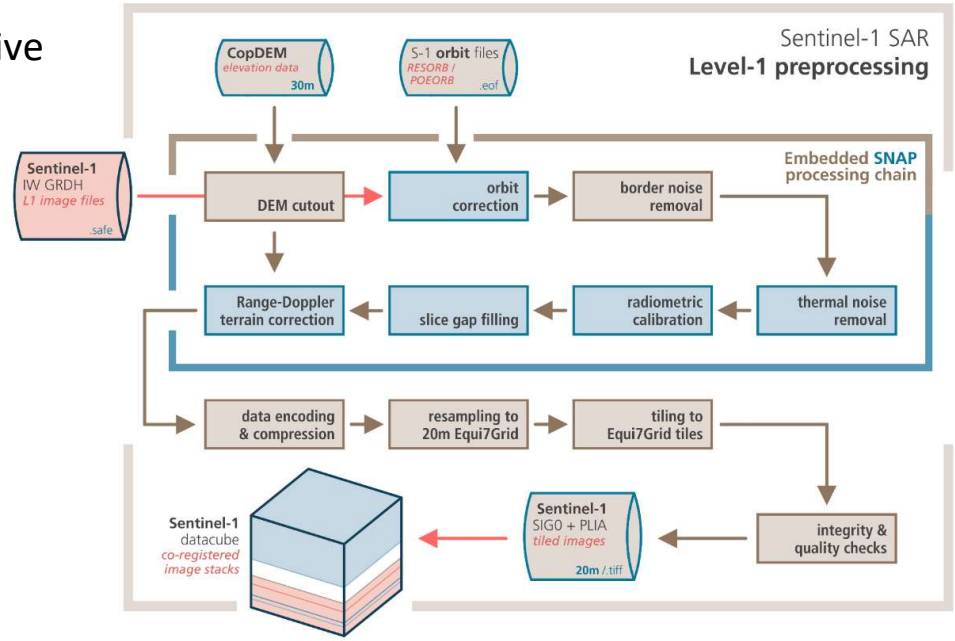
Year	Africa	Asia	Europe	NA	Oceania	SA	Total
2015	12.7	15.1	22.0	6.2	4.9	5.3	66.2
2016	20.6	19.2	31.9	11.5	6.6	9.0	98.8
2017	45.0	53.9	71.8	31.4	18.4	23.1	243.6
2018	48.0	58.1	70.3	35.3	20.2	24.7	256.6
2019	94.4	61.1	119.9	38.5	21.1	26.9	361.9
2020	97.3	63.3	130.7	41.4	21.3	28.6	382.6
Total	318.0	270.7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

