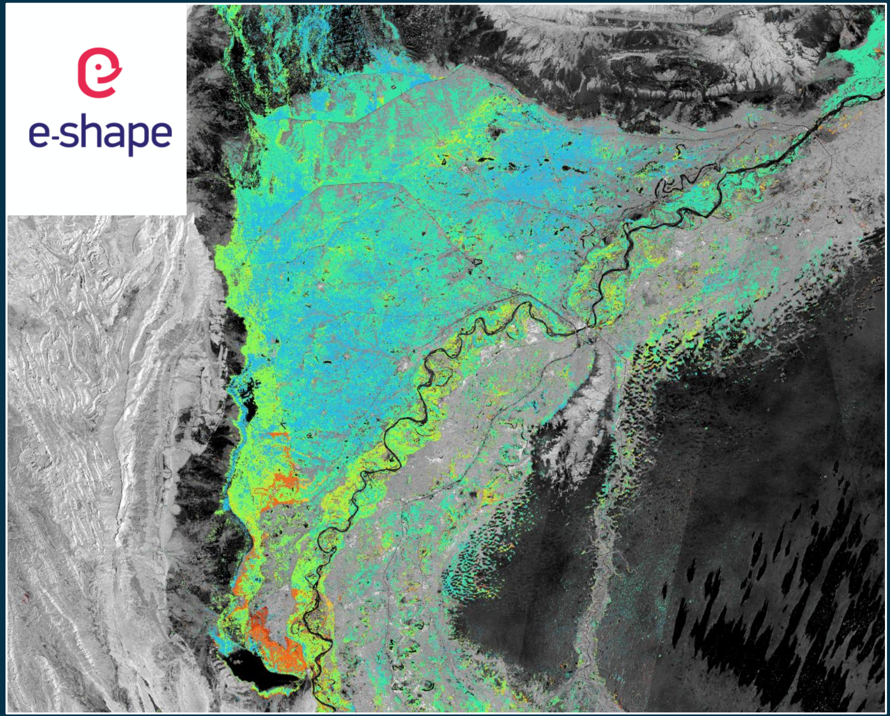
e-shape pilot 5.2

Satellite Earth Observation-derived water bodies and floodwater record



LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY

Before e-shape: setting the scene

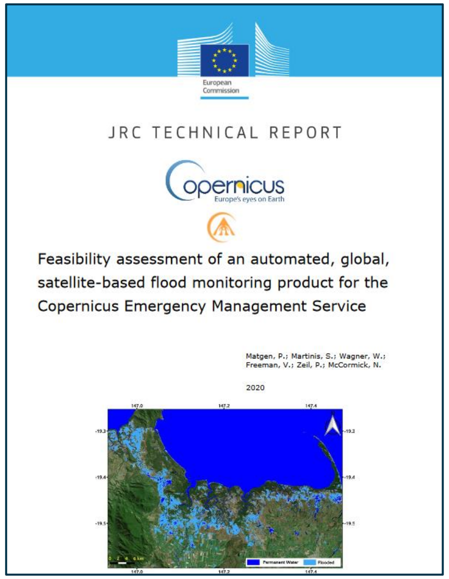
- Sentinel-1 A/B enabling **systematic**, high-frequency radar observations at global scale
- Automated SAR-based flood retrieval algorithms have reached **high technical readiness levels**
- **Fast & easy access to imagery**
- **Fast (pre-)processing of data** via cloud-based platforms
- Successful launch of large scale applications enabling a fully automated SAR-based monitoring of water bodies

Possibility to envisage a fully automated, global, Sentinel-1 based flood monitoring service ?

Co-designing the GFMS

Limitations of CEMS as of 2020:

- No constant automatic monitoring
- Requires user activation
- Activation requests often arrive late (missing flood peak)
- Currently not possible to map all floods (resource limitations)


European Commission

JRC TECHNICAL REPORT

Copernicus Europe's eyes on Earth

Feasibility assessment of an automated, global, satellite-based flood monitoring product for the Copernicus Emergency Management Service

Matgen, P.; Martinis, S.; Wagner, W.; Freeman, V.; Zeil, P.; McCormick, N.

2020

© Copernicus EMS

User requirements:

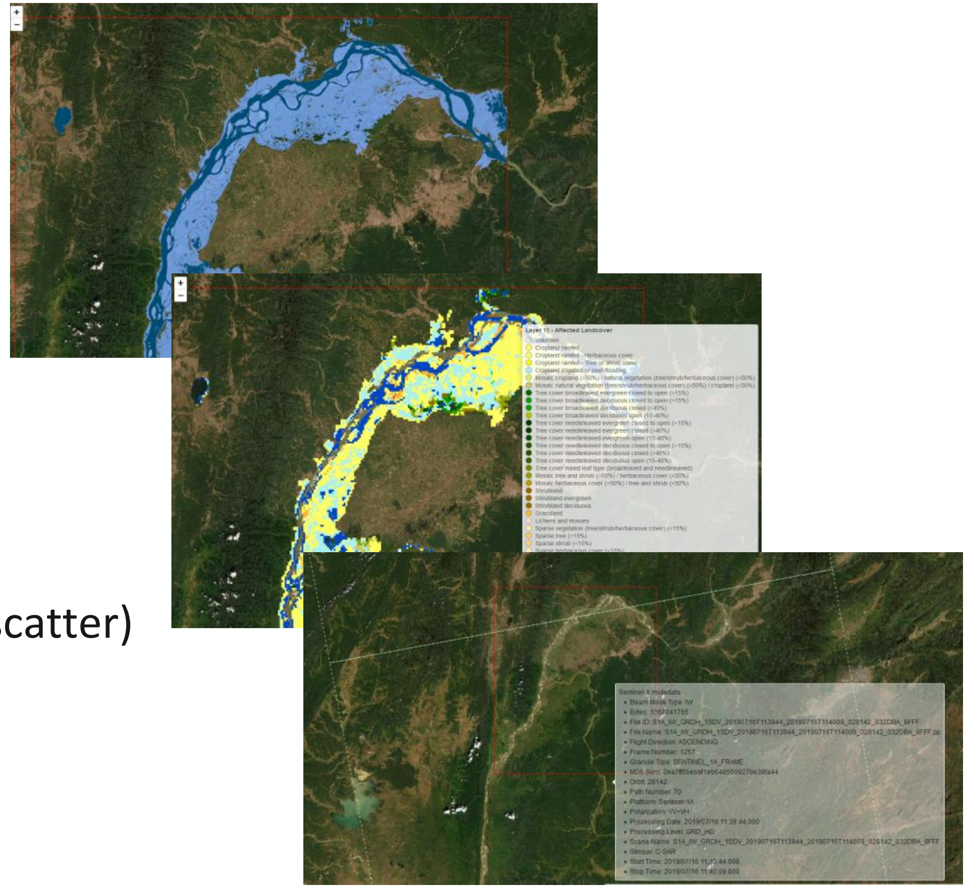
- **Timeliness**: better response planning
- **Continuous monitoring**: adapt measures depending on the evolution of the flood
- **High resolution**: needs to be adequate for impact assessment
- **Historic data**: improved prevention planning
- **Access**: as diverse as possible to account for all user needs

Co-designing the GFMS

Requested data layers:

- Observed water/flood extent
- Reference water mask

  Seasonal/permanent based on historical Sentinel-1 time-series
- Ensemble uncertainty
- Advisory flags (snow, ice, frost, dry soil, wind)
- Exclusion layer (urban, dense vegetation, radar shadows, low backscatter)
- Impact information
- Sentinel-1 metadata - footprint - schedule



Available < 12 hours after data acquisition!

Research and development within e-shape

Challenge #1:

The retrieval algorithm needs to be
efficient and robust and achieve **high classification accuracies** in diverse landscapes and different acquisition conditions

Challenge #2:

Fast access to imagery and **high performance computational resources** to respond to needs of emergency responders and disaster risk financing sector.

