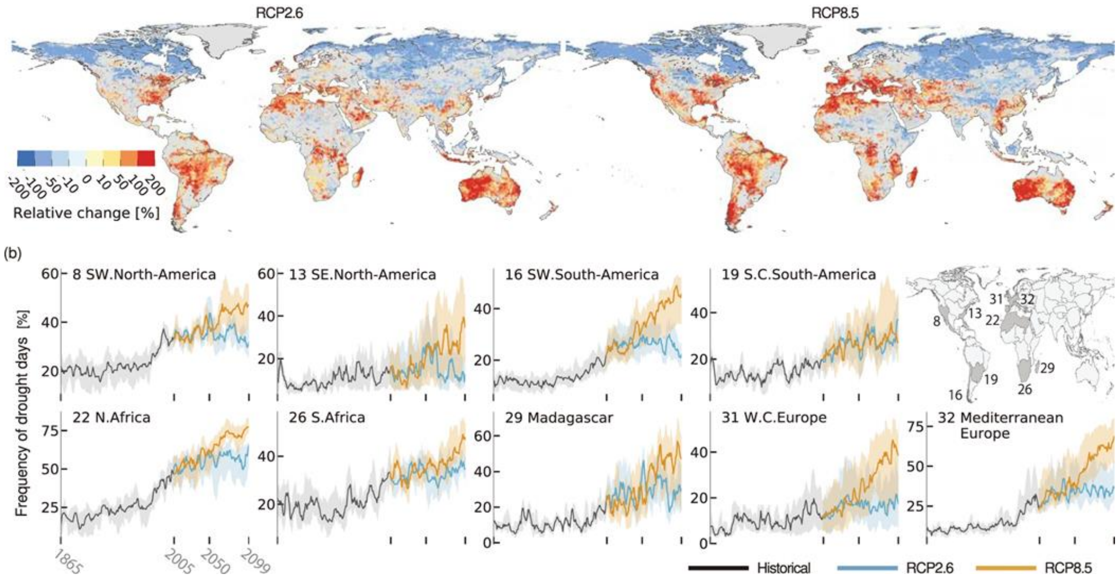
The CASCADES project: Automated processing chains for the monitoring of inland surface water using satellite images

Renaud Hostache, Thibault Catry, Chhenglang Heng, Christophe Révillion, Vincent Herbreteau, Vannak Ann

Context

Water is one of the most impacted ressources by climate change with more and more intense extreme events and by increasing societal demand (Kreibich et al., Naure, 2022). This increases the vulnerability of social-ecological systems and further augments tensions between potentially competing uses (usage vs environmental safeguarding).



After Satoh, Y., Yoshimura, K., Pokhrel, Y. *et al.* The timing of unprecedented hydrological drought under climate change. *Nat Commun* **13**, 3287 (2022).

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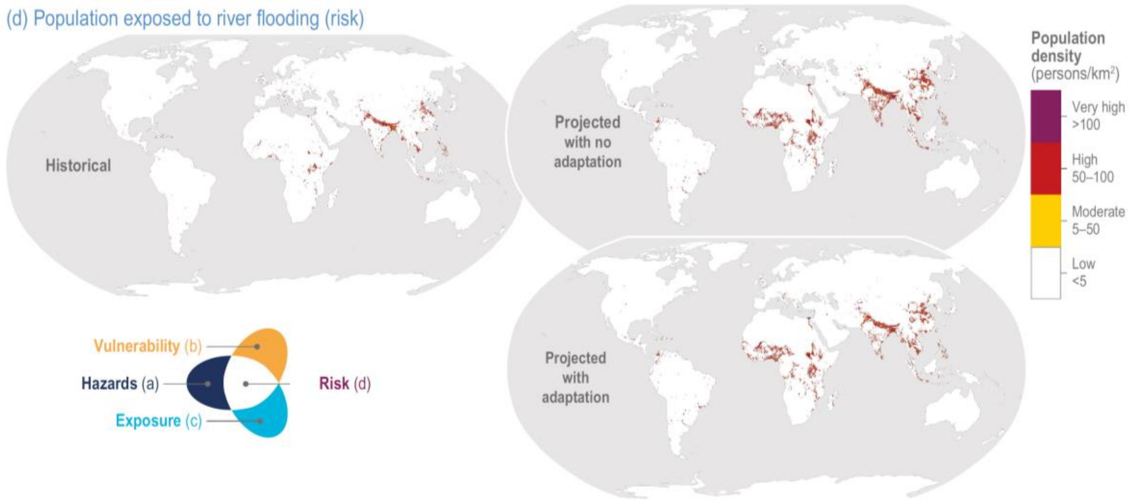


Source : IPCC

It is of primary importance to develop tools to evaluate and monitor the availability of water resources in a continuous and regular manner, as well as follow its trajectory over time to better understand and assess the impact of global changes on it.

CASCADES's objectives

1. Automatise from end to end Earth observation satellite image processing chains (Sentinel-1 et 2) to provide the following monitoring products:
   - Surface water maps
   - Flood depth and elevation maps during large flood events, by combining water extent maps and CopDEM)

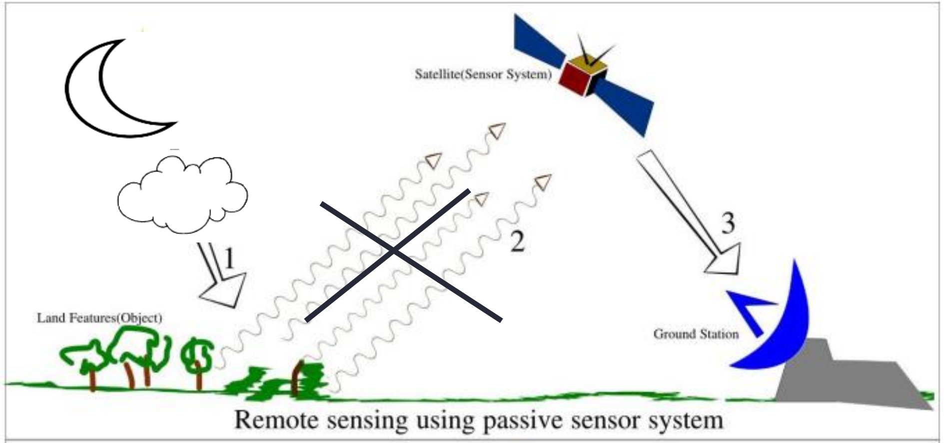
2. Co-develop a plateform in a participatory way with end-users to provide access to the maps.

The processing chains will be based on several algorithms developped and frequently utilized by project partners (e.g., Matgen et al. 2011, Chini et al. 2017, Alexandre et al., 2020, Frappart et al., 2021, Johary et al. 2023, Ayoub et al. Submitted).

