The new Copernicus Sentinel-1 Global Flood Monitoring Service

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Traditional Approach to Flood Mapping with Satellites

Identify Event

- A flood warning has been issued
- Flooding is already on-going

Order Image

- Programming of satellite image acquisitions
- Search for flood images acquired by chance

Map Flood

- Expert interpretation of images
- Supervised classification with contextual knowledge

- Advantage: Growing number of satellites
- Disadvantage: Each step takes time

Fully Automatic Flood Mapping

- Process all incoming images on-the-fly ….

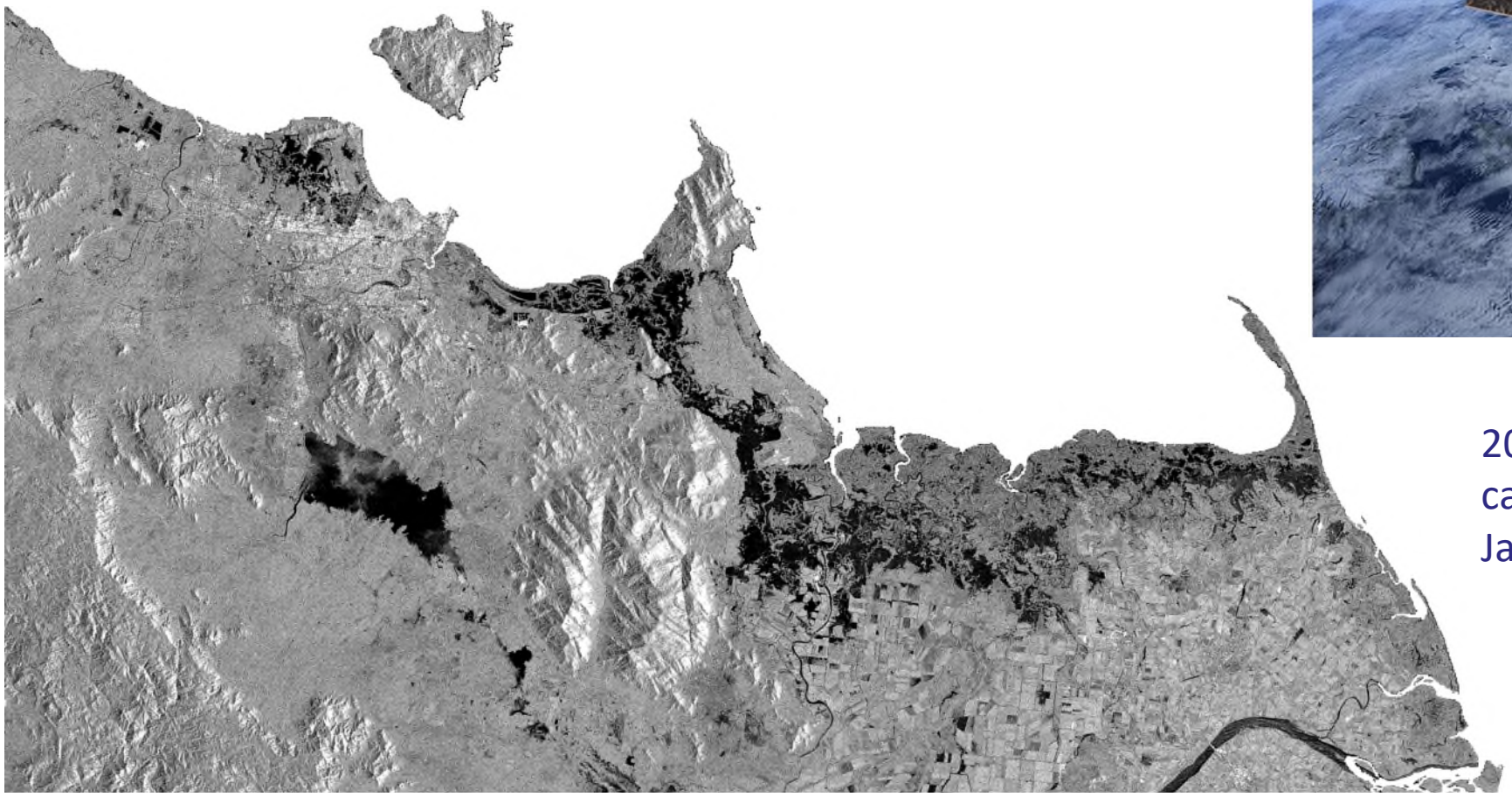
… which is like looking for a needle in a haystack

https://commons.wikimedia.org/wiki/File:Needle_in_haystack5.jpg

- Advantages
  - No time is lost due to human intervention
  - Discover unreported events
- Disadvantages
  - False alarms
  - Processing overhead
  - In practice restricted to single satellites respectively satellite constellations
- Challenges
  - Accuracy
  - Timeline