Data Volume in TB

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



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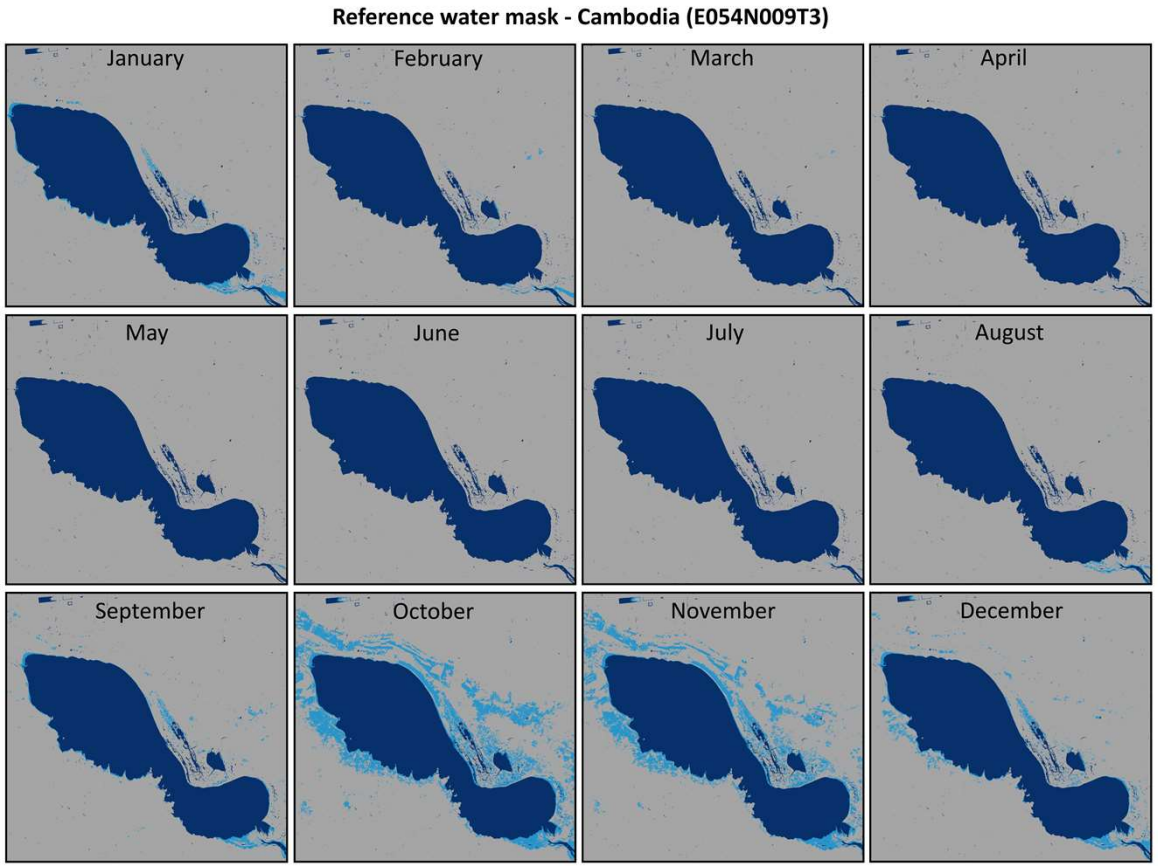
Seasonal water mask



Seasonal water mask commensurate with historic Sentinel-1 time series

PERMANENT WATER
SEASONAL WATER
NON-WATER

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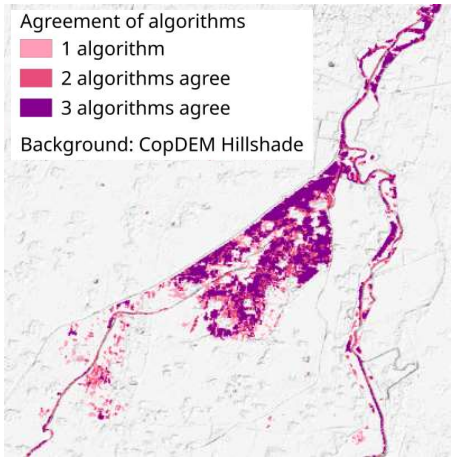
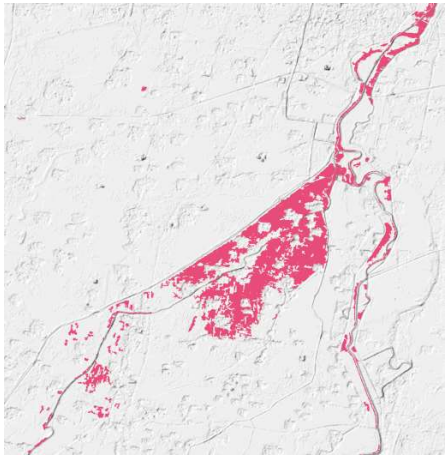
Ensemble Approach