Research and development

Objectives:

- Development of methods & retrieval algorithms enabling generation of ‘observed flood extent’ product at global scale:
  - ➢ Need to overcome challenges due to water look-alikes (e.g. wet snow, dry land, vegetation) & roughening of water surfaces
  - ➢ Identification and exclusion of “blind spots”

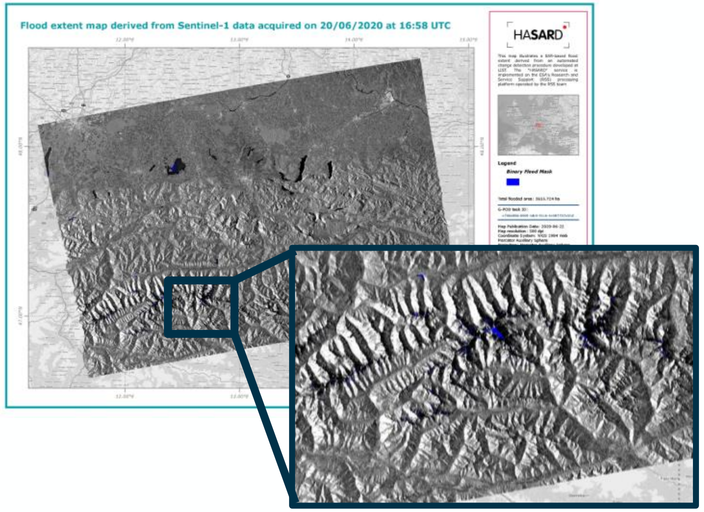
- Improve efficiency of workflows
  - ➢ Minimize lag between image acquisition and product dissemination

Research questions:

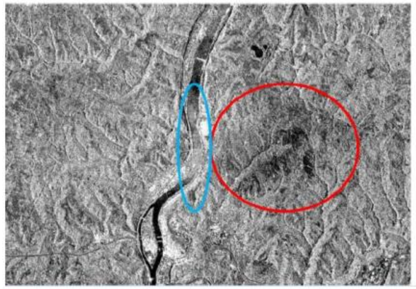
- Can an **<u>ensemble approach based on three independent retrieval algorithms</u>** improve the accuracy and robustness of individual mapping approaches?

- What areas have to excluded because of current shortcomings of SAR technologies and retrieval algorithms?

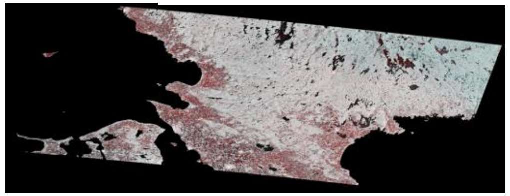
Wet snow



Rain cell



Vegetation



Methodology

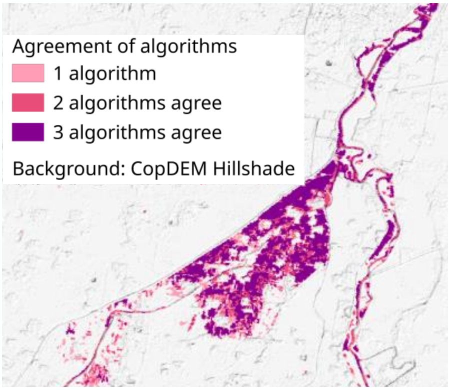
3 scientific retrieval algorithms:

- DLR[1]: Image classification using fuzzy logic with post classification and region growing
- LIST[2]: Change-detection using hierarchical split-based approach
- TUW[3]: Bayesian classifier informed by full per-pixel Sentinel-1 signal history

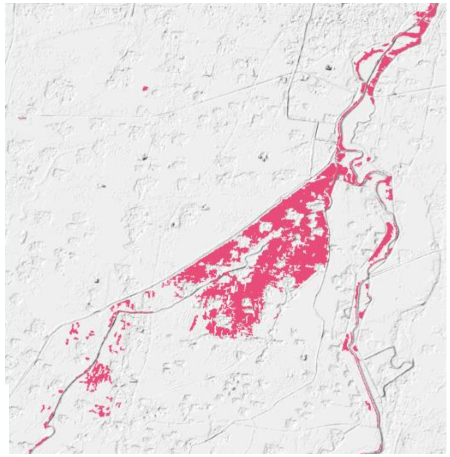
Representative of single-image, dual-image and time series approaches

Ensemble:

- 'Consensus decision': Pixel-based classification based on 2-3 agreeing algorithms
- 'Split decision': Pixel-based classification based on uncertainties of 2 algorithms



