

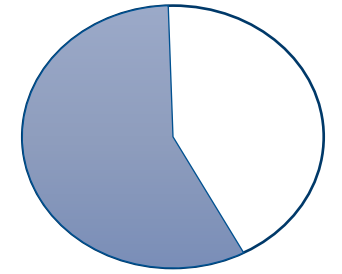


GLOBAL APPROACH FOR RESERVOIR STOCK MONITORING BY SATELLITE

STOCK-WATER

19/09/2022

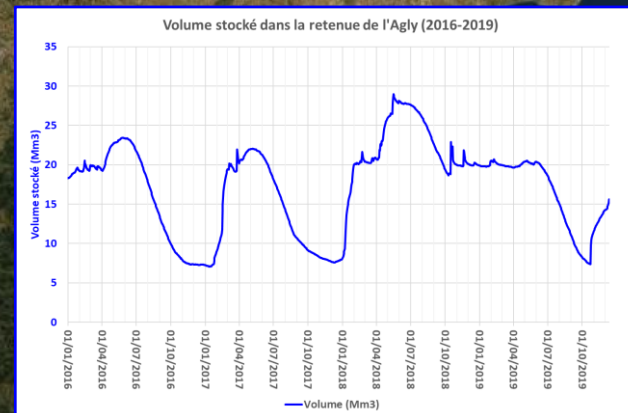
Santiago PENA LUQUE (CNES)



Reservoirs Water Stock ?

Context

- CNES involved in **SWOT Downstream** (Hydrology) :
 - surface waters (rivers/lakes),
 - snow,
 - water quality, ...
- Key variable - **Reservoir stocks** :
 - Agriculture, human consumption, industry
 - Environemnt



CONTEXT



MINISTÈRE
DE LA TRANSITION
ÉCOLOGIQUE

*Liberté
Égalité
Fraternité*



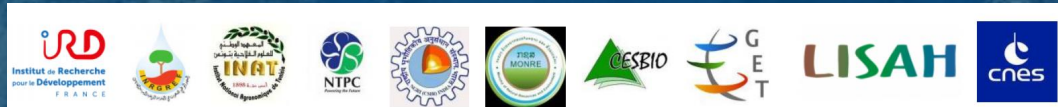
Prototype (2019 – 2020)

- Monitoring of 100 reservoirs in Occitanie region (France)
- **Surface, Volume and Filling Rate** monitoring
- Evaluation on 29 reservoirs