- 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

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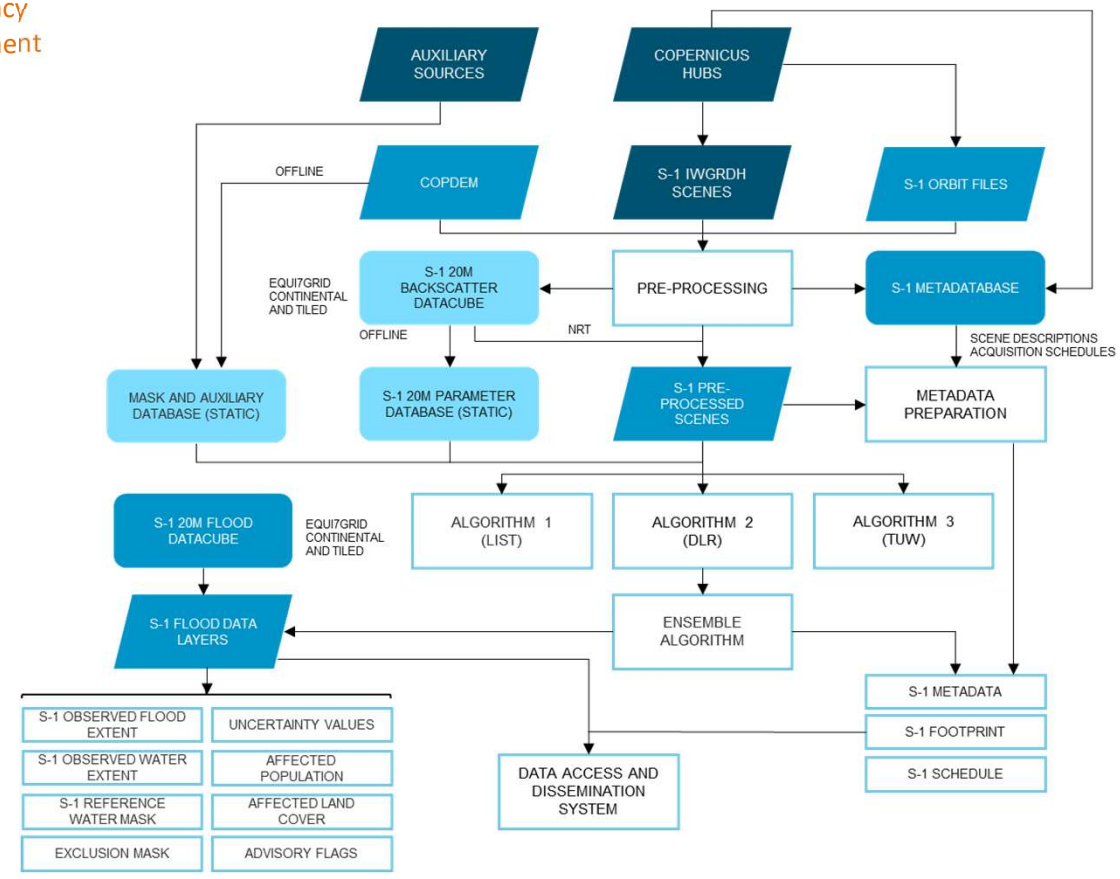
Processing Workflow



- Preprocessing starts from IW GRDH scenes & orbit files
- Algorithms require switching between tile and scene representation
- Timeliness
  - 70 min for fetching images from hubs
  - 40 min for preprocessing
  - 170 min for ensemble