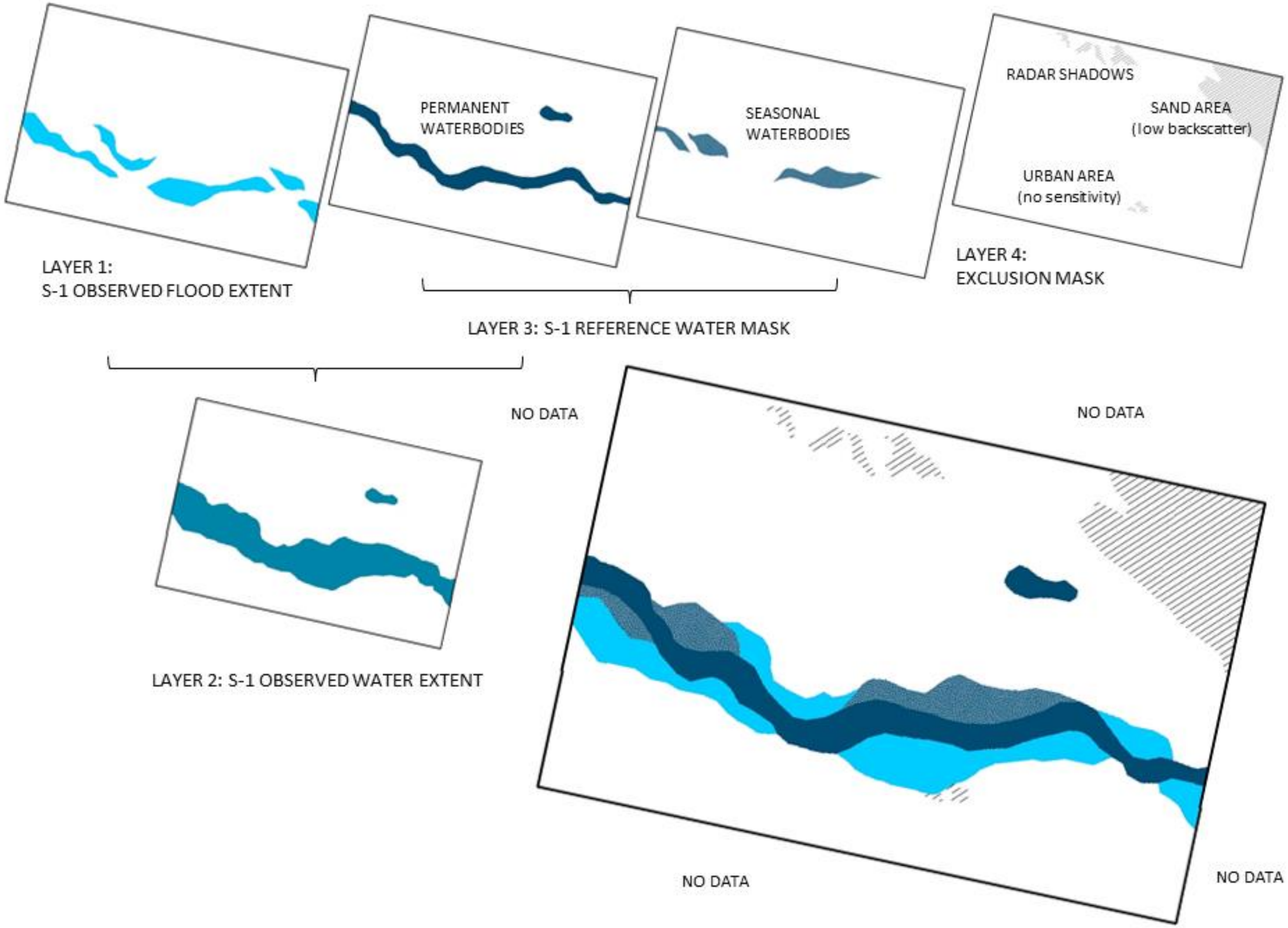
Ensemble



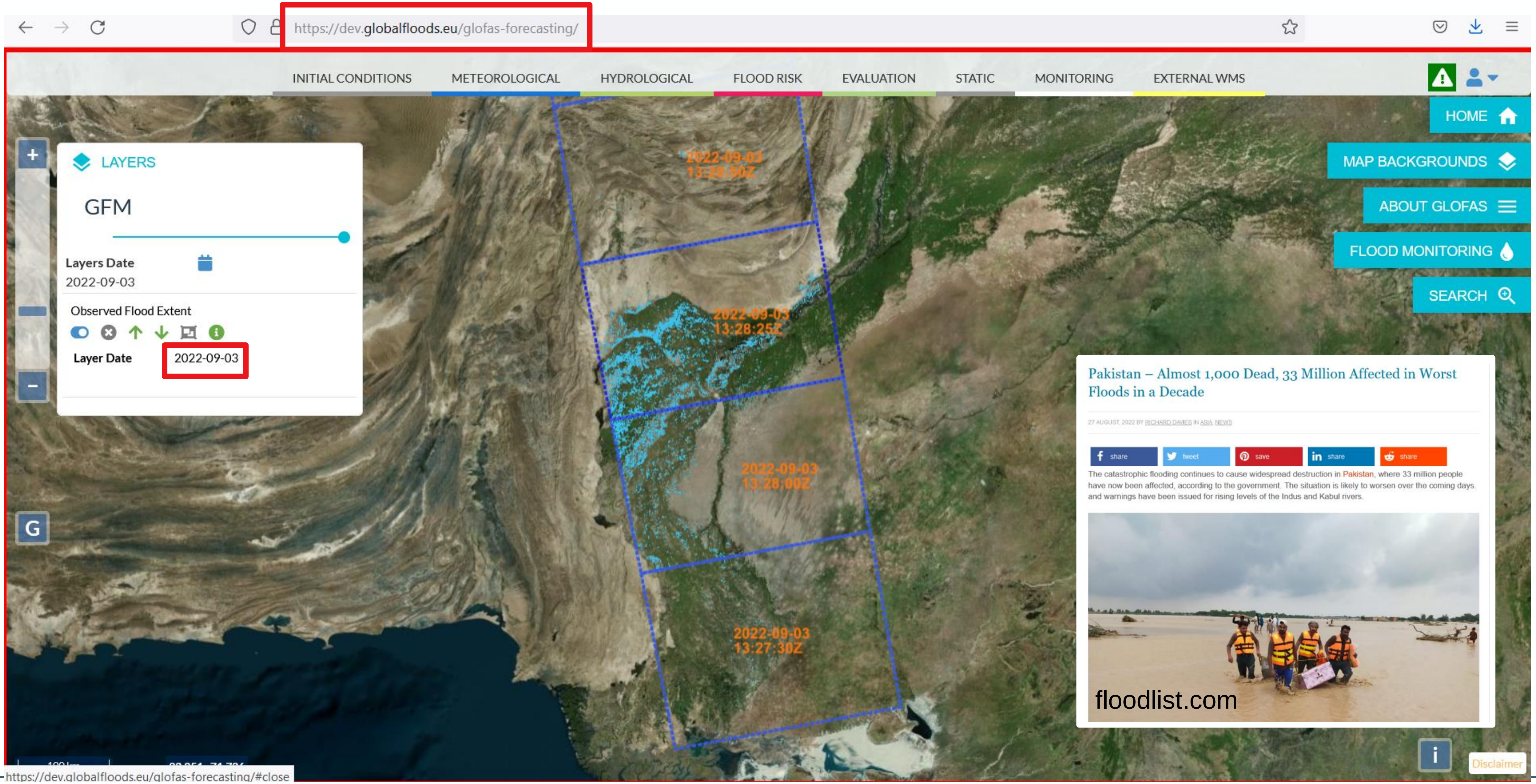
Flooding near Guantao, China
Sentinel-1 scene from 14.10.21

[1] *Martinis et al., ISPRS Journal of Photogrammetry and Remote Sensing, 2015*
[2] *Chini et al., IEEE Transactions on Geoscience and Remote Sensing, 2017*
[3] *Bauer-Marschallinger et al., Remote Sens., 2022*

