EGU 2023

Cutting-edge developments in rapid mapping

Sertit

ICUBE

PICO

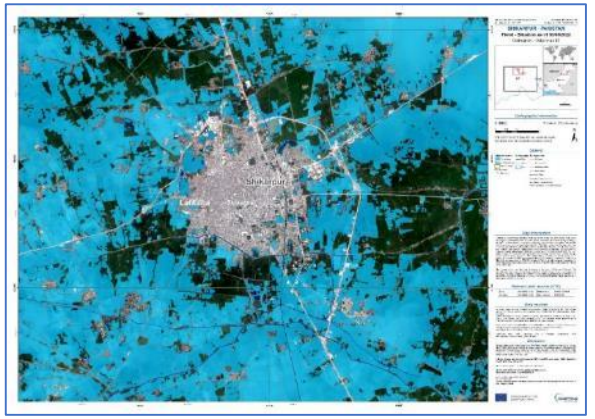
Université de Strasbourg

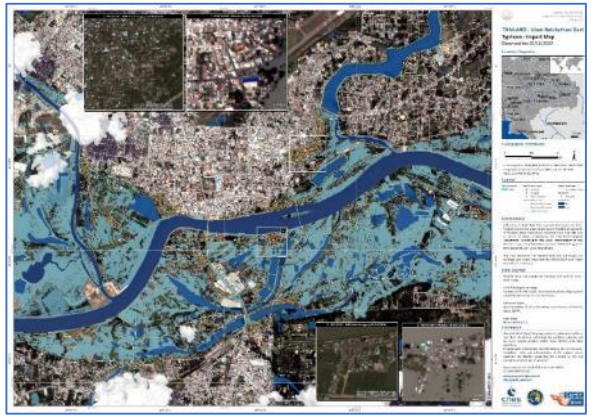
Sertit ICUBE

ICube-SERTIT, University of Strasbourg

- More than **35** years of experience of **valorisation** and **technological transfer** in space techniques and **Earth Observation** applications

https://sertit.unistra.fr/





- Production of **geo-information** for:

Environmental studies

Urban planning

Forest management, Natural ressource monitoring

Natural disaster and crisis management

24/7 Rapid Mapping Service

ExtractEO – Rapid Mapping end-to-end pipelines

extracteo

Capacity to process all remote sensing sensors

Optical/SAR. HR/VHR

Automatic thematic algorithms

Flood

Fire

Processing time meet rapid mapping timeliness

Operational software for rapid mapping production

In-house

SaaS

High quality of crisis delineation

Mean F1 score: 0,90

Ability to process large volumes of EO data

Mega-disaster coverage

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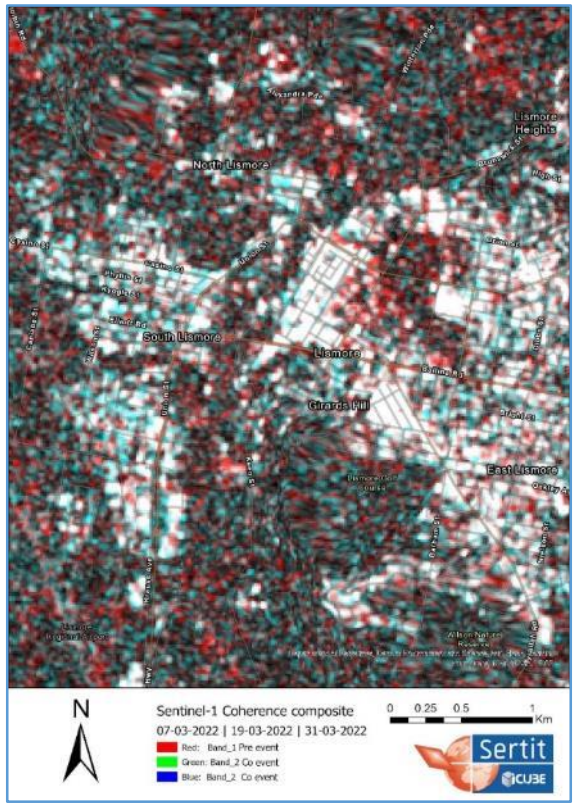
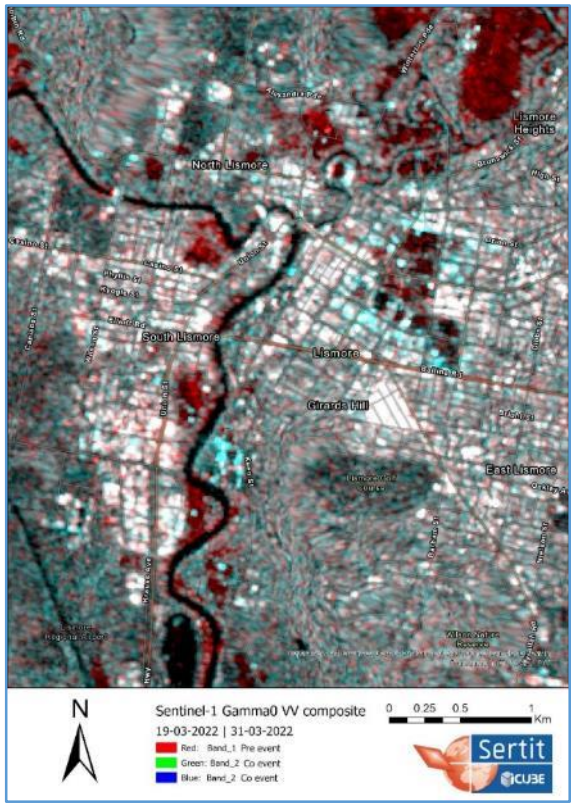
FLORIA – SAR Urban Flood extraction

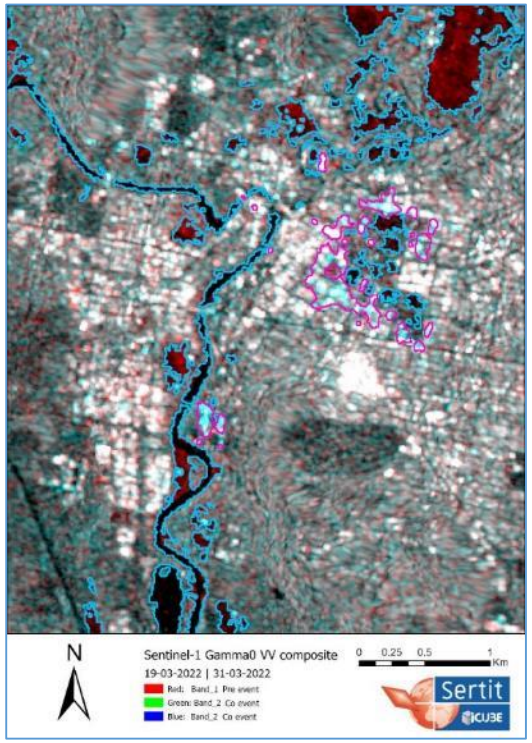
- Urban flood detection with using **inSAR**
- Fully automated and open-source-based software



Coherence decreasing

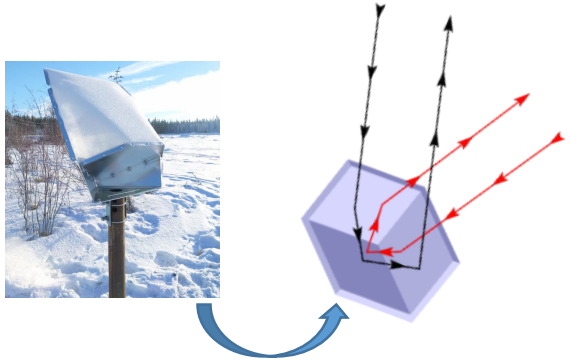


Amplitude increasing

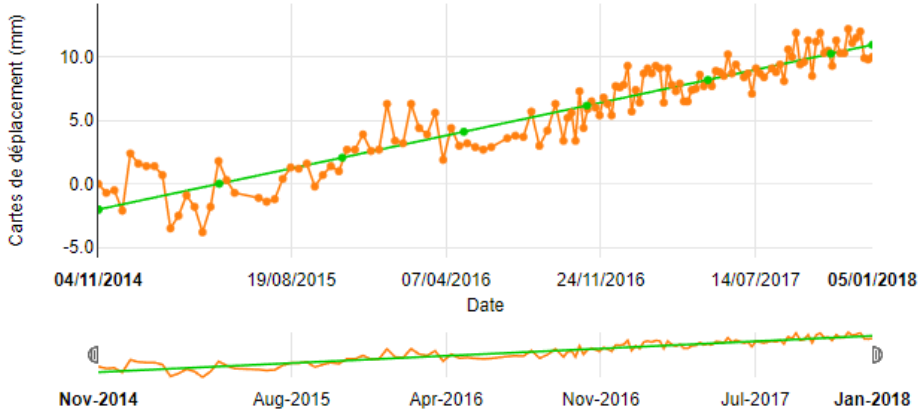


QuickSTAMPS – Point displacement maps

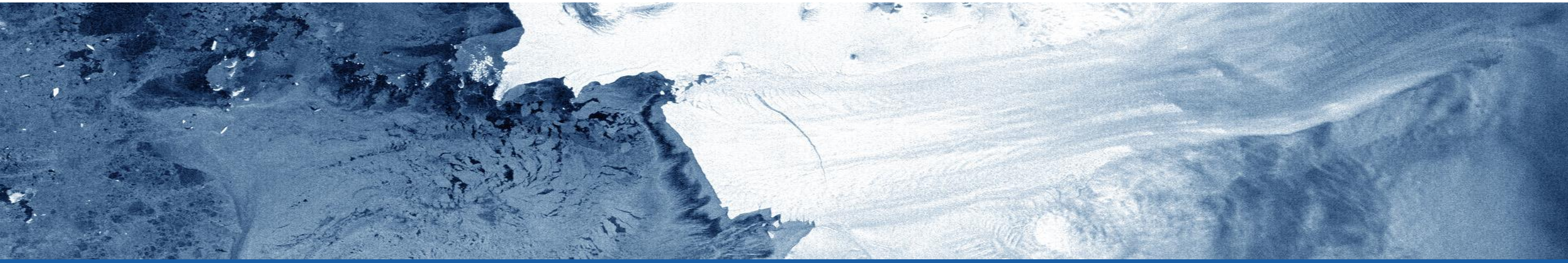
- Uses **permanent scatterer interferometry**
- Fast and semi-automated tool, based on software used by the community



Lochwiller, Grand Est, France [LAT: 48.6957; LON: 7.4171]



Whole presentation



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What to expect

- Introduction
- ExtractEO
  Rapid Mapping end-to-end pipelines
- FLORIA
  SAR Urban Flood extraction
- QuickSTAMPS
  Point displacement maps
- Wrap-up

Introduction

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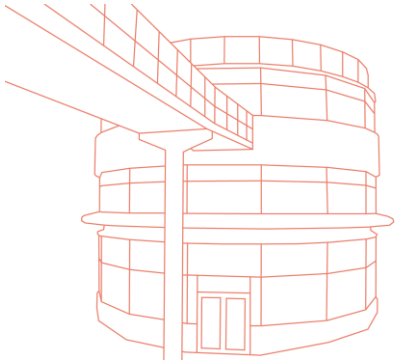
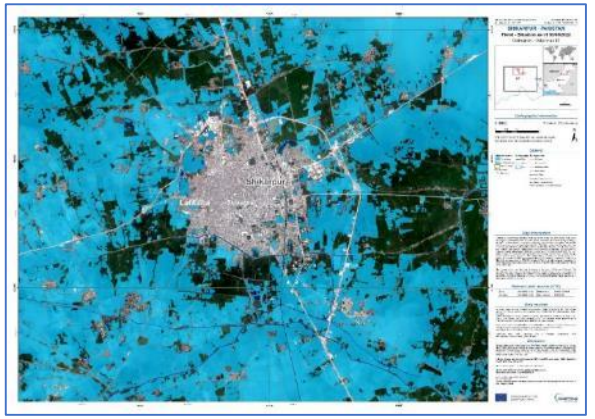


Technological and service platform producing geoinformation from space imagery for:

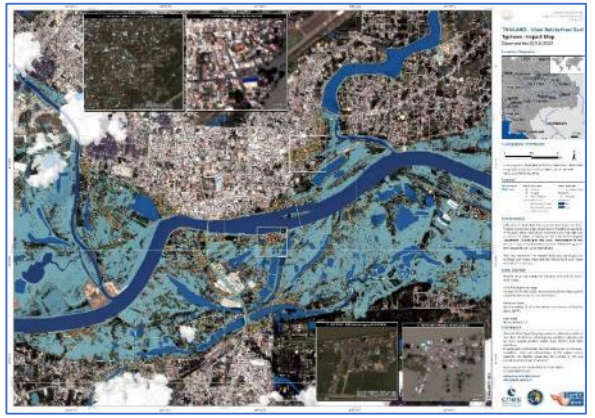
- Natural disasters and risk management
- Natural resources management
- Urban and regional planning

https://sertit.unistra.fr/

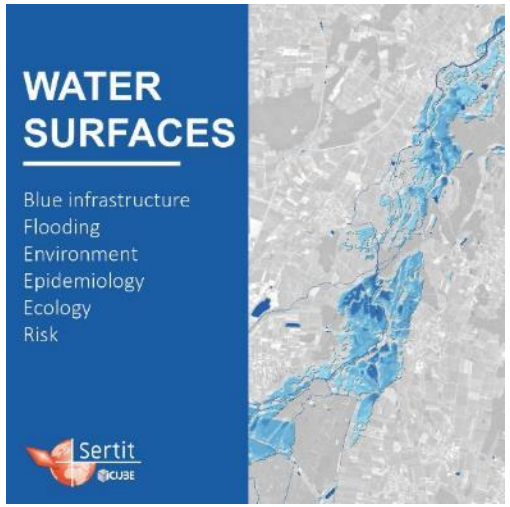


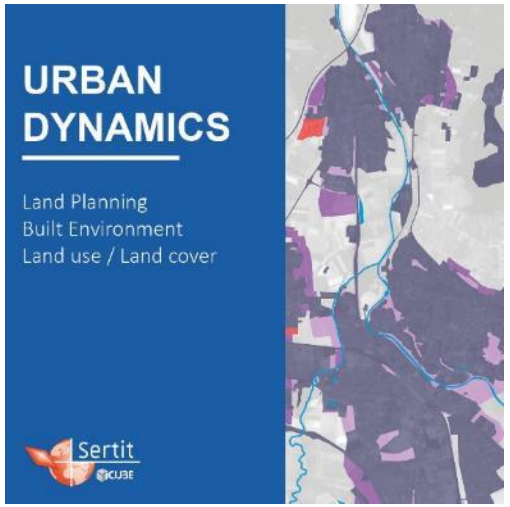
24/7 Rapid Mapping Service involved in:

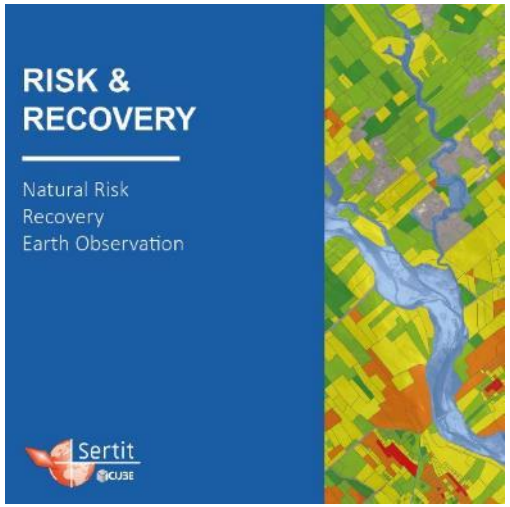
- CEMS Rapid Mapping (RM) and Risk & Recovery Mapping (RRM)
- International Charter Space and Major Disasters
- CEOS Recovery Observatory
- Insurance applications
- Local / regional disaster and risk management
- IWG-SEM (International Working Group on Satellite-based Emergency Mapping)