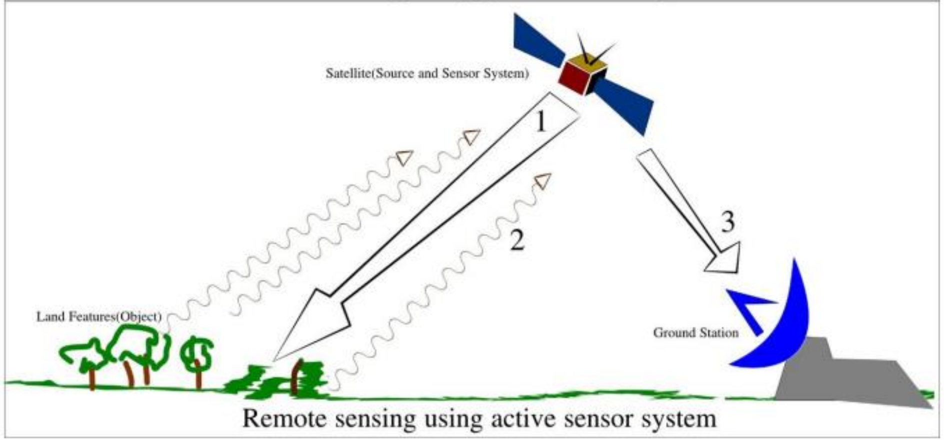
→ This will allow us to systematically process S-1 and S-2 images over selected areas and will therefore enable a continuous temporal monitoring.