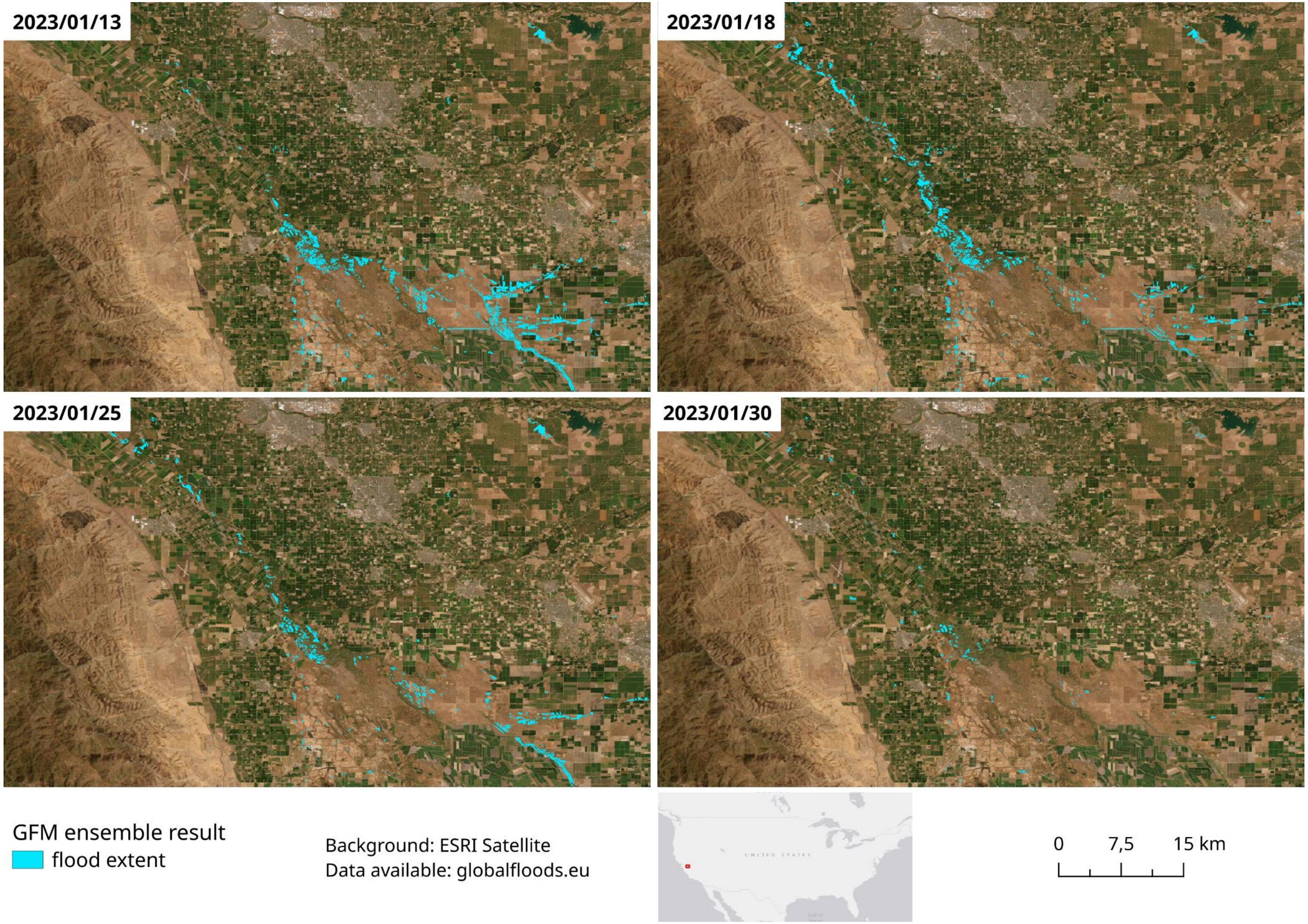
Methodology



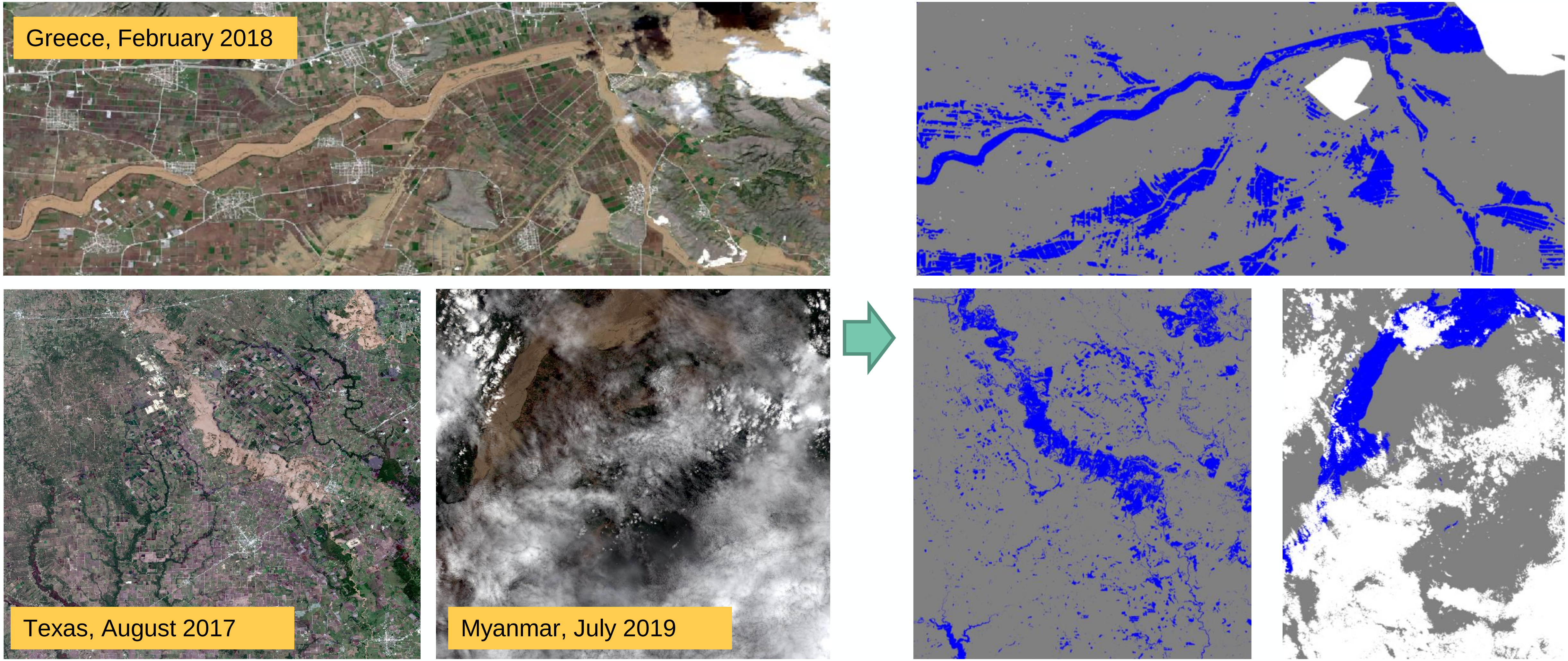
Demo


https://dev.globalfloods.eu/glofas-forecasting/
INITIAL CONDITIONS
METEOROLOGICAL
HYDROLOGICAL
FLOOD RISK
EVALUATION
STATIC
MONITORING
EXTERNAL WMS
HOME
MAP BACKGROUNDS
ABOUT GLOFAS
FLOOD MONITORING
SEARCH
LAYERS
GFM
Layers Date
2022-09-03
Observed Flood Extent
Layer Date
2022-09-03
2022-09-03 13:28:50Z
2022-09-03 13:28:25Z
2022-09-03 13:28:00Z
2022-09-03 13:27:30Z
Pakistan – Almost 1,000 Dead, 33 Million Affected in Worst Floods in a Decade
The catastrophic flooding continues to cause widespread destruction in Pakistan, where 33 million people have now been affected, according to the government. The situation is likely to worsen over the coming days, and warnings have been issued for rising levels of the Indus and Kabul rivers.
floodlist.com
Disclaimer
https://dev.globalfloods.eu/glofas-forecasting/#close