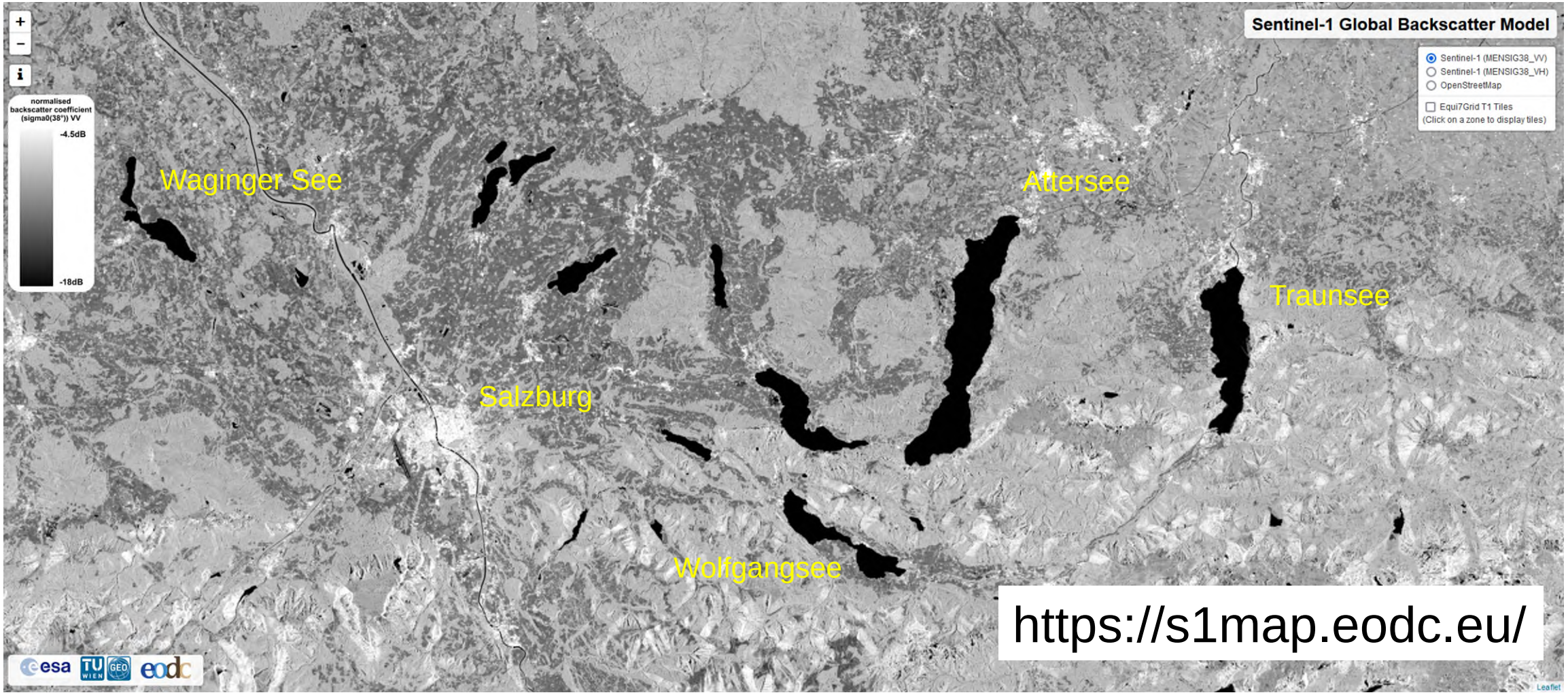
Sentinel-1 Synthetic Aperture Radar (SAR) for Flood Mapping

- Sensor design & acquisition planning optimised for coverage
- Day and night measurement capability
- 20 m at C-band



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

Water Bodies as seen by Sentinel-1



Bauer-Marschallinger et al. (2021) The normalised Sentinel-1 Global Backscatter Model – mapping Earth's land surface with C-band microwaves, Scientific Data, 8, 277.

What do we look for?