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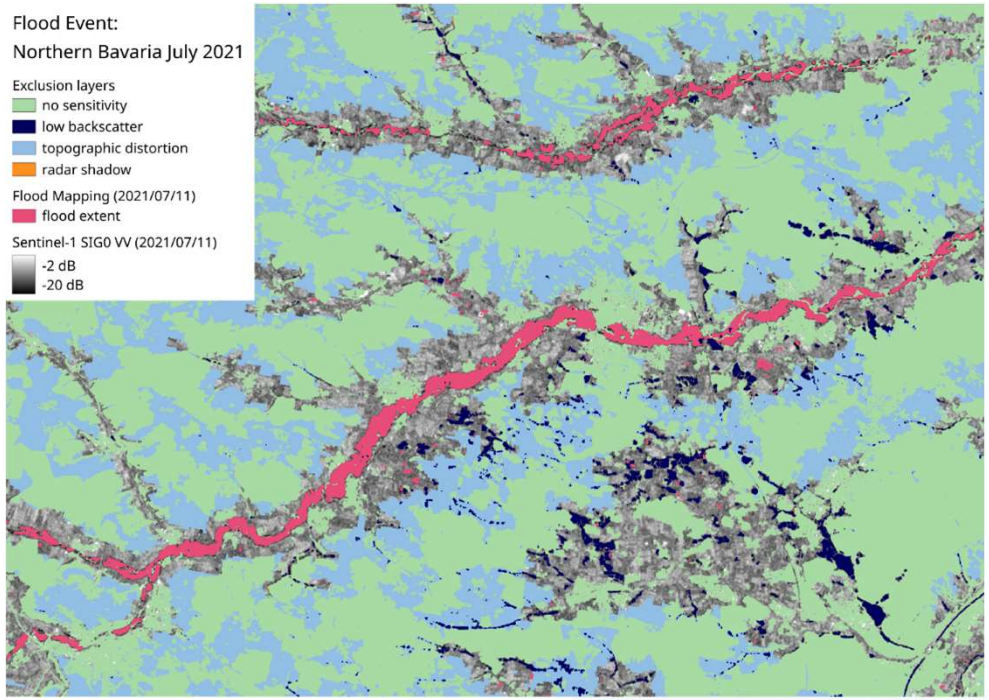
Exclusion Mask

Exclusion Mask Overview:

- Masking of pixels where Sentinel-1 is unable to detect flooding
- Applied on the ensemble results
- 4 layers:
  - No sensitivity
  - Low backscatter
  - Topographic distortion
  - Radar shadows

Advisory flags:

- Mask dynamic influences
  - Low regional backscatter (snow, ice dryness)
  - Rough water surface (Wind)



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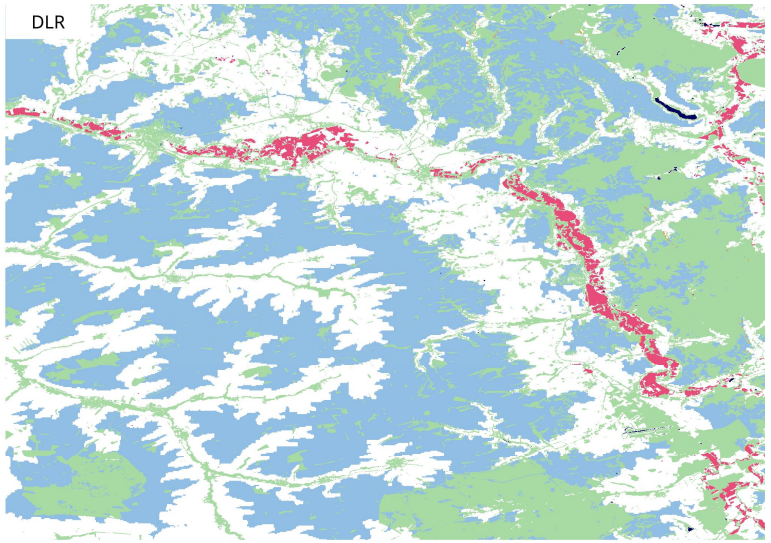
GFM use case: Belgium

Exclusion layers
- no sensitivity
- low backscatter
- topographic distortion
- radar shadows

Flood mapping
- flood extent (2021/07/17)