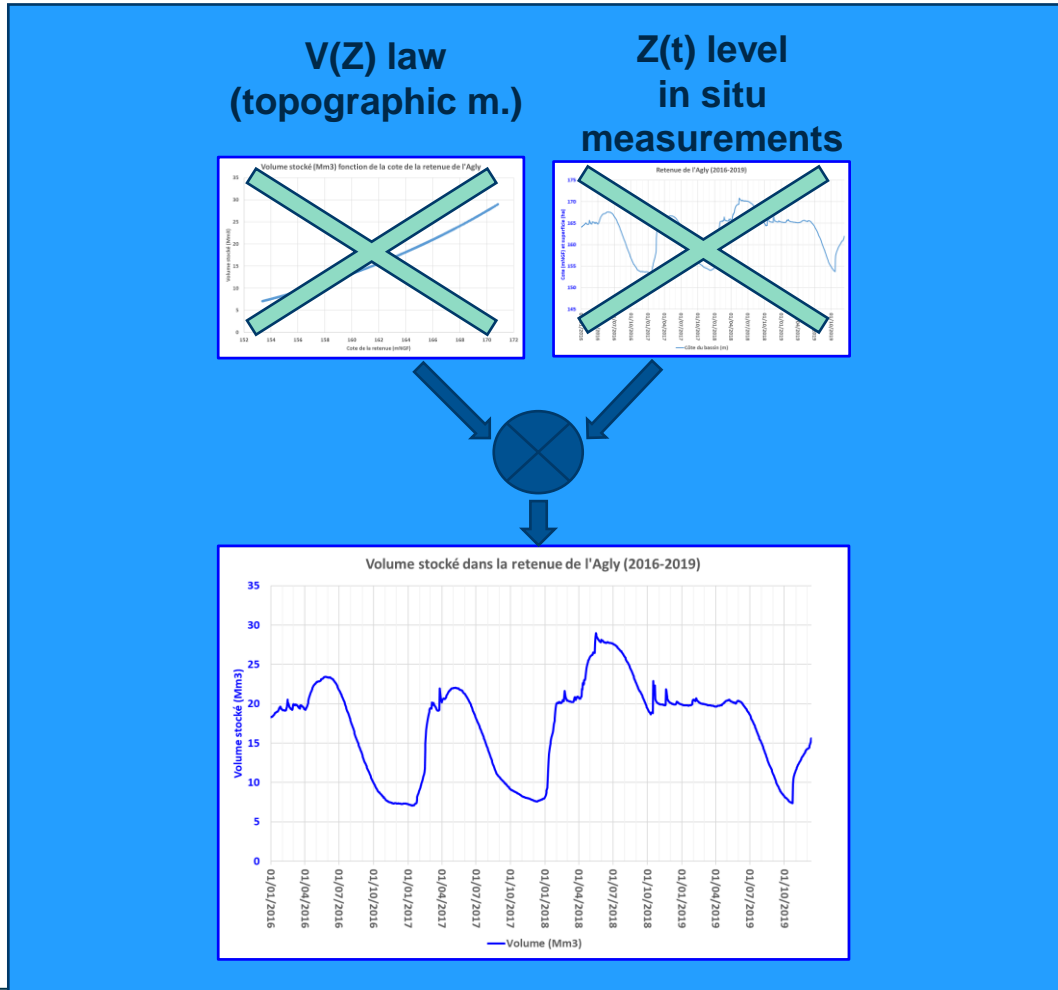
StockWater project (2021 – 2022)

- Evaluation and monitoring of 100 reservoirs
- Data evaluation in :
 - France, Spain, India, Brazil, Laos, Burkina, Tunisia