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

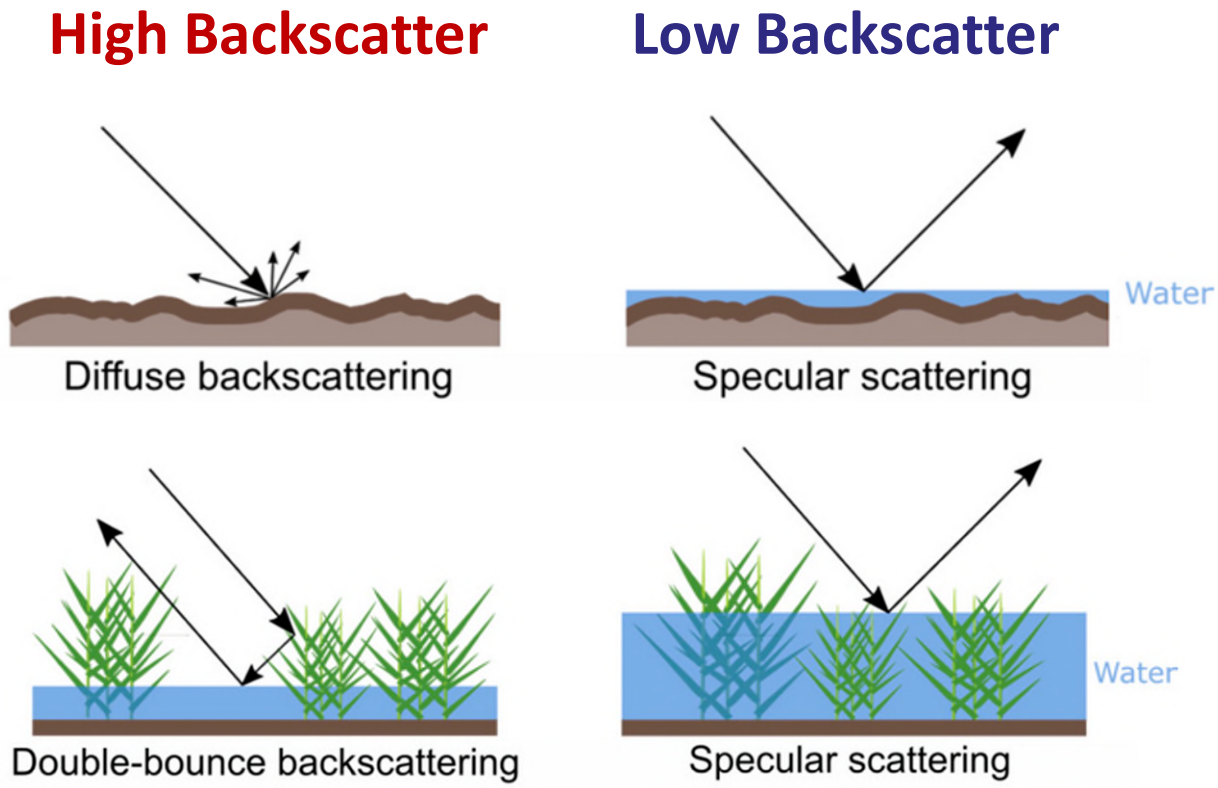


Figure modified from Ottinger and Kuenzer (2020) Spaceborne L-Band Synthetic Aperture Radar Data for Geoscientific Analyses in Coastal Land Applications: A Review, Remote Sensing, 12(14).

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

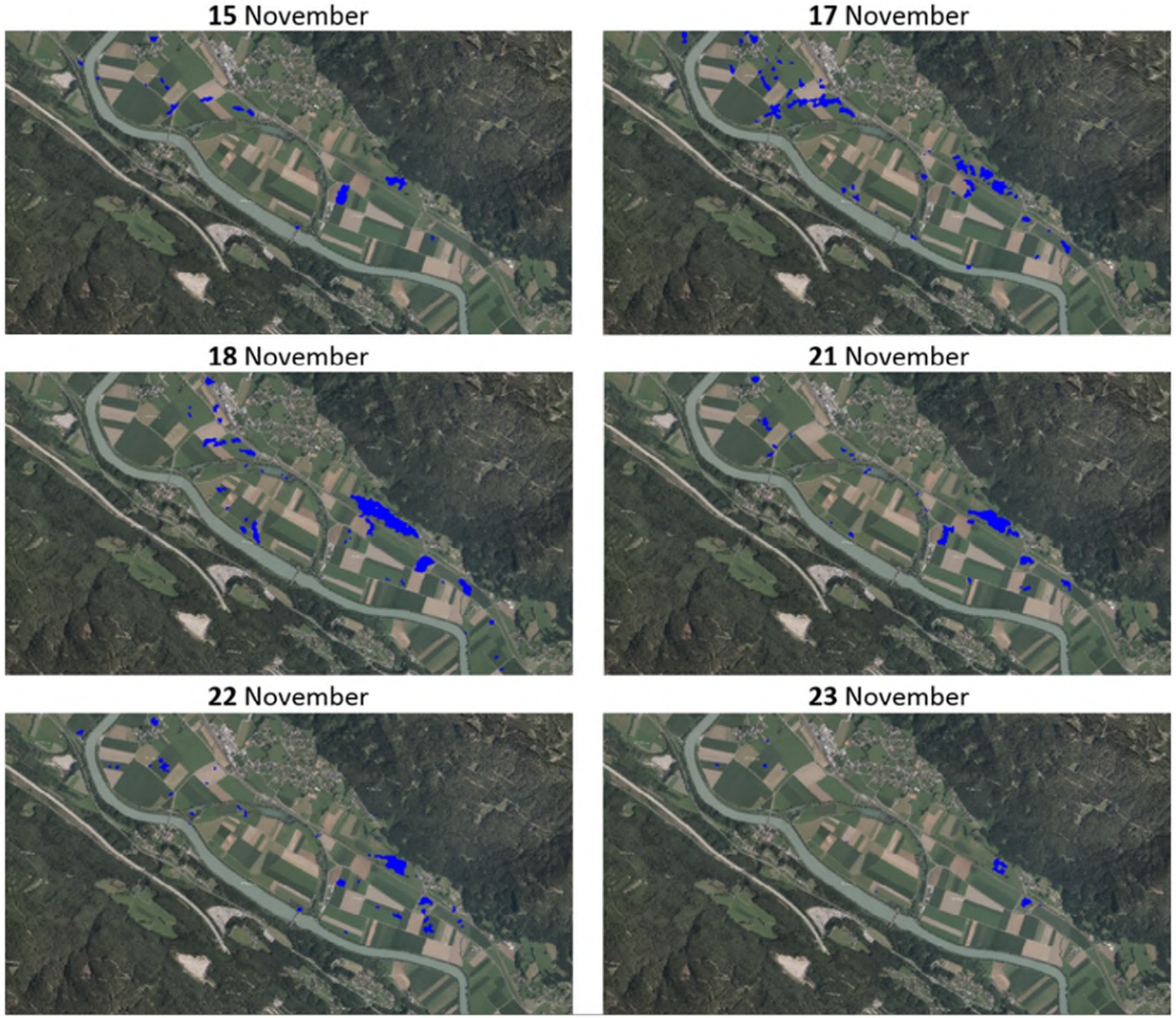
may be problematic for no-flood scenes (i.e. in >>99% of all cases)

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

may cause false negatives

may be problematic for flood scenes

Frequent Coverage



Progression of the November 2019 flooding along the river Drau near Weißenstein in Carinthia, Austria, for the period 15 to 23 November 2019 as captured by Sentinel-1