Active and passive sensors for flood monitoring

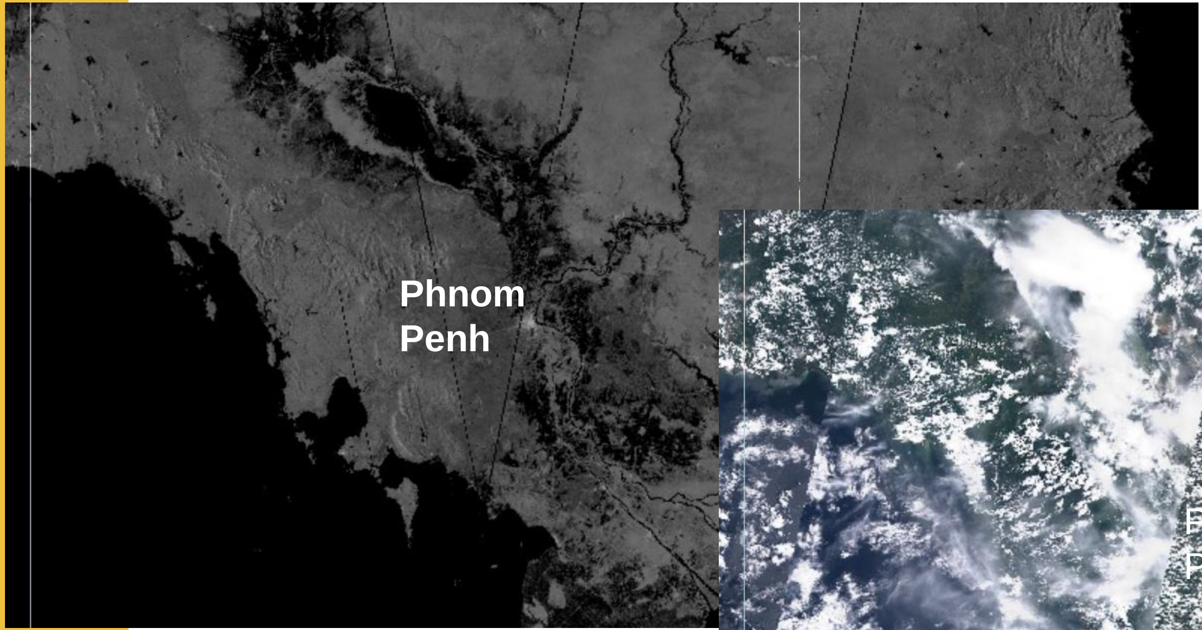
Optical remote sensing



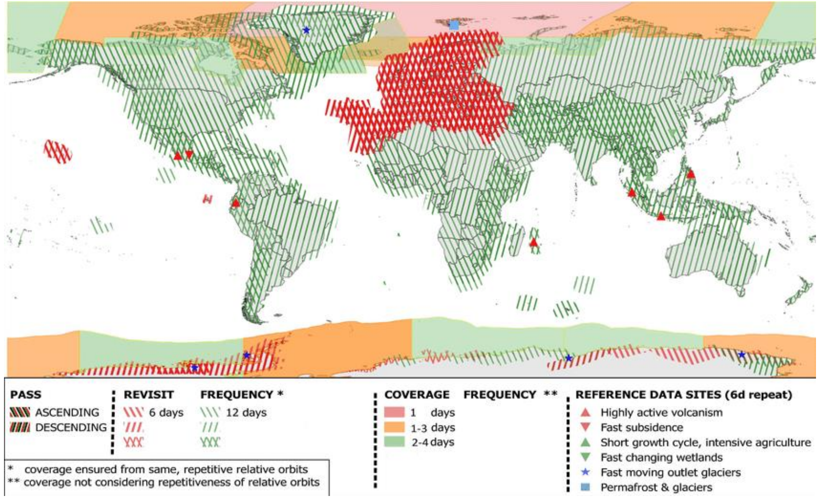
RADAR remote sensing



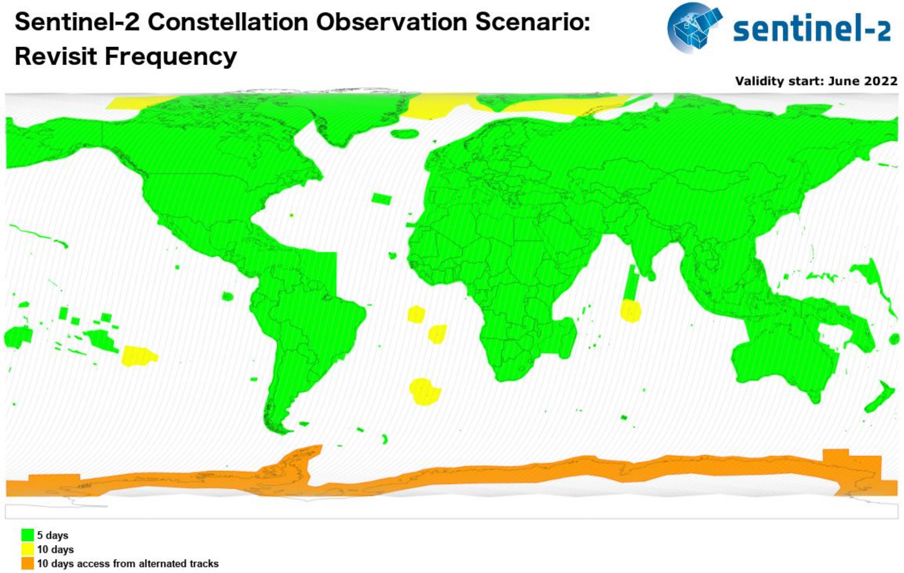
Active and passive sensors: S-1 and S-2



Sentinel -1 revisit time

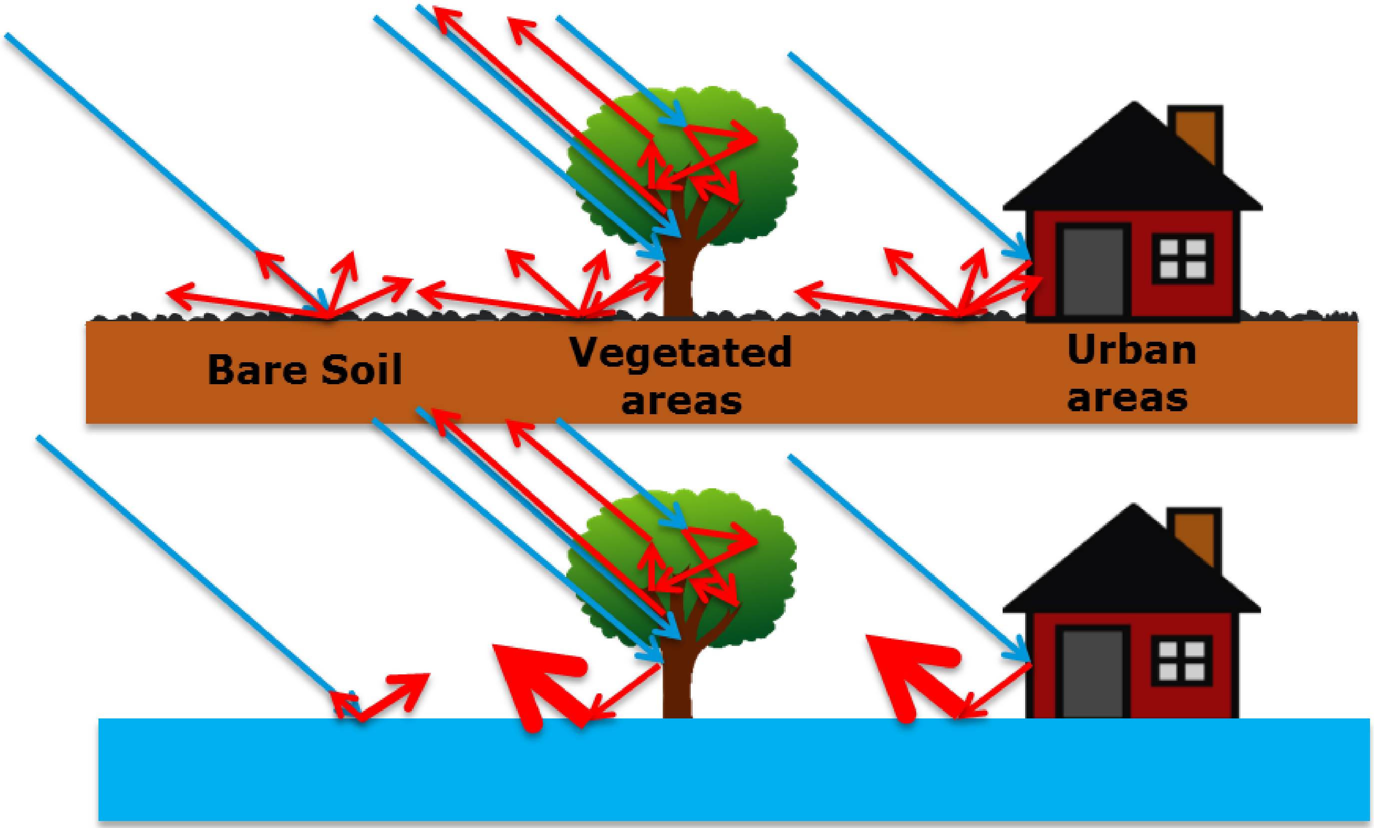


Sentinel-1 constellation observation, revisit and coverage scenario (April 2021), after Mullissa et al (2021)