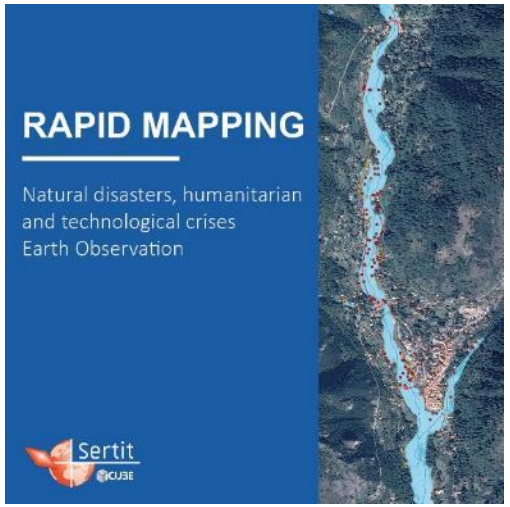


ICube-SERTIT, University of Strasbourg



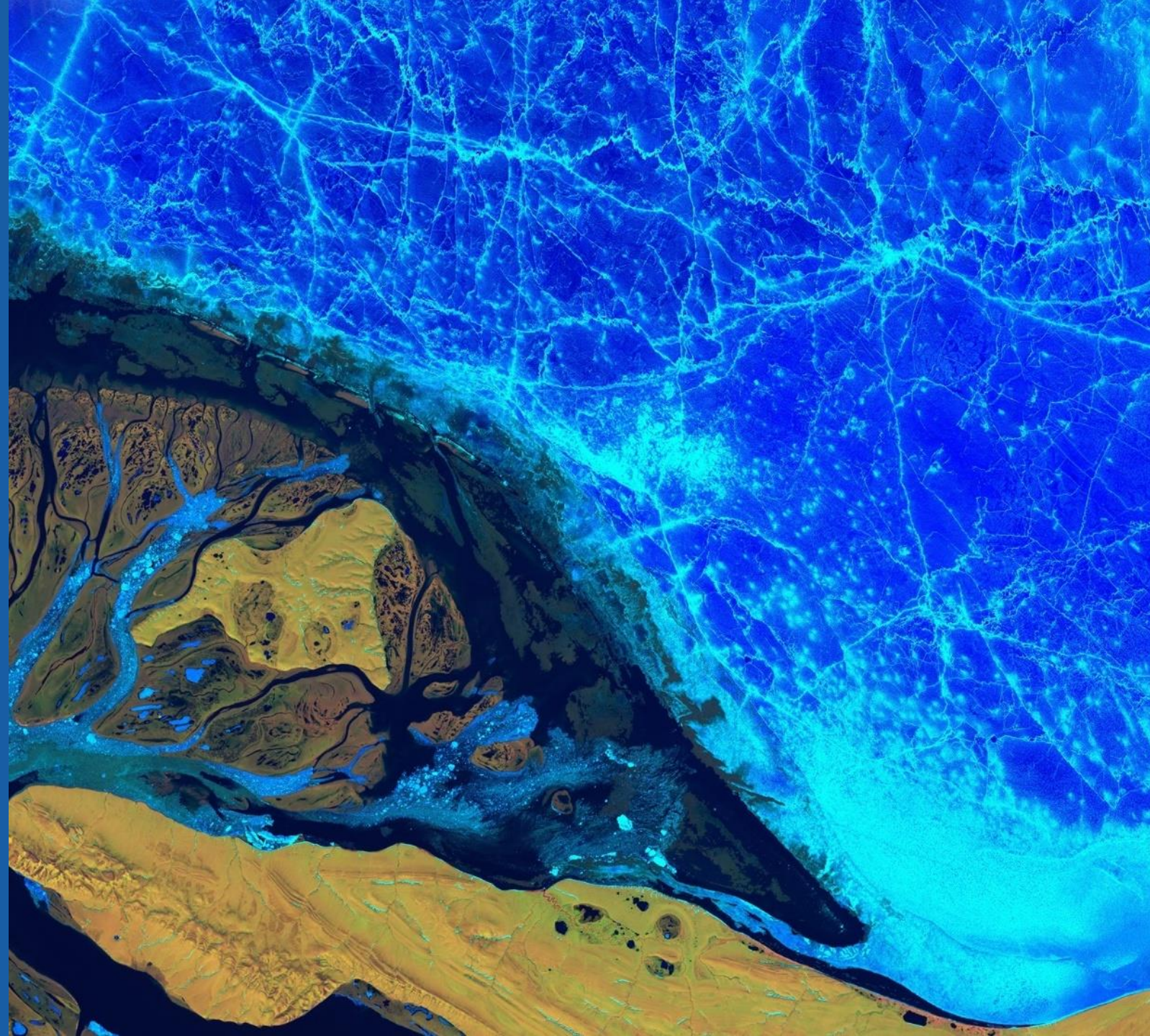






ExtractEO

Rapid Mapping end-to-end pipelines

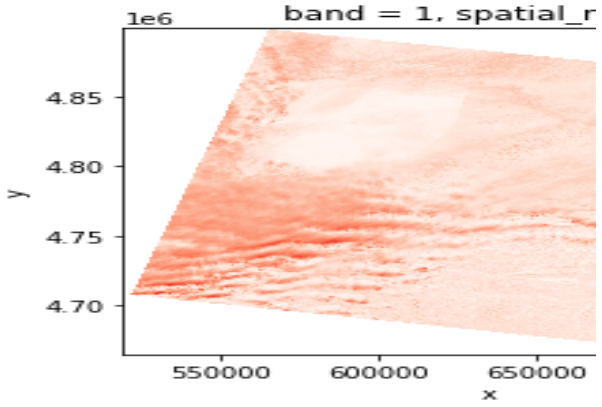


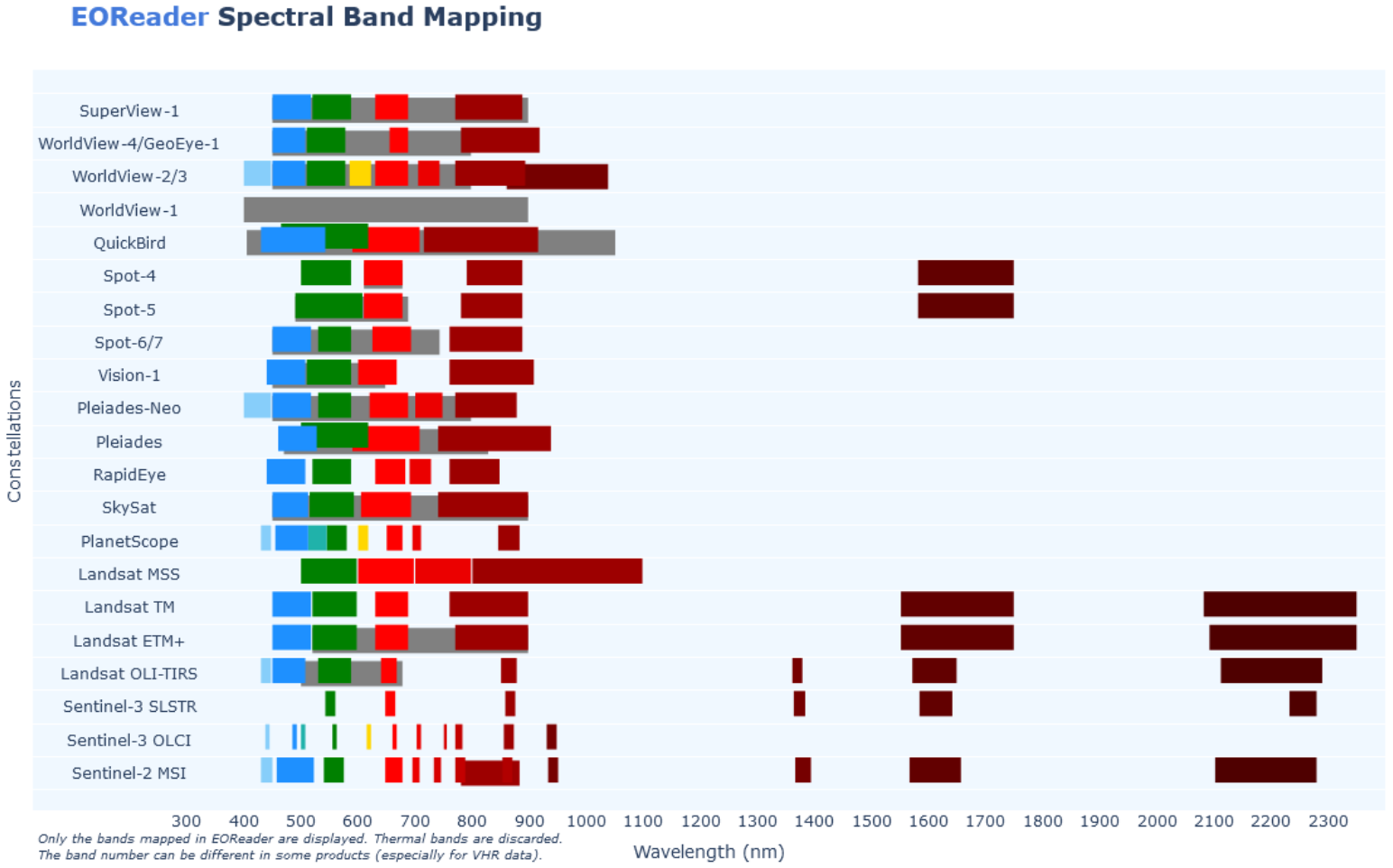
EOReader

- Open source library ingesting satellite data agnostically

Notebook

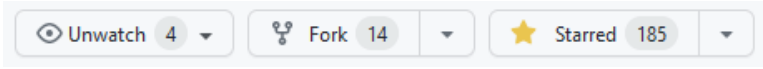
```
%matplotlib inline
reader = Reader()
for path in paths:
    # Open the product
    prod = reader.open(path

    # Load NIR
    nir = prod.load(NIR)[NI

    # Plot
    nir[:, ::5, ::5].plot(
    plt.show()
```





Why EOReader?

- **Simplify** and **harmonize** the use of satellite data
  - Code is **sensor-agnostic**
  - **Easy** to update with **new sensors**
  - **Automatic preprocessing** and **spectral index calculation**
- **Increase the reliability** of the production tools
  - Maintenance and testing are **simplified**
  - Code is **more readable**
- **Opensource** and **community friendly**



@eoreader

EOReader – Available constellations

Optical constellations	SAR constellations
Sentinel-2 and **Sentinel**-2 Theia **Sentinel**-3 OLCI and SLSTR	**Sentinel**-1
Landsat 1 to 9 (MSS, TM, ETM and OLI)	**COSMO-Skymed** 1st and 2nd Generation
Harmonized Landsat-Sentinel (**HLS**)	**TerraSAR-X**, **TanDEM-X** and **PAZ SAR**
PlanetScope, SkySat and **RapidEye**	**RADARSAT**-2 **RADARSAT**-Constellation
Pleiades-Neo and **Pleiades** **SPOT**-6/7 and **SPOT**-4/5	**ICEYE**
Vision-1	**SAOCOM**-1
WorldView-1 to 4, **GeoEye**-1, **QuickBird**	**Capella**
SuperView-1	
GEOSAT-2	

ExtractEO

- Software designed for rapid mapping
  - Fast, reliable, automated, adaptable and modular

extracteo

Capacity to process all remote sensing sensors Optical/SAR. HR/VHR	Automatic thematic algorithms Flood Fire	Processing time meet rapid mapping timeliness
Operational software for rapid mapping production In-house SaaS	High quality of crisis delineation Mean F1 score: 0,90	Ability to process large volumes of EO data Mega-disaster coverage

ExtractEO

- Software used for usual crisis
  - Fire
  - Floods
  - Landslides

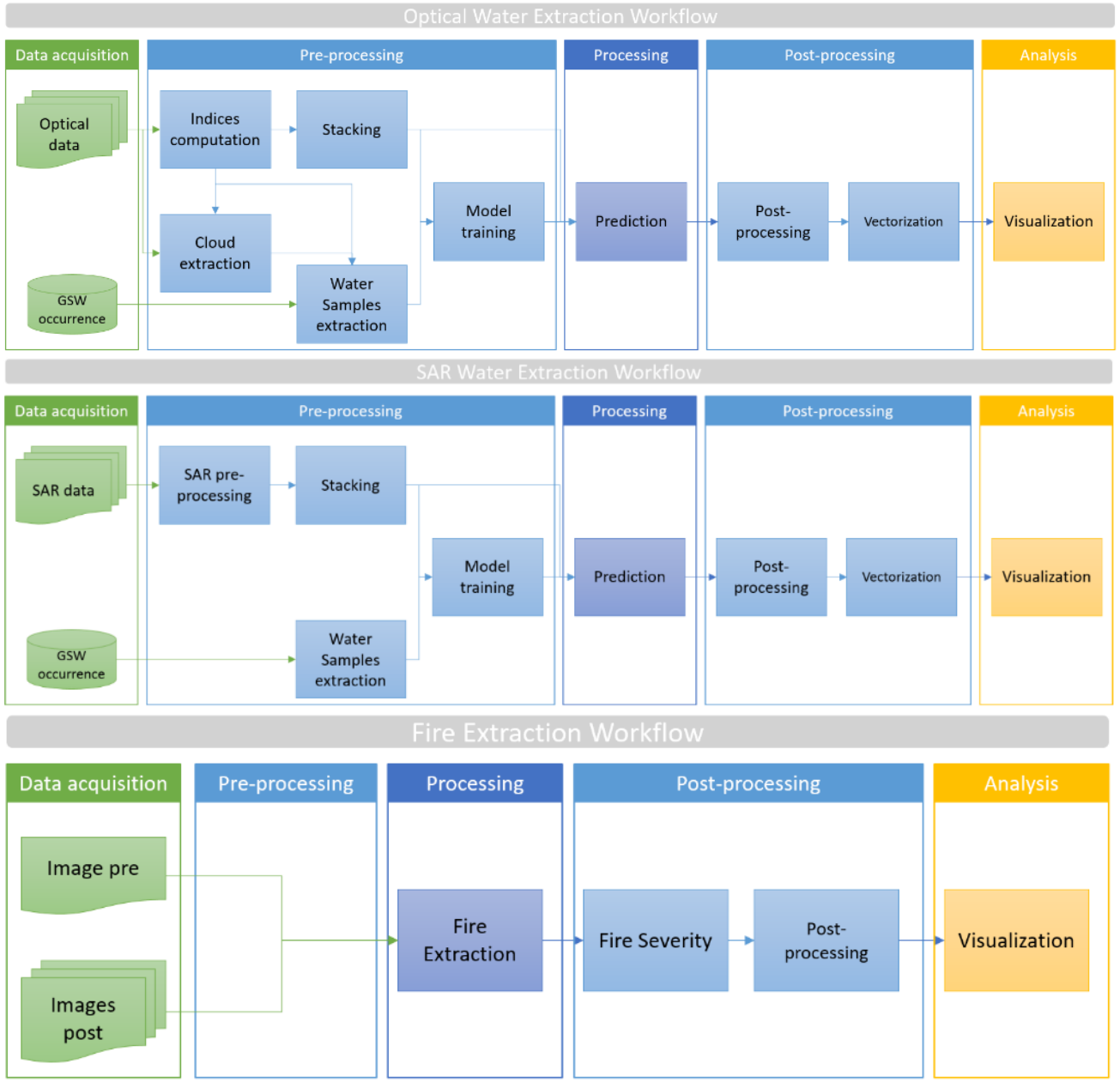
- Product handling with EOReader

- End-to-end pipelines
- **Technical note** in Remote Sensing

ExtractEO, a Pipeline for Disaster Extent Mapping in the Context of Emergency Management