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ACube4Floods

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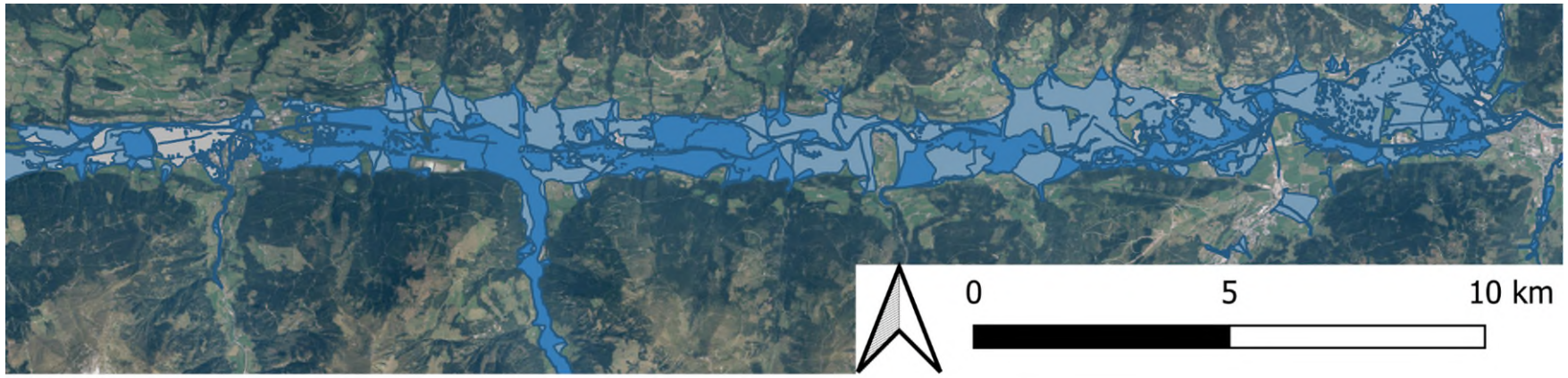
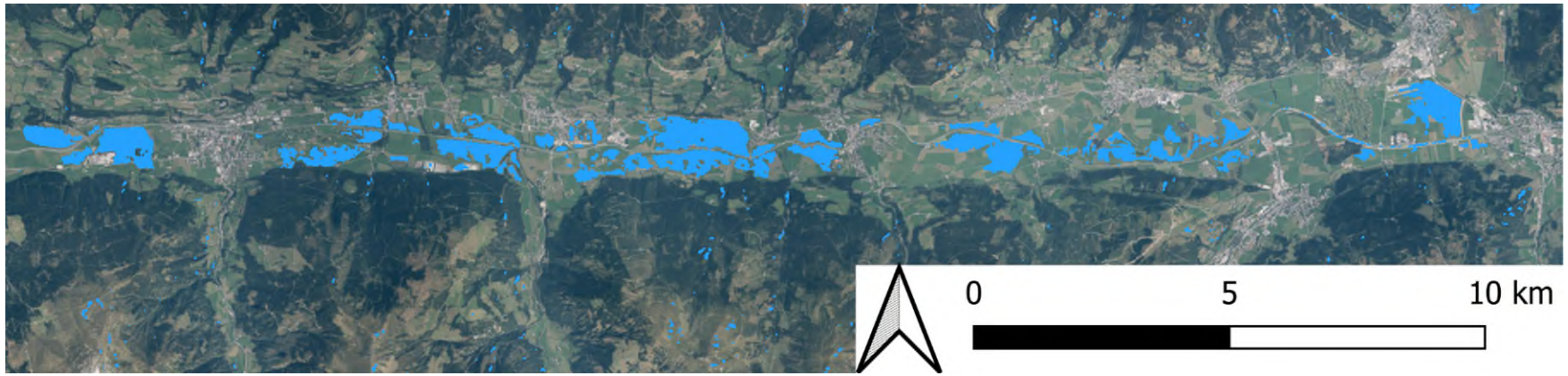
Salzach Flooding in July 2021

Flood scenarios for a 30, 100 and 300 year events



Bundesministerium
Landwirtschaft, Regionen
und Tourismus

Sentinel-1 flood map 19 July 2021 05:18 UTC



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Copernicus Emergency Management Service - Global Flood Monitoring

Emergency Management

GFM Team

Emergency Management

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Luca Molini, Roberto Rudari, Elisabetta Fiori, Isabel Gomes, …