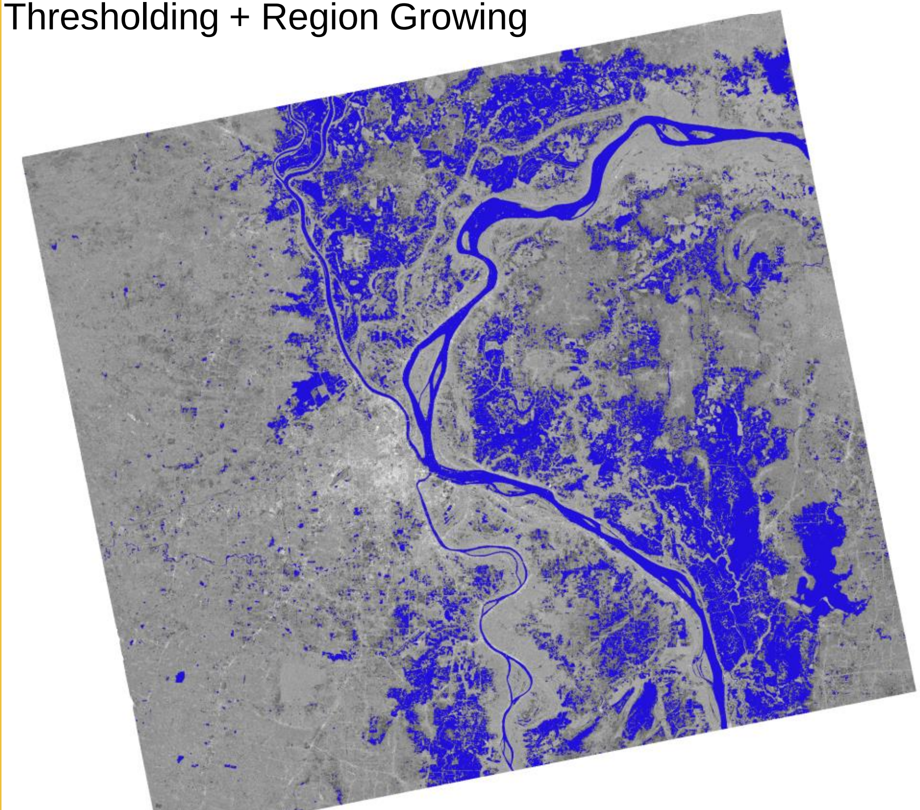
https://www.esa.int/

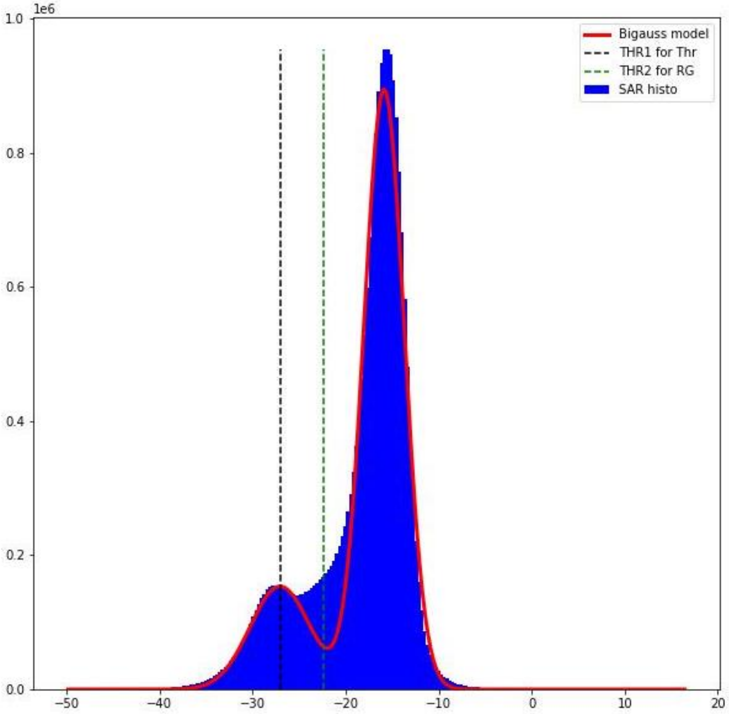
Detection of water on SAR images



Surface water mapping using S1

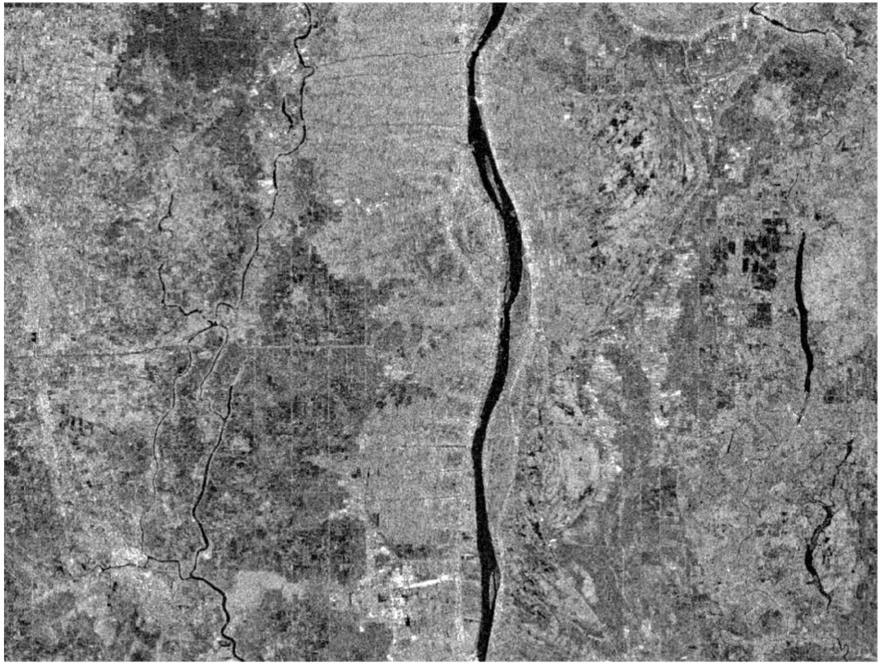
Thresholding + Region Growing

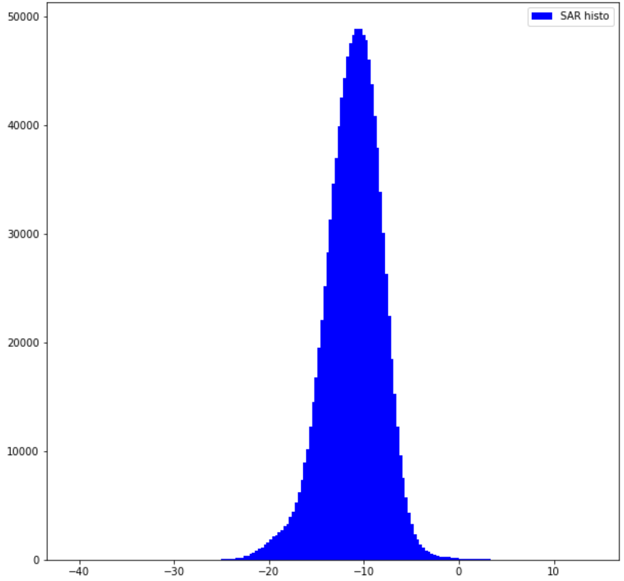




P. Matgen, R. Hostache, G. Schumann, L. Pfister, L. Hoffmann & H.H.G. Savenije. Towards an automated SAR-based flood monitoring system: Lessons learned from two case studies. PCE, 36(7-8):241-252, 2011, https://doi.org/10.1016/j.pce.2010.12.009.
M. Chini, R. Hostache, L. Giustarini & P. Matgen, A Hierarchical Split-Based Approach for Parametric Thresholding of SAR Images: Flood Inundation as a Test Case, IEEE TGRS, 55(12):6975-6988, 2017, https://doi.org/10.1109/TGRS.2017.2737664

Surface water mapping using S1





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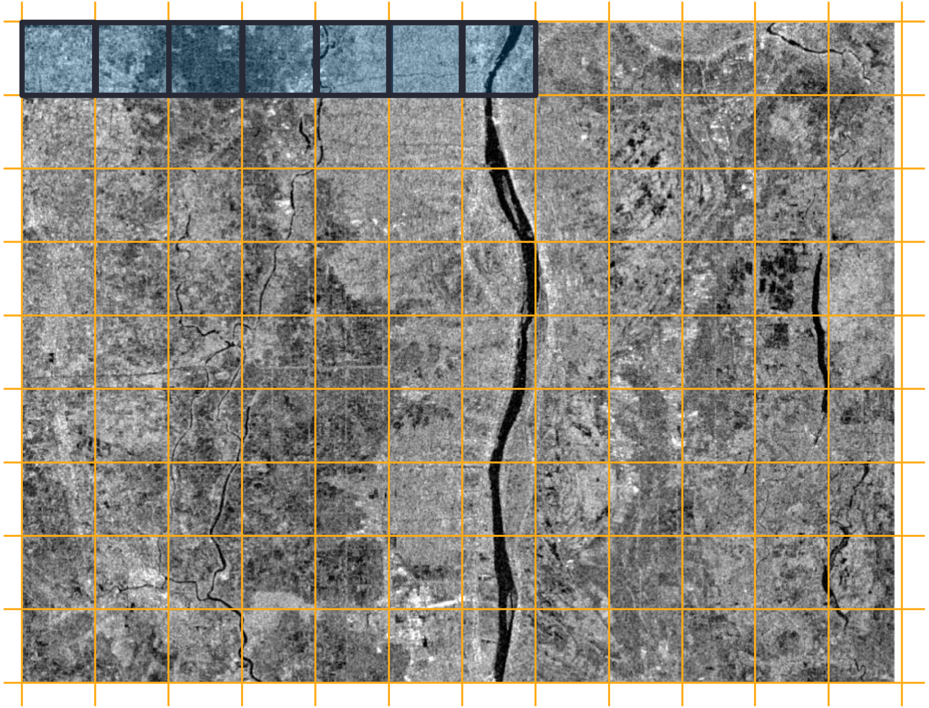
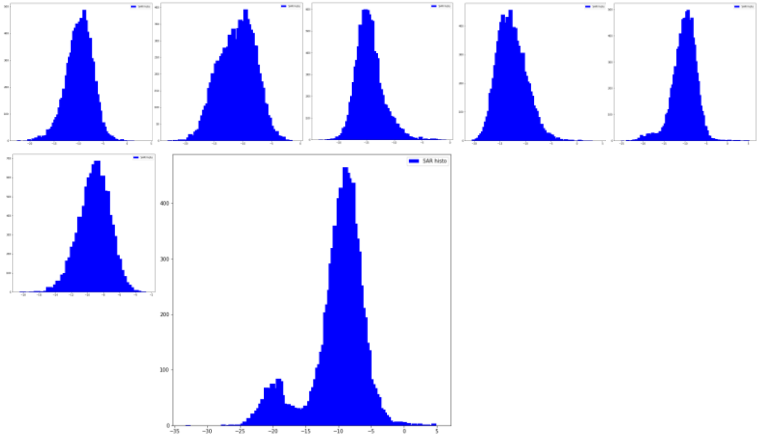
Surface water mapping using S1

Splitting the input image into smaller blocks (e.g., 100*100 pixels)