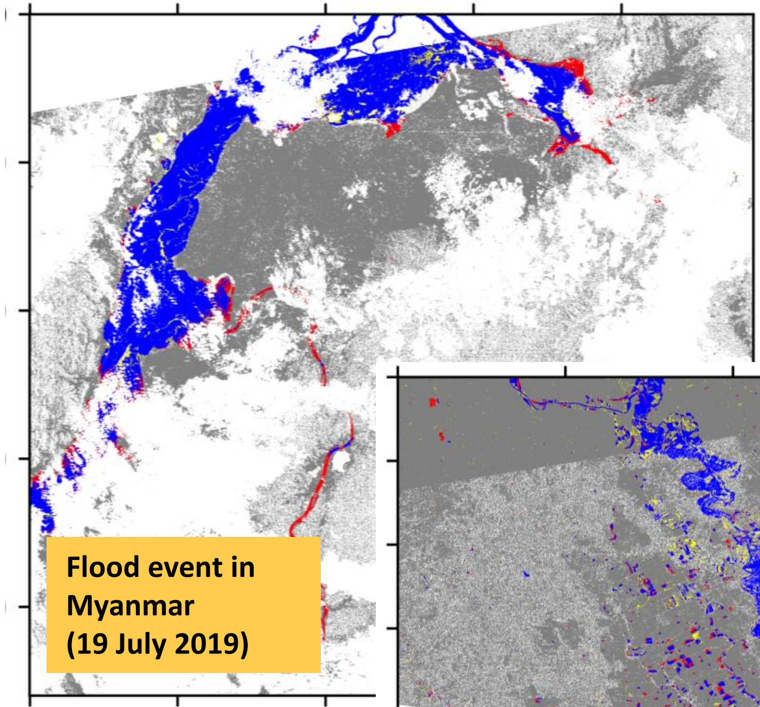
California Flood 2023



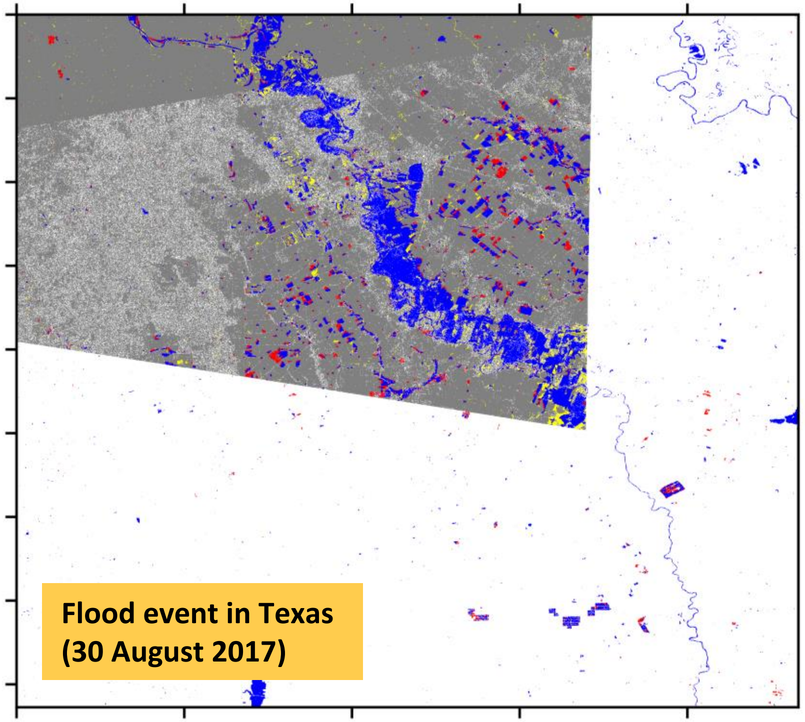
Quantitative evaluation



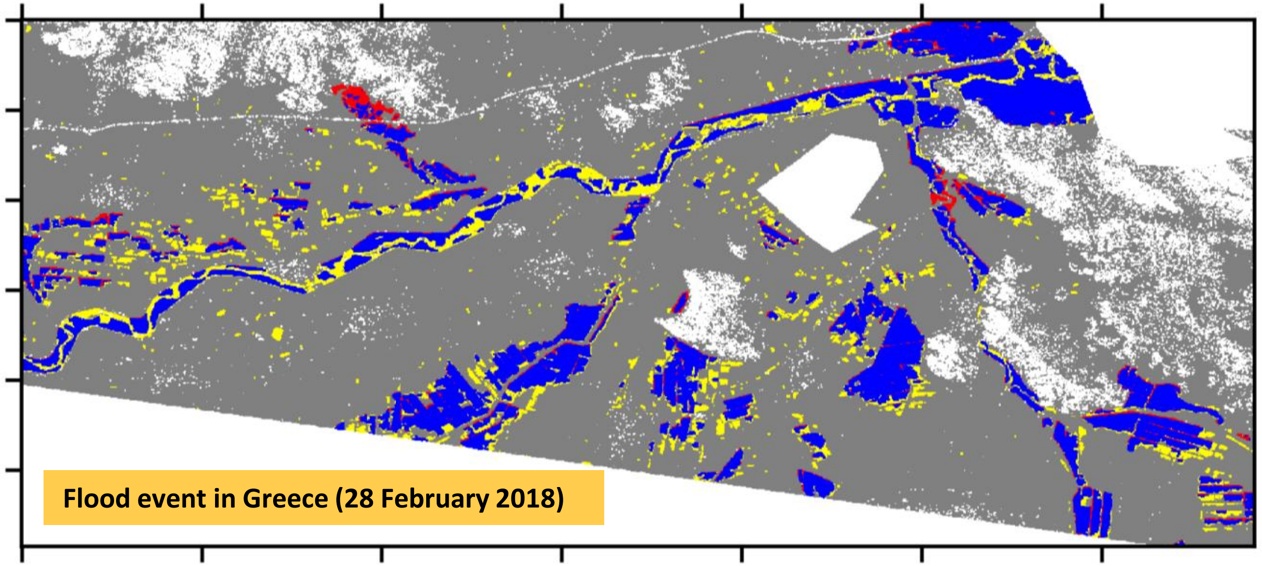
Quantitative evaluation



Flood event in Myanmar (19 July 2019)



Flood event in Texas (30 August 2017)

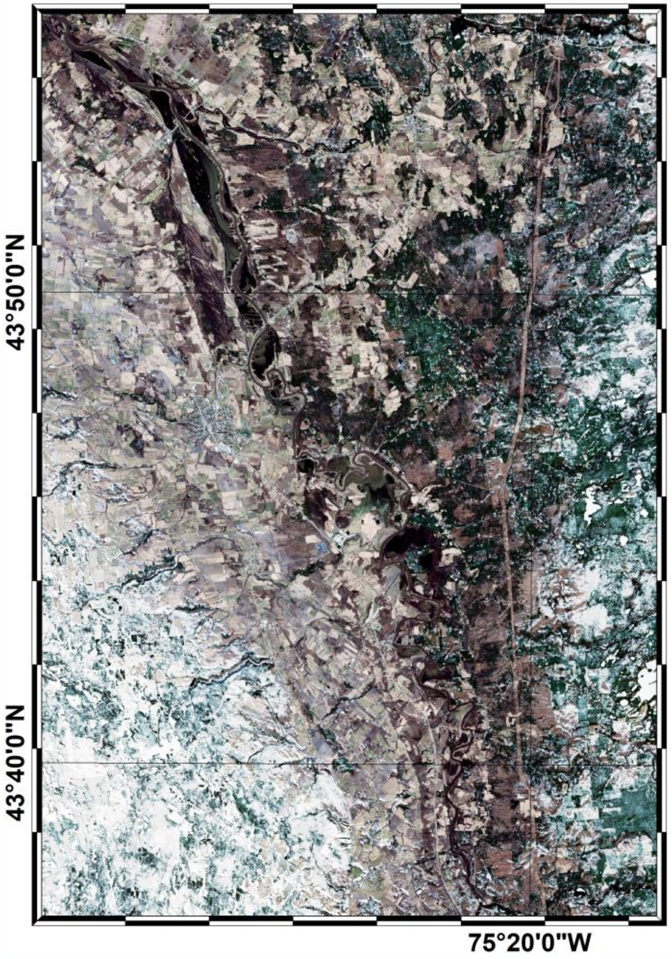


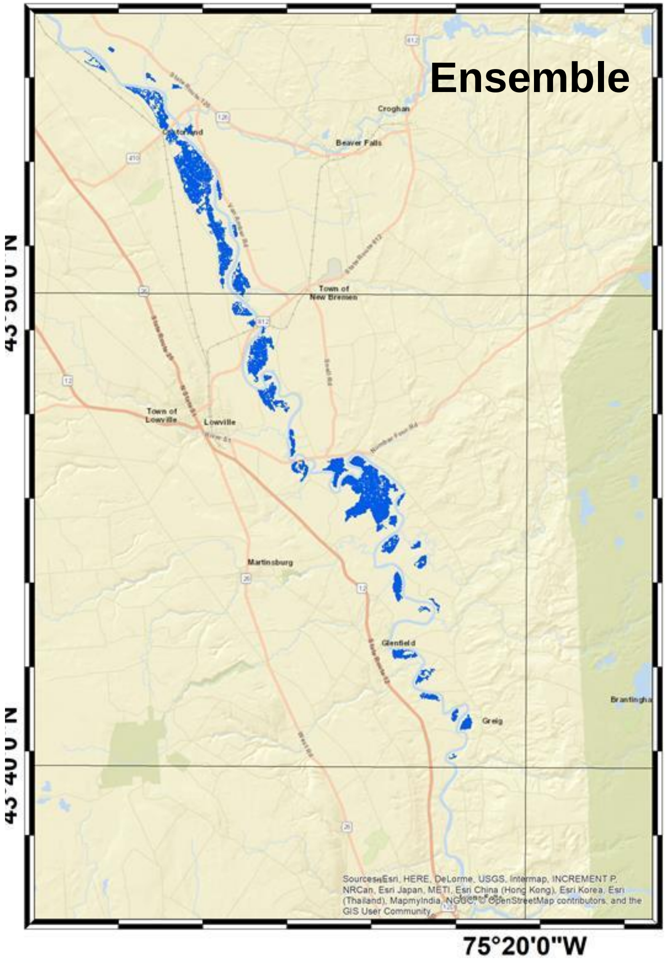
Flood event in Greece (28 February 2018)

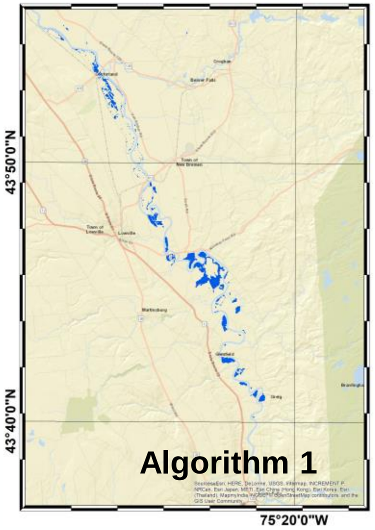
CSI	Texas	Myanmar	Greece
Algorithm 1	0.67	0.78	0.59
Algorithm 2	0.69	0.84	0.66
Algorithm 3	-	0.82	0.73
Ensemble	**0.73**	**0.85**	**0.66**

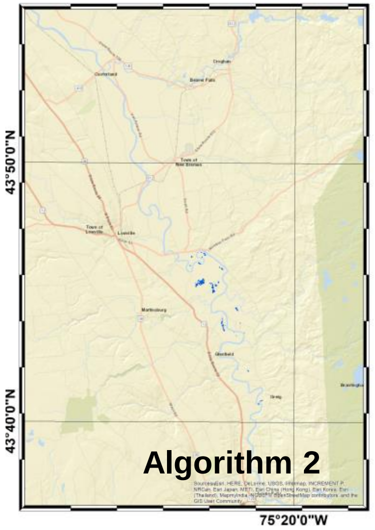
Qualitative Evaluation

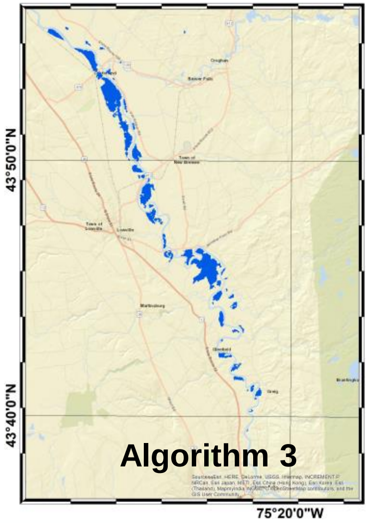
Snow-water separation: use case Black River in Vermont, US (2019 – 2020)