DLR



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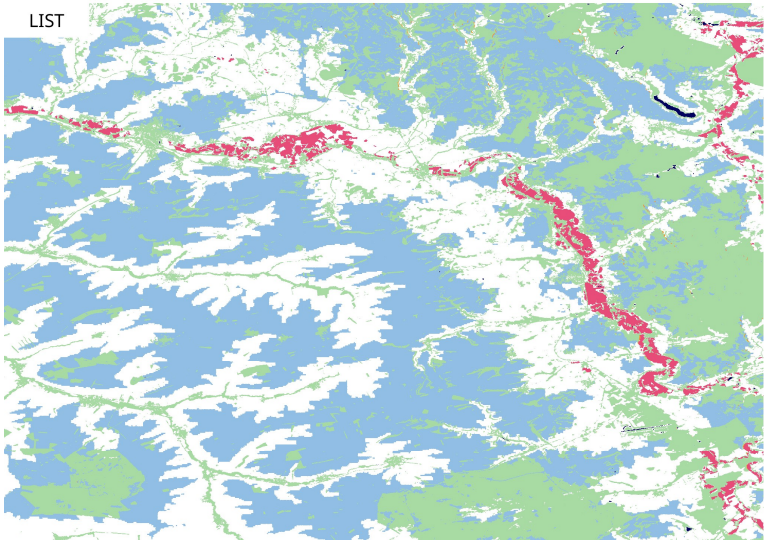
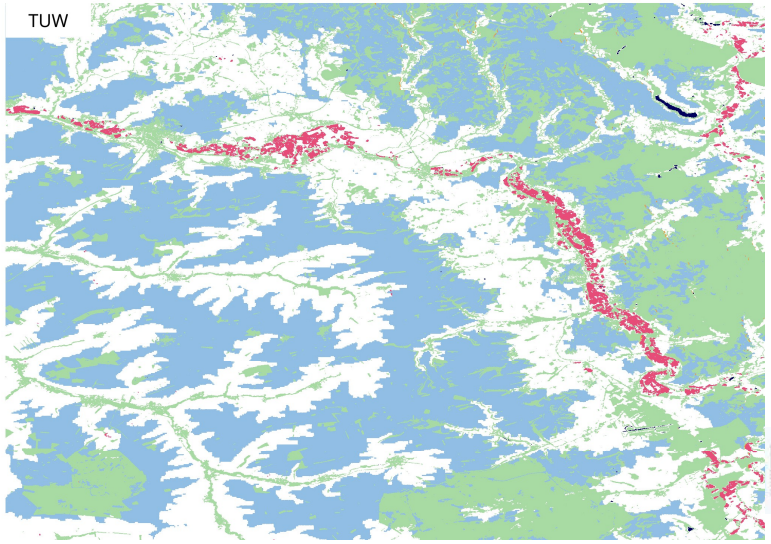


TUW



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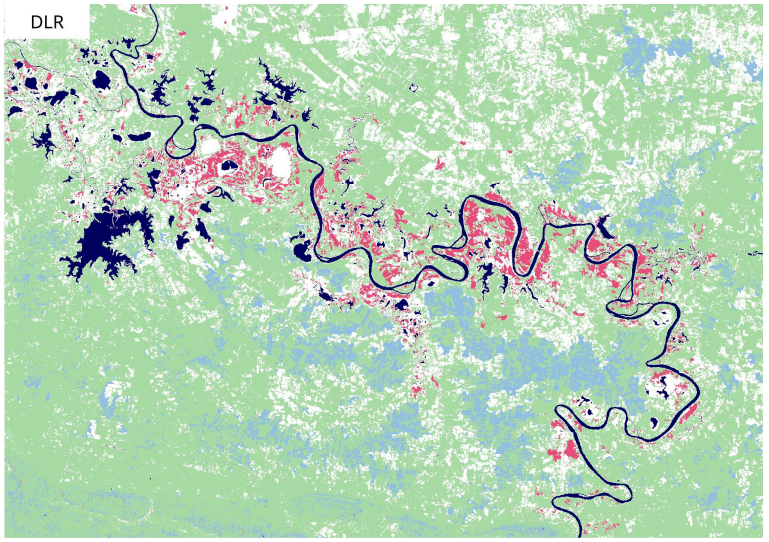
GFM use case: Mexico