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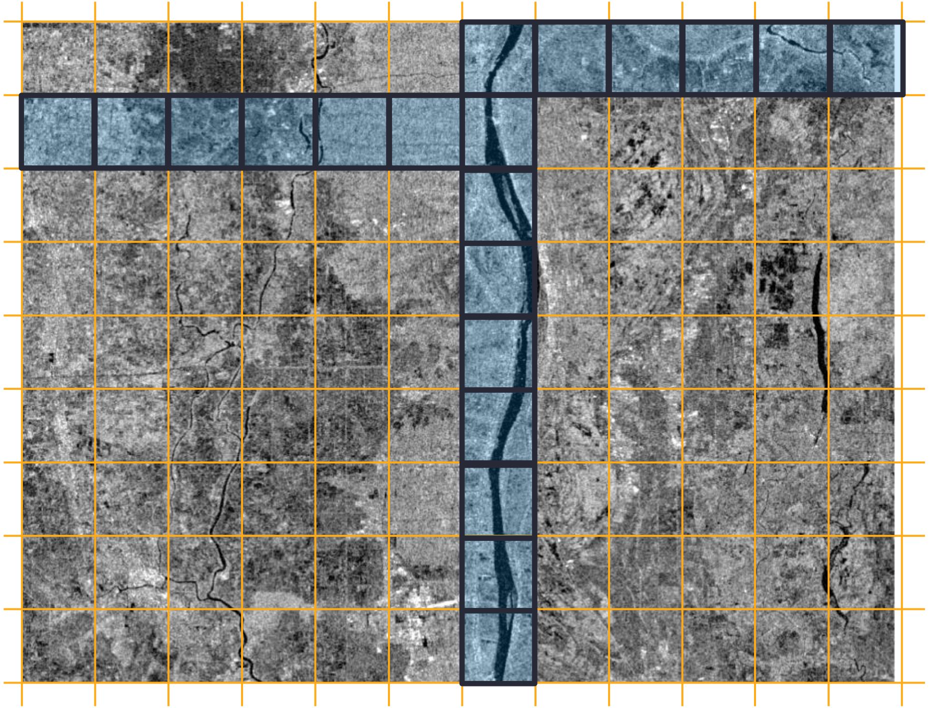

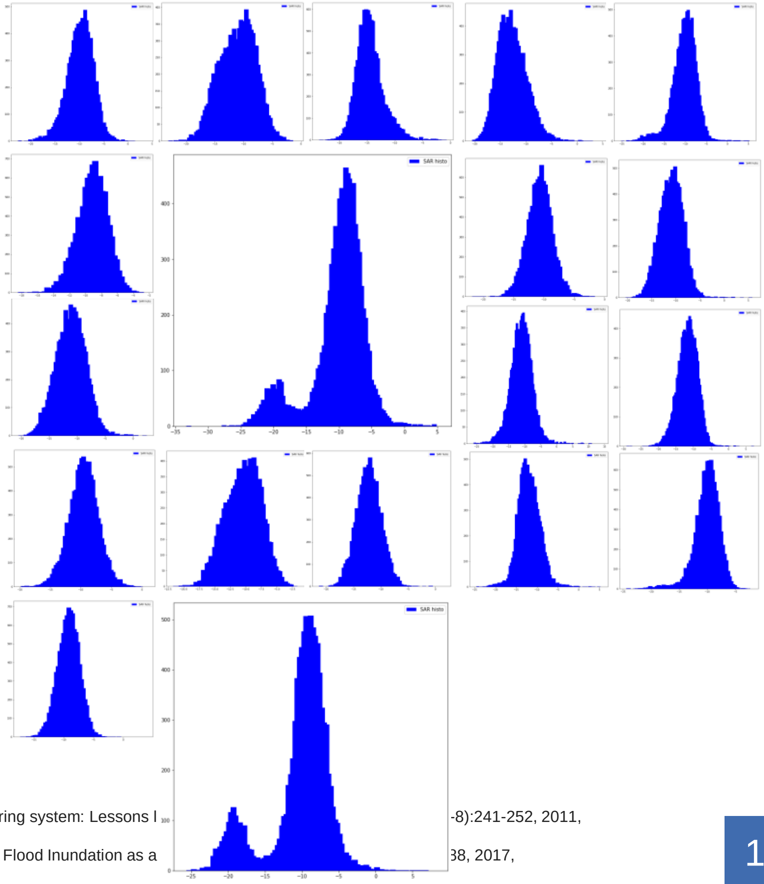

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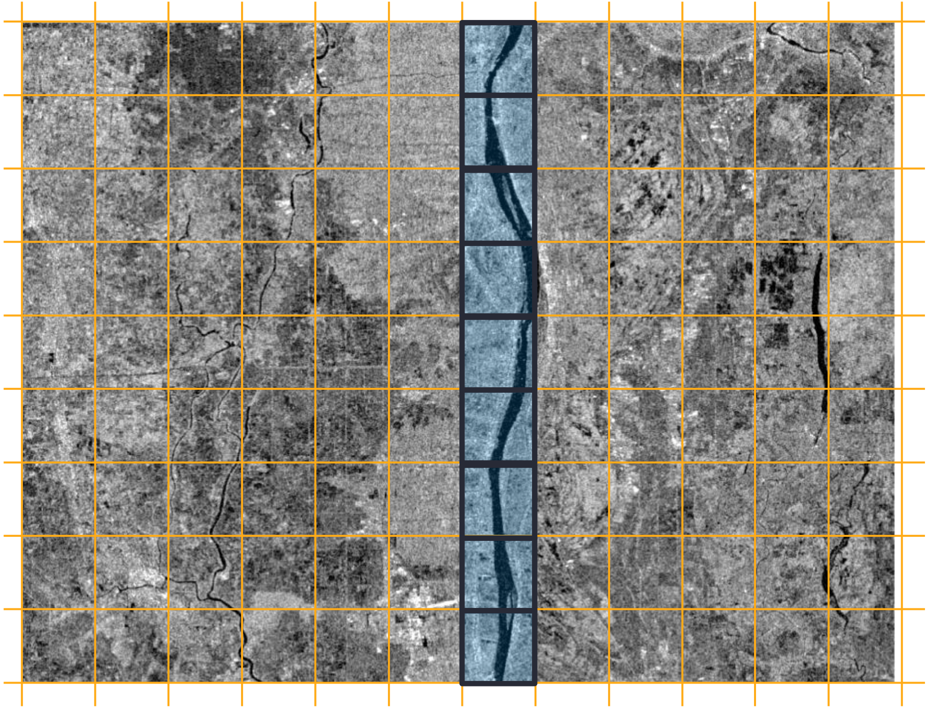