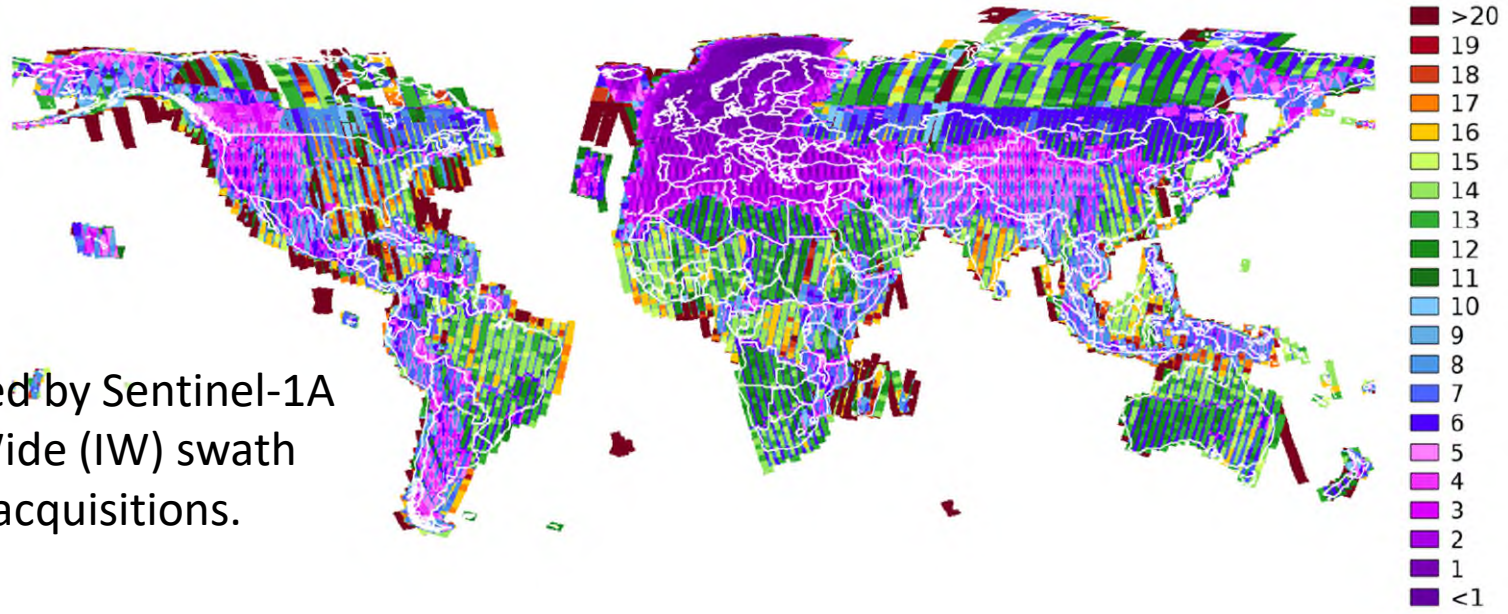
Peter Salamon, Niall McCormick, ...

Emergency Management

Global Flood Monitoring Service

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 Processing

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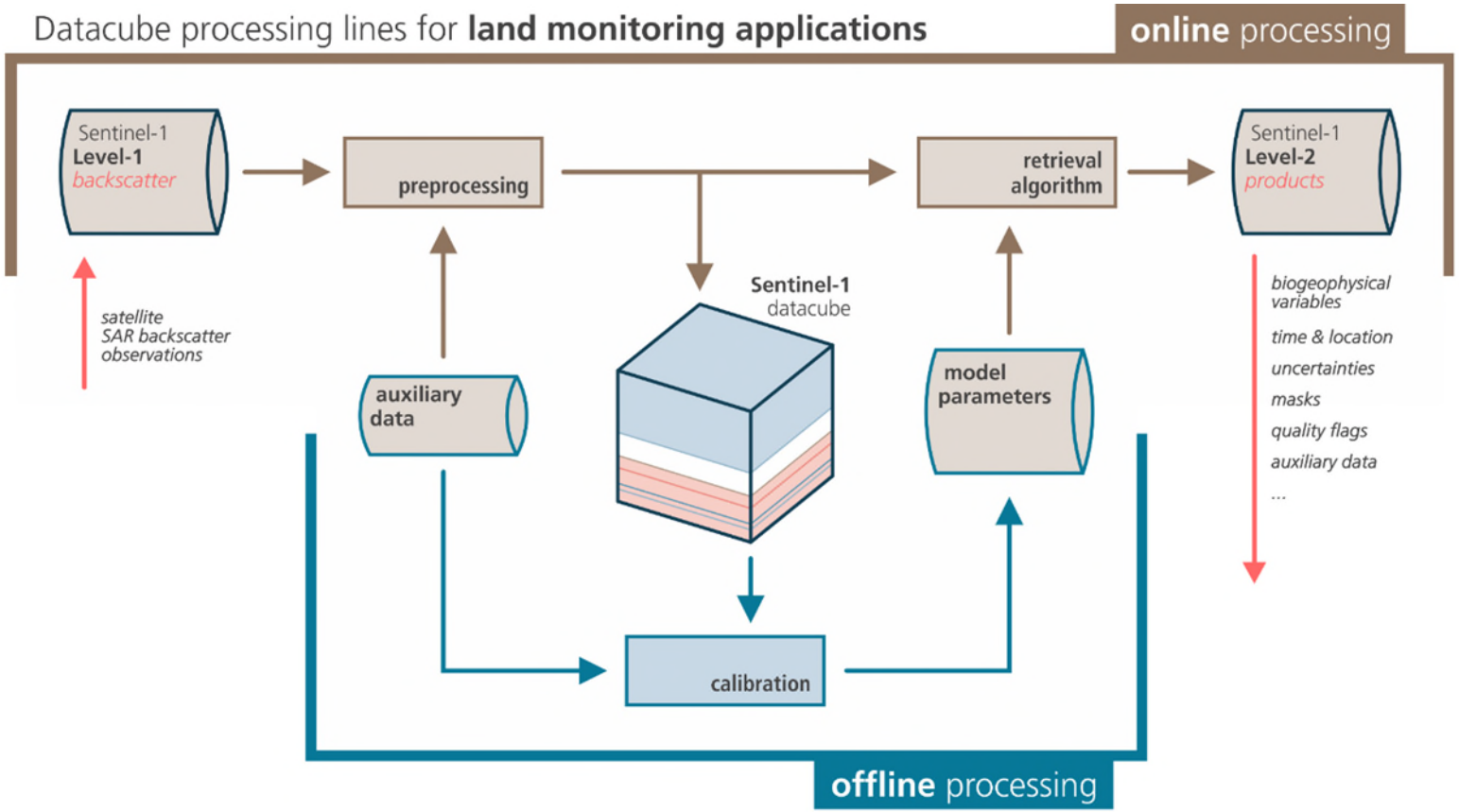
- Based upon a Sentinel-1 datacube processing architecture
  - Copernicus DEM



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*, 13, 4622.