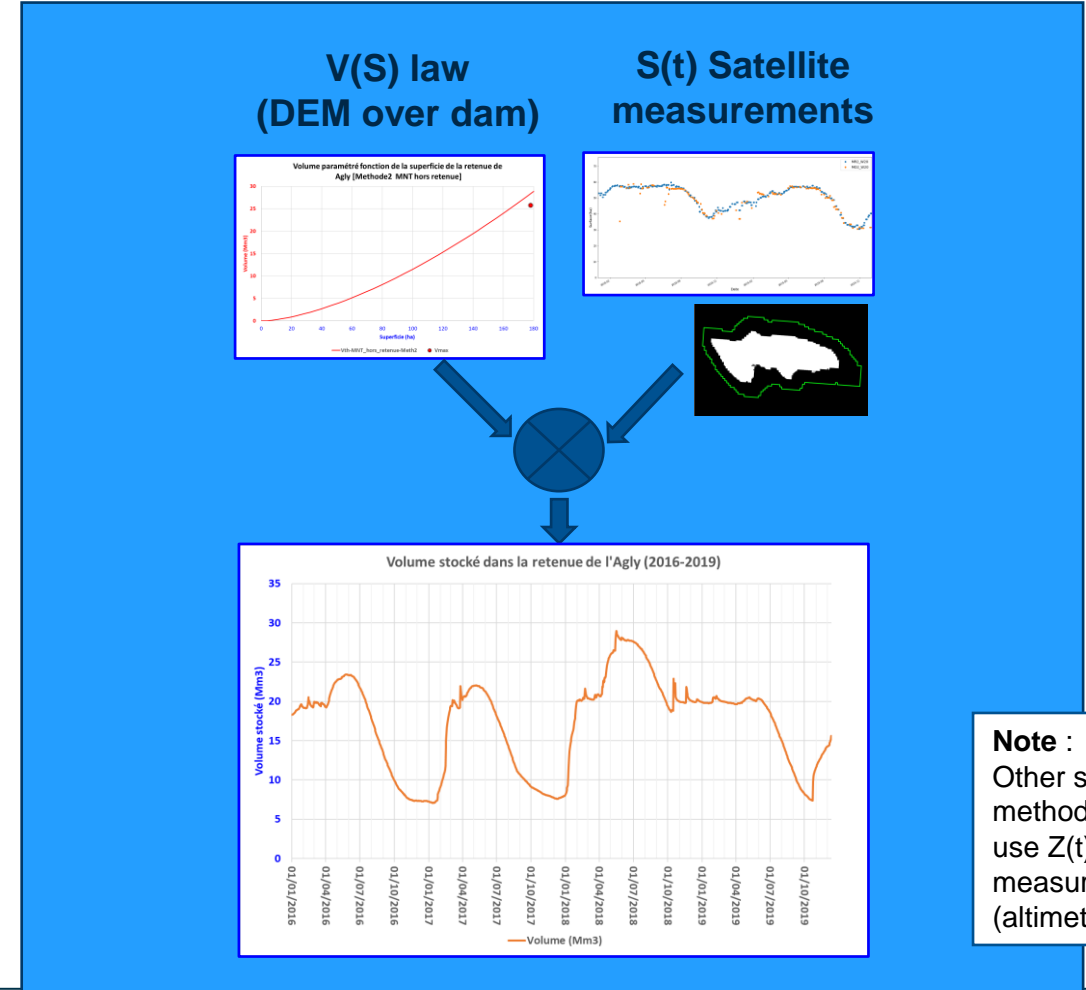


VOLUME ESTIMATION METHODS

In situ



Satellite



Note :
Other satellite methods might use Z(t) measurements (altimetry)

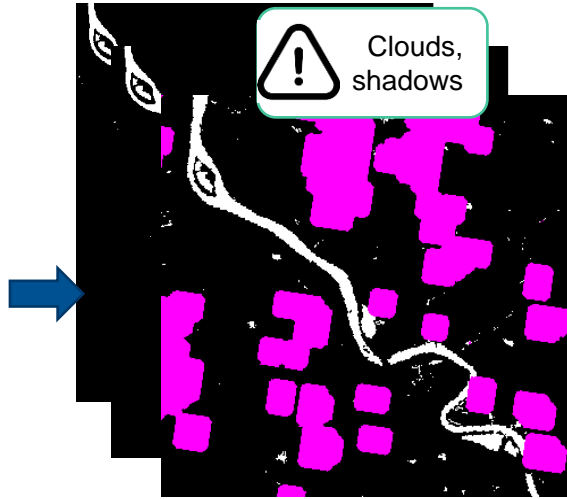
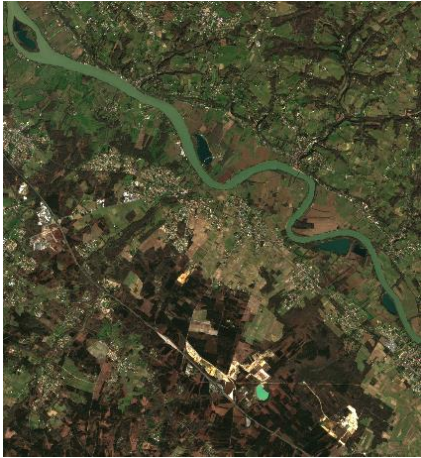
SURFACES