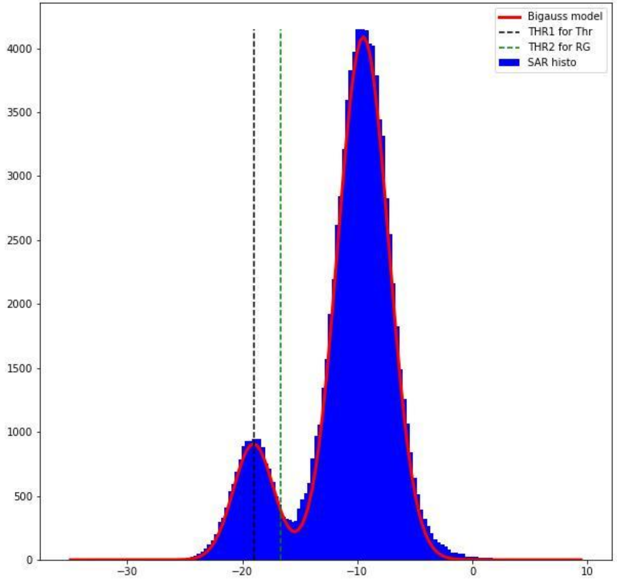

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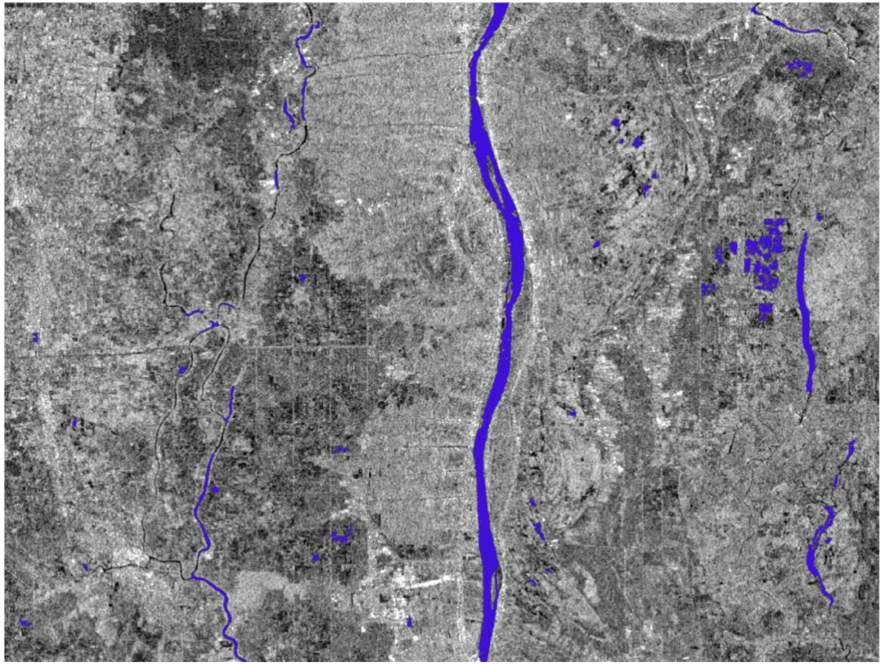
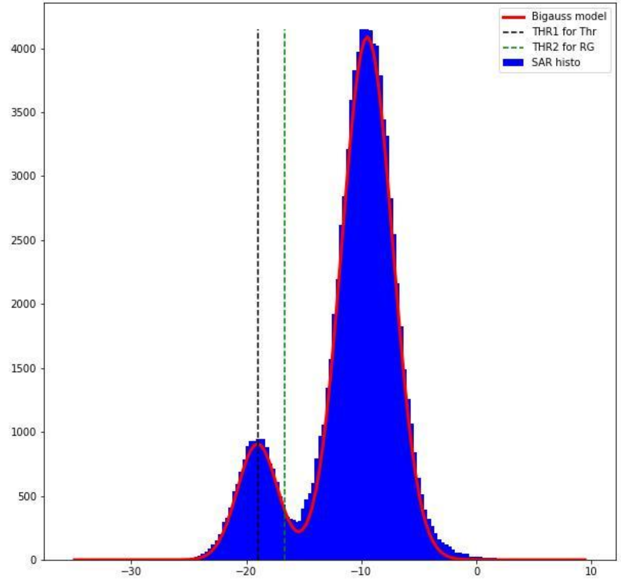
Surface water mapping using S1

Thresholding + Region Growing



The algorithm also integrates Change Detection on the same principle and will soon integrate VV and VH polarization



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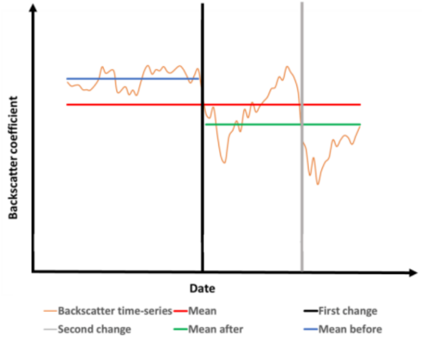
Surface water mapping using S1: 3 algorithms

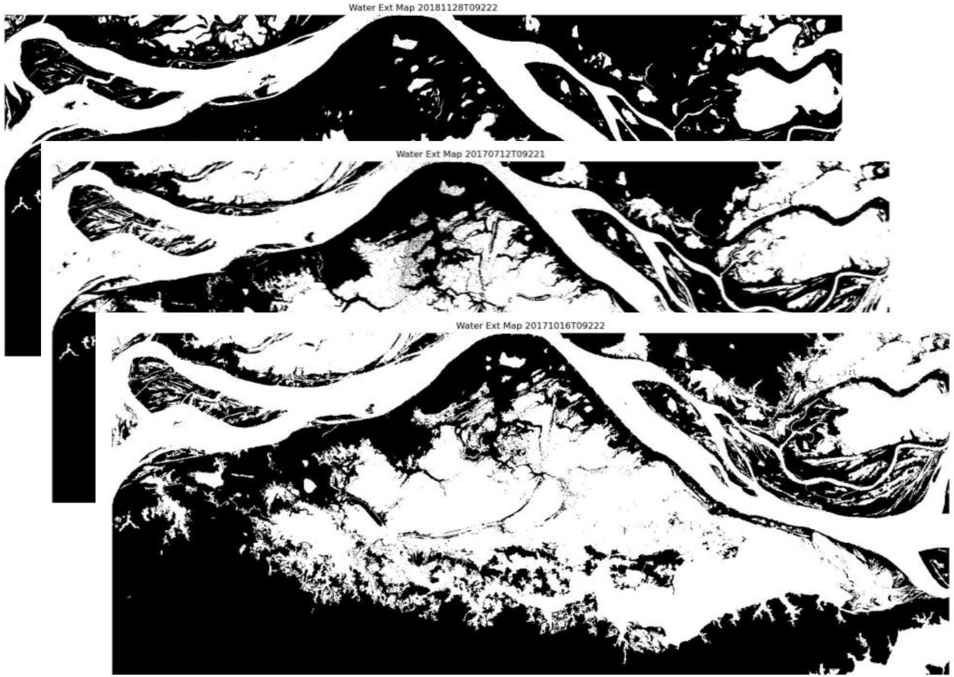
CuSum is an algorithm designed for time series processing (Manogaran and Lopez, 2018).
It uses a unique input parameter: Tc the critical threshold corresponding to the level of confidence of a change detection (bootstrap analysis). Cumsum is applied on VV and VH polarization.



Ygorra, B., Frappart, F., Wigneron, J. P., Moisy, C., Catry, T., Baup, F., ... & Riazanoff, S. (2021). Monitoring loss of tropical forest cover from Sentinel-1 time-series: A CuSum-based approach. *International journal of applied earth observation and geoinformation*, *103*, 102532.

Ygorra, B., Frappart, F., Wigneron, J. P., Moisy, C., Catry, T., Pillot, B., ... & Riazanoff, S. (2023). ReCuSum: A polyvalent method to monitor tropical forest disturbances. *ISPRS Journal of Photogrammetry and Remote Sensing*, *203*, 358-372.