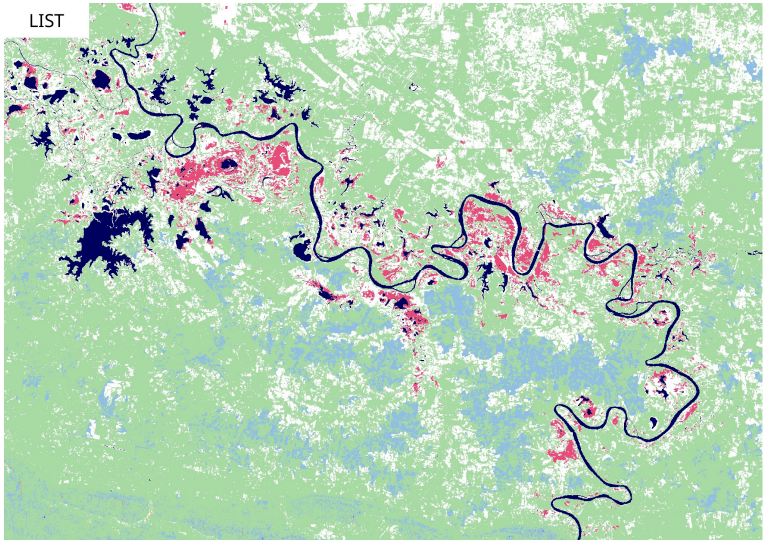
Exclusion layers
- no sensitivity
- low backscatter
- topographic distortion
- radar shadows

Flood mapping
- flood extent (2020/11/15)