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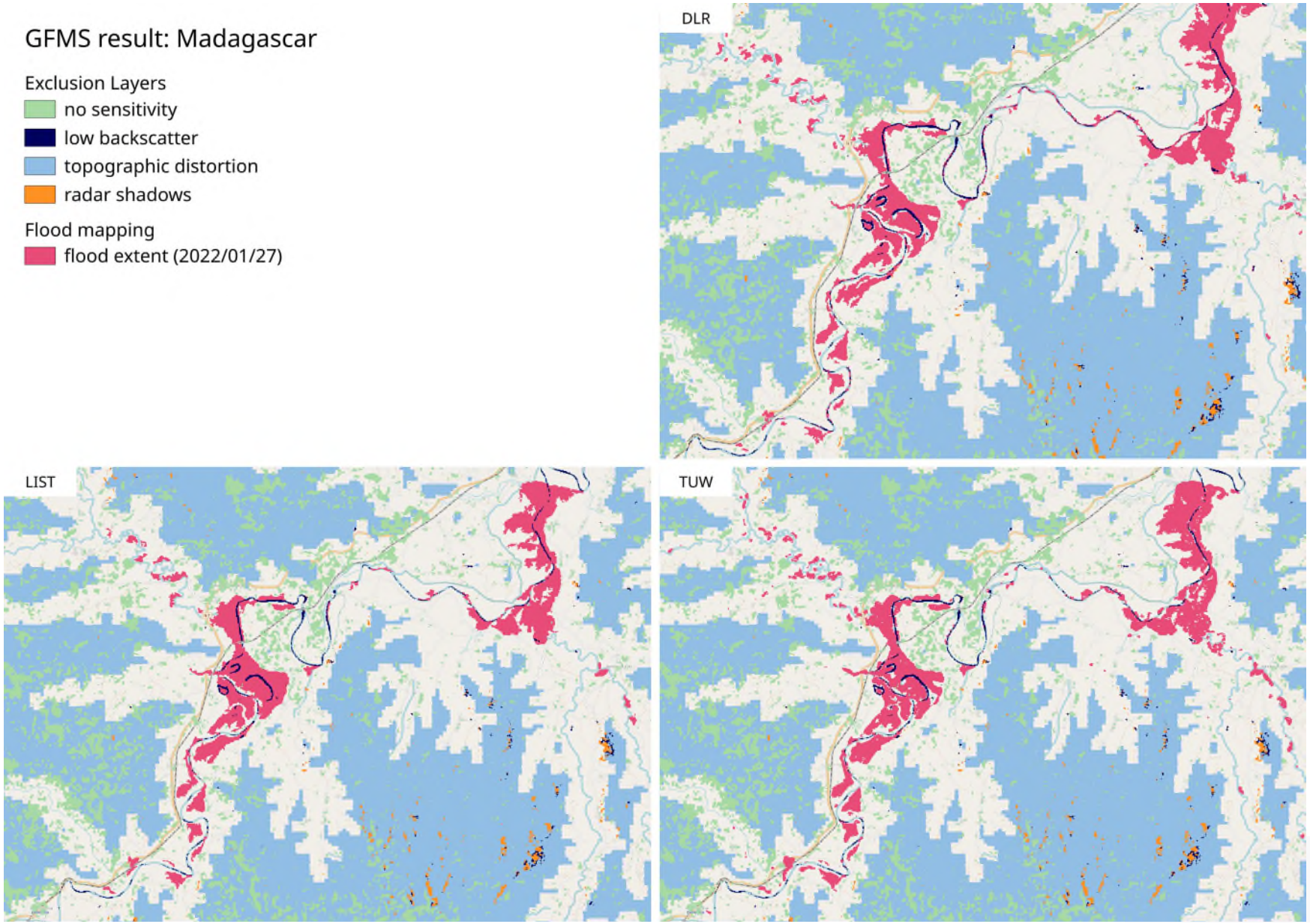
3 Scientific Algorithms