A third approach will be also applied and evaluated:
This automated method is based on multotsu thresholding applied to VV and VH polarizations

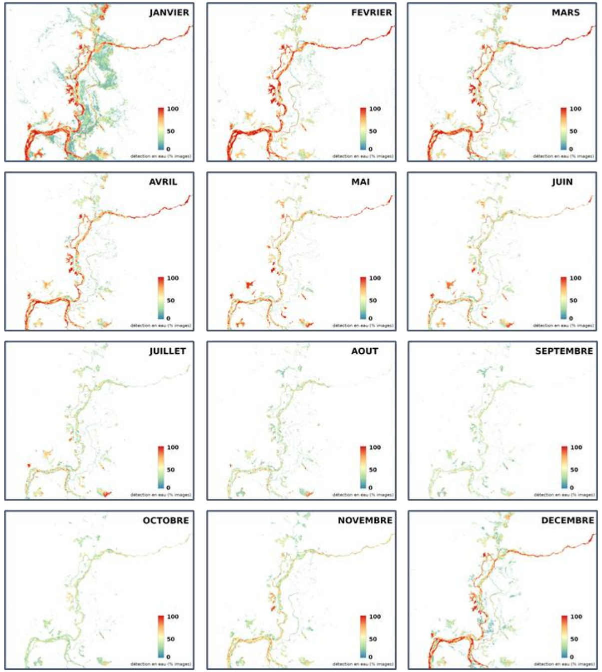


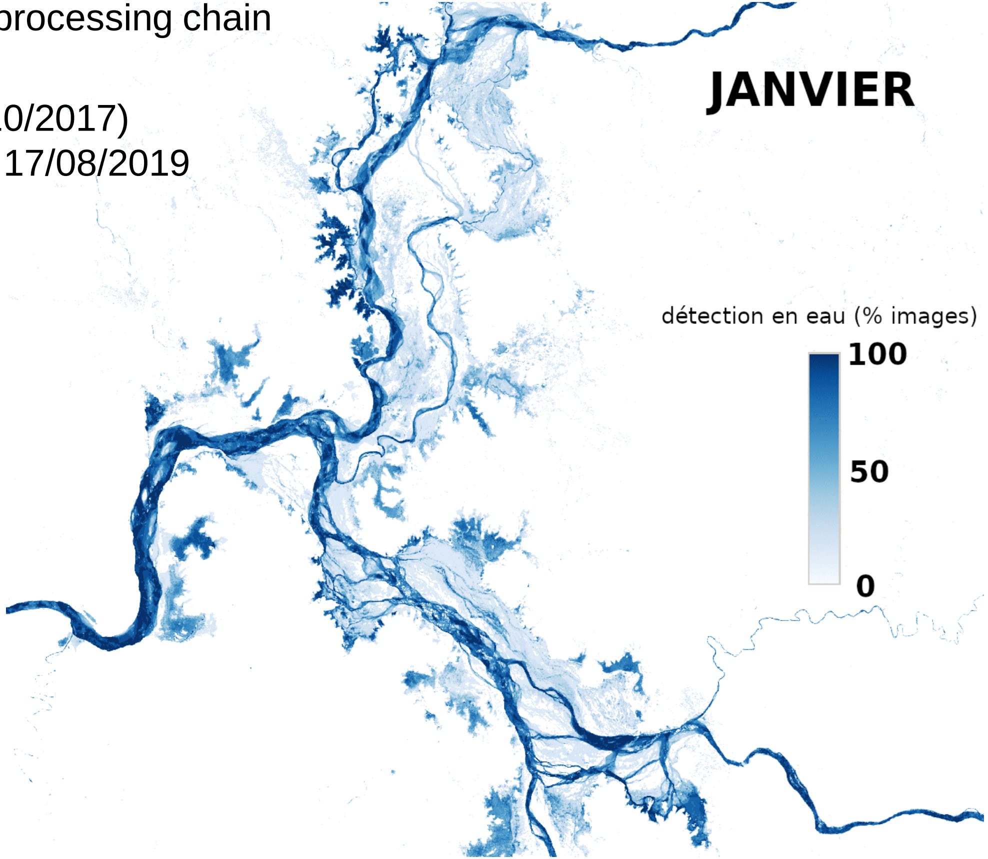
Master Thesis, Ana Carolina Pires Pereira

Surface water mapping using S2

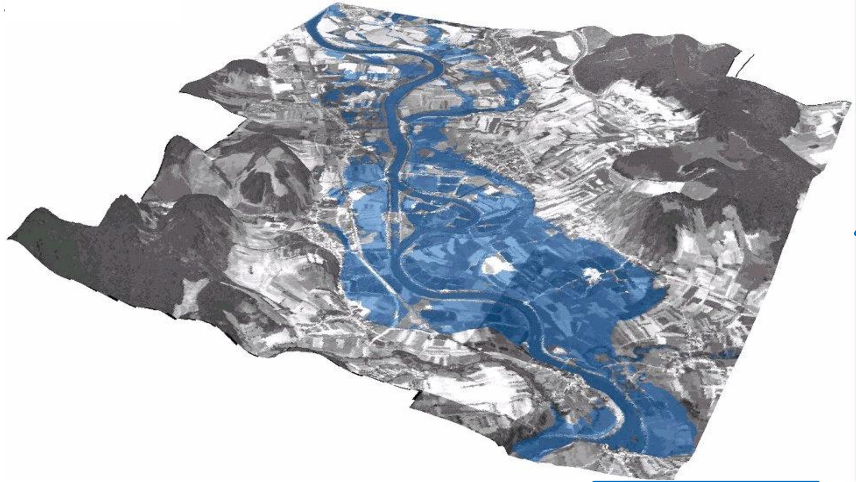
Analysis of Water Class using Sen2Change processing chain

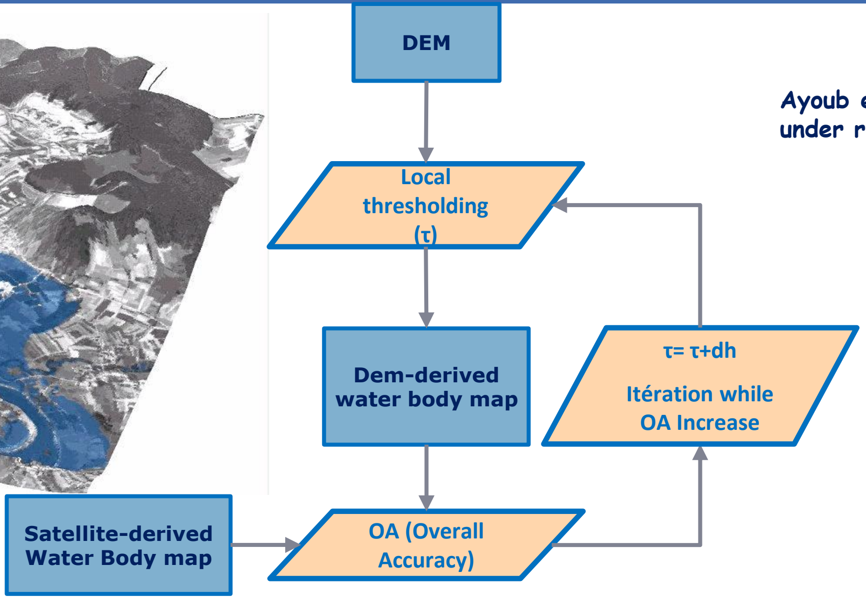
- 225 images
- Reference taken from dry season (11/10/2017)
- Monthly composite from 22/10/2015 -> 17/08/2019