by Jérôme Maxant * , Rémi Braun , Mathilde Caspard and Stephen Clandillon

EOReader and ExtractEO
https://doi.org/10.3390/rs14205253

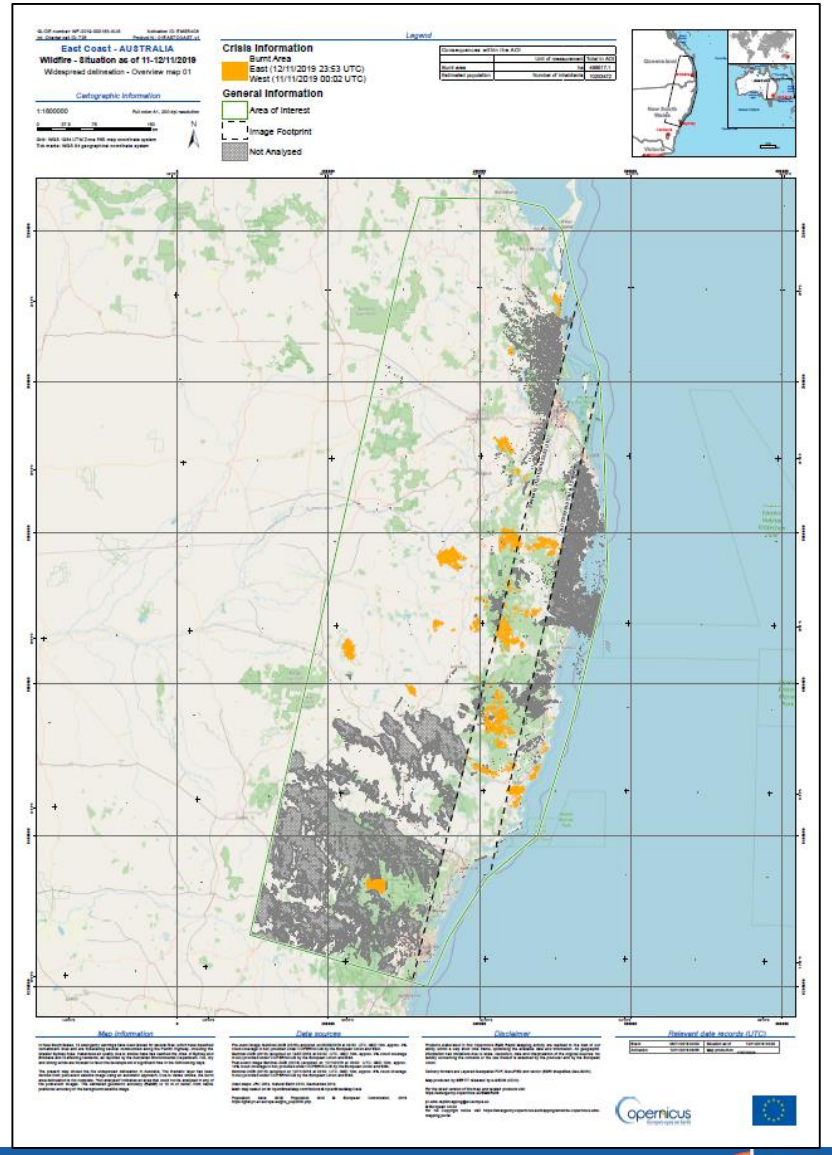


Results – Mega Disasters

Fires in Australia (11/2019)

- 315 000 km² analyzed
- 5 000 km² burnt
- 51x2 + 21x2 Sentinel-2 tiles
- 1h of automatic process (51x2)

Download, fire and cloud detection, MMU, stacking, mosaicing and vectorisation



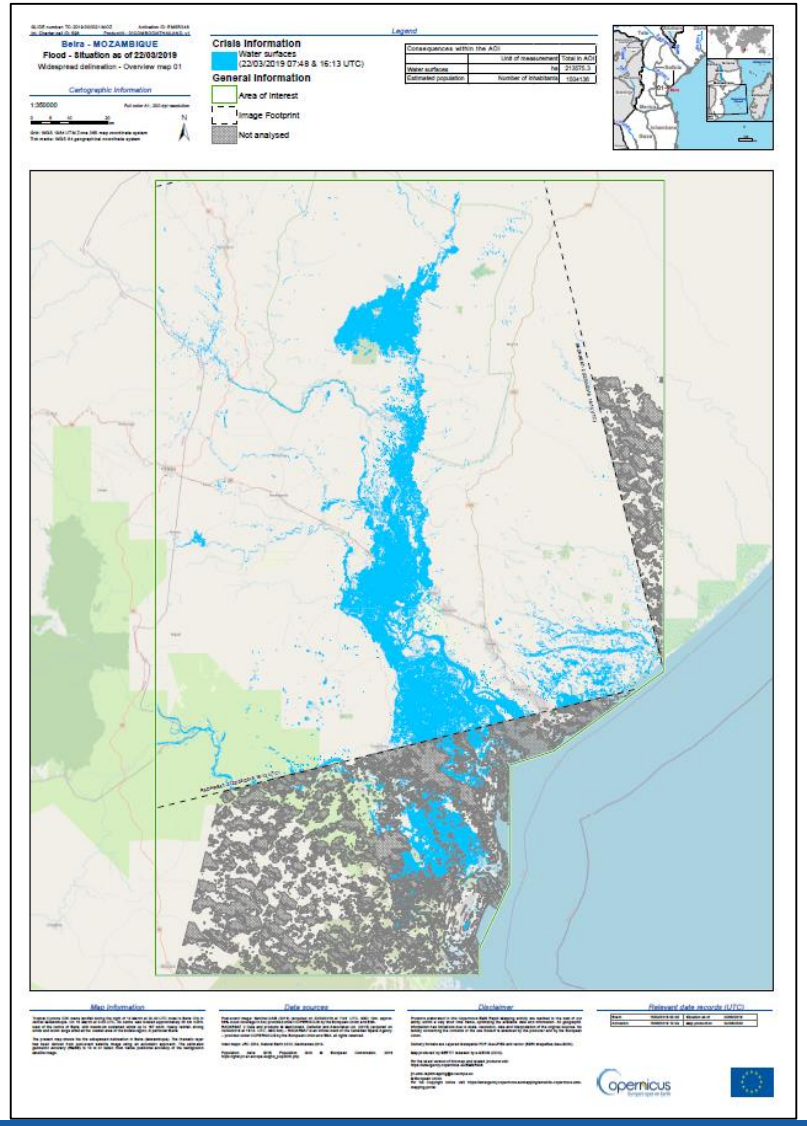
Results – Mega Disasters

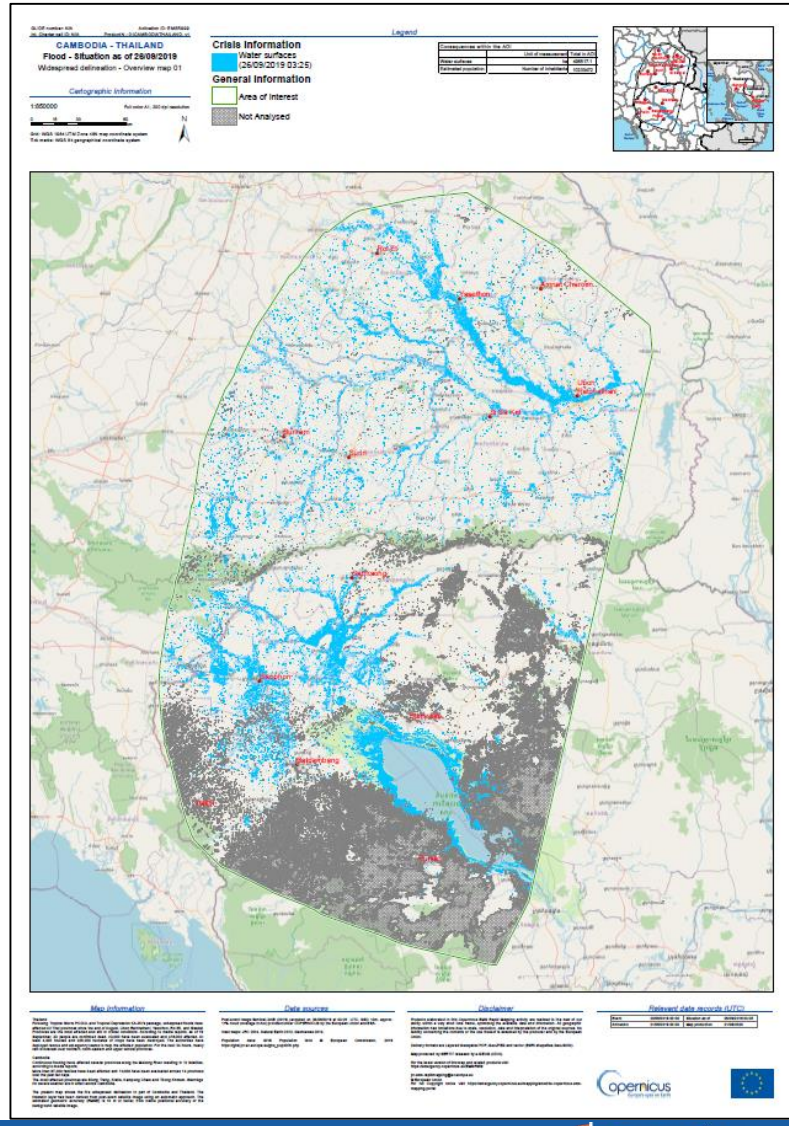
Floods in SE Asia (09/2019)

- 115 000 km² analyzed
- Sentinel-2

Floods in Mozambique (03/2019)

- 25 000 km² analyzed
- Sentinel-2 / Radarsat-2
  Multi-sensor (SAR et optical)

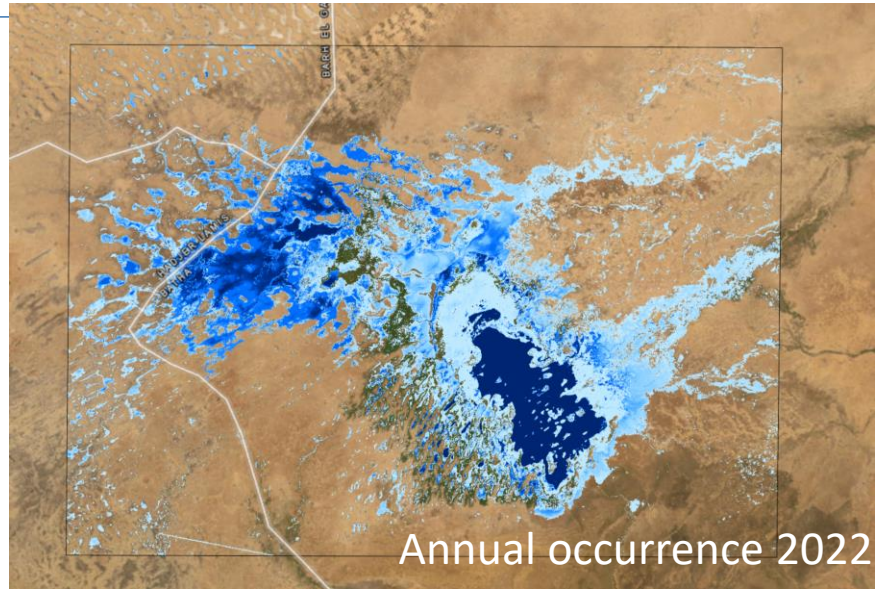


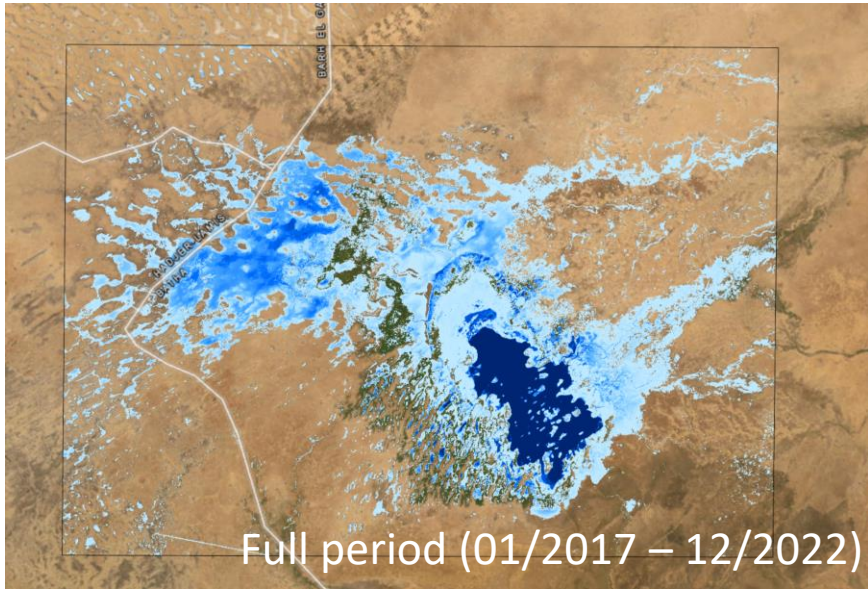


Results – Time Series and Occurrences

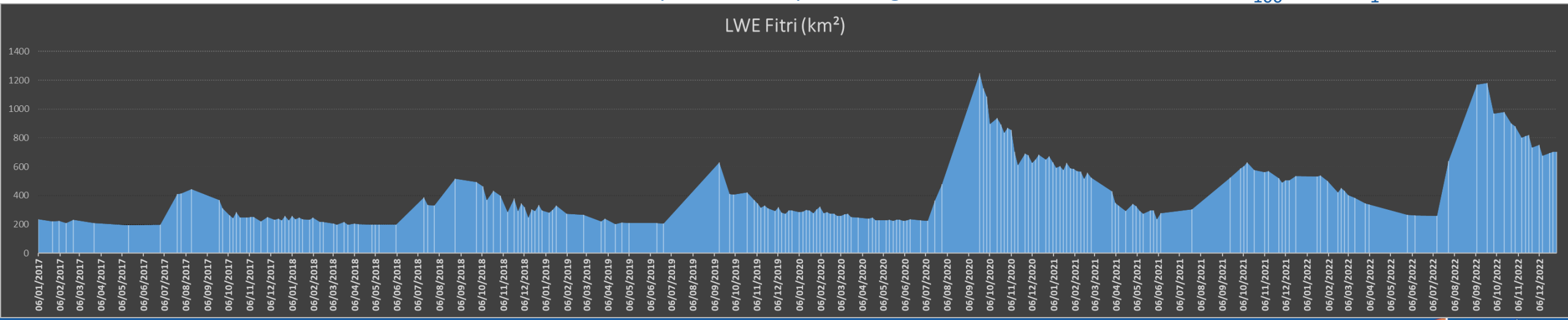
Lake Fitri (Chad)

- Sentinel-2 time series exploitation
- From 01/2017 to 12/2022





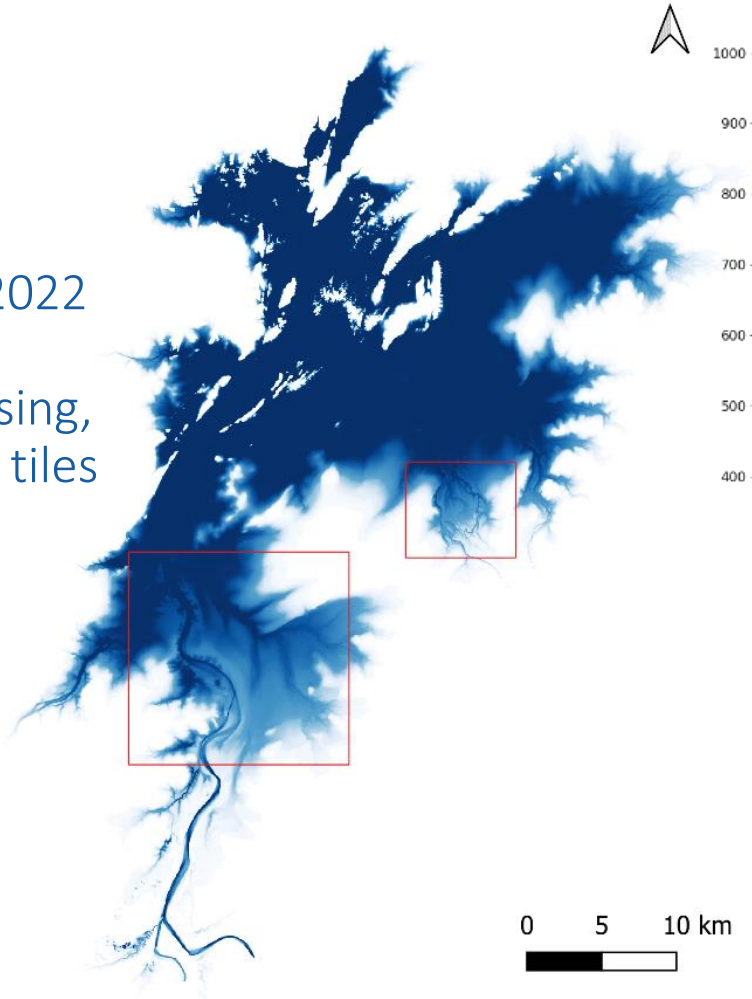
Occurences expressed as a percentage of total observations [0;100]