SURFWATER - Algorithm

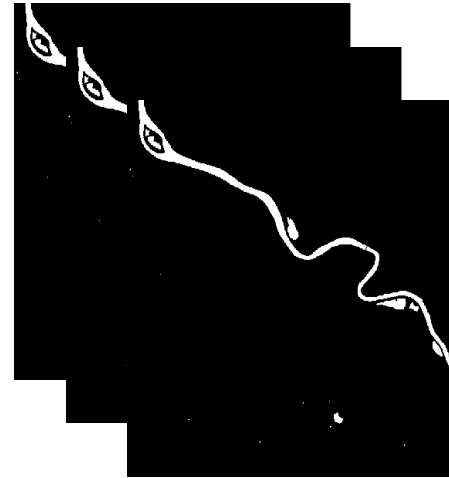


**Sentinel
2**

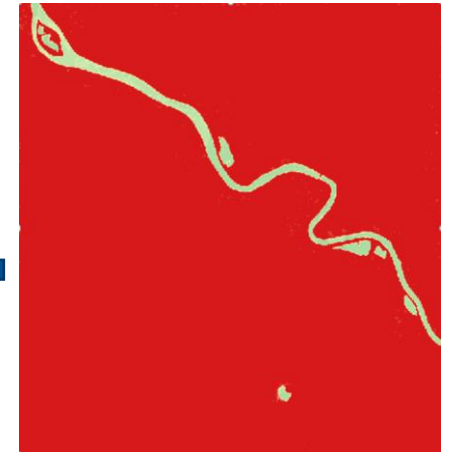
5 days
revisit
time



Single-date masks



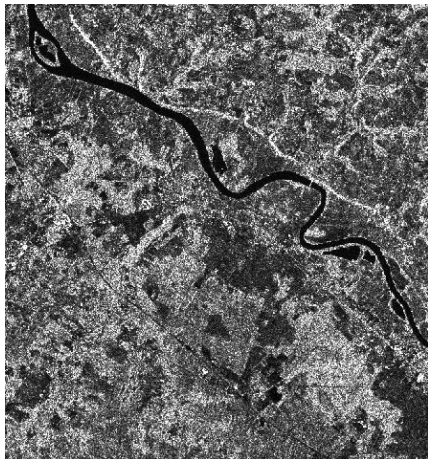
Multiple-date masks



**Synthesis
(monthly, yearly)**

Sentinel 1

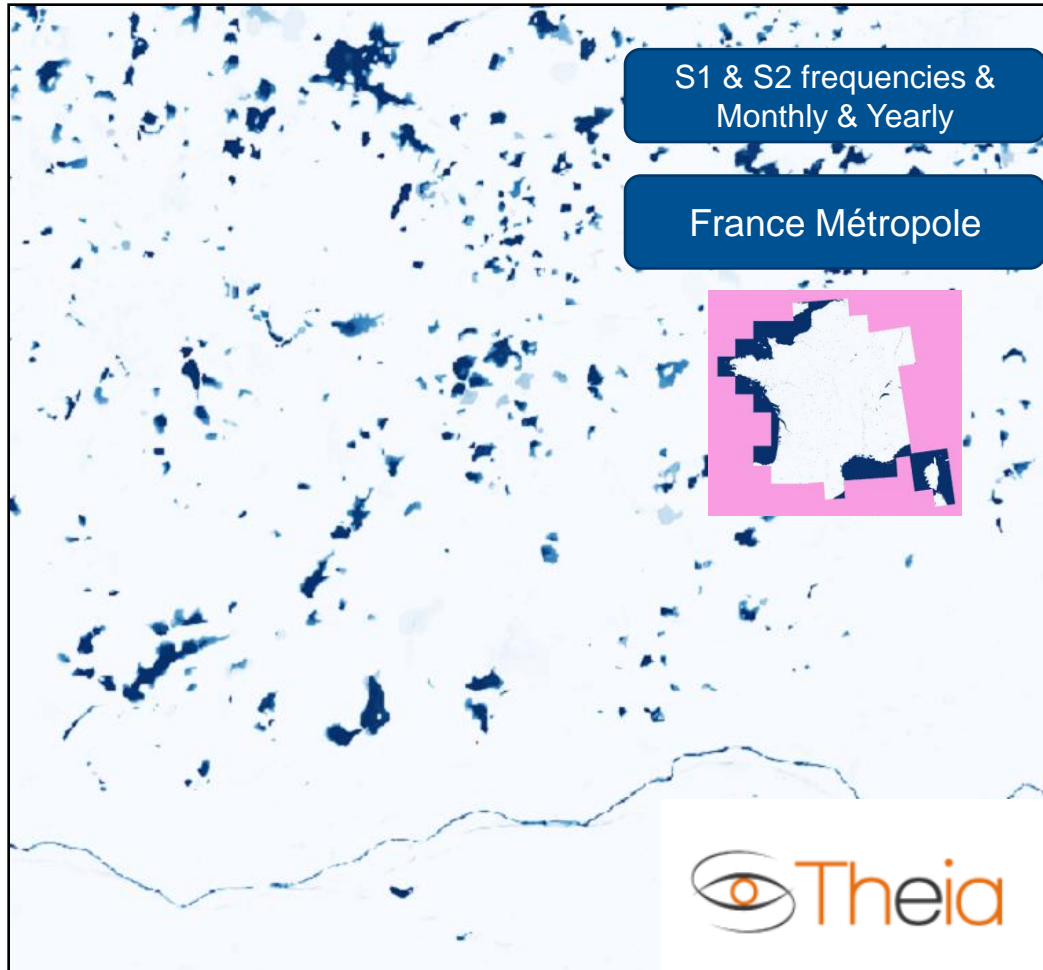
6/12 days
revisit
time



**Speckle,
Water/soil
roughness**

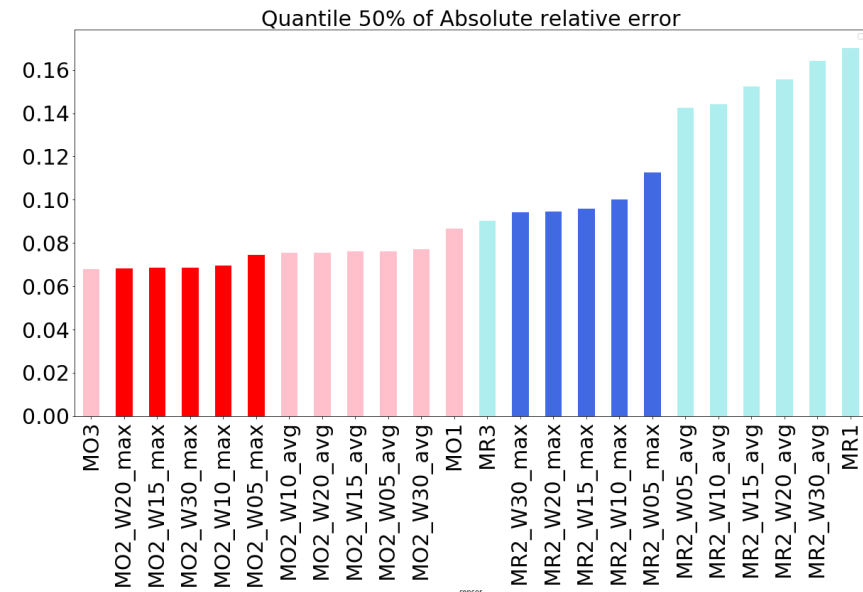
SURFACES

SURFWATER - Product



<https://thisme.cines.teledetection.fr/home>

- Available Water product at :
 - THEIA server (France)
 - hydroweb.next (Europe, Africa 2023)
- Last publication :
 - S2 water area estimations outperform S1



Sentinel-1&2 Multitemporal Water Surface Detection Accuracies, Evaluated at Regional and Reservoirs Level (Pena-Luque et al, 2021)

BATHYMETRY

Analysis of Global DEMs

- Copernicus, ALOS, SRTM

Bathymetry estimation from DEM

- Automatic Algorithm

DEM4WATER - Algorithm

1 – Start : Dam location

2 – Dam bottom location

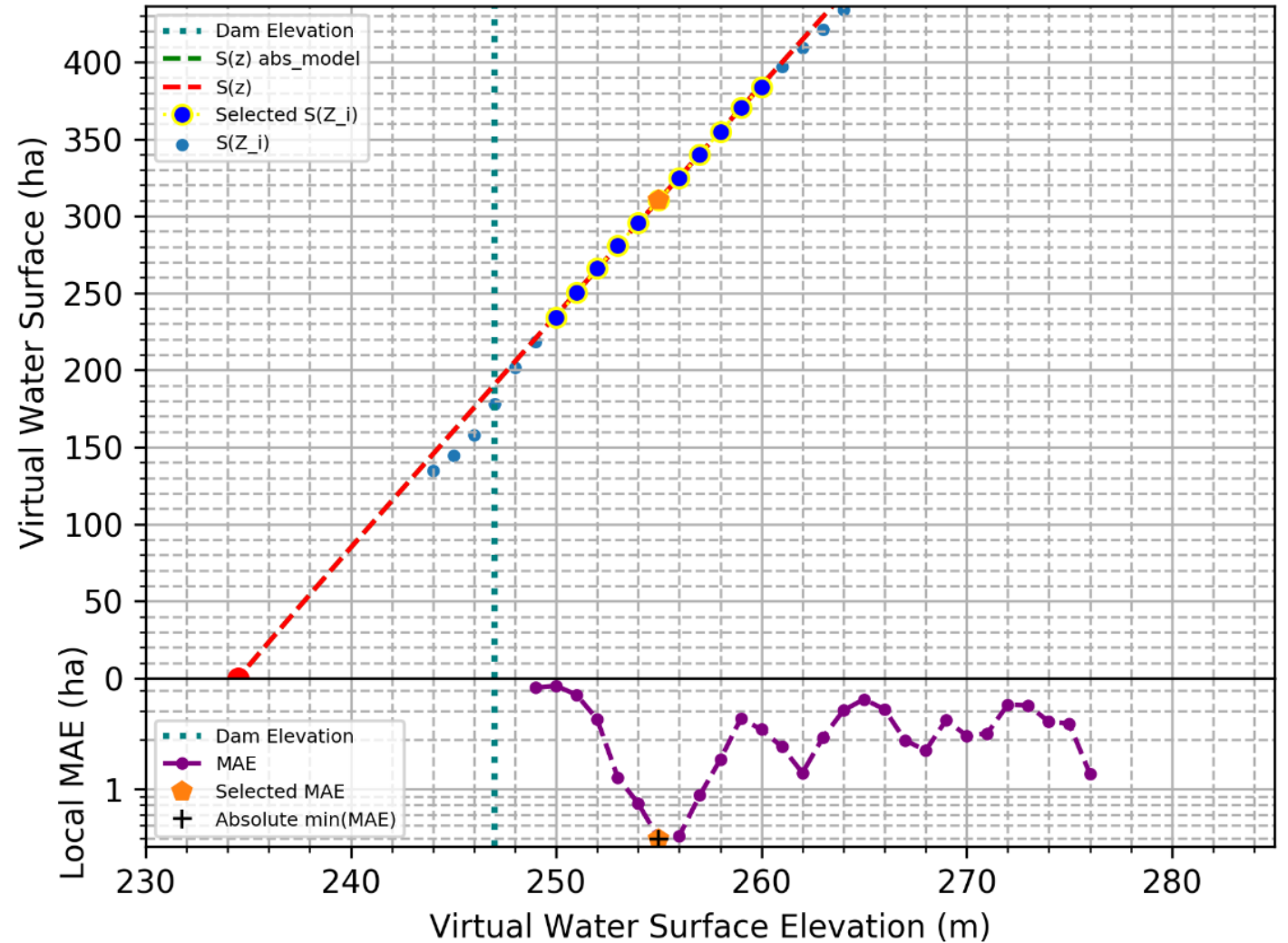
3 – Valley cutline

4 – Contourline determination: (S,Z points)

5 – S(Z), V(S), V(Z) Power laws : **alpha, Beta, Z0** determination

$$\text{Astarac: } S(Z) = 1.587E+05 * (Z - 234.52)^{9.846E-01}$$

α
 Z_0
 β



STOCKWATER PHASES



Phase 1 Goals (2021)

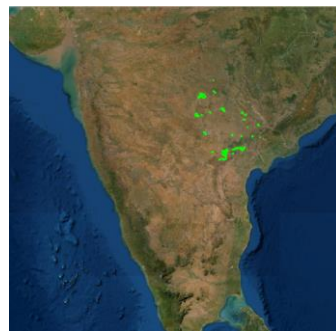
- Automate processes
- Evaluate Bathymetries depending on DEM (SRTM, Copernicus, Alos)
- Evaluate Volumes series of 50 reservoirs with **insitu data** [V(t), Z(t) -> S(t), VR(t)] = 3 years data

Phase 2 Goals (2022)

- Improve Process/Quality - S(t), V(S)
- Evaluate 100 end-to-end volume series
- Sharing Platform & Capacity building



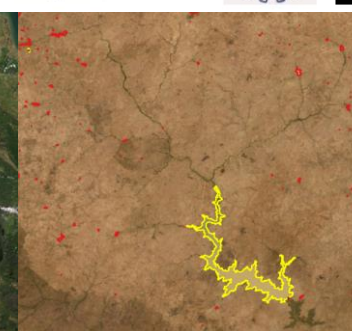
France & Spain



India



Laos



Burkina



Tunisia



Brazil

- Dam Database construction :

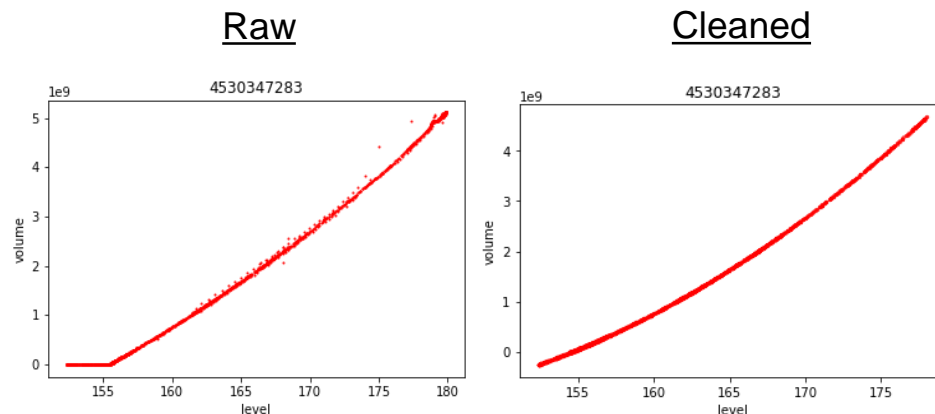
- Based on Grand, GeoDAR, GODD2 , SWOT Lake Database (PLD) and Global Surface Water(GSW)



José Torán Reservoir in Sevilla, yellow for GRand /GeoDAR extent, GSW in red

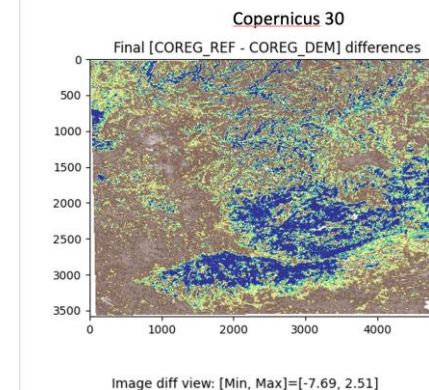
- In-situ data validation:

Nagarjuna Sagar



- DEM Validation & Analysis:

DIFFERENCE COREGISTRED



DEMs

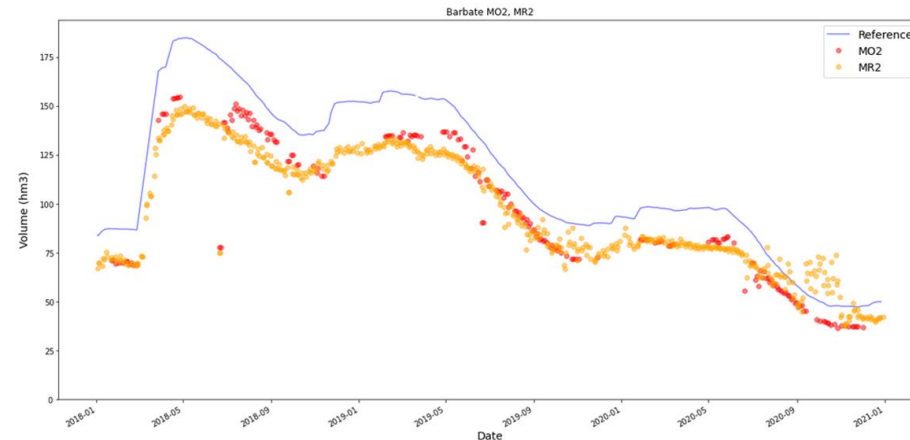
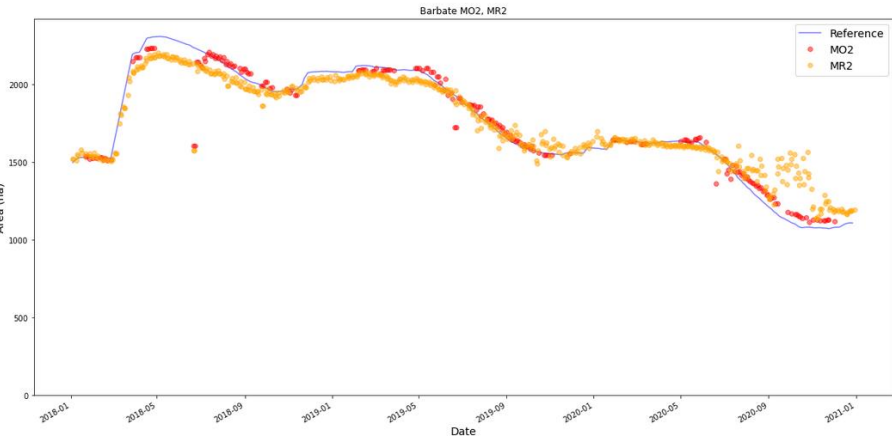
- Copernicus 10m
- **Copernicus 30m**
- SRTM 30m
- Alos Dem 25 m

Ground truth

- IGN BD Alti 5m

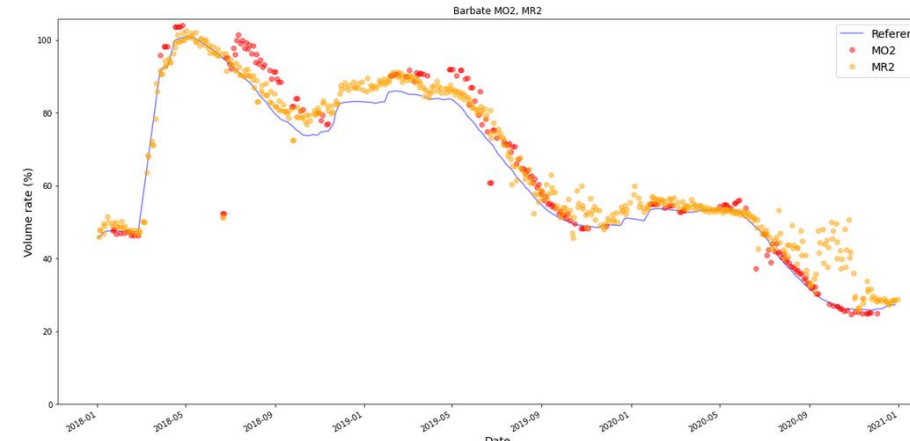