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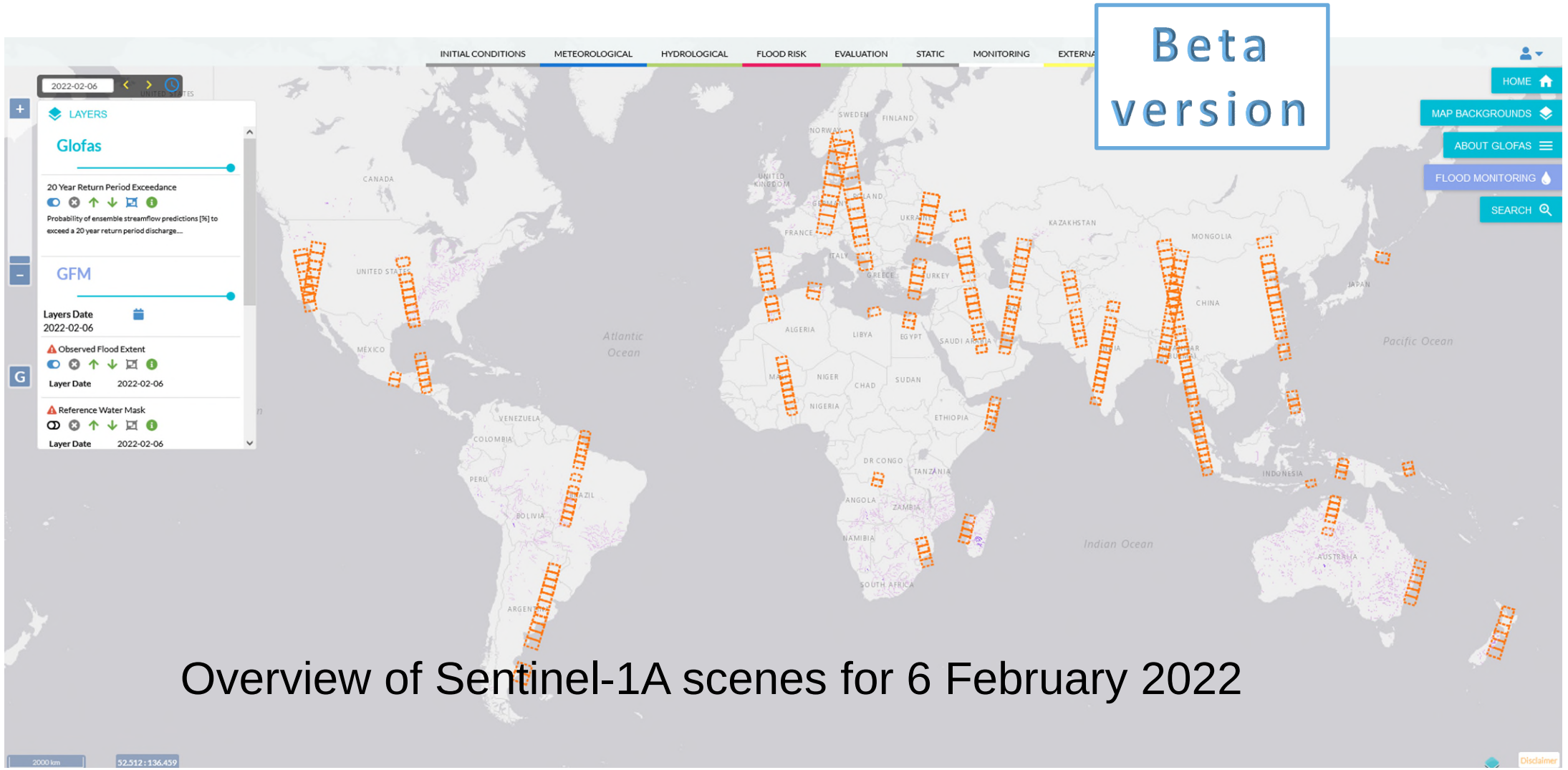
GLOFAS User Interface



Overview of Sentinel-1A scenes for 6 February 2022

https://www.globalfloods.eu/glofas-forecasting/

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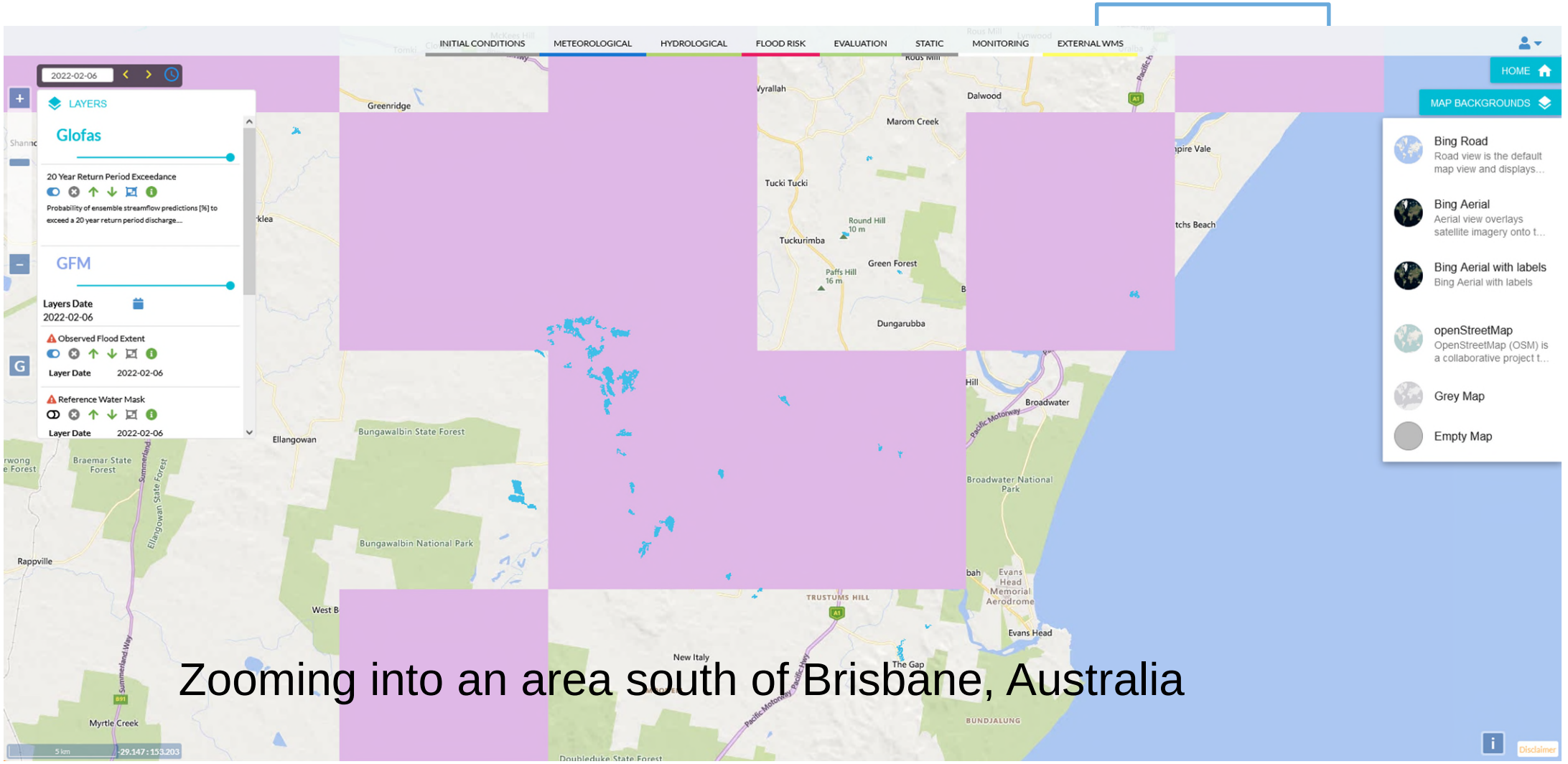
GLOFAS User Interface