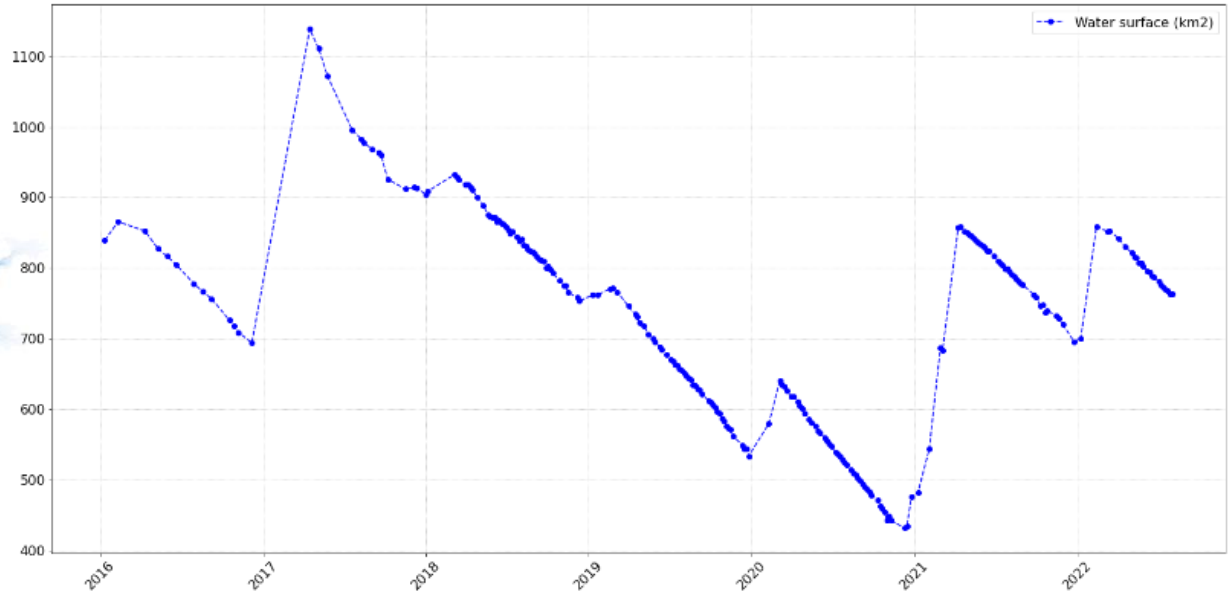


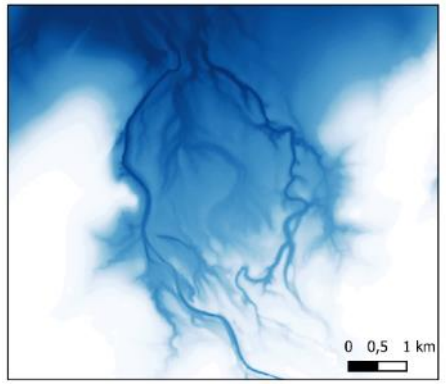
Results – Time Series and Occurrences

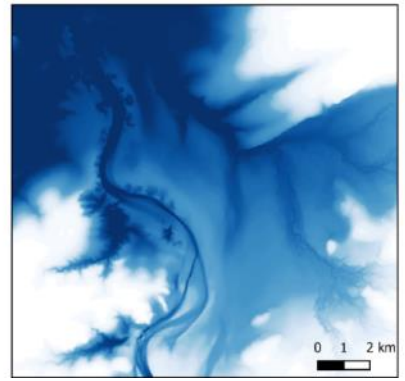
Lake Argyle (Australia)

- 1280 km² analyzed
- 390 dates between 23/10/2015 and 02/08/2022
- 40h of automatic processing, 3 minutes per Sentinel-2 tiles









Limitations, conclusion and perspectives

Conclusion

- Tool satisfying every rapid mapping needs in term of:
  - Performances
  - Sensor versatility

Limitations

- Complicated thematic cases not handled
- Limited use of Deep Learning for now (hard to scale to operations)

Perspectives

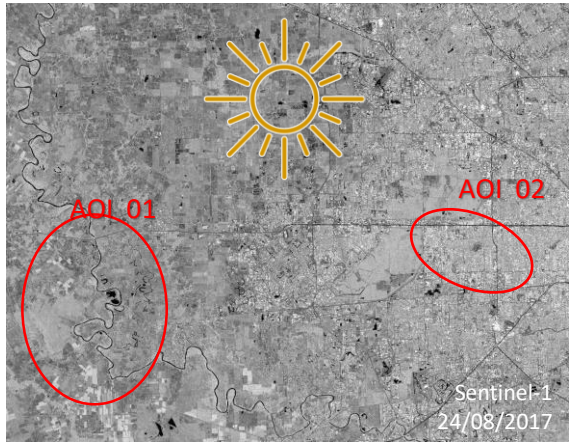
- Cloud infrastructure
  Parallelization, clusterization, SaaS
- Other thematic extractions

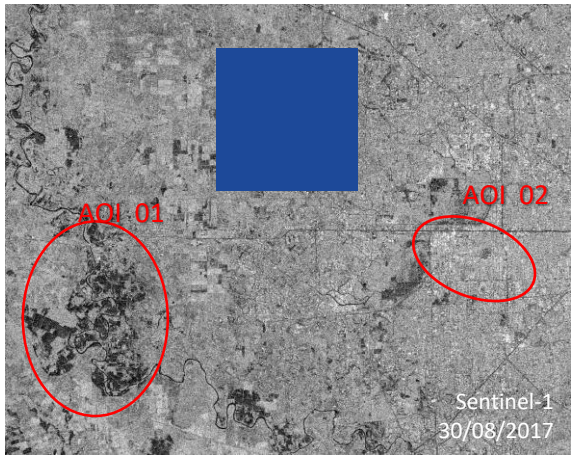
FLORIA

FLOodwater detection over urban areas using Radar and artificIAl intelligence

Why FLORIA ?

- Observe through the clouds ?
  - ⊘ Optical
  - ✓ SAR
- One SAR image can map the flood ?
  - ✓ AOI01 (open air)
  - ⊘ AOI02 (urban area)
- Several SAR images can map the flood ?
  - ✓ AOI01 (open air)
  - ✓ AOI02 (urban area)





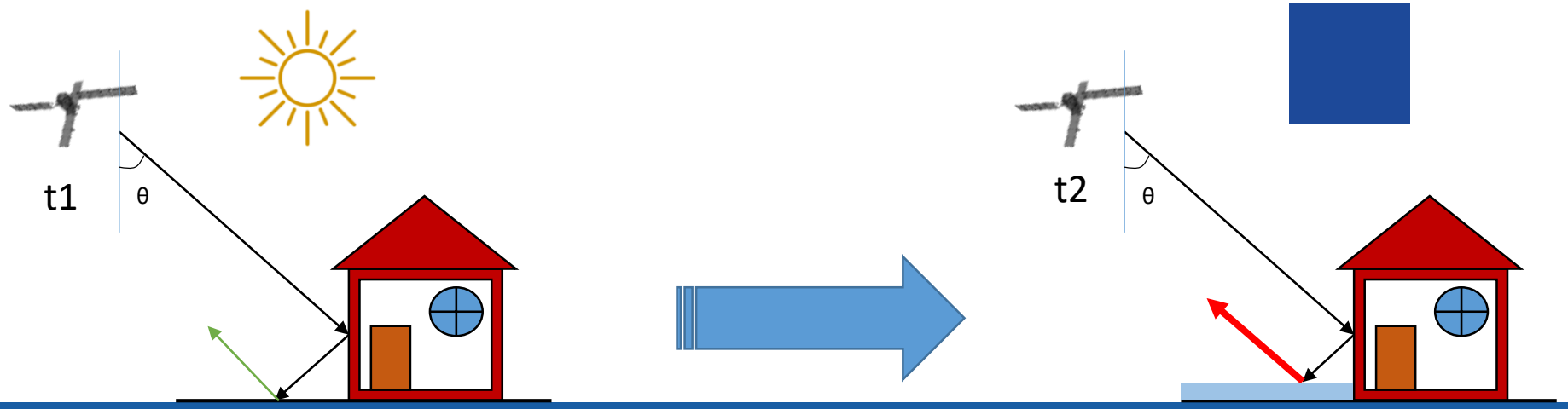
How does it work?

During flood events

- Coherence (ρ) : normalized cross-correlation between 2 signals.

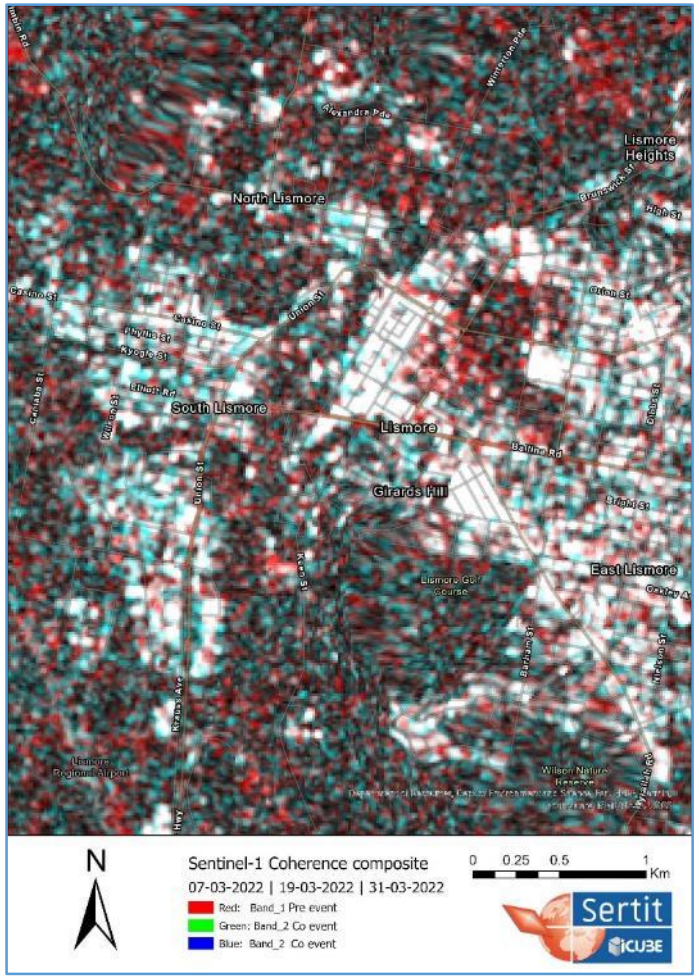
$$\rho_{t-1} < \rho_{t0}$$

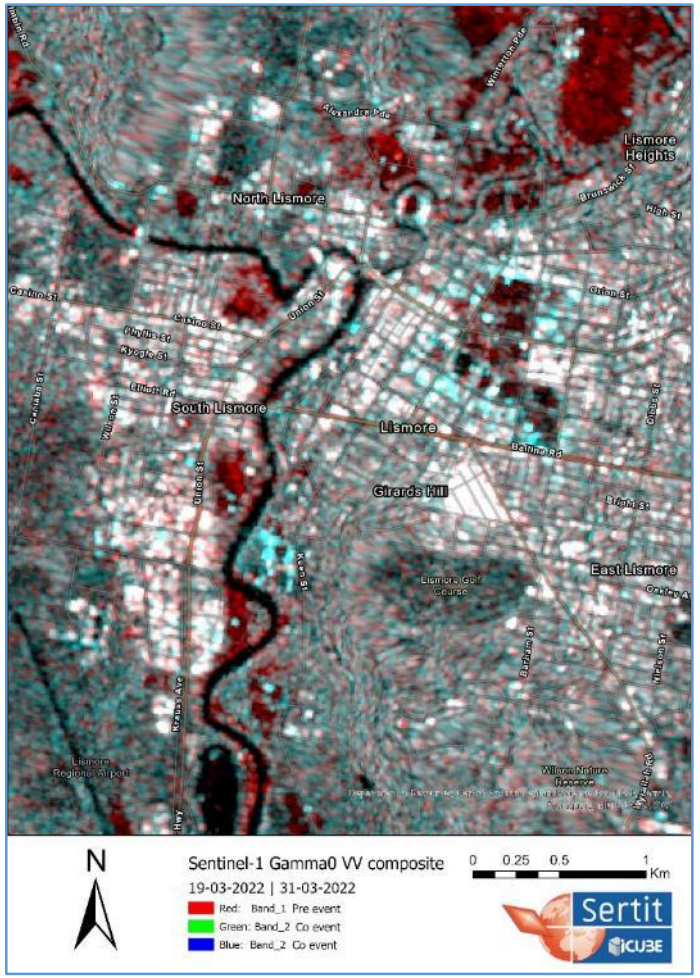
- Amplitude: intensity of the backscattered signal.