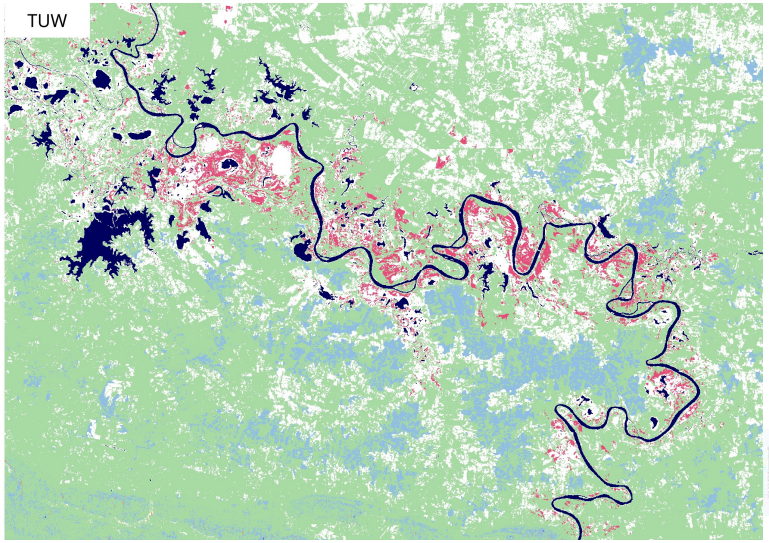
DLR



LIST



TUW



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User Interface

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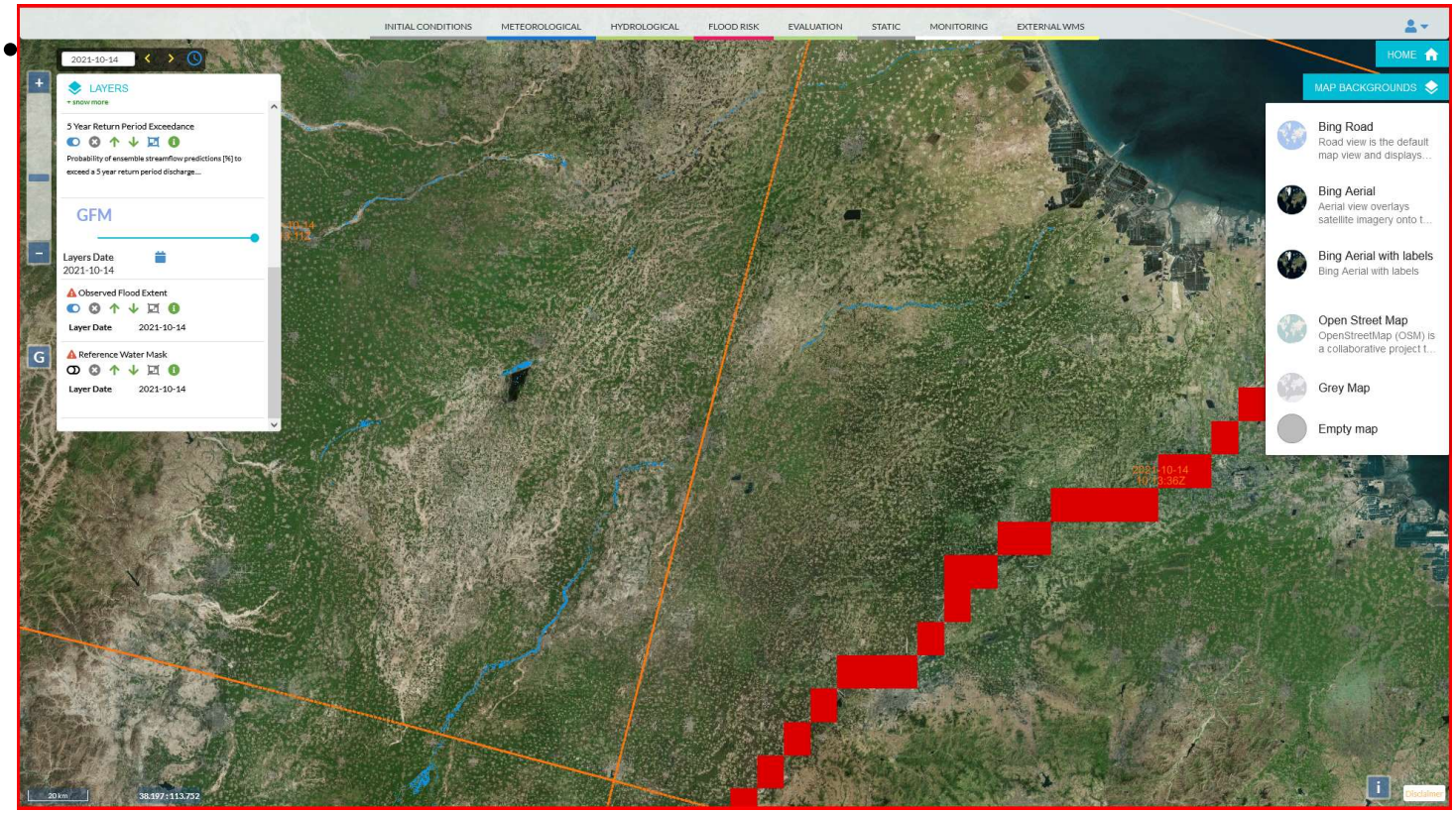

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Summary

- First-of-its-kind fully automatic SAR based flood monitoring service
  - No time is lost due to human intervention between image acquisition and flood map display

Beta version

- The primary output is a complex scientific data product with several novel data layers
  - The flood pixels have to interpreted taking account of the uncertainty layer, the masks, and environmental factors
    - Not all retrieval errors can be captured, e.g. information on wet snow extent and frozen soils is not available with the required resolution and timeliness → false positives
- User interface must hide much of this complexity and will require experience to improve

For details attend afternoon session: GFM talks start at 14:30

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