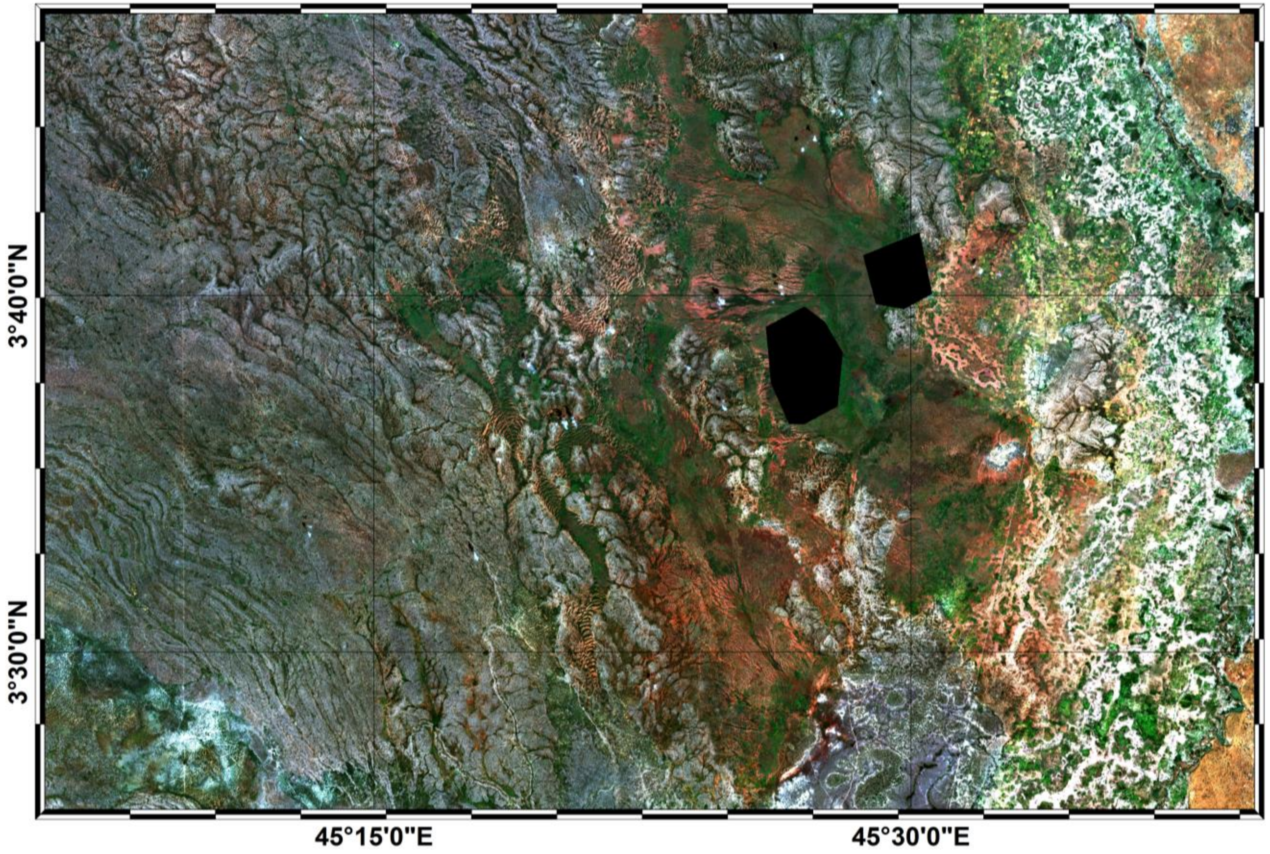


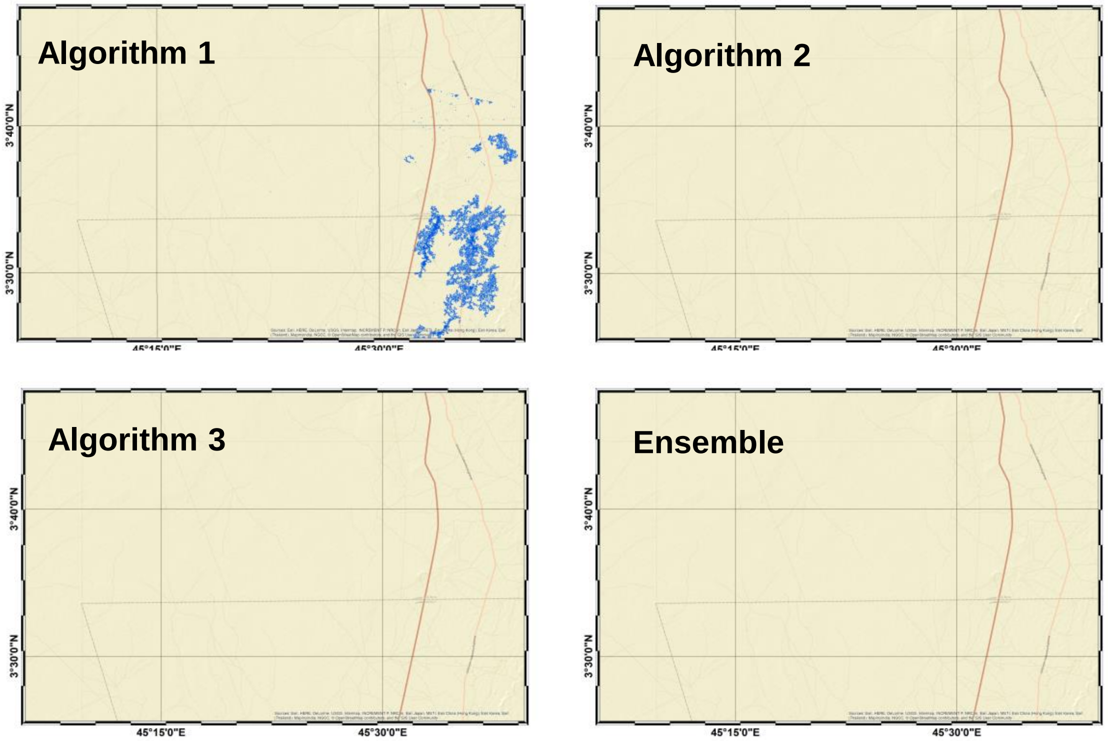


- **Good match with manually delineated water bodies from optical imagery**
- **No over-detection due to snow!**
- **Failure of one algorithm is mitigated by the ensemble**

Qualitative Evaluation

Very dry areas: use case in Somalia (June 2019)