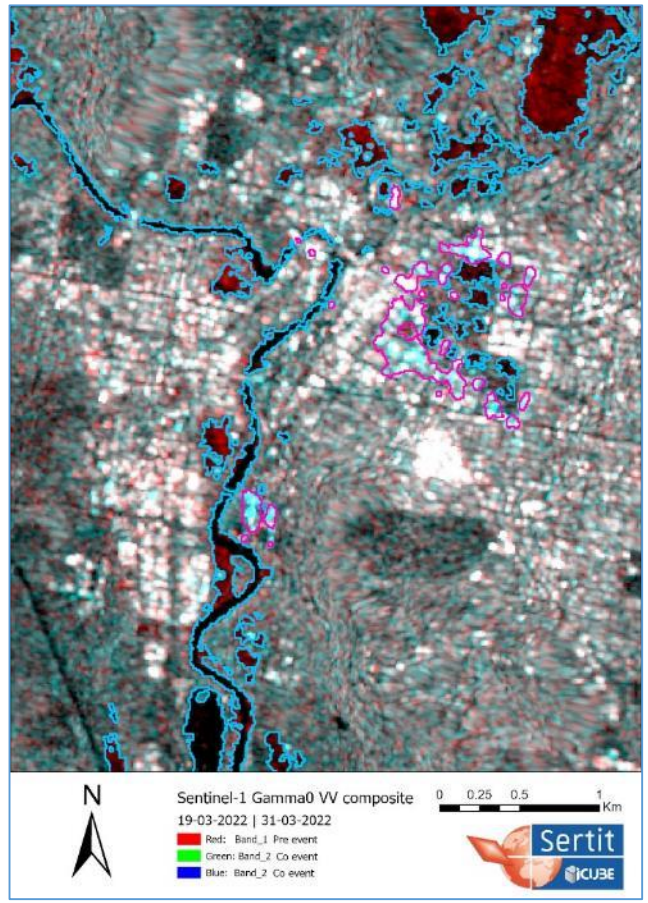


Lismore exemple

- Coherence decreasing
- Amplitude increasing

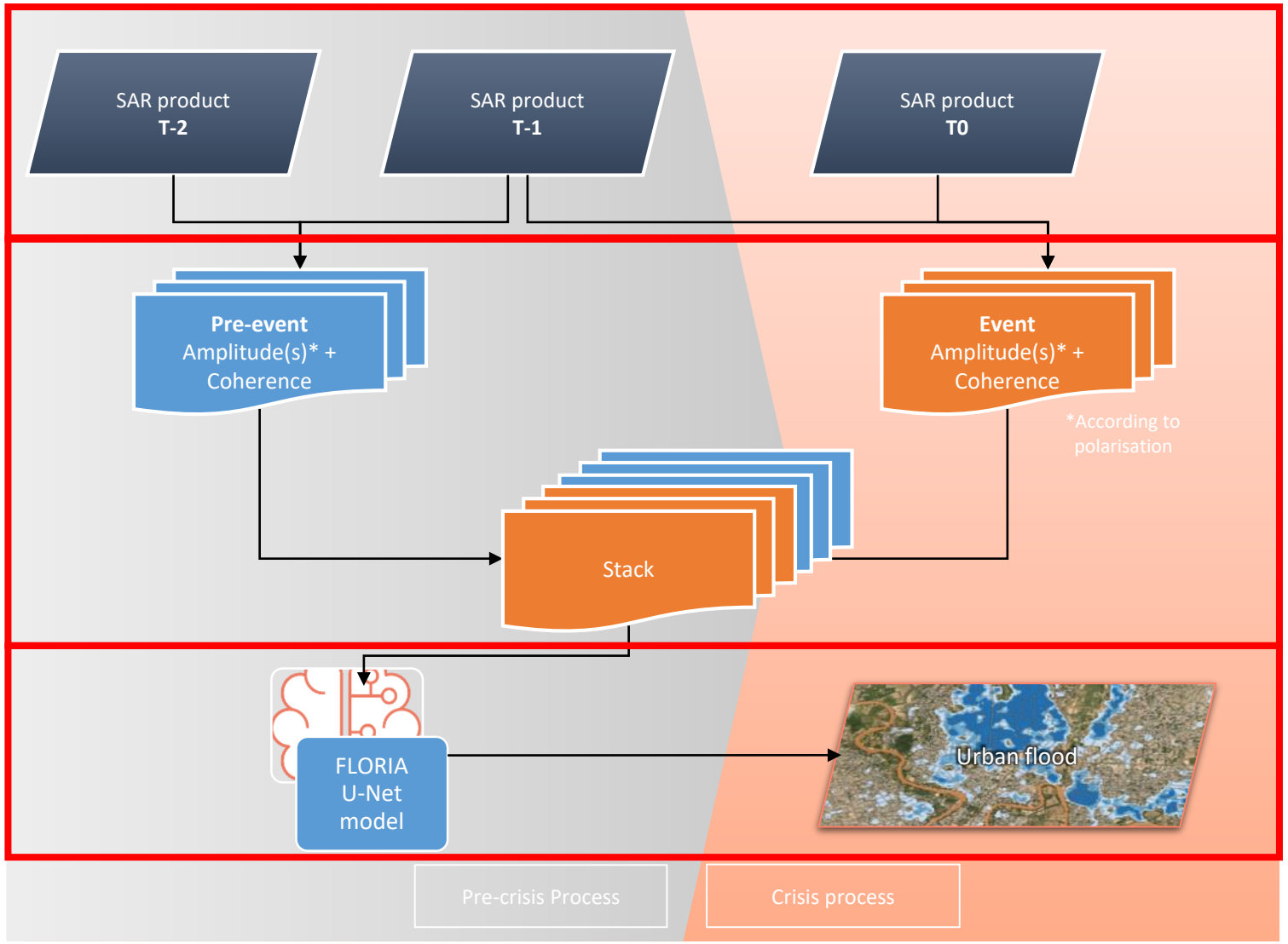






FLORIA's Workflow

FLORIA



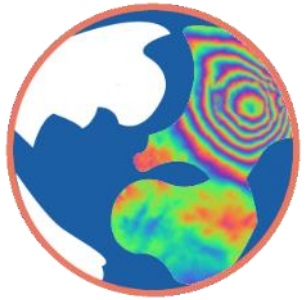
EOReader

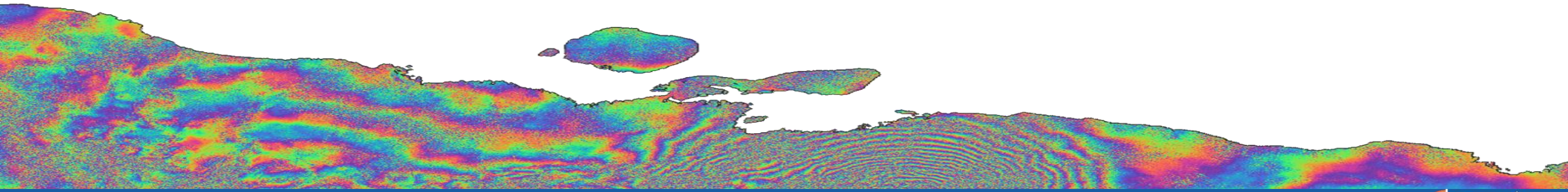
SAR processing

Extraction

SAR processing

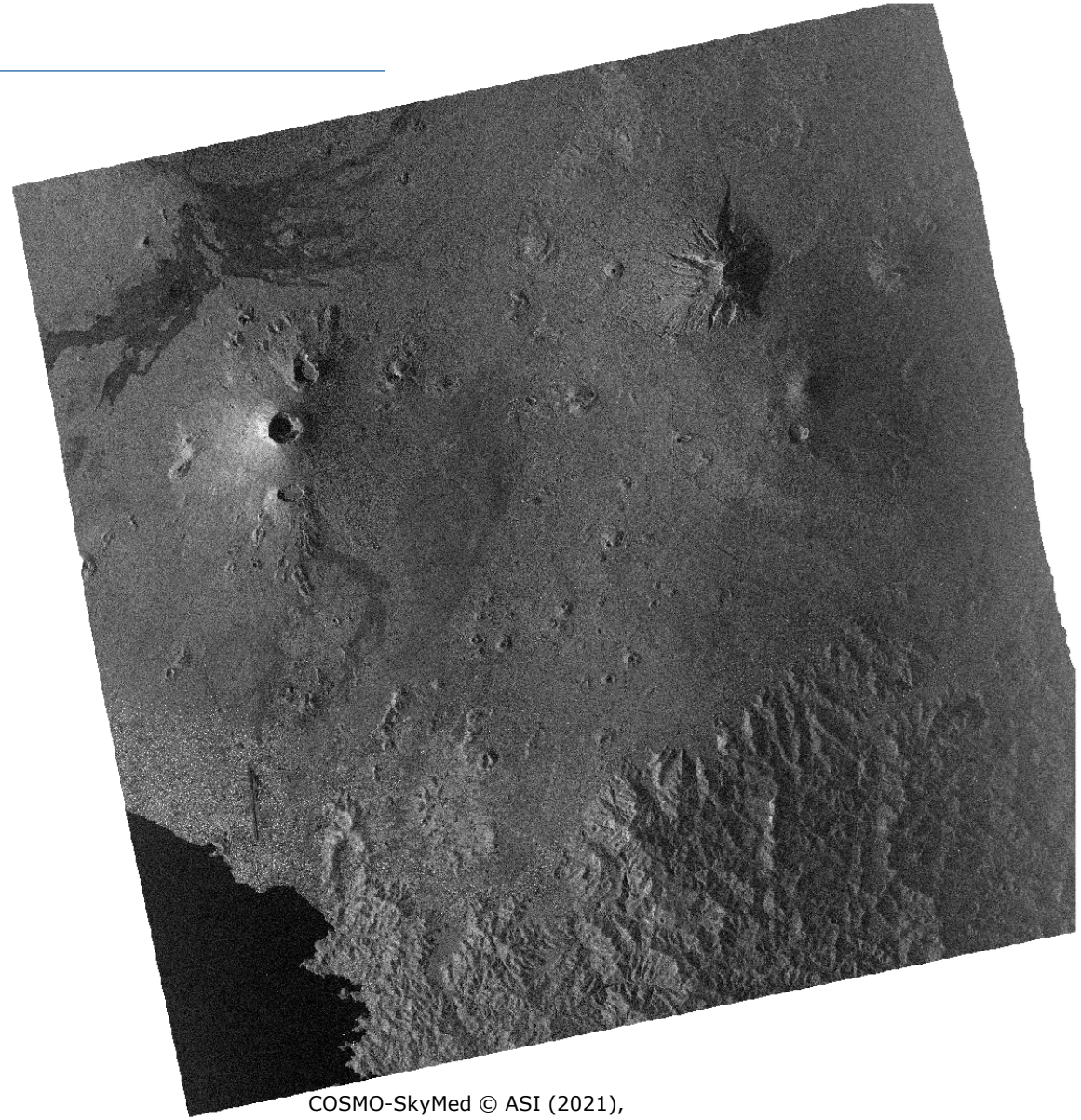
- **SarPair** : a Python interferometry-oriented library
  - Built in **Python**
  - Based on **EOReader**
  - Calling **SNAP** (an ESA open source software)
  - Specific to pairs of SAR products for interferometric processes, but not only.
  - Private code, only on SERTIT ’s forge





SAR processing

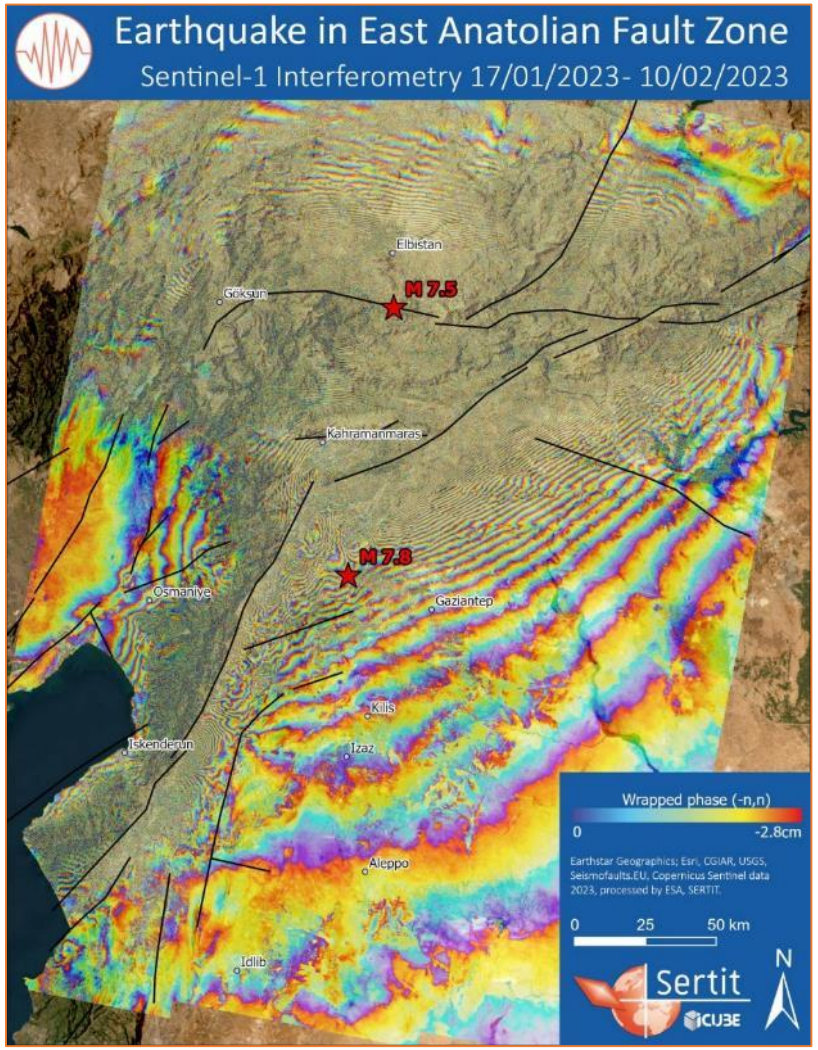
- **SarPair SAR** processes
  - Orthorectification
  - Calibration
  - Object detection
  - Fine tuning

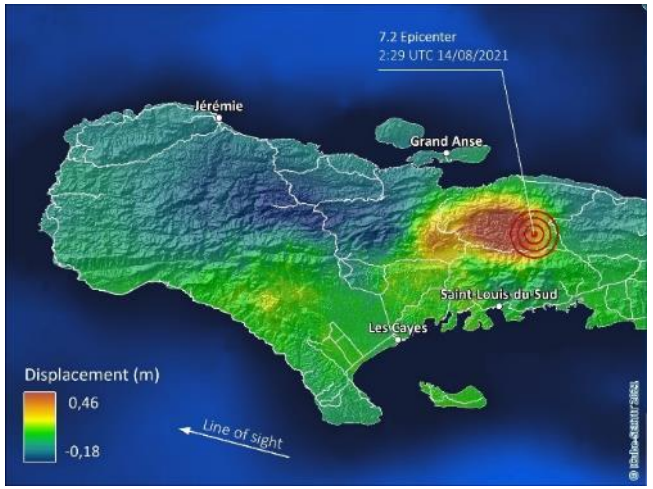


COSMO-SkyMed © ASI (2021),

SAR processing

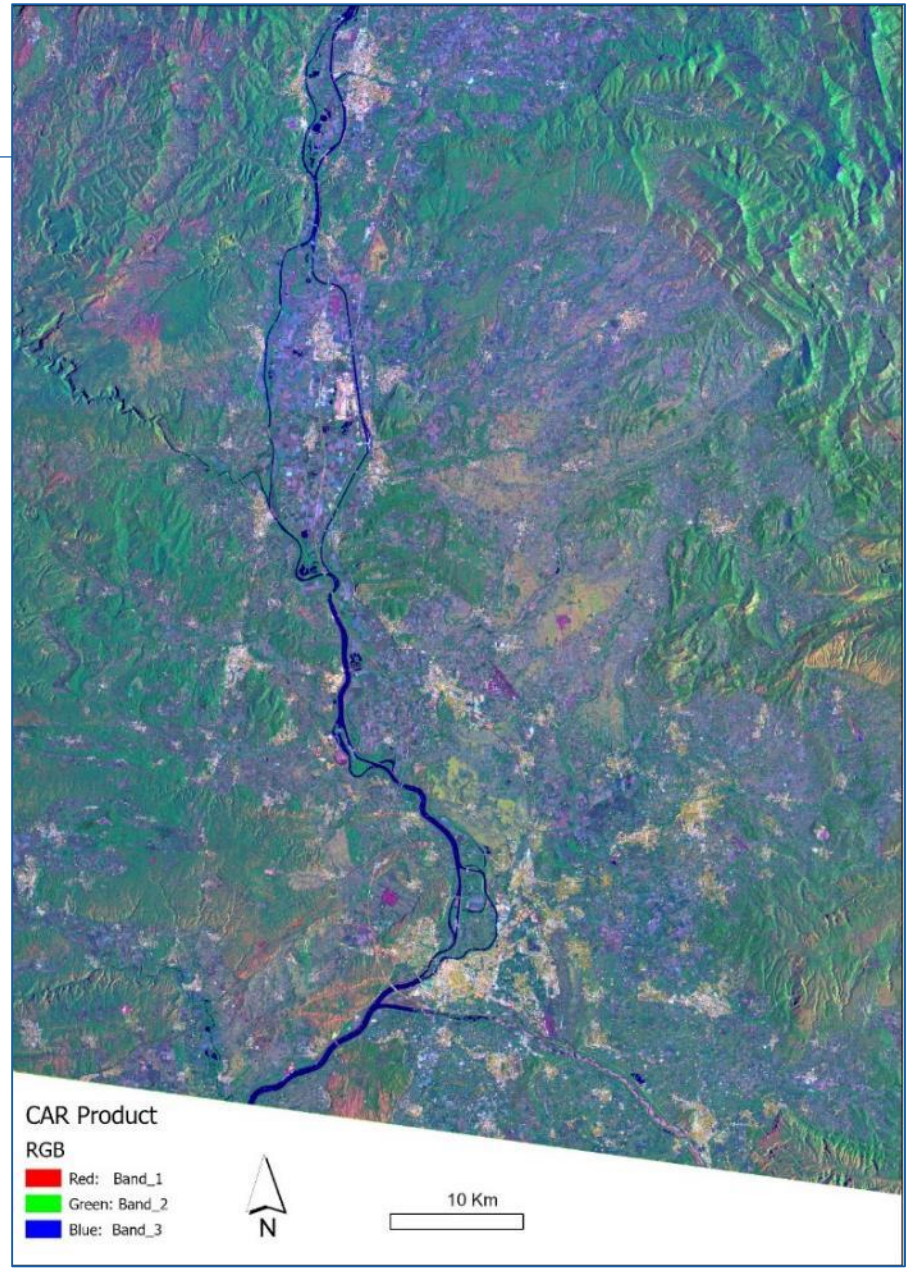
- **SarPair inSAR** processes
  - Ground Movement
  - DEM generation
  - Coherence