Zooming into an area south of Brisbane, Australia

https://www.globalfloods.eu/glofas-forecasting/

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British Columbia November 2021

https://www.nytimes.com/2021/11/21/canada-flooding-climate-change.html

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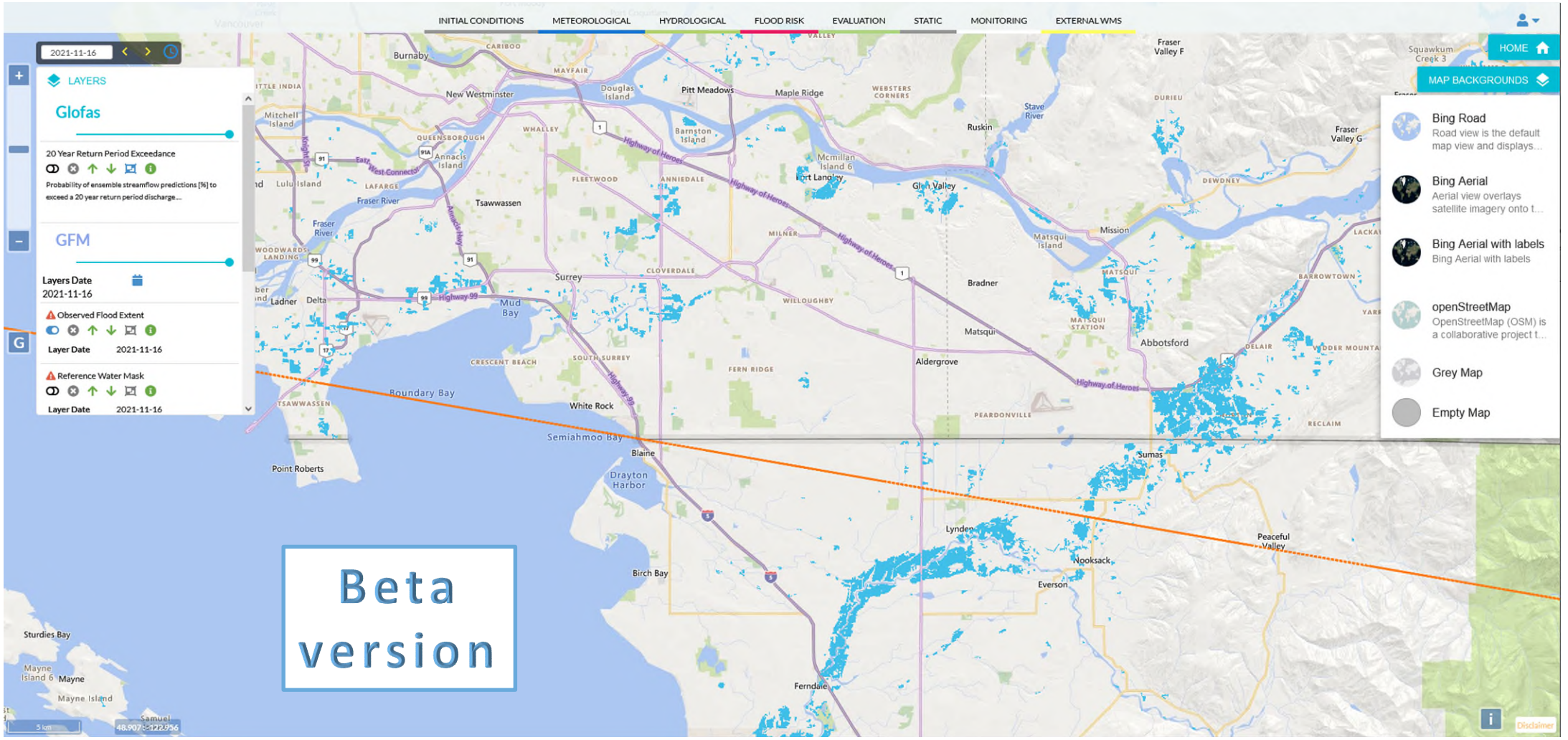
British Columbia 26 November 2021



https://www.globalfloods.eu/glofas-forecasting/

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Summary

- CEMS GFM is the 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
  - Free & open data service

Beta version

- Enhancing the socioeconomic benefits by
  - Improving the algorithms and developing post-processing methods
  - Improving the spatiotemporal coverage (Sentinel-1C and 1D, Radarsat, ROSE-L, …)
  - Developing use cases that optimally take stock of the benefits of the service while avoiding misinterpretations

Acknowledgements

Copernicus: Emergency Management Service | ESA: Sentinel-1 Global Backscatter Model | FFG: ACube4Floods, FAIR2Earth | BMBFW: GEOCLIM