



Forum **TERATEC** **23**

Unlock the future

31 MAI & 1^{er} JUIN 2023 • Au Parc Floral, Paris

Un événement organisé par

 **infoprodigital**





**Unlock
the future**

SCO FloodDAM - DT

Towards a Digital Twin for flood detection, prediction and risk assessment

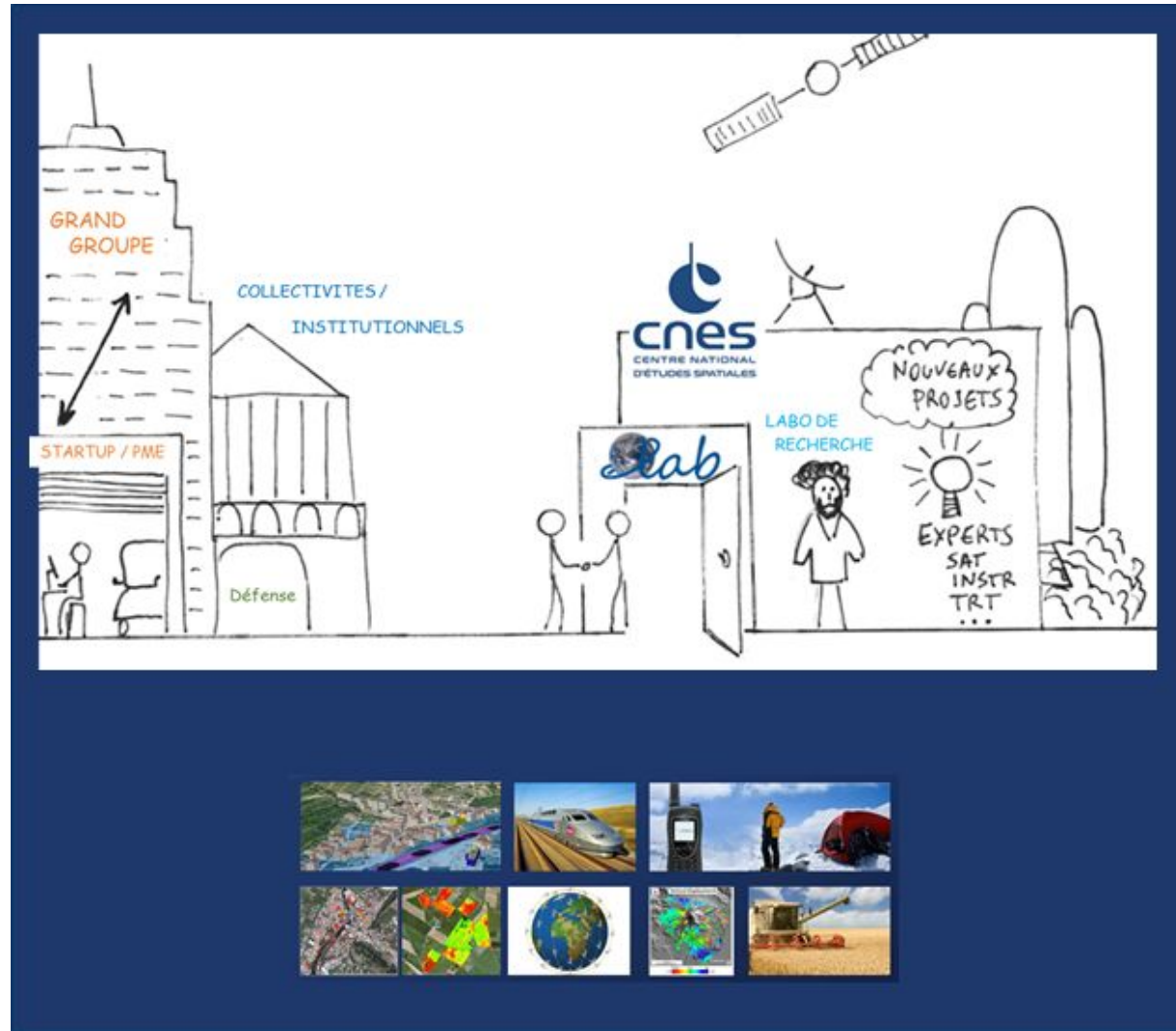


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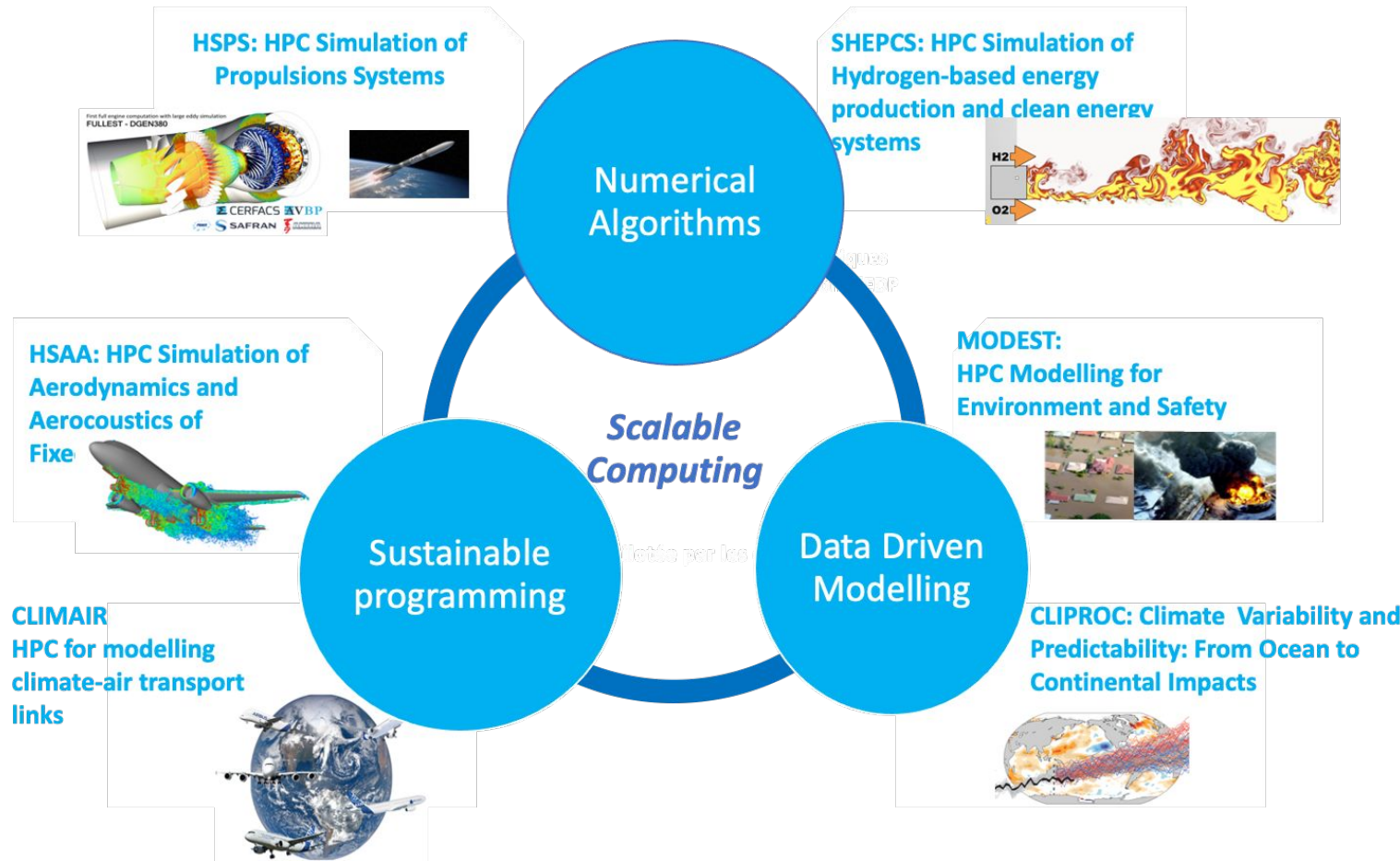
SUMMARY

- **CNES' Earth Observation Lab**
- **CERFACS**
- **SCO FloodDAM Digital Twin project**
- **Selected sites for demonstration**
- **FloodDAM-DT Pipeline**
- **Project timeline**
- **Perspectives**