SAR processing

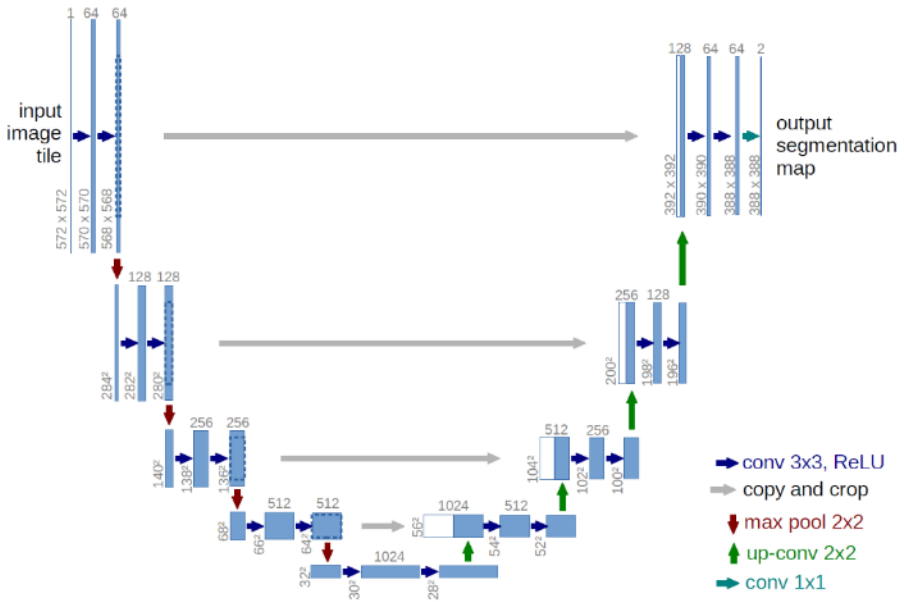
- **SarPair** Custom Stacks
  - CAR Products (Coherence-Amplitude-Ratio)
  - FLORIA stack

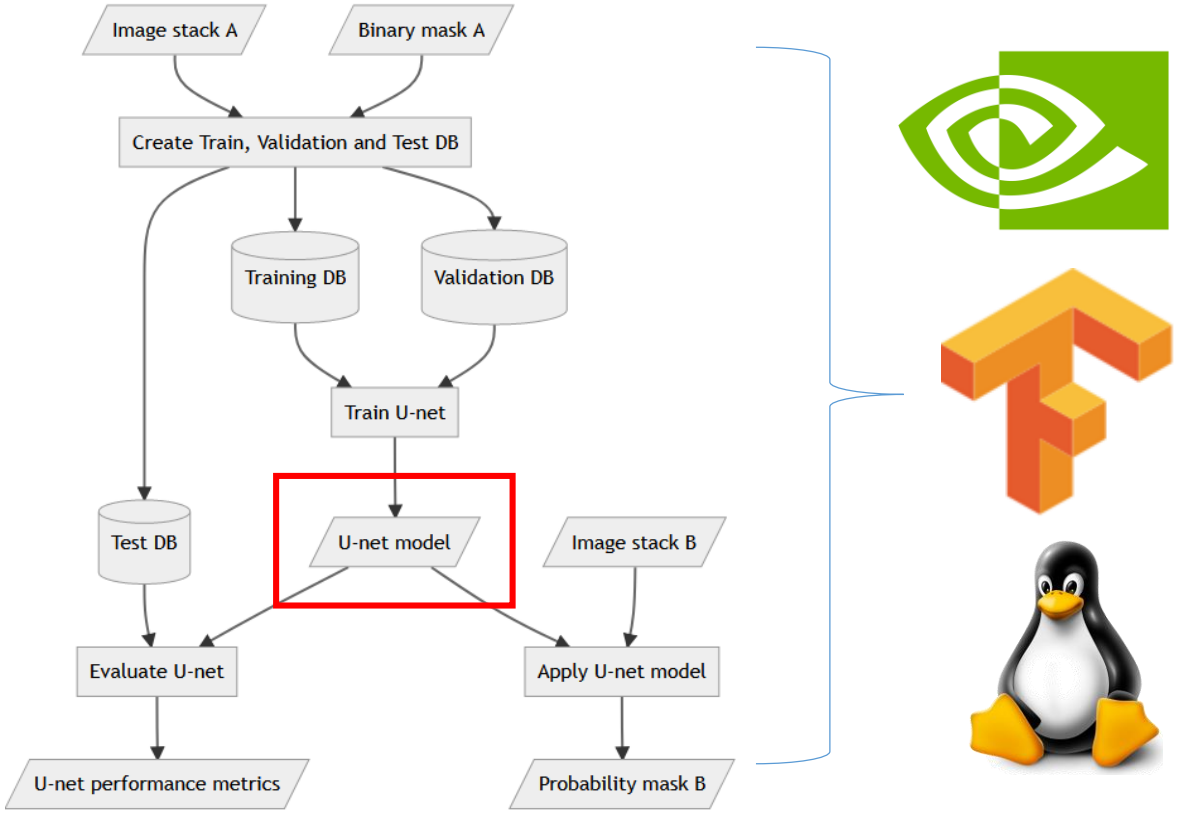


Extraction

RUST: *Remarkable U-net for Semantic-segmenTation*

Python custom library for processing satellite imagery via U-Net convolutional neural network

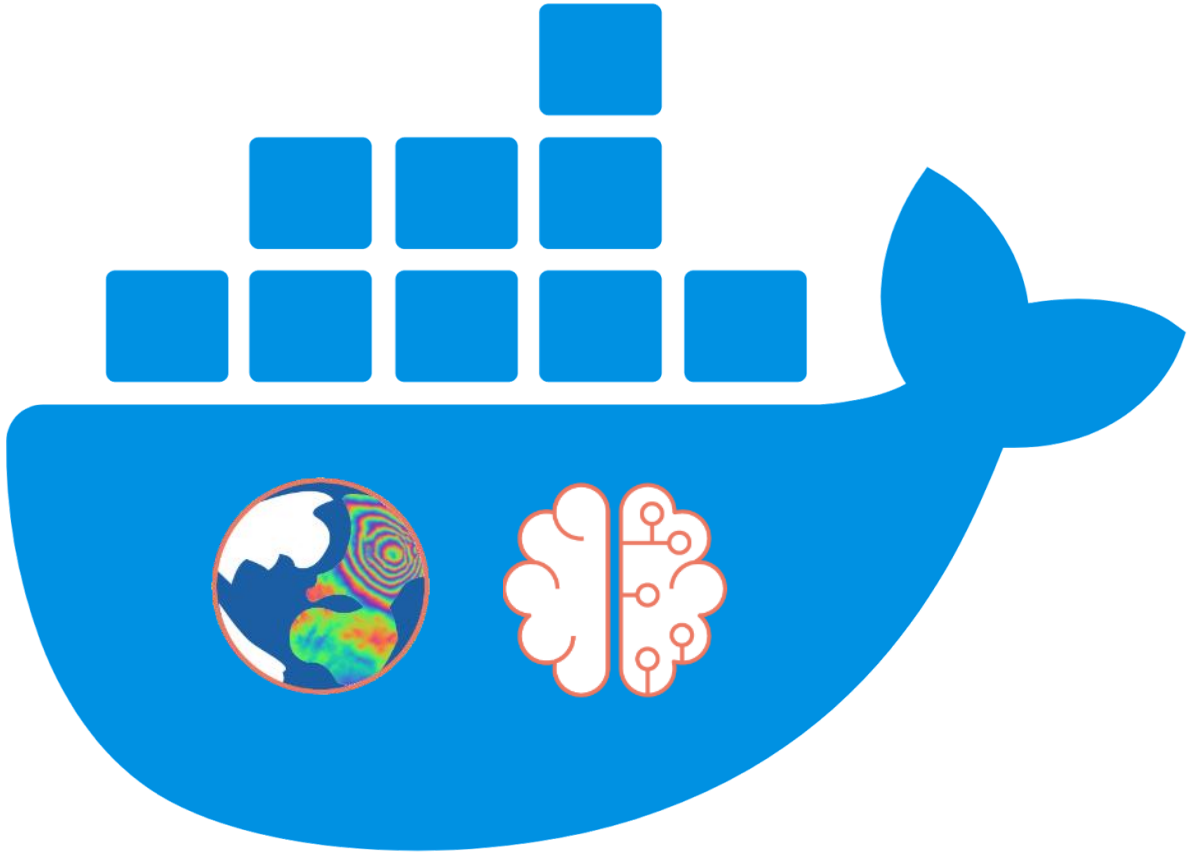




Containerization

Docker: a container to master the environment

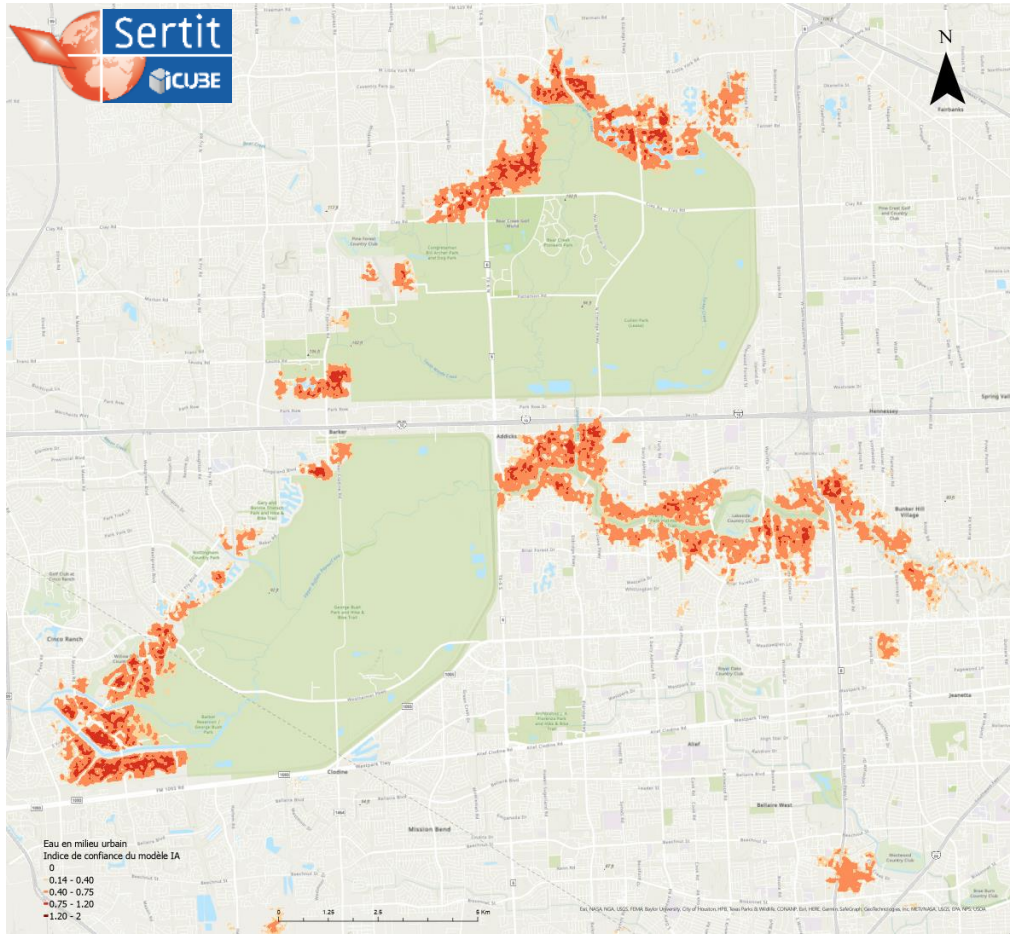
- One FLORIA's container
- Easy to Share
- Easy to Run