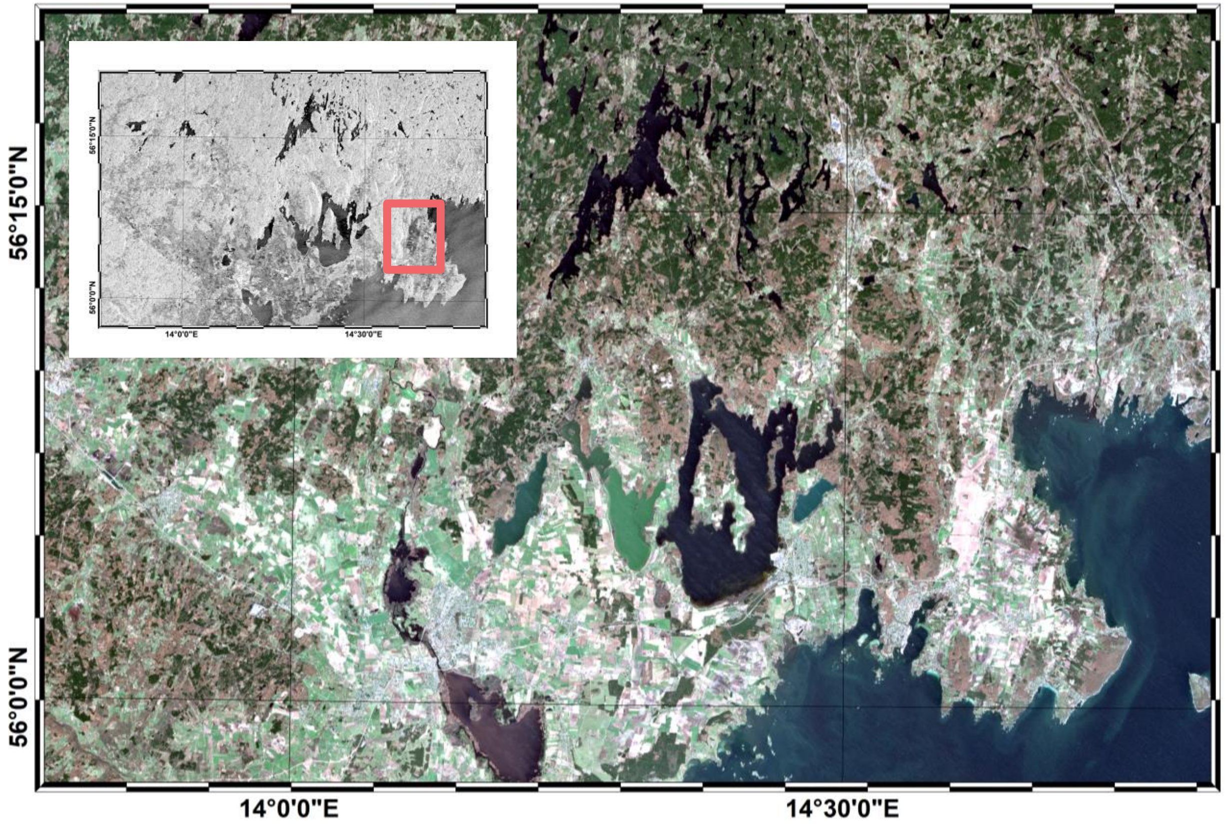


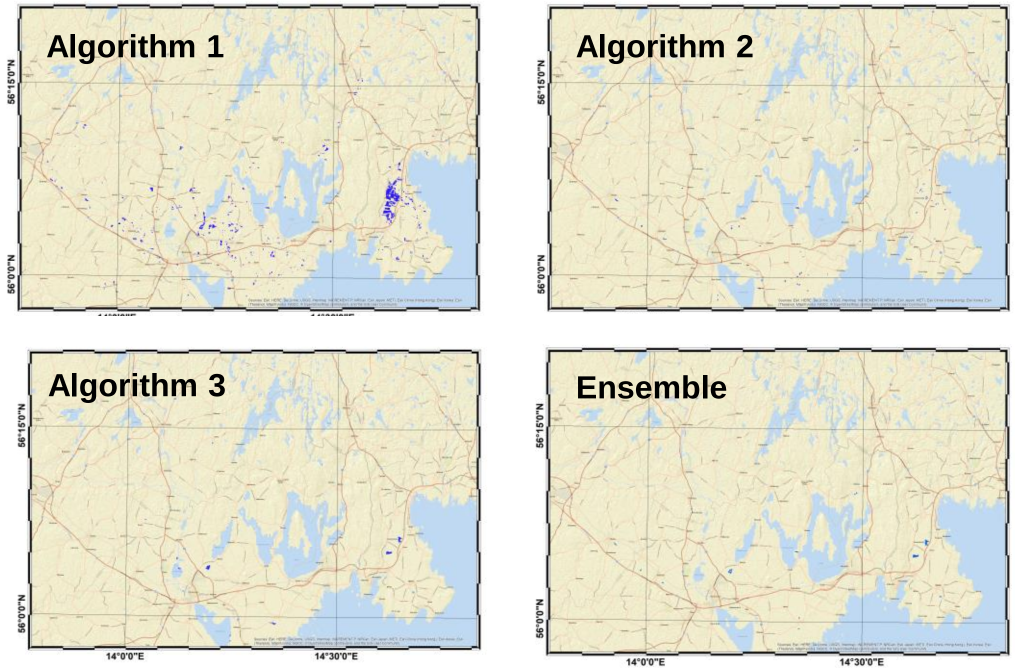


- **One algorithm over-estimates the extent of flooding in very dry areas**
- **The over-detection of one algorithm is mitigated by the ensemble**

Qualitative Evaluation

Vegetated areas: use case in South Sweden (May 2019)





- **Some over-detection of floodwater in vegetated areas (on several dates during the growing season)**
- **The risk of significantly over-estimating the extent of floodwater is reduced by the ensemble**

Preliminary conclusions

In terms of accuracy, for specific events and areas of interest, individual approaches outperform the ensemble

- However, overall, the ensemble approach outperforms individual mapping approaches in terms of accuracy
- Large flooding events are mapped with satisfying accuracy

The ensemble approach helps controlling the number of over-detections

➡ **‘Go’ for generation of Sentinel 1 based generation of flood record 2015-2023**

Building the flood record 2015 - 2023

- main processing infrastructure hosted by eodc
- computation took place on **VSC5** on 100 nodes with 128 CPUs and 512 GB per node
- 10 Sentinel-1 scenes in parallel per node => 1000 scenes processed in parallel

high-level statistics on the processing effort

- **> 1.4 million processed scenes**
    - average runtime of one scene: 13:12 min
    - total cpu-time for flood archive processing (excl. auxiliary data) ~ 330000 hours
      ~ 38 years (if they would have been sequentially processed)
- → **110TB** of storage consisting of
    - **37TB** of GFM output layers (advisory flags, exclusion mask, flood extent, observed water extent, likelihood)
    - **73TB** of interim layers (flood extent, likelihood) of individual flood algorithms