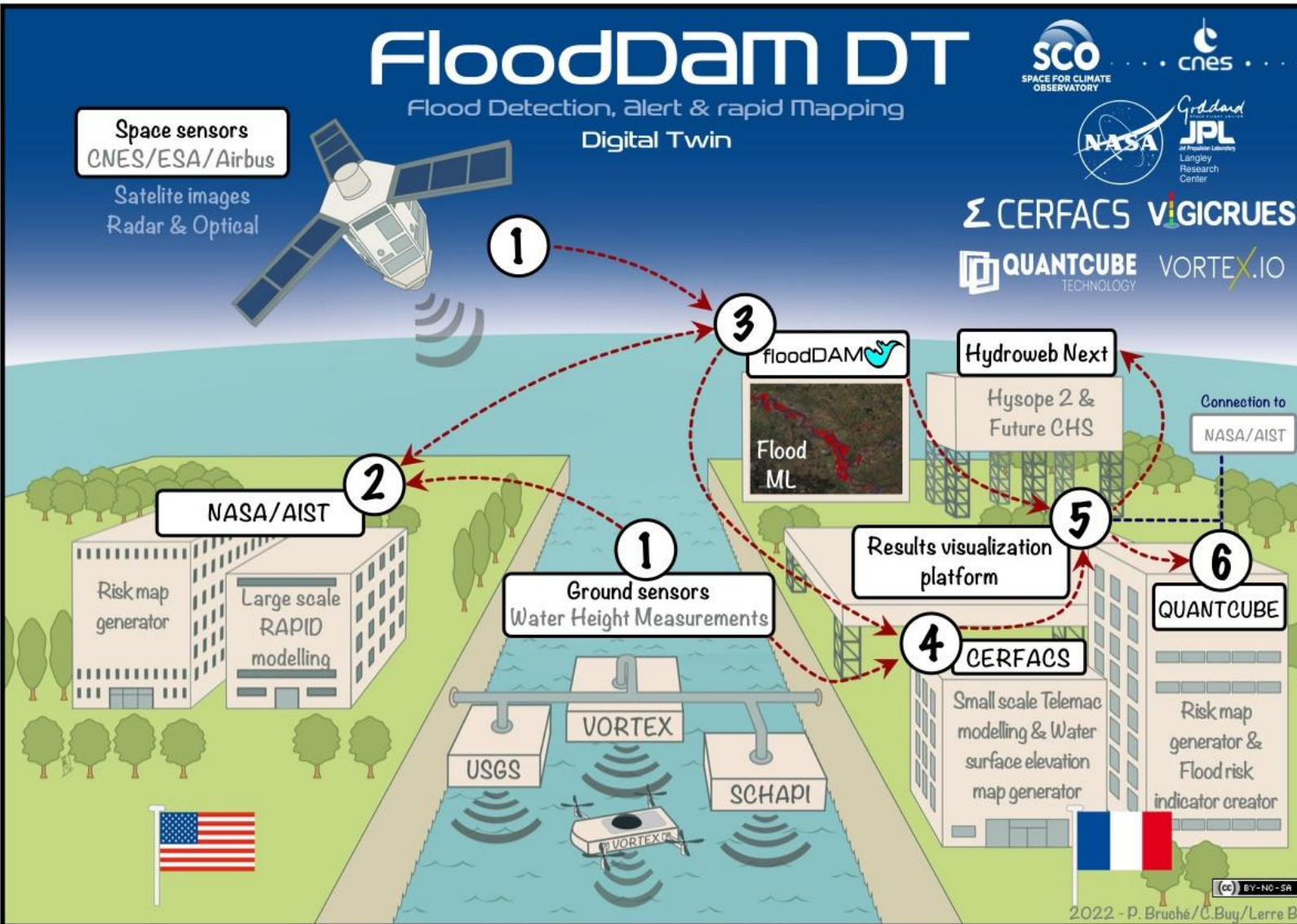


*promote space solutions and support users in the development of **applications with an Earth Observation component.***

- The Earth Observation Lab created in 2018
- Space-based Earth Observation solutions
- Space-based algorithms and methodologies
- Encourage the emergence of applications implementing an Earth Observation component
- Prepare the downstream use of future data, participate in the definition of new missions
- Training, monitoring



- Private center of research, development and transfer in simulation, modelling and HPC
- Both private and public entity, affiliate to CNRS (CECI, UMR5318)
- Hot topics in climate and environment modelling:
 - Air transport and climate,
 - Climate variability and predictability,
 - Environment and Safety.
- With the increase of satellite and field measurements, we enhance physical modelling with data-driven methods such as data assimilation, uncertainty quantification and artificial intelligence.



- SCO FloodDAM project labelled in 2020.
- Digital twin FloodDAM-DT with NASA AIST IDEAS (Integrated Digital Earth Analysis System) in progress until early 2024
- **Objective:** develop Federated Digital Twins solutions between NASA IDEAS and SCO-FloodDAM for alert systems and flood risk maps on local and global scales using space technologies

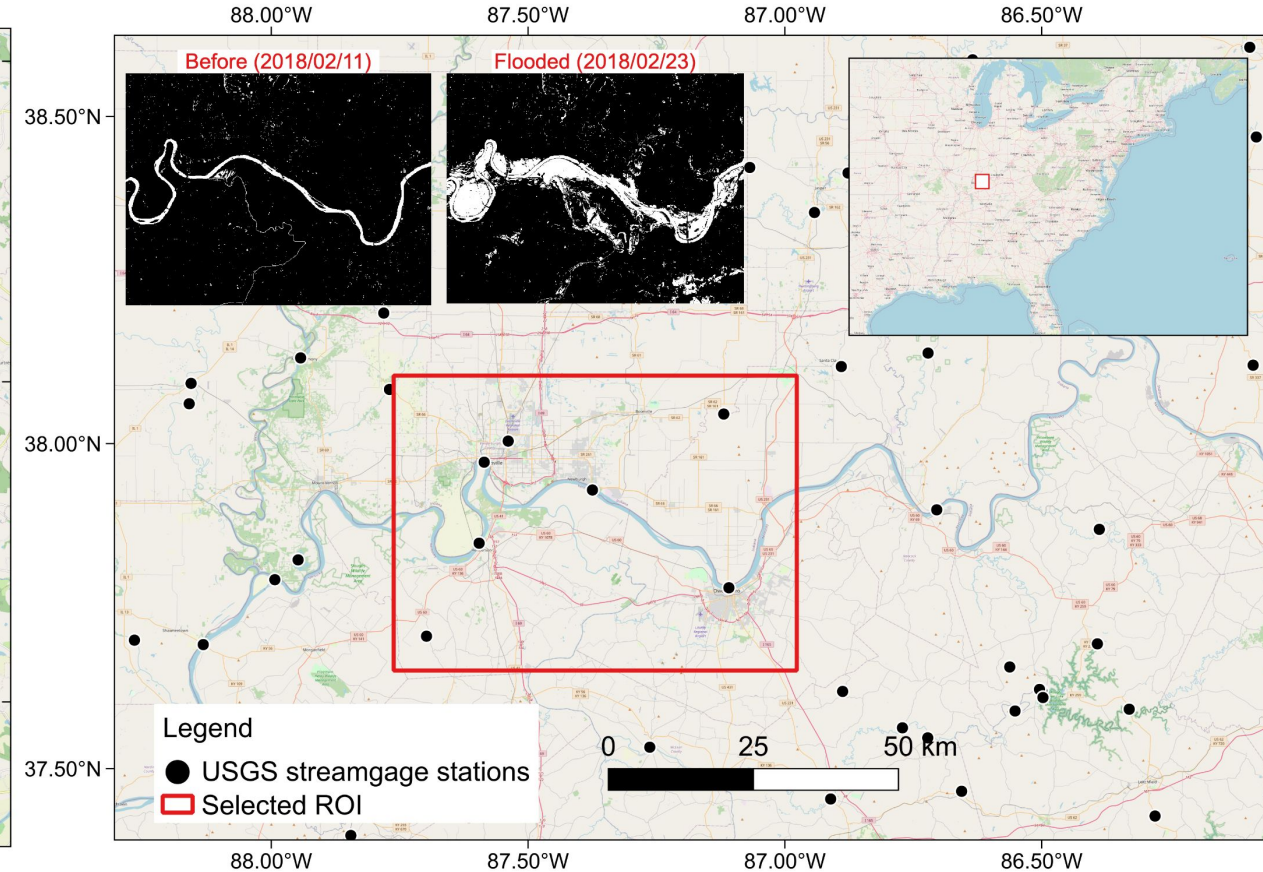
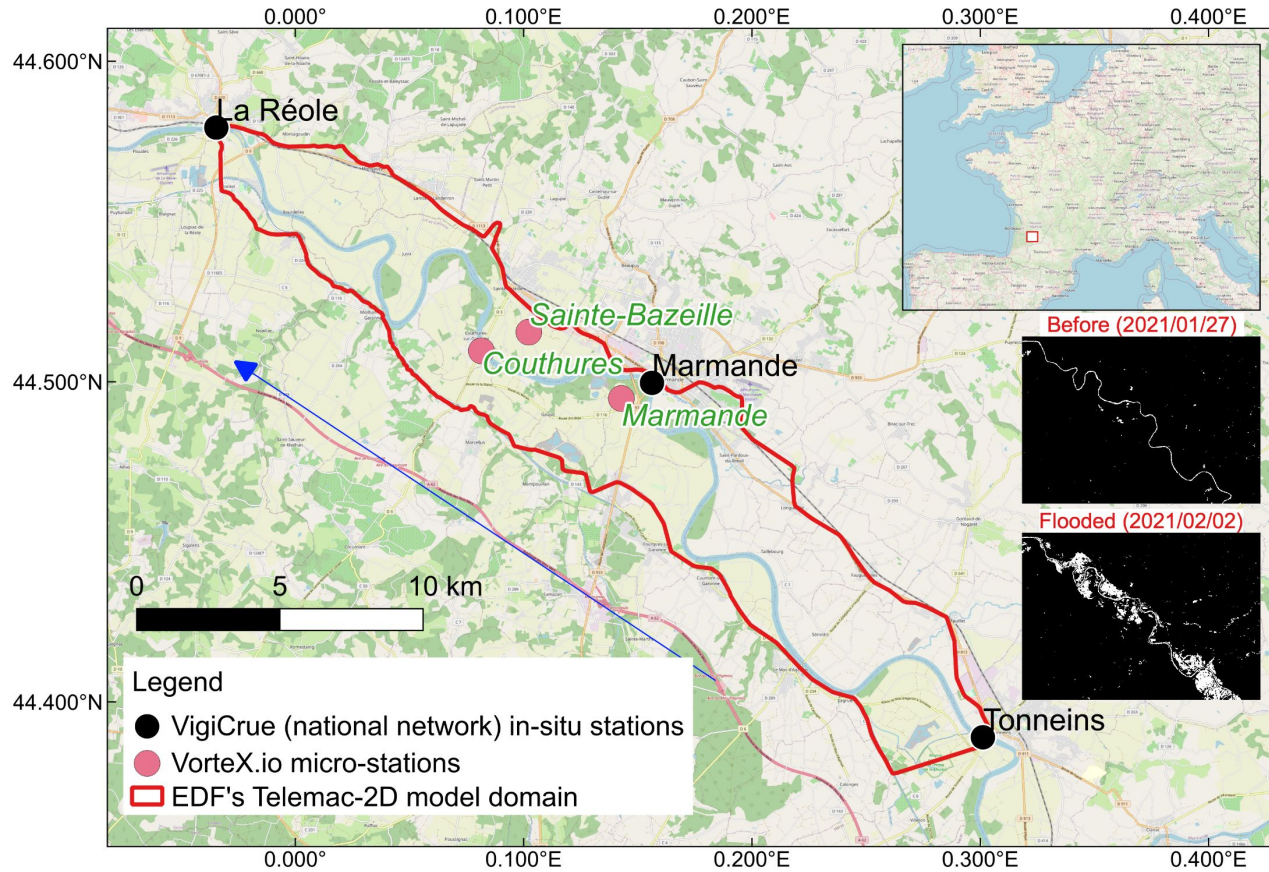