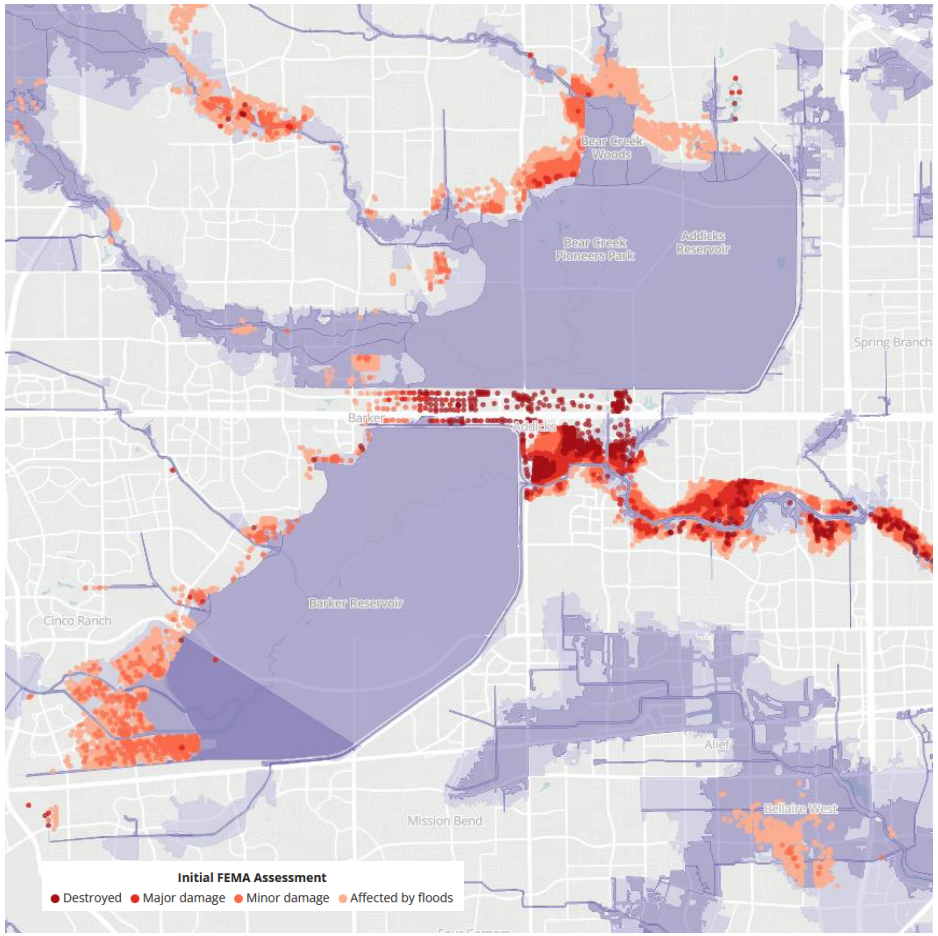
Results

Houston and Hurricane Harvey, USA 2017

FLORIA



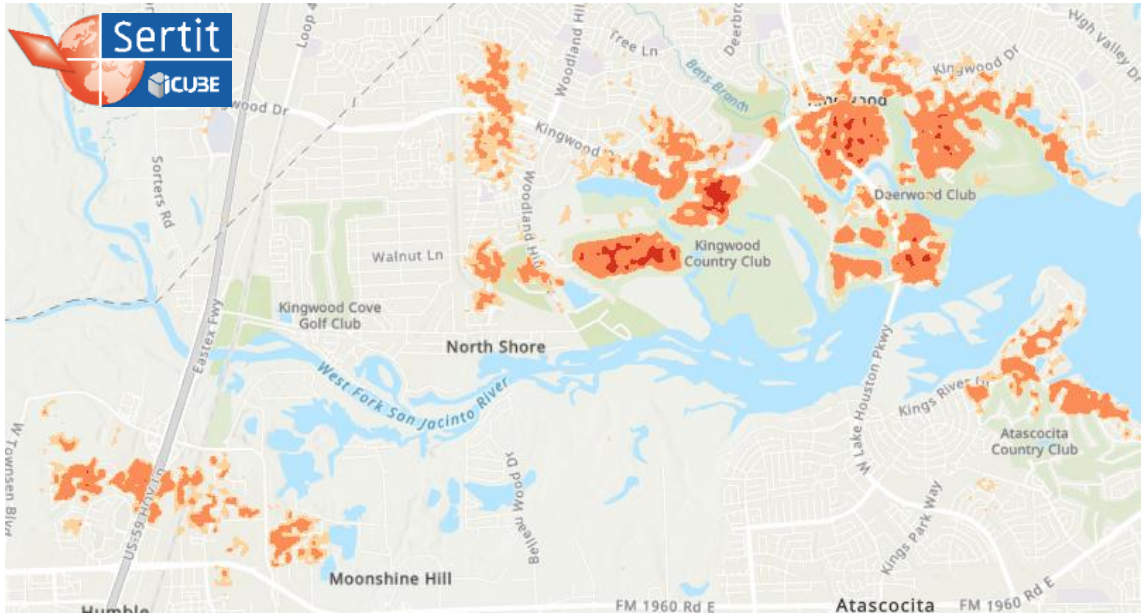
Initial FEMA model assessment



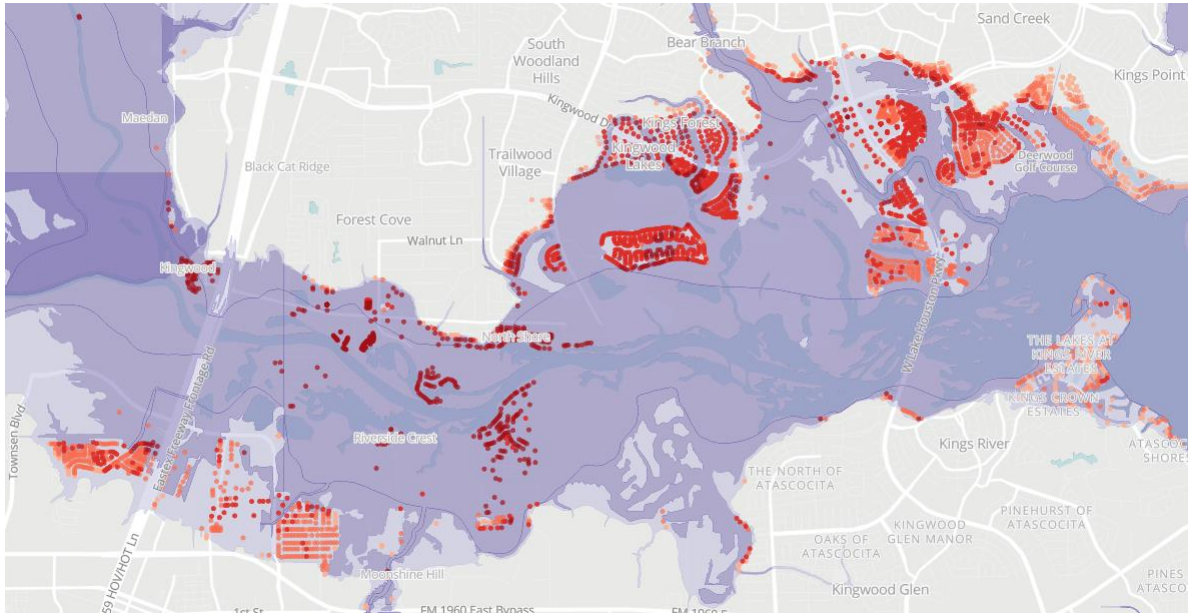
Results

Houston and Hurricane Harvey, USA 2017

FLORIA



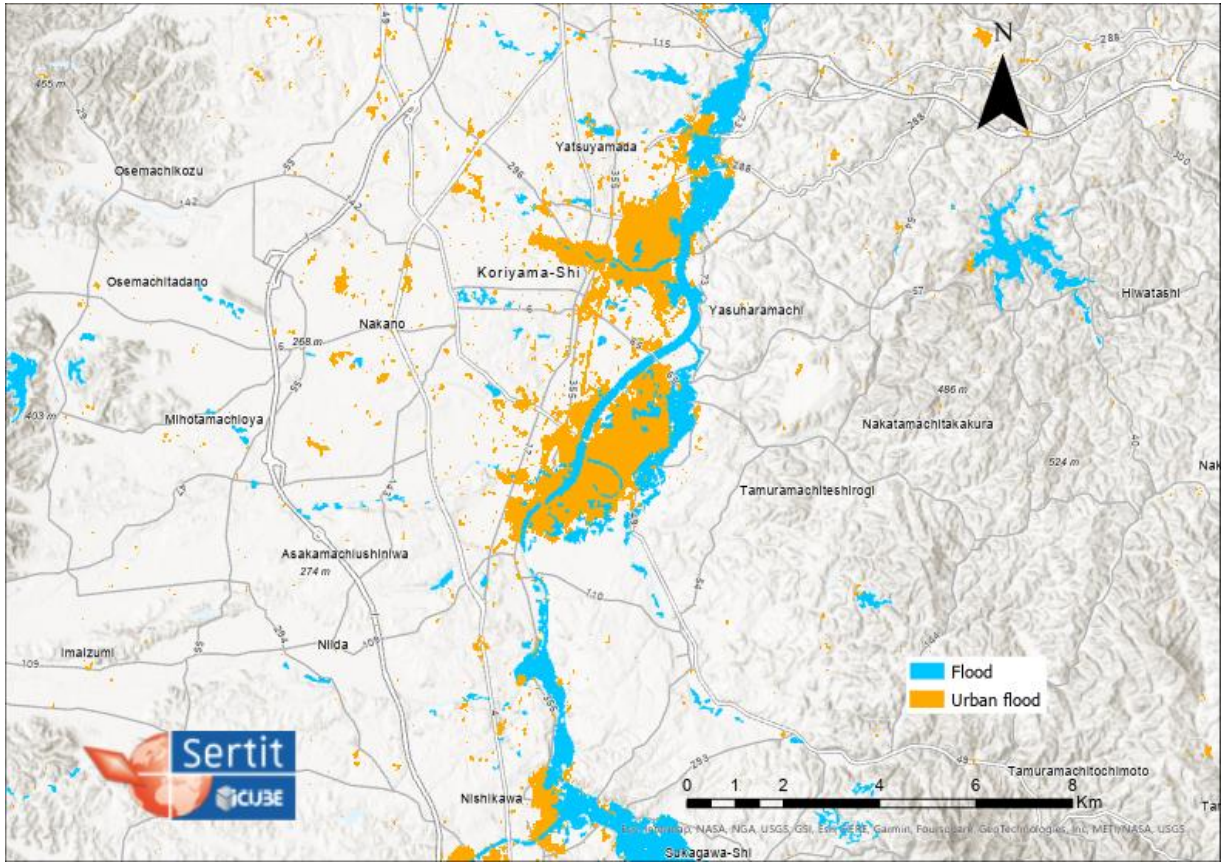
Initial FEMA model assessment



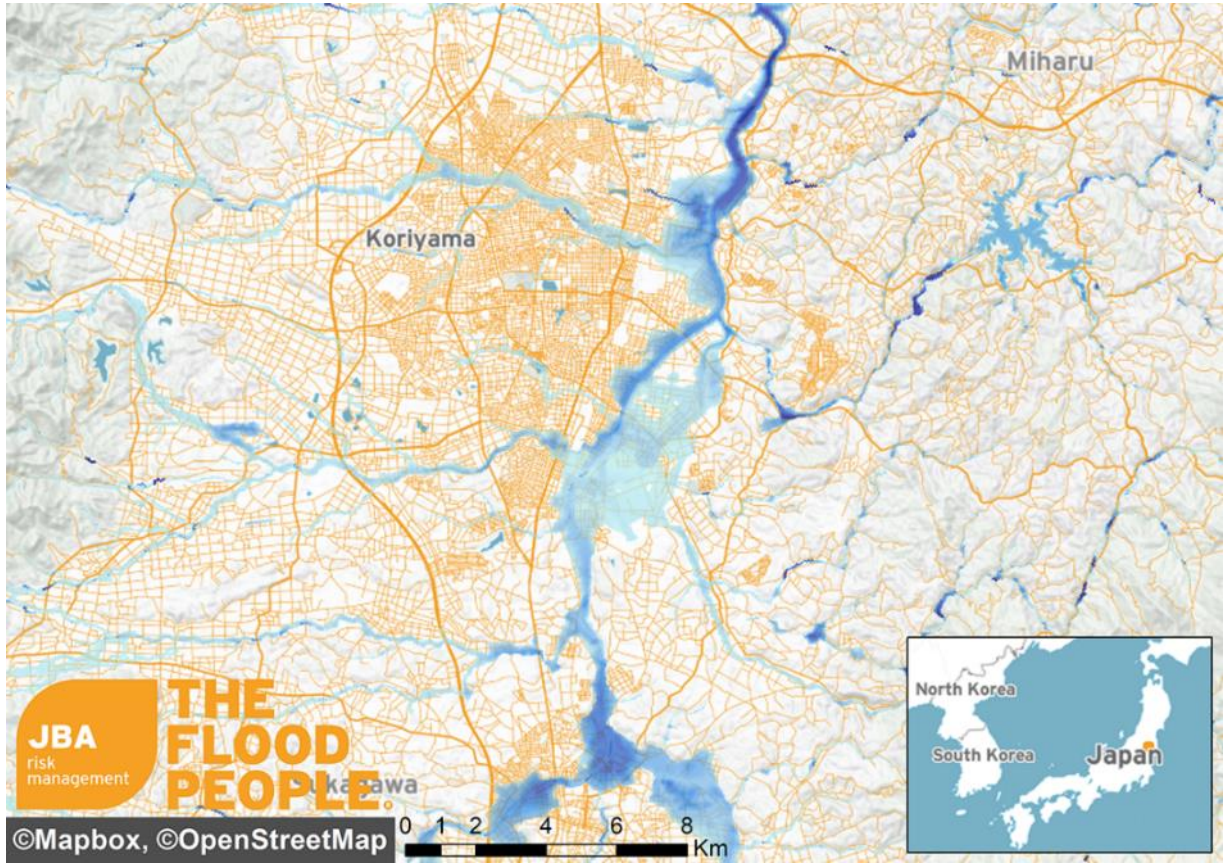
Results

Koriyama and Typhoon Hagibis, Japan 2019

FLORIA



JBA risk management



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Limitations, conclusion and perspectives

Limitations

- Acquisition geometry *(line of sight, resolution, urban structures)*
- Atmospheric variations
- Acquisition timing
  - Satellite must fly over during the flood
  - Needs 2 pre-flood SAR images

Conclusion

- Fully automated
- **We are able to detect urban flood with SAR images !**

Perspectives

- **Operational** integration in CEMS – Rapid Mapping
- Export on High Performance Computing (**HPC**)

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Emergency Management
COPERNICUS EMERGENCY MANAGEMENT SERVICE
State of Play: In situ data requirements

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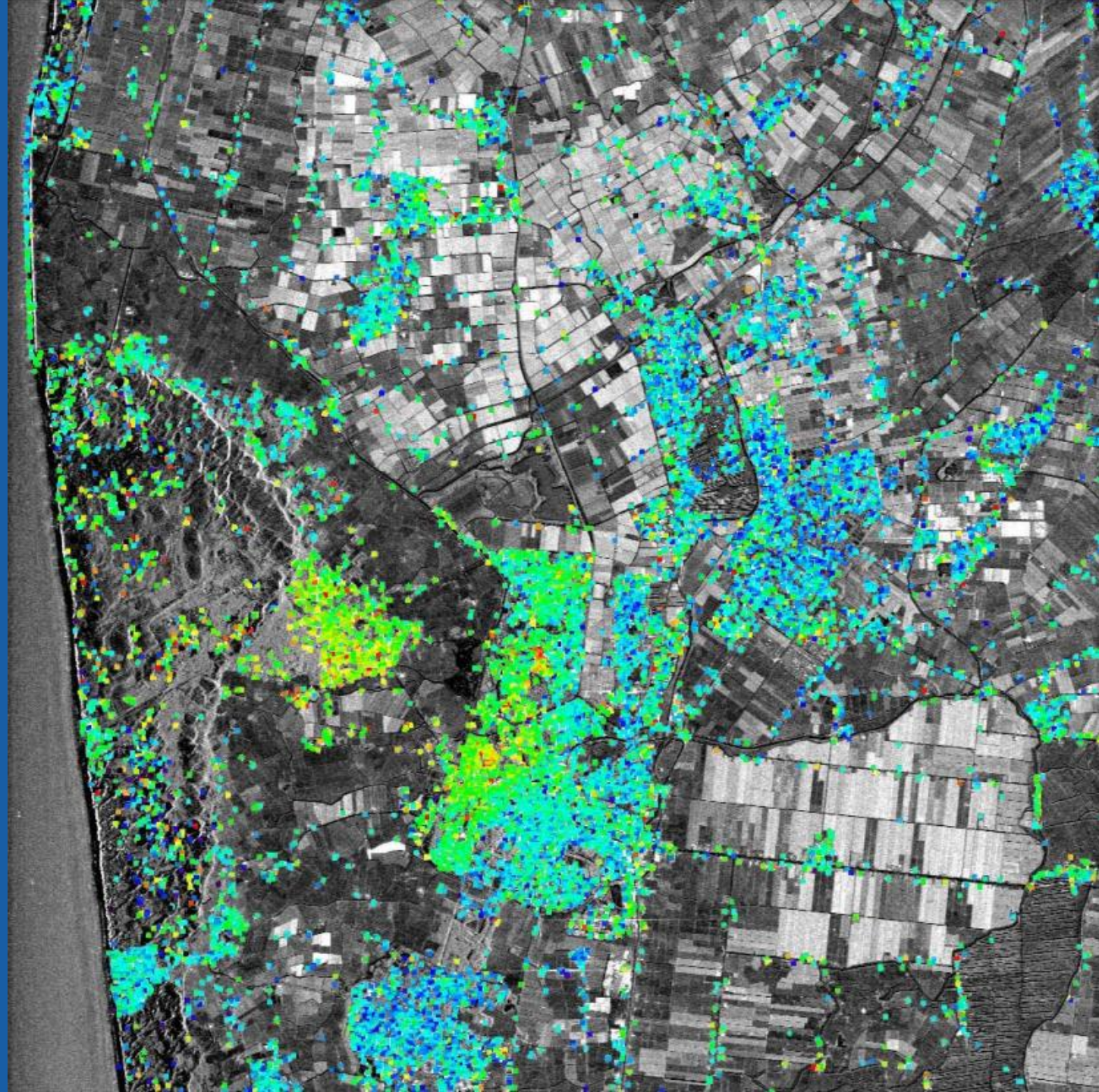
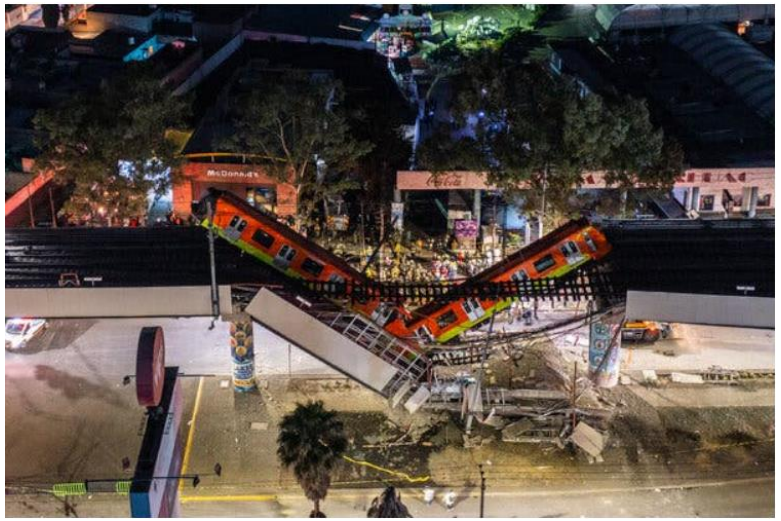
QuickSTAMPS

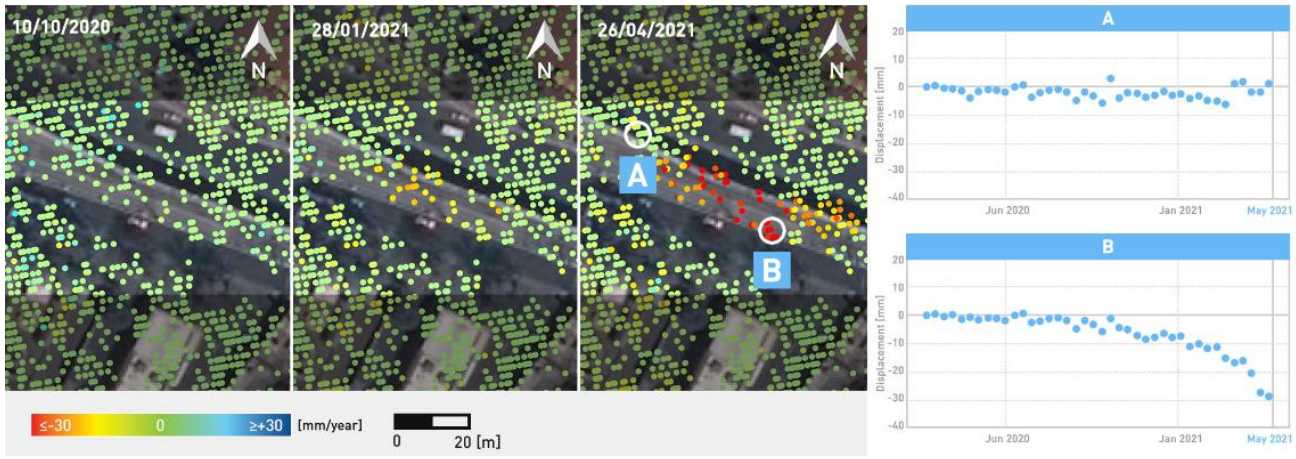
Method for generating point displacement maps based on permanent reflectors using STAMPS



PSI for Ground Movement Monitoring with SAR

- **PSI**: Persistent Scatterer Interferometry
- A precise and robust technique for **urban areas and infrastructure** analysis
- Focus on **stable** radar reflectors in urban areas and infrastructures
- Mitigates limitations of traditional DInSAR in the presence of temporal decorrelation, atmospheric effects and low deformation rates.