VIENNA SCIENTIFIC CLUSTER

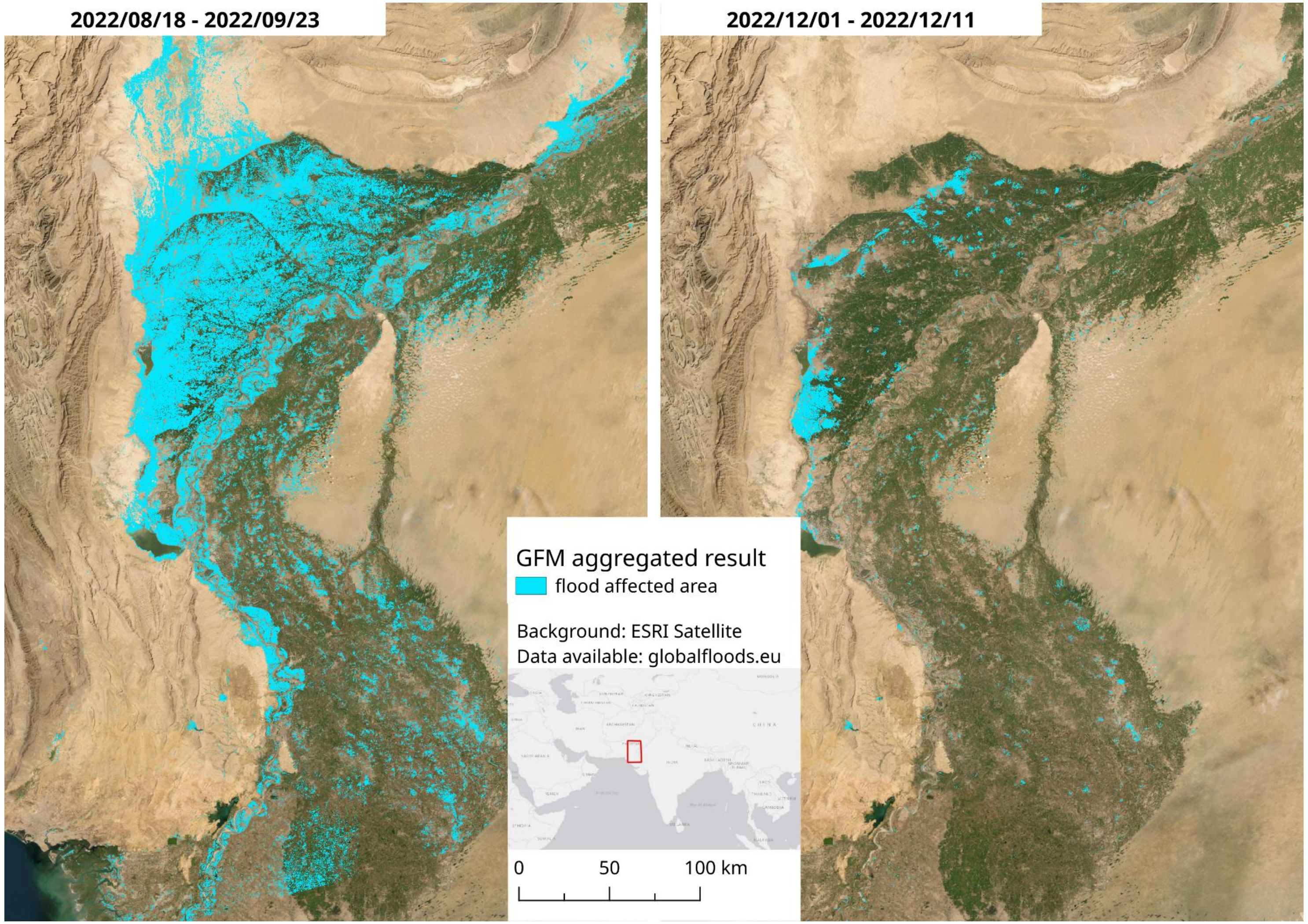
Building the flood record 2015 - 2023

Pakistan Flood 2022

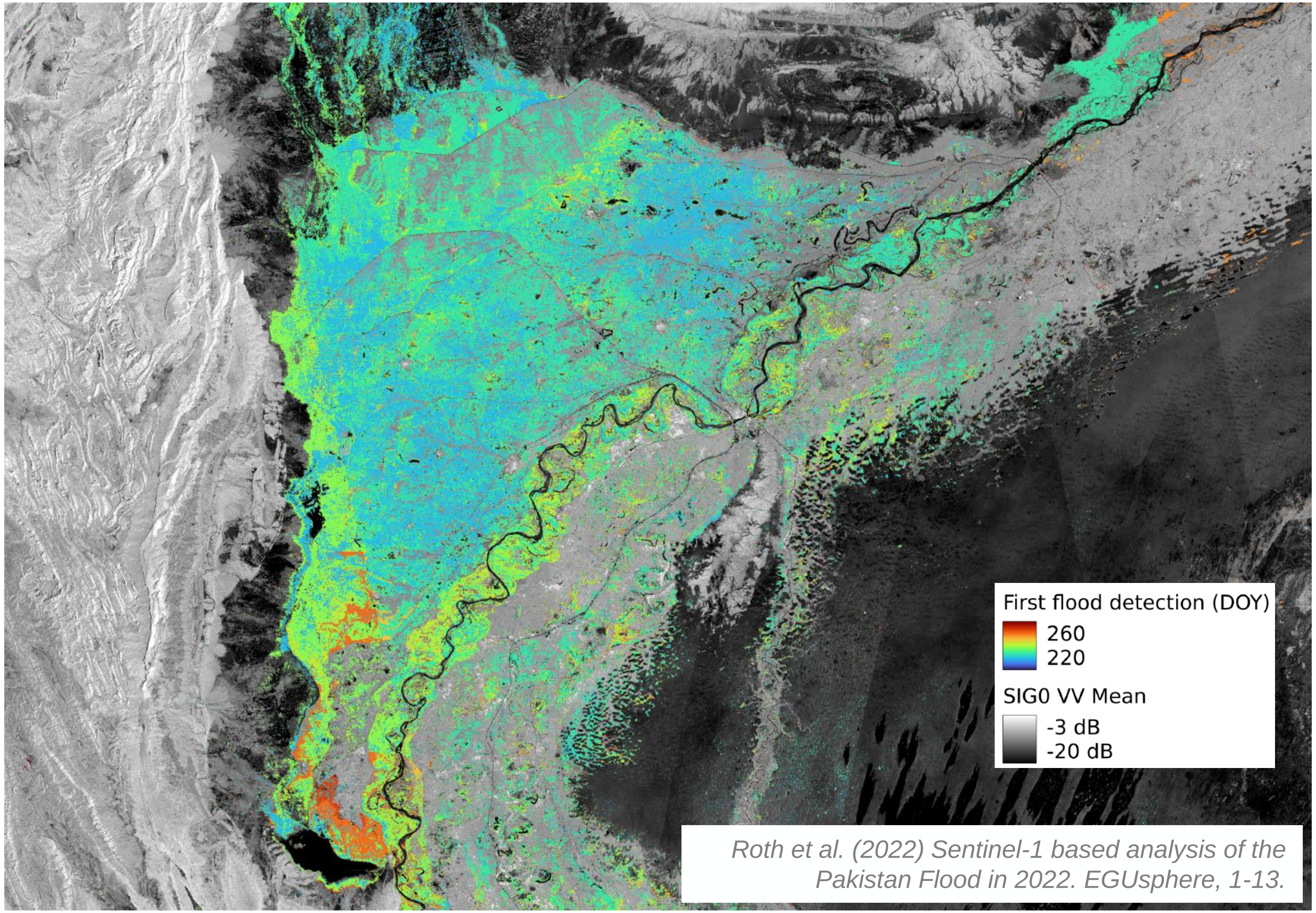
- extremely large event
- crisis persisted into 2023

climate.copernicus.eu, 2022/09/21

ifrc.com, 2022/12/13



Building the flood record 2015 - 2023



Roth et al. (2022) Sentinel-1 based analysis of the Pakistan Flood in 2022. EGUsphere, 1-13.

Pakistan Flood 2022

- progression from August to September

Beyond e-shape: product evolutions

- Improving the overall accuracy & reliability of current service (e.g. integrate approaches adaptive to vegetation/crop changes, test alternatives for ensemble computation)
- Reducing size of excluded areas: e.g. by mapping floodwater in urban areas considering coherence data in addition to intensity data
- Developing value adding services:
    - data assimilation into flood forecasting systems
    - global scale flood hazard and risk analyses

etc.

Data access & user manual

For Product Visualization

https://www.globalfloods.eu/

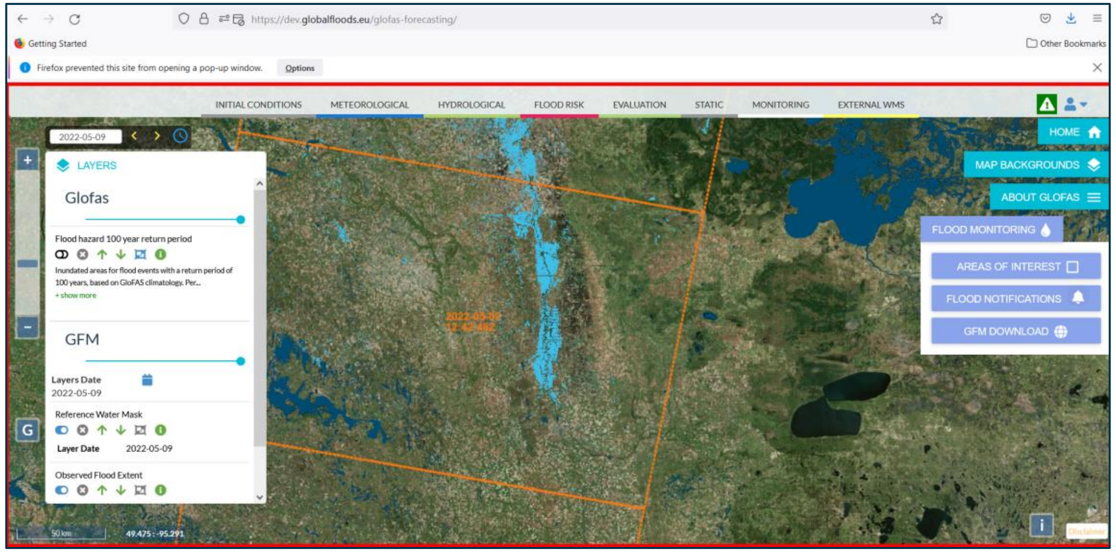
For Product Download and configuration log in at

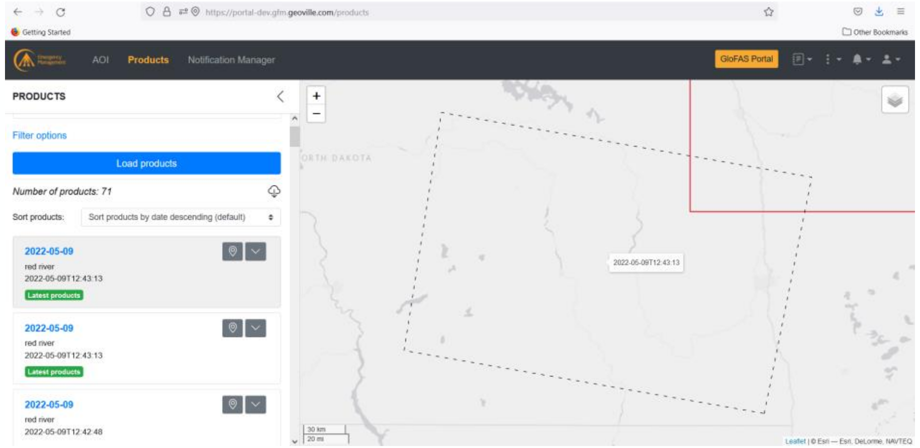
https://gfm.portal.geoville.com/

One login for all components and functionalities (synchronised in the backends)

Product user manual & Product definition document

https://extwiki.eodc.eu/en/GFM





Thank you

patrick.matgen@list.lu

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