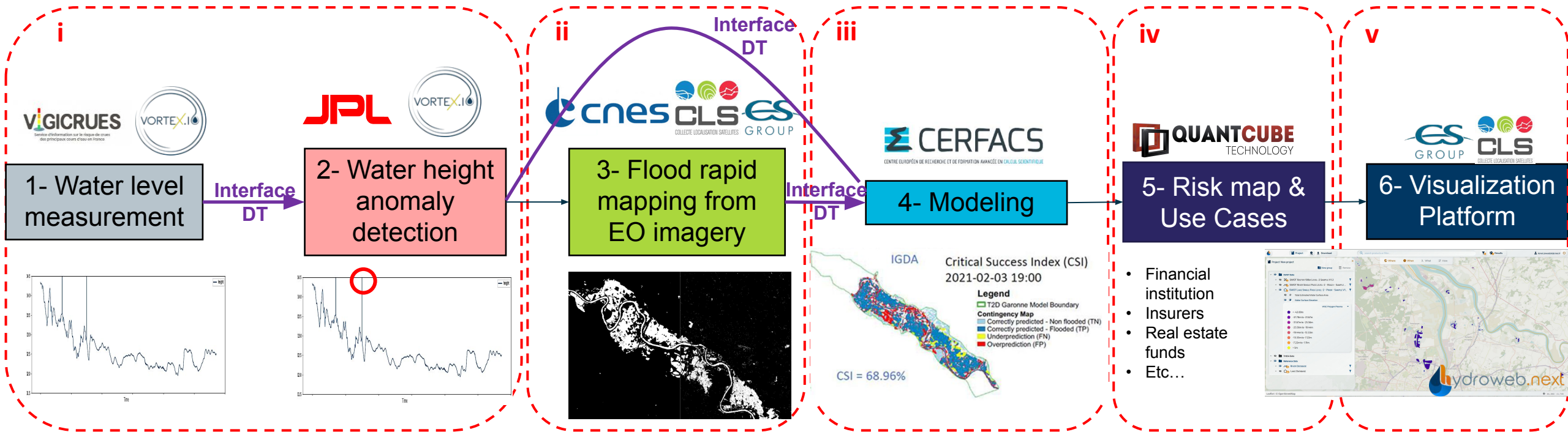
Selected Sites for Demonstration



 France Catchment : **Garonne river**

 USA Catchment : **Ohio River**





Standardize resource interfaces using emerging DT specifications (OGC standards)

(i) Anomaly Detection and Alarm System

• Analyze live **micro-stations** data collected by Vortex.io



API interface
Real Time measurements



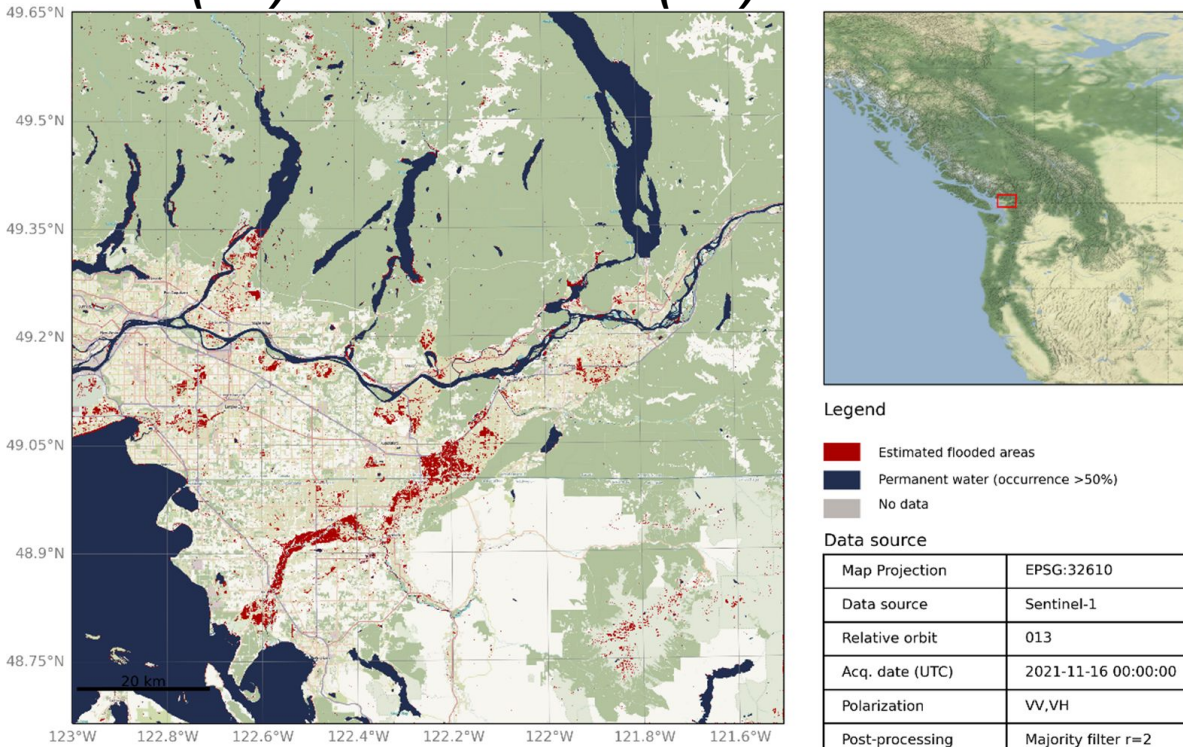
Drone Flight



(ii) Flood Rapid Mapping from EO data

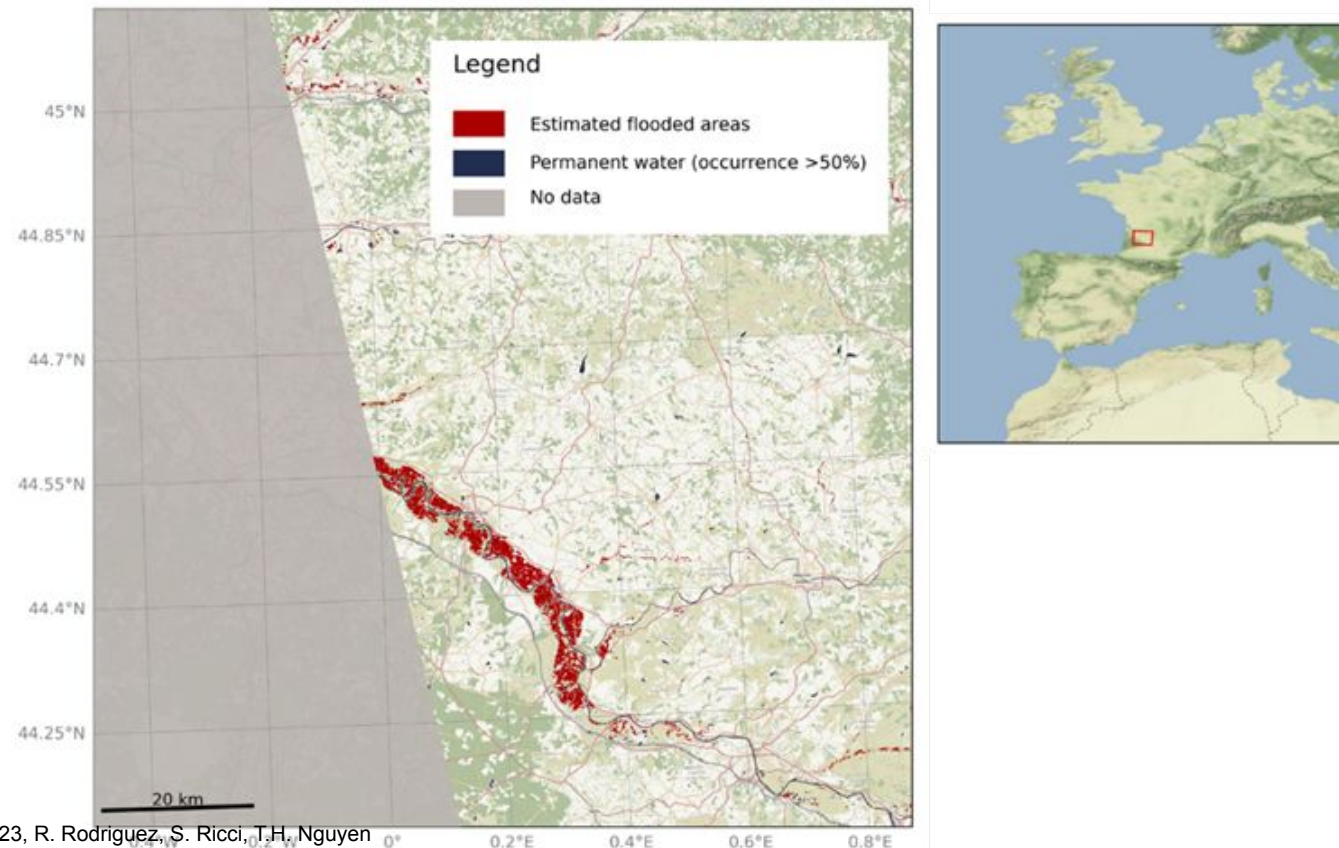
- Flood rapid mapping from SAR and optical data **over the world**
- Developed by CLS (Collecte Localisation Satellite) in France