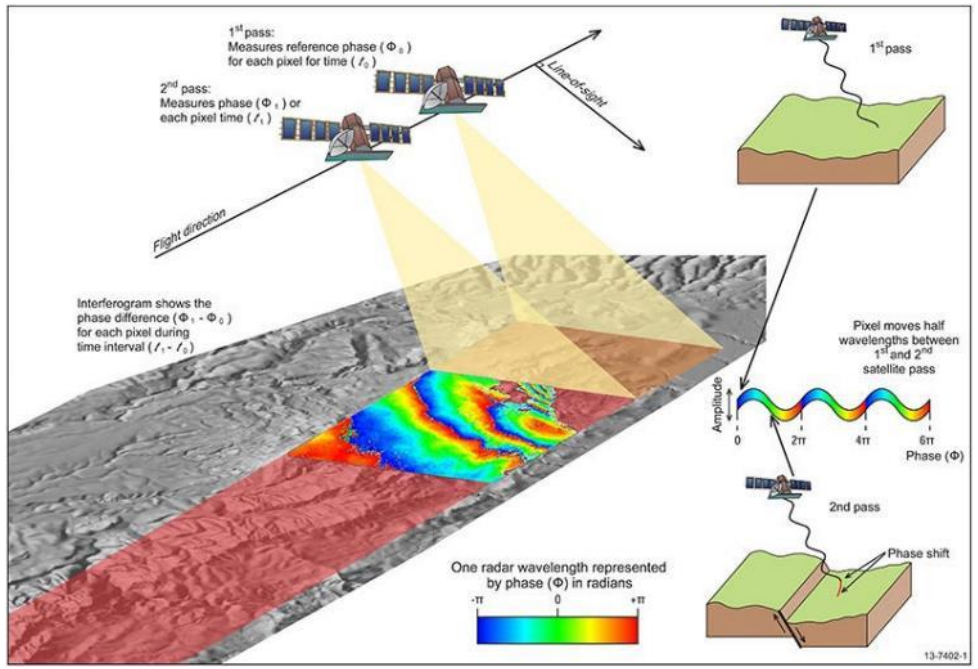


The collapse of Mexico metro on May 2021 (Interferometric processing done by TreAltamira.)

SAR Interferometry and Persistent Scatterers

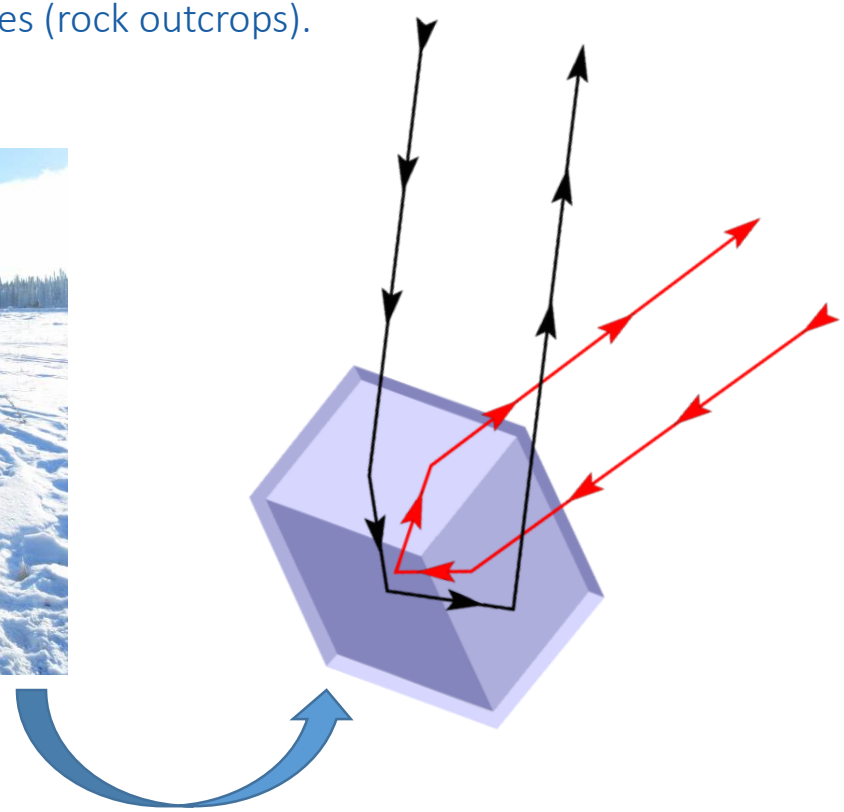
SAR Interferometry

- Measures phase difference between images to generate an interferogram.



Persistent Scatterers (PS)

- Ground targets that maintain consistent radar backscattering properties over time.
- Often man-made structures (buildings, bridges) or stable natural features (rock outcrops).



Corner reflector has a very high backscattering efficiency.

PSI Methodology

- ✓ **Step 1: PS Candidate Identification**
  - ✓ **Analyze** multi-temporal SAR images to identify points with stable radar backscatter properties
    i.e. potential Persistent Scatterers (PS)
- ✓ **Step 2: Phase Unwrapping**
  - ✓ Extract the **interferometric phase difference** between pairs of SAR images and **unwrap the phase** to retrieve displacement information.
- ✓ **Step 3: Atmospheric Phase Estimation**
  - ✓ Estimate and **remove the atmospheric phase contribution** to enhance the accuracy of the displacement measurements.
- ✓ **Step 4: Displacement Time Series Estimation**
  - ✓ Combine the corrected interferometric phase measurements from multiple SAR image pairs to generate a **time series of displacement** for each PS point.

PSI Advantages over DInSAR

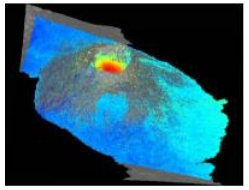
- Reduced Temporal Decorrelation

PSI's focus on stable scatterers minimizes the impact of temporal decorrelation, enabling more reliable displacement measurements.

- Improved Atmospheric Correction

PSI's multi-image approach enables a more robust estimation and removal of atmospheric phase artifacts compared to DInSAR's pairwise analysis.

STAMPS & QuickSTAMPS



STAMPS

Stanford Method for Persistent Scatterers.

QuickSTAMPS

OPTIMIZED BY SERTIT.

STAMPS

- Advanced algorithm and software that focuses on identifying and analyzing persistent scatterers within a series of SAR images

QuickSTAMPS

- Tool built on top of STAMPS framework.
- Seeding up and automate initiation procedures, scripting, and processing stages

	STAMPS	QuickSTAMPS
User friendly	★☆☆☆☆	★★★☆☆
Processing velocity	★★☆☆☆	★★★☆☆
Processing automation	★☆☆☆☆	★★★★☆

Case Study – Lochwiller, France

- Village of Lochwiller, Bas-Rhin, Grand-Est, France.

  - Ground displacement (swelling phenomenon) due to a geothermal drilling done a few years ago.

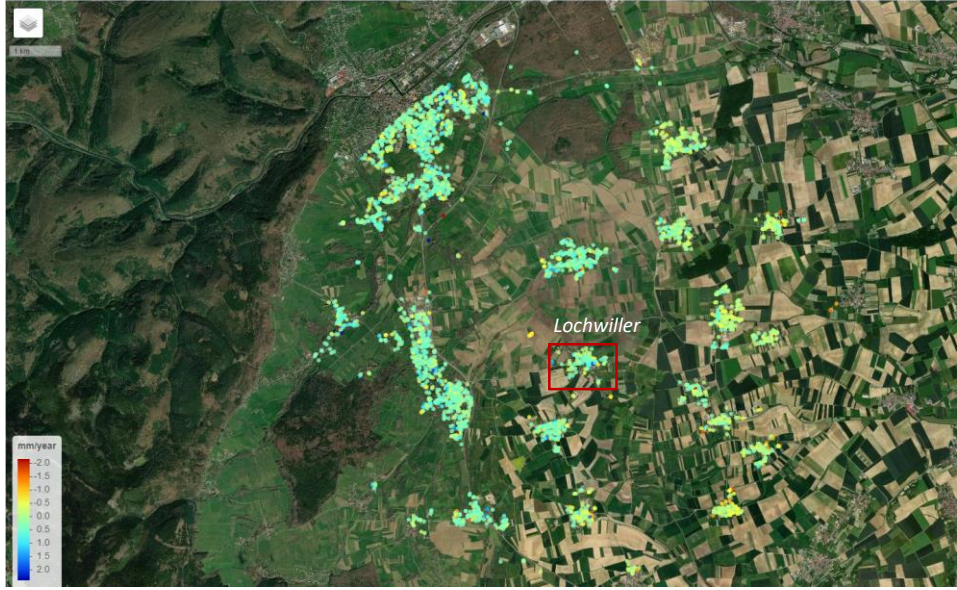
  - The houses are cracking and the inhabitants are forced to leave their homes.

Case Study – Lochwiller, France

- Generation of point displacement maps by the QuickSTAMPS tool

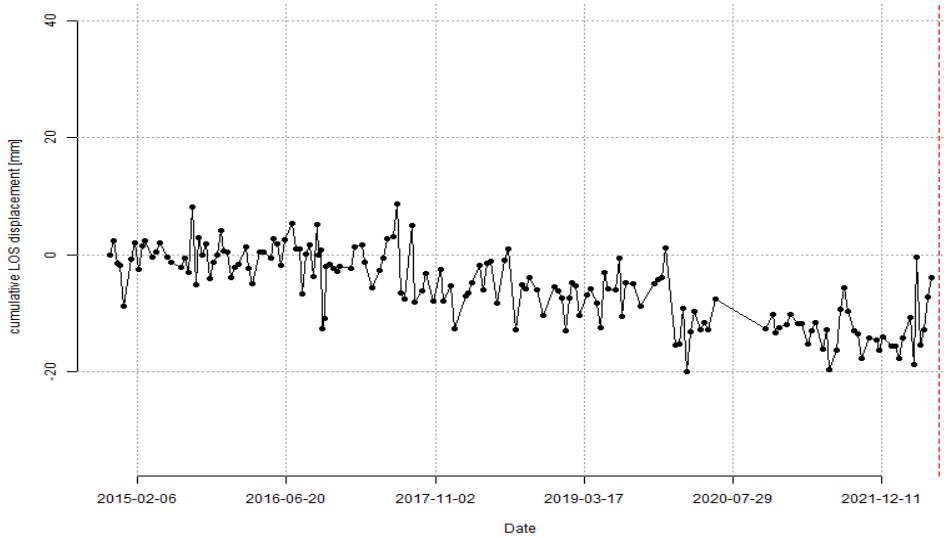
  - Sentinel-1 data Single Look Complex

  - Time period 2014-11-04 to 2022-05-26
    166 Sentinel-1 measures by Sentinel-1



General view of ground movements in and around Lochwiller

Focus on Lochwiller

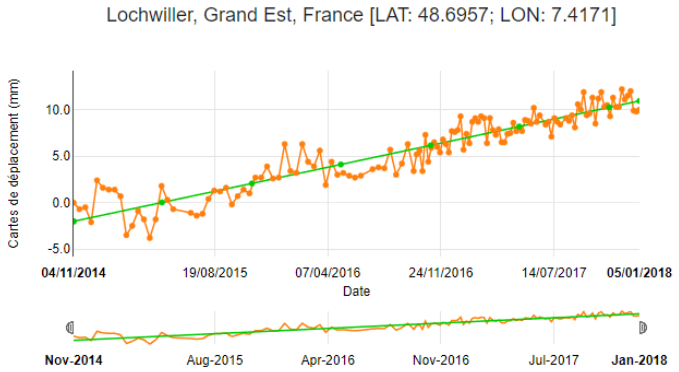


Displacement in mm of a point on the 2014/2022 time series

Case Study – Lochwiller, France

Results

- As expected, the houses and other buildings in the village are **good stable points**, consistent in time in terms of their phase.
- Some points on the roads or on the hard grounds also make good permanent scaterrers.



Conclusion & Perspectives

Conclusion

- Fast and semi-automated tool
- Based on softwares widely used by the community
- Promising results
- Still in early stage of development

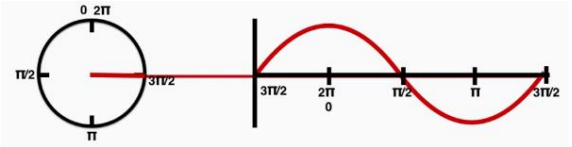
Perspectives

- Requires improvements in user experience, processing speed and automation
- Improvement of the results validation process
- Processing on HPC

Limitations

Temporal

- Deformation measurement can only be ambiguous
- Not suitable for vegetated areas or rapidly urbanizing areas.

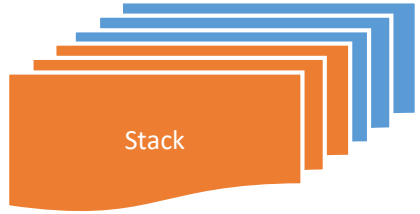


Geometric

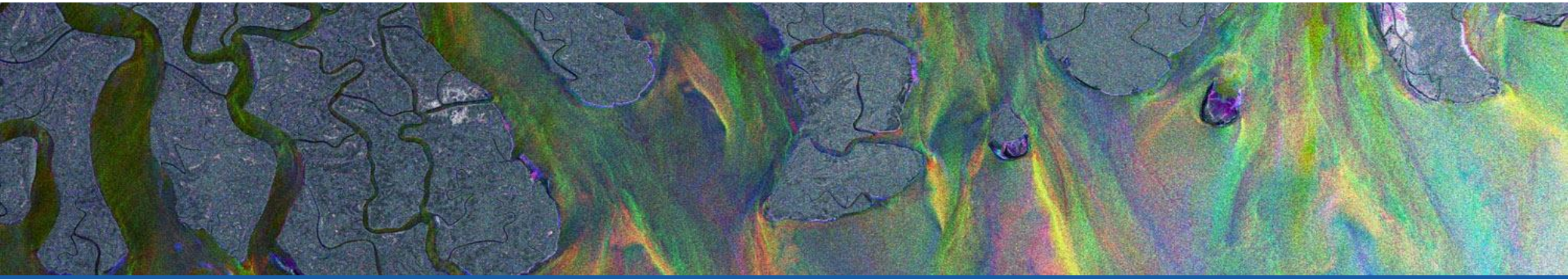
- PSs are not objects, limiting its use in deformation analysis of a specific part of a structure.
- A stable reference point must be selected by operator.

Atmospheric

- Accurate atmospheric correction requires **multiple images** – *at least 15 for C-band.*



Wrap up



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Wrap up

- Generic pipelines for usual crisis cases - **ExtractEO**
  - Using an opensource python library (**EOReader**) for product handling
  - Fast, reliable, automated, adaptable and modular
  - Limitated to the easiest thematic cases

- SAR Urban floods - **FLORIA**
  - Urban flood detection with using **inSAR**
  - Fully automated and open-source-based software

- Point displacement maps - **QuickSTAMPS**
  - Uses **permanent scatterers interferometry**
  - Fast and semi-automated tool, based on softwares used by the community


Thank you for
your attention