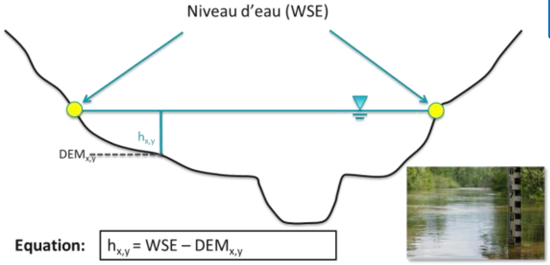


Water level estimation during flooding periods





Ayoub et al., RSE, under review



RMSE~50cm-2m depending on the resolution of the SAR and the DEM used

Various products

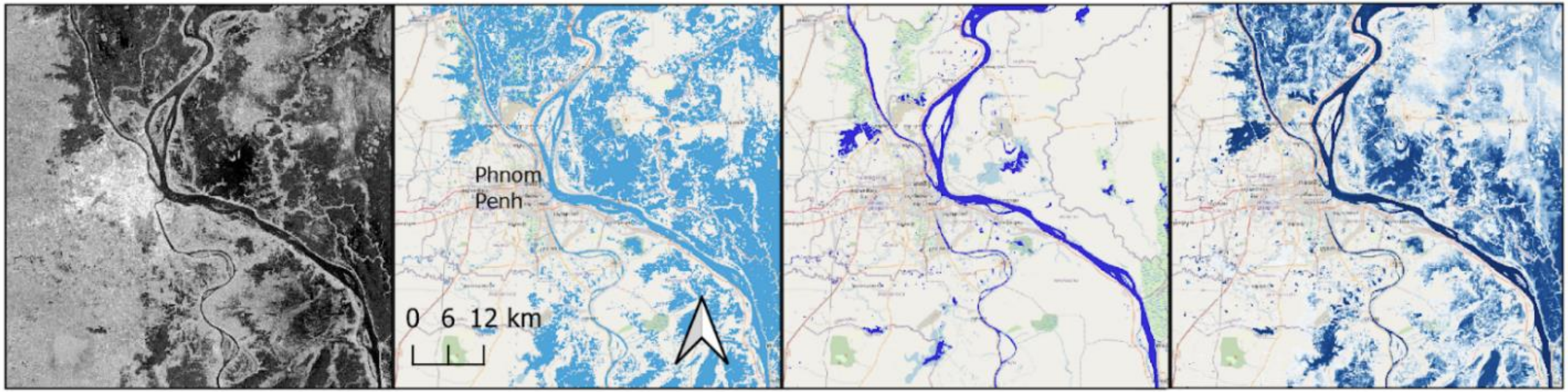


Image Sentinel-1 du 28 septembre 2018
Bande 1 (Gray)
-0,212582
-28,1645

Carte des eaux de surface du 28 Sep 2018
Bande 1 (Gray)
Eau
OpenStreetMap

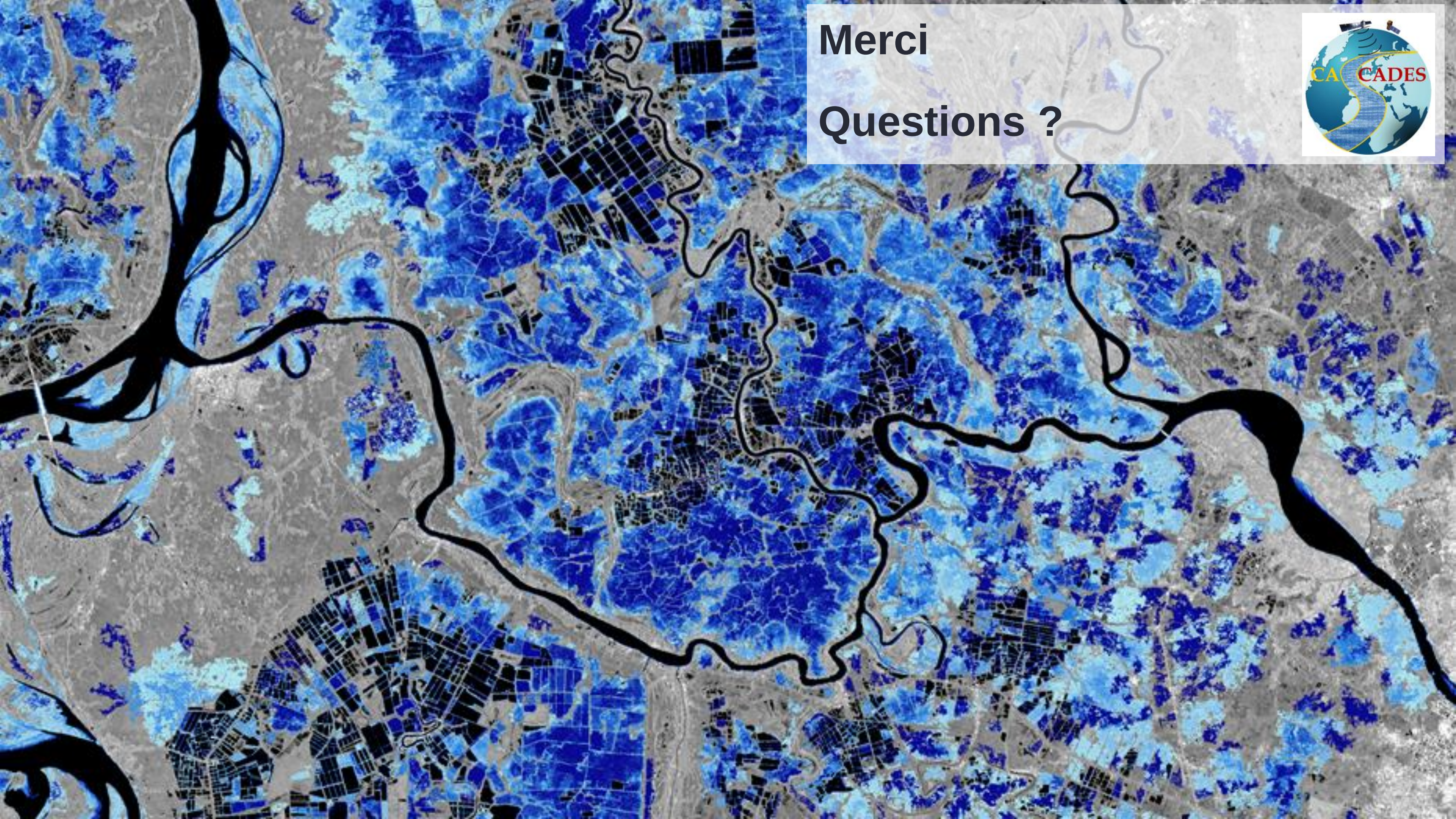
Carte des eaux de surface "Habituelles"
Bande 1 (Gray)
Eau de surface "Habituelle"
OpenStreetMap

Carte d'occurence d'eau S-1 ([%] 2014-2023)
Bande 1 (Gray)
89,539749
0,1
OpenStreetMap

Output products will be made available via a platform codesigned with end users

Several markedly different test case around the world

i) **The Tonle Sap lake and the mékong delta/floodplains**, ii) Madagascar (focus on Betsiboka Basin), iii) Several floodplains in Brasilian Amazon, iv) the Titicaca, Poopó, Desaguadero, Salar (TDPS) Basins on the bolivian/peruvian altiplano, v) the Guayas in Equador, and vi) the Goulbi Maradi basin in Niger



Merci

Questions ?