Seattle (US) and Vancouver (CA) flood event 2021-11-16



Disclaimer
 - This map is derived automatically using the FloodDAM Rapid Mapping (FloodM1) tool.
 More info: <https://www.spaceclimateobservatory.org/flooddam-garonne>
 - How to cite this map: FloodDAM Rapid Mapping (© CNES-CLS-CS, 2019-2021).
 - Surface Water Occurrence (SSW) data: Jean-François Pottel, Andrew Collins, Noel Gorelick, Alan S. Belward.
 High-resolution mapping of global surface water and its long-term changes. Nature 540, 418-422 (2016). (doi:10.1038/nature20984)
 Fond de carte par Yahoo! Bousillage & Humanitarian OpenStreetMap Team sous licence domaine public CC0

Garonne Marmandaise (FR) flood event 2021-02-03



(iii) Hydrodynamics modeling and data assimilation

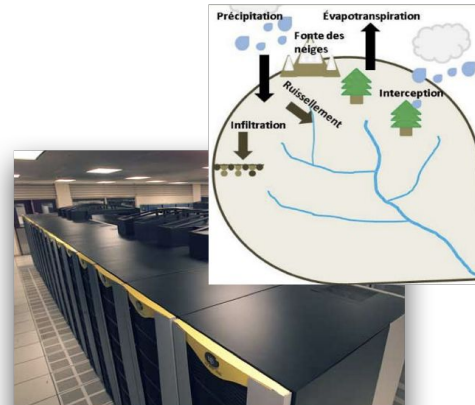
Operational issue

How to predict river discharge for flood forecasting and water balance estimation?



Observations

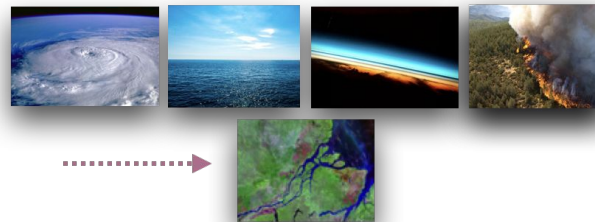
- in-situ : high frequency but sparse
- remote sensing : spatial coverage (SWOT) but low temporal coverage
- Various nature of errors



HPC Numerical simulations

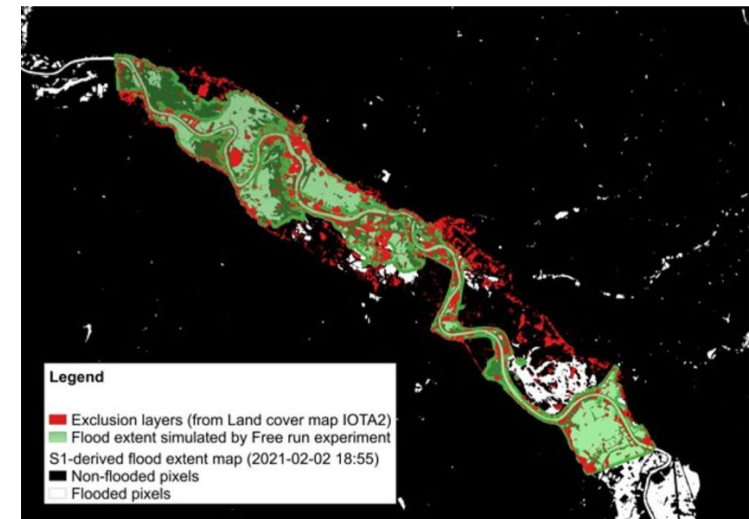
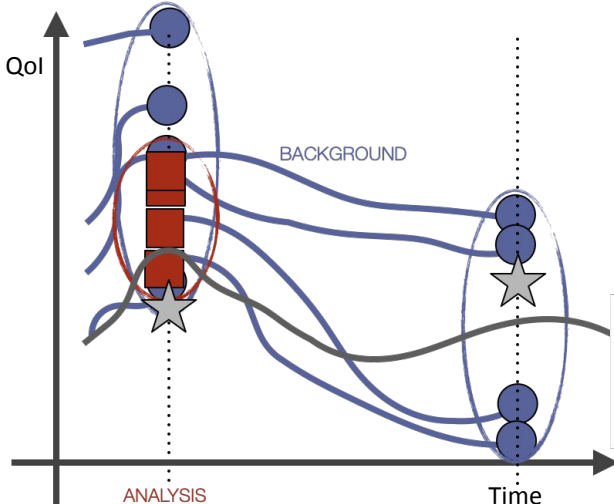
- Simplified Navier Stokes equations 1D, 2D, 3D
- Limited information on bathymetry, topography, friction, hydrology, rainfall and maritim forcing

Data assimilation



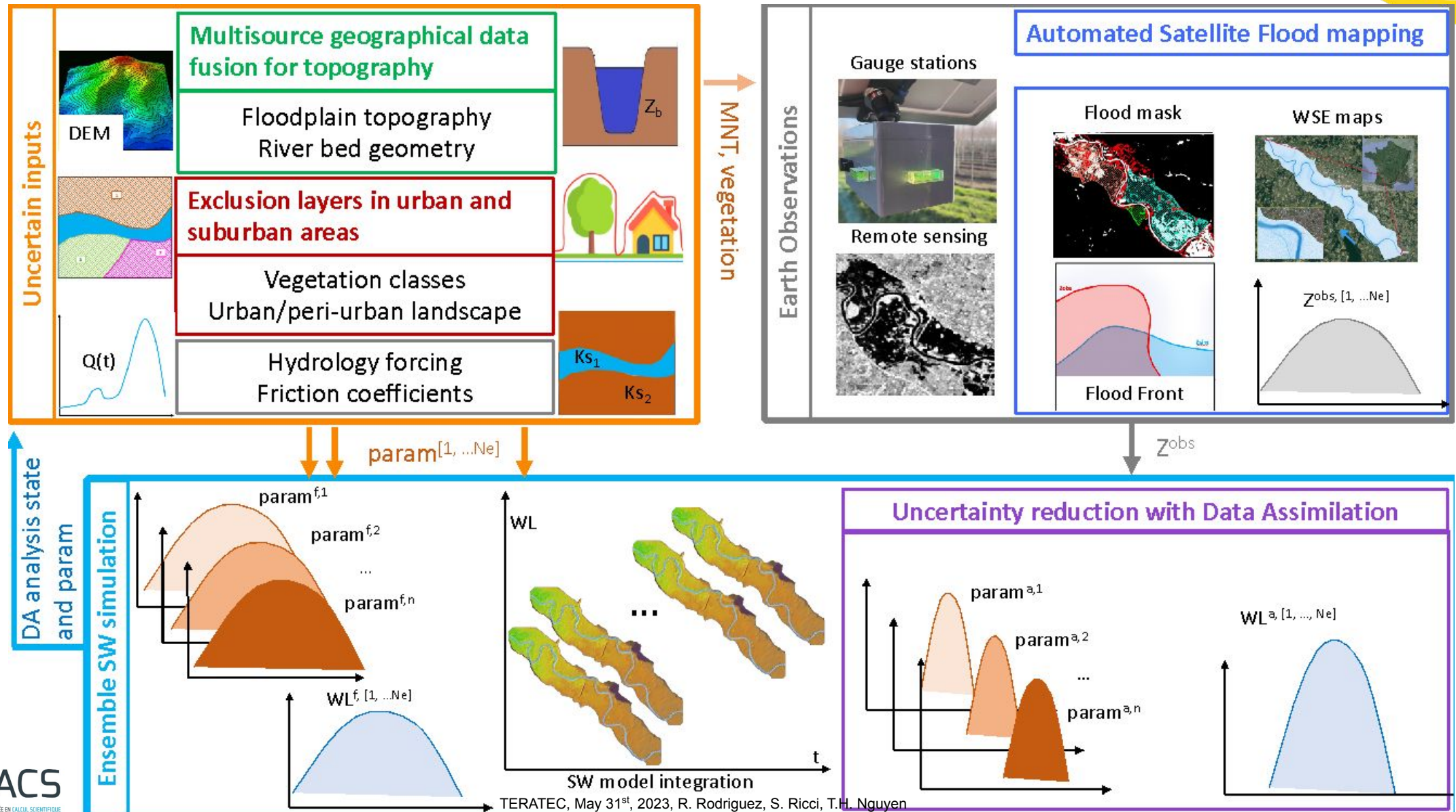
Assimilation of RS flood extent for flood forecasting improvement

- ★ observations y^o
- background x^b (prior, forecast)
- analysis x^a (posterior, update)



- Legend**
- Exclusion layers (from Land cover map IOTA2)
 - Flood extent simulated by Free run experiment
 - S1-derived flood extent map (2021-02-02 18:55)
 - Non-flooded pixels
 - Flooded pixels

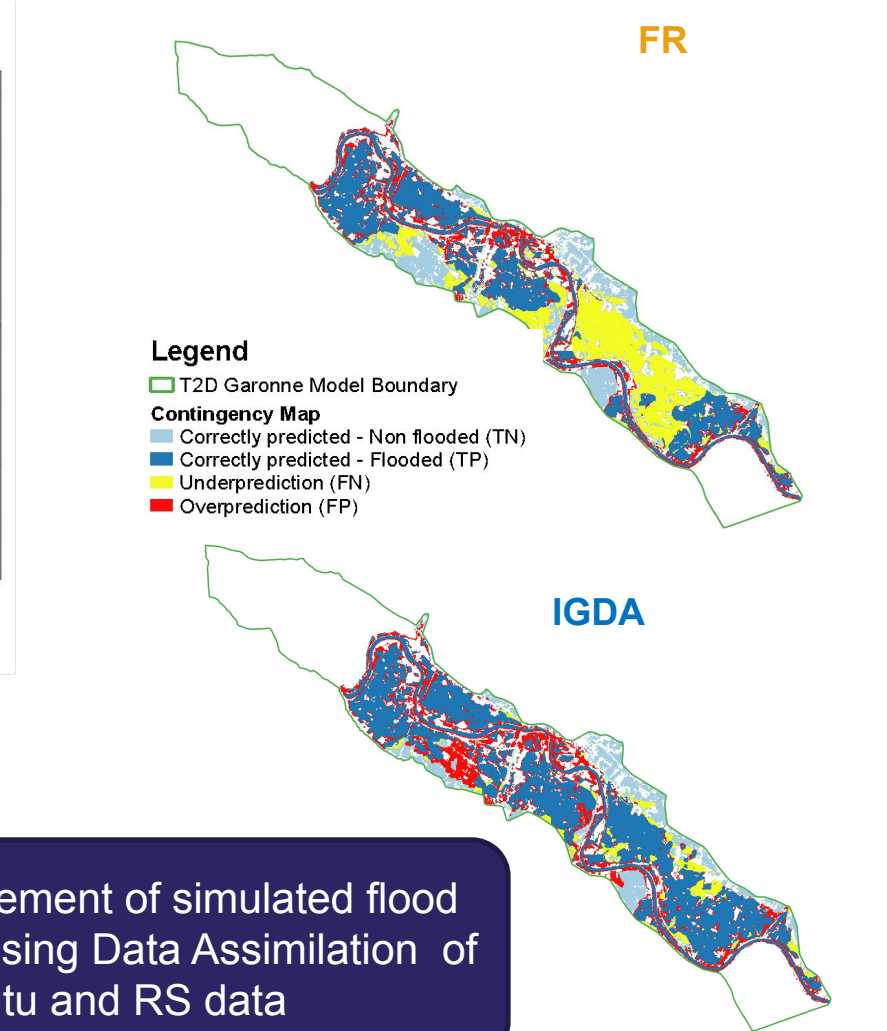
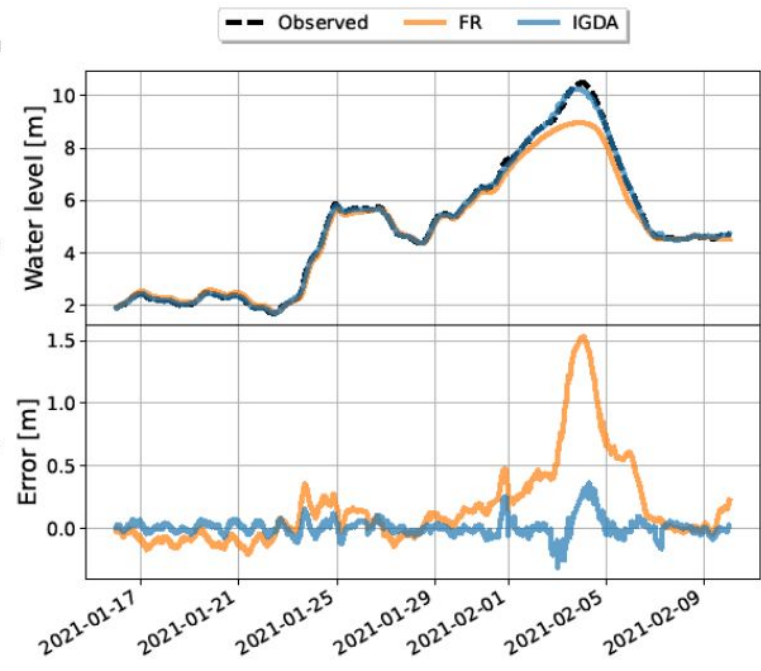
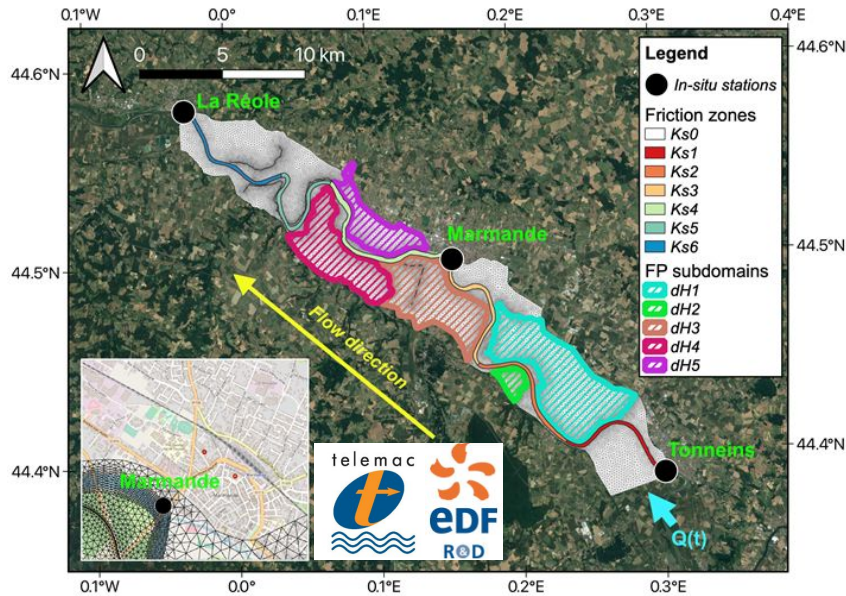
(iii) Hydrodynamics modeling and data assimilation



Garonne Marmandaise catchment - flood event Feb. 2021

Simulated vs. observed water level

Simulated vs. observed flood extent maps



Hydrodynamic model : Telemac 2D

FR : Free run simulation

IGDA : FR simulation with Data assimilation of in-situ and remote sensing observations

Publications:

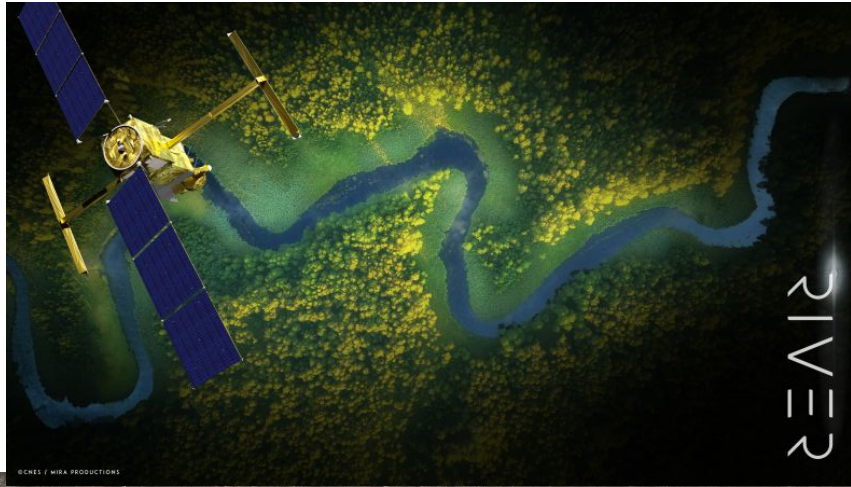
- Nguyen et al., (2022) Improvement of Flood Extent Representation with Remote Sensing Data and Data Assimilation, *IEEE Transactions on Geoscience and Remote Sensing*, 60 (4206022), pp. 1-22, doi:10.1109/TGRS.2022.3147429
- Nguyen et al., (2022) Dual State-Parameter Assimilation of SAR-Derived Wet Surface Ratio for Improving Fluvial Flood Reanalysis, *Water Resources Research*, 58 (11), pp. e2022WR033155, doi:10.1029/2022WR033155
- Nguyen et al., Gaussian Anamorphosis for Ensemble Kalman Filter Analysis of SAR-Derived Wet Surface Ratio Observations. *IEEE Transactions on Geoscience and Remote Sensing*, (Under review)

Clear improvement of simulated flood extent maps using Data Assimilation of in-situ and RS data

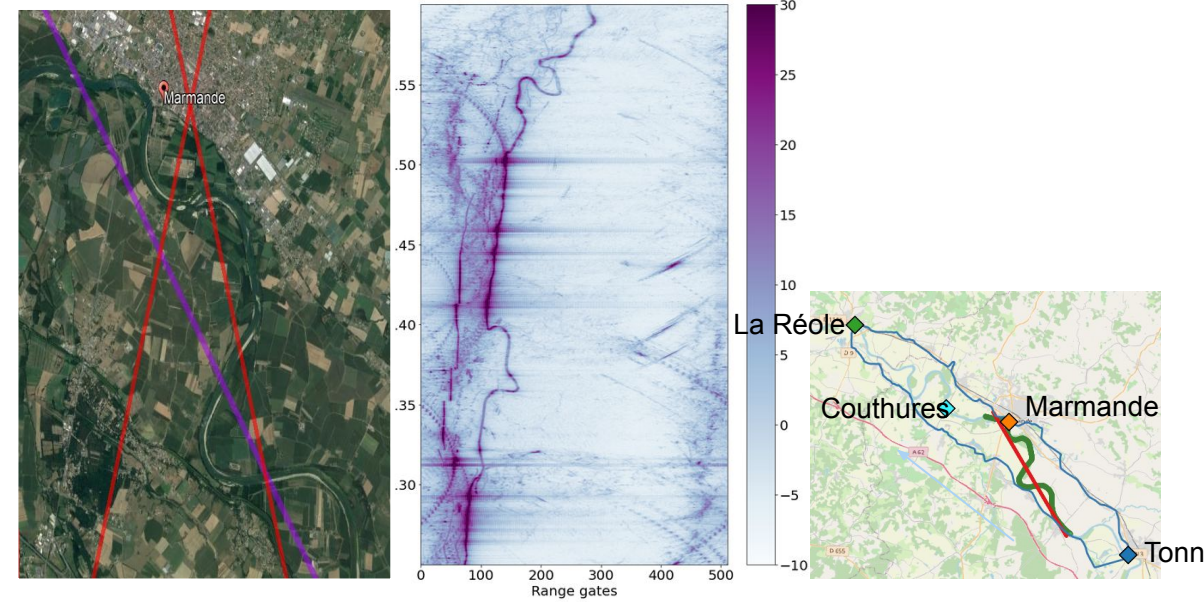
(iii) Towards altimetry data assimilation



Wide swath interferometric altimetry with SWOT

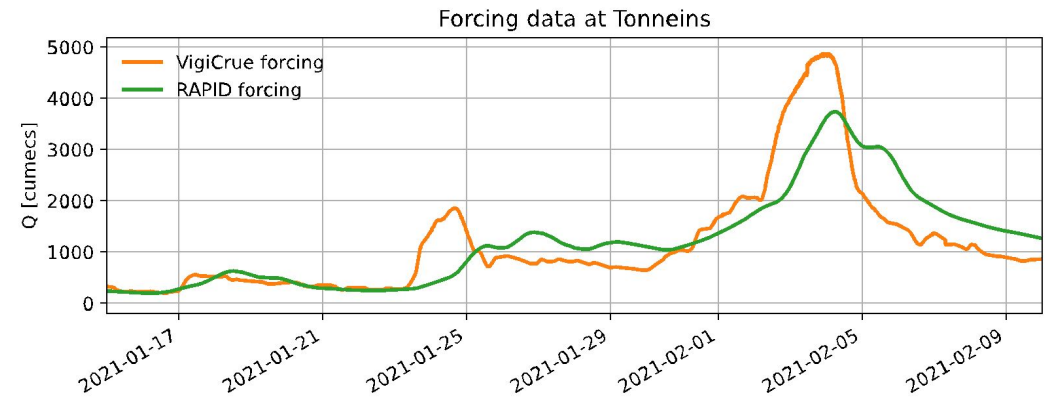
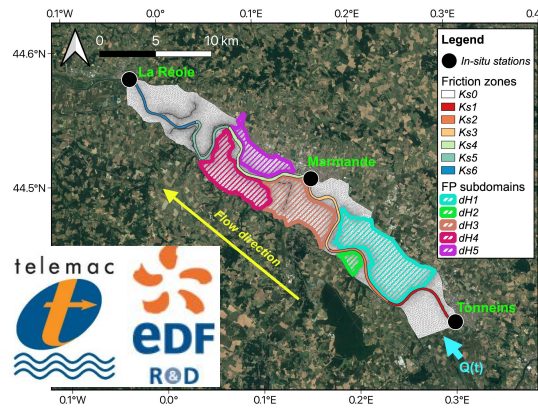


Radar altimetry with Sentinel 6

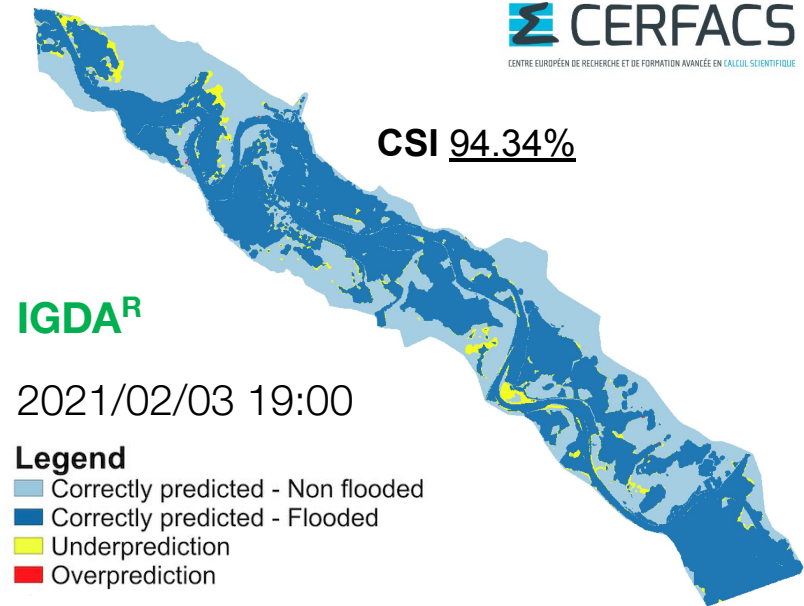
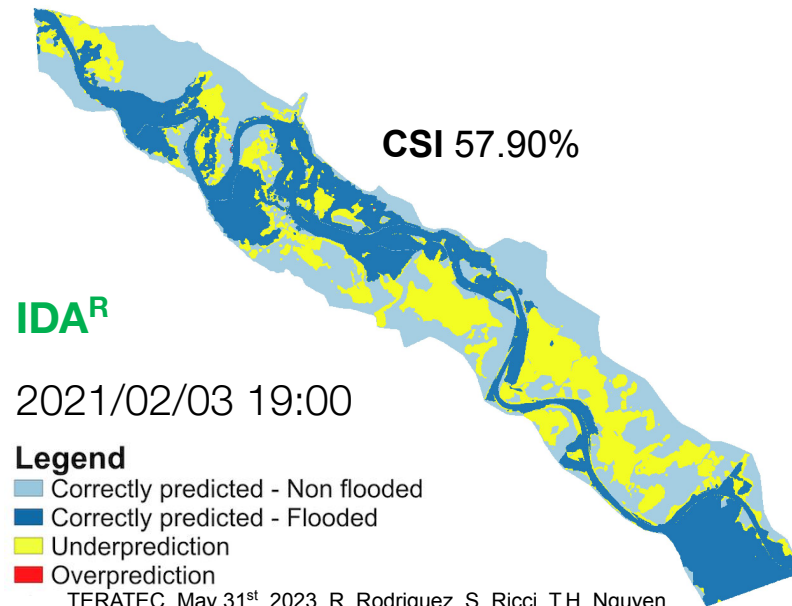
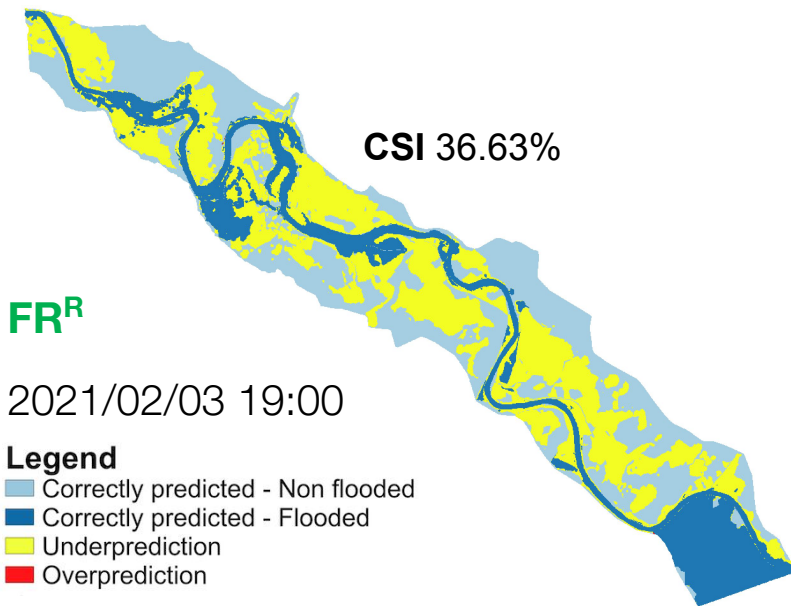


| | Obs to assim. | Z RMSE at S6 center line | | |
|--------------|----------------------------|--------------------------|--------|--------|
| | | 12 Dec | 31 Dec | 10 Jan |
| Free Run | - | 0.373 | 0.255 | 3.598 |
| In-situ only | In-situ data | 0.469 | 1.203 | 4.765 |
| RS only | S1-derived WSR and S6 data | 0.121 | 0.093 | 3.043 |

(iii) Large-scale/Local-scale modeling with data assimilation



Correction of large-scale inflow to the local model using Data Assimilation of in-situ and RS data



(iv) Financial Risk Map

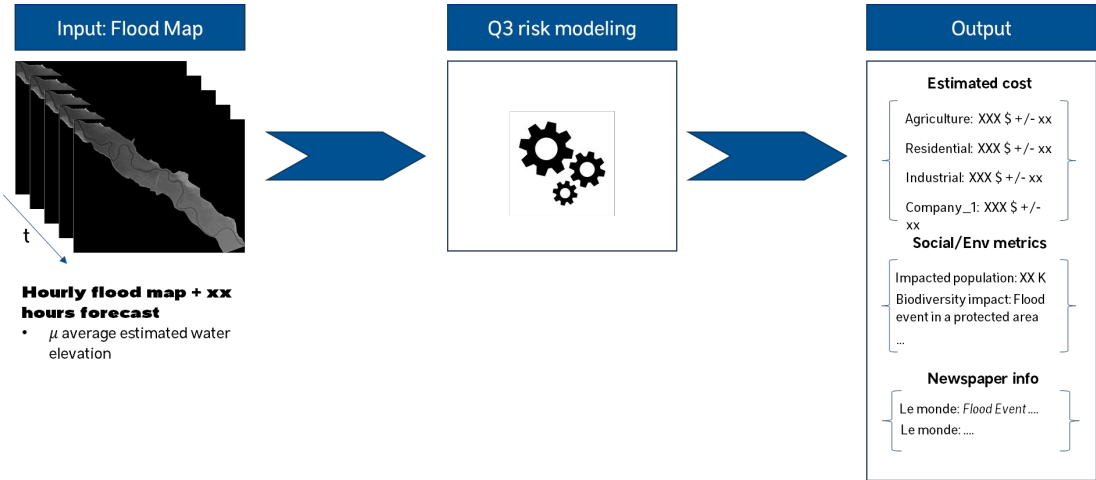


- Environmental Intelligence Platform and API
- Real time product on financial risk estimation and risk map generation of flooding for different type of assets

Flood risk map from FloodDAM-DT data combination with :

- Geolocation data of physical assets
- Geolocated Social media data

Pipeline

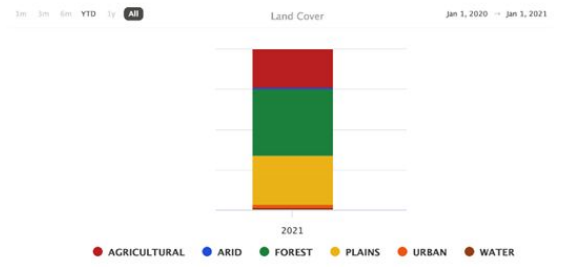


Marmande - Residential area

Asset valuation: \$

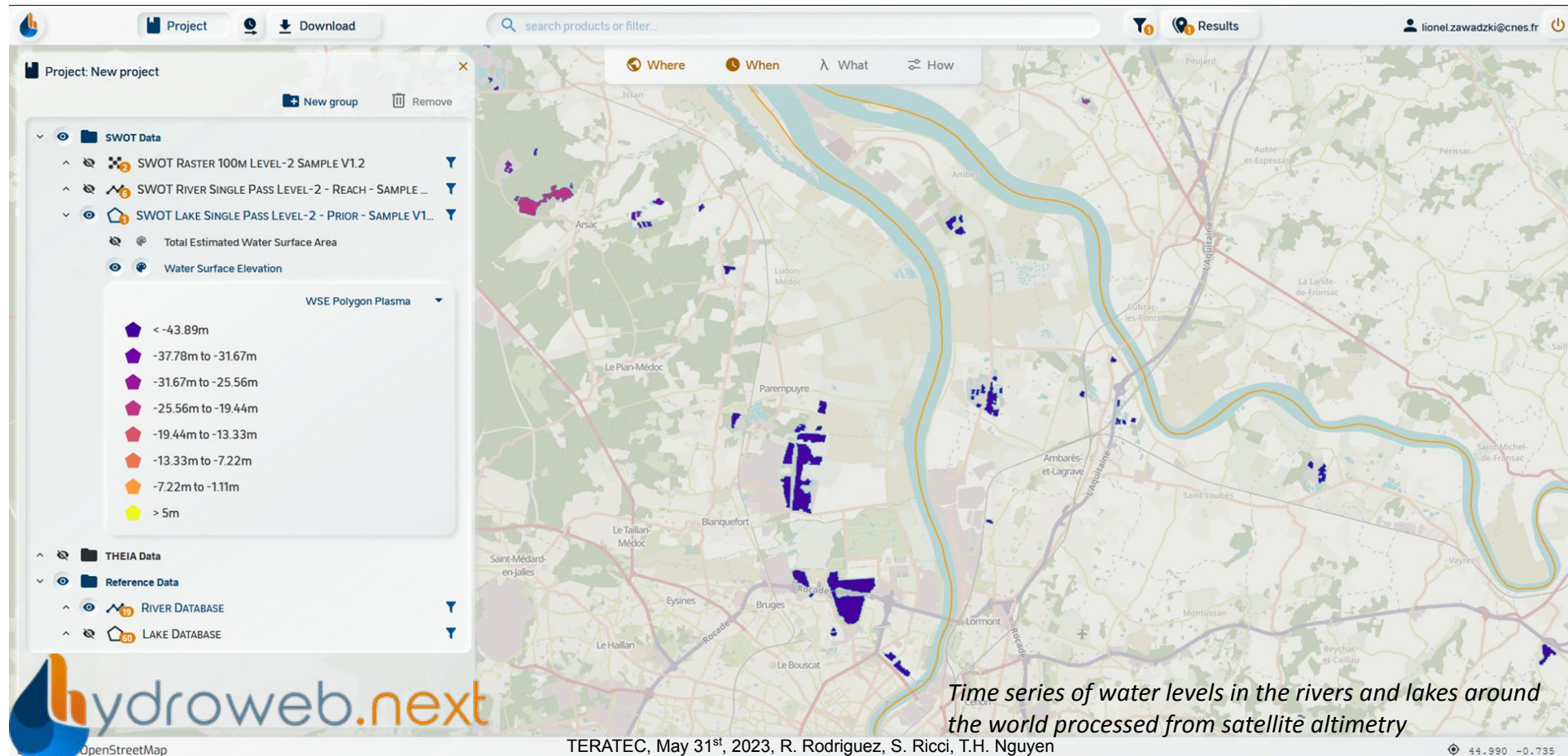
Area: 3.7 km²

Total population on area : 850 hab





- FloodDAM-DT processing chain will be integrated in the hydrological platform Hydroweb.next
- CS-Group responsible of the FloodDAM integration, inter-operability and interfaces

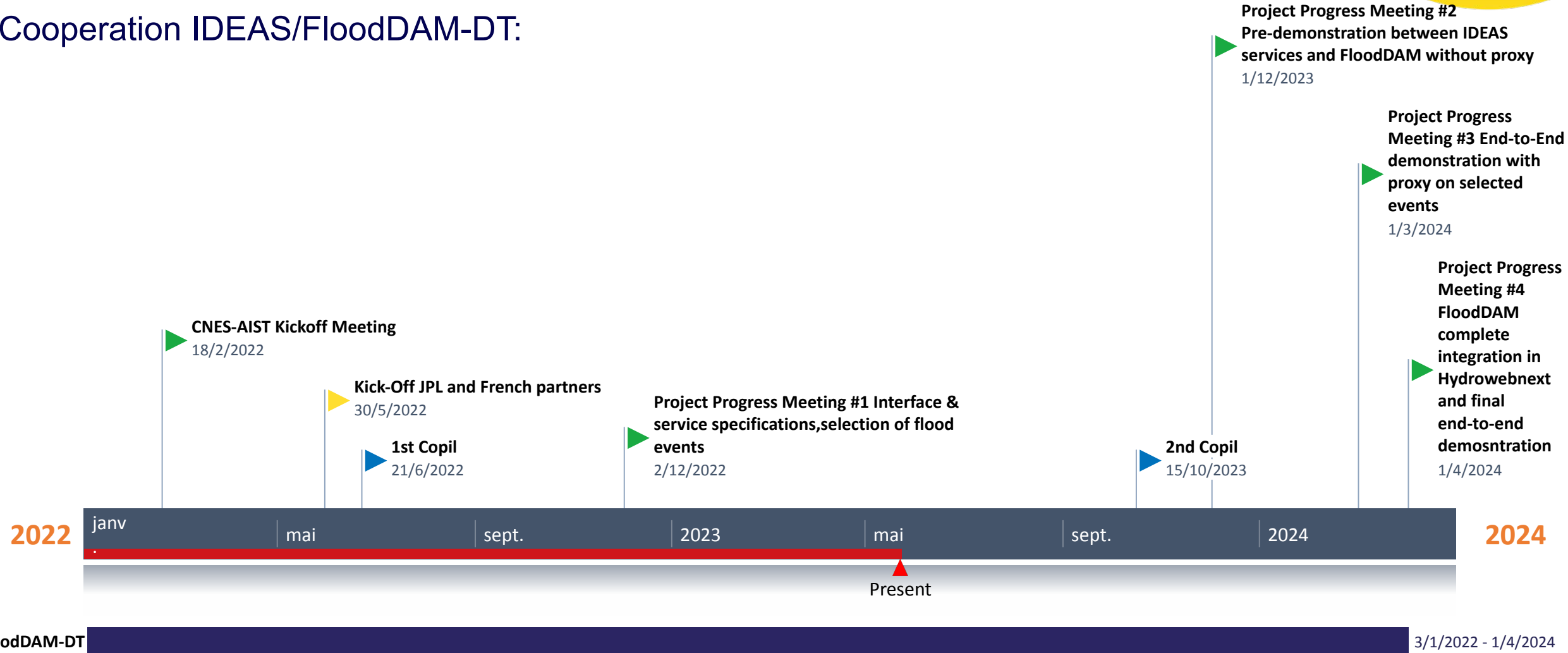


Time series of water levels in the rivers and lakes around the world processed from satellite altimetry

IDEAS/FloodDAM-DT Timeline



Cooperation IDEAS/FloodDAM-DT:



Shared platform for:

Project monitoring, documentation, meeting reports (Confluence and GitHub)

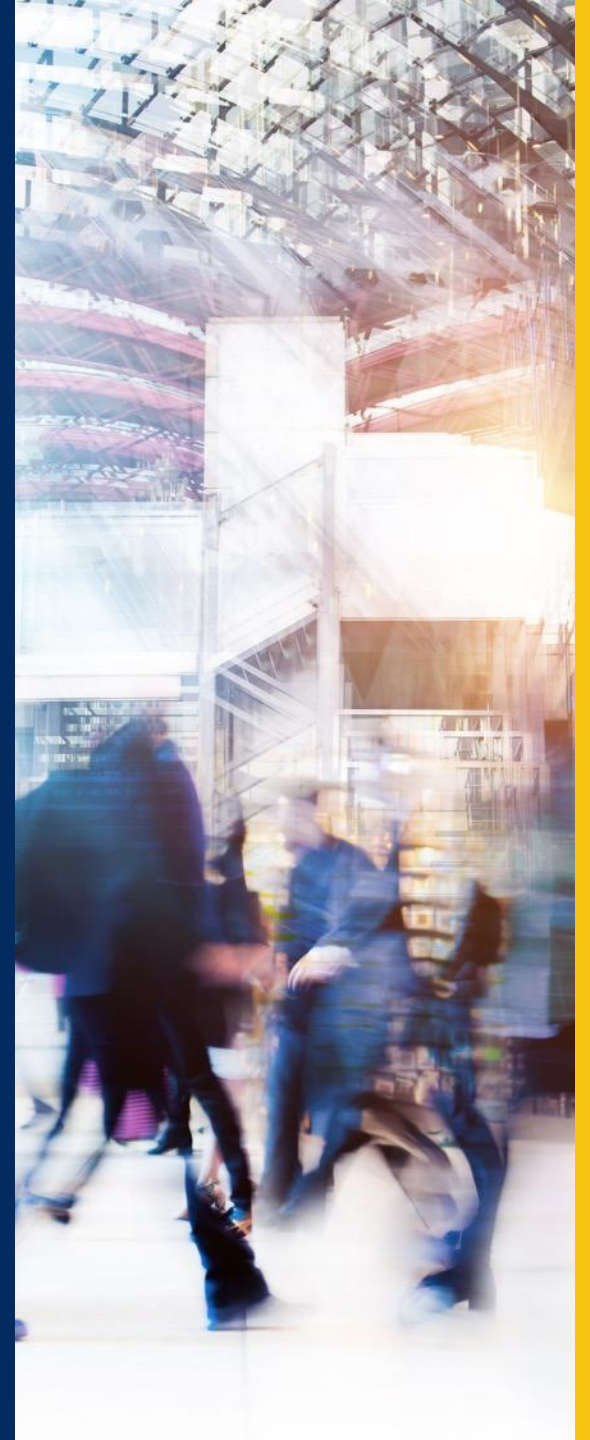
Code (Gitlab)

- ❖ **Towards Earth Digital Twins with a focus on hydrology**
- ❖ **Improvement of Flood extent mapping algorithm from SAR and optical data**
- ❖ **Generation of hydro-compatible high-resolution Digital Elevation Models and Land-use-land-cover maps from remote sensing**
- ❖ **Multi-sensors Data Assimilation for floods with 2D hydrodynamic models: Water Level from Sentinel-6MF, WSE maps from SWOT, front-like structures from water masks**
- ❖ **Coupled Data Assimilation with chained large-scale/local-scale hydrology models**
- ❖ **Assessment of safety and socio-economic impacts of flooding**
- ❖ **Application to other catchments of interest with safety and financial stakes**
- ❖ **Automatization of the entire chain**
- ❖ **Interoperability using standardized interfaces and data homogenization from the emerging Digital Twin specifications**

THANK YOU

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BACK-UP SLIDES

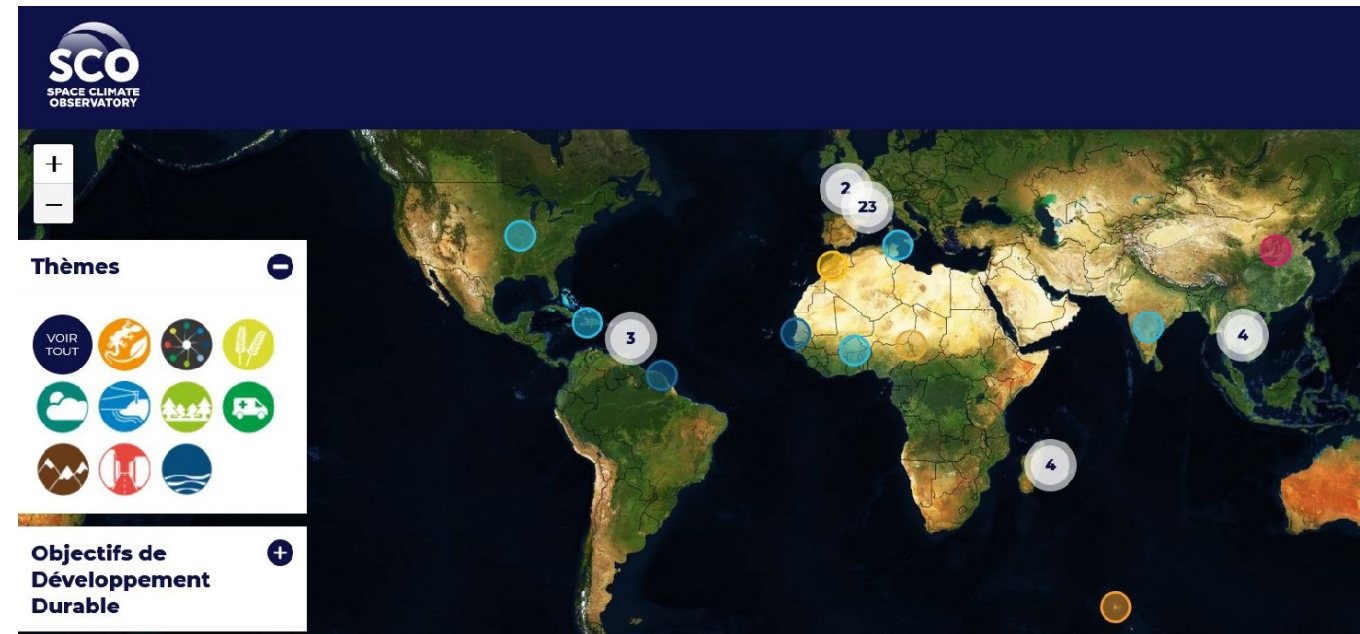
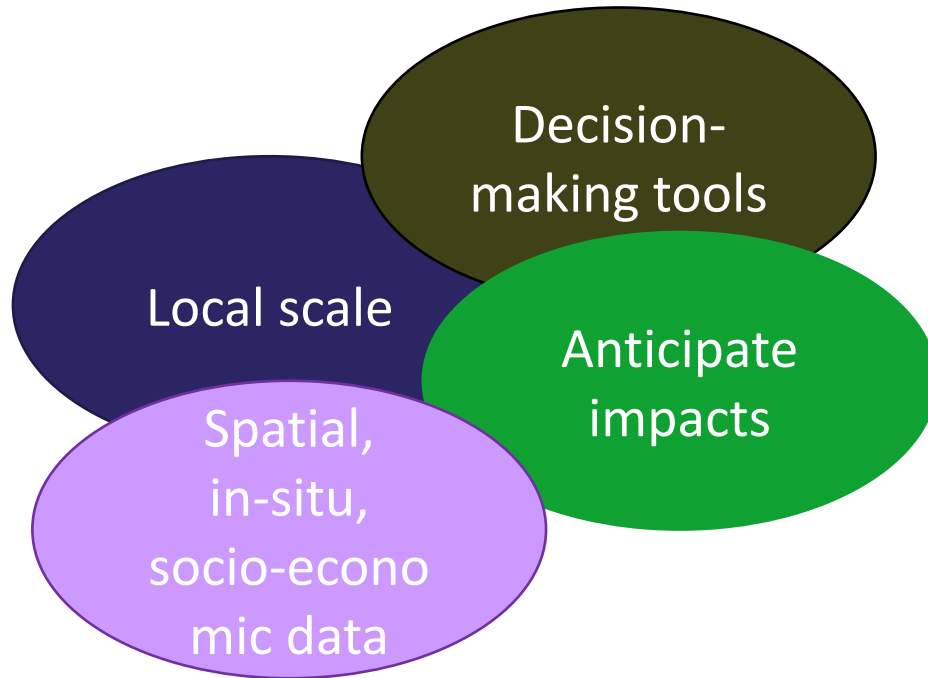


Space For Climate Observatory (SCO)

The SCO is one of the actions of the commitment n°5 (Zero Emission Goal) of the One Planet Summit (Dec. 2017)

- Initiative proposed by the President of CNES during the first OPS
- Acting against the impacts of climate change
- Signature of a Declaration of Intent by 35 space agencies and international org (June 2019)





<https://www.spaceclimateobservatory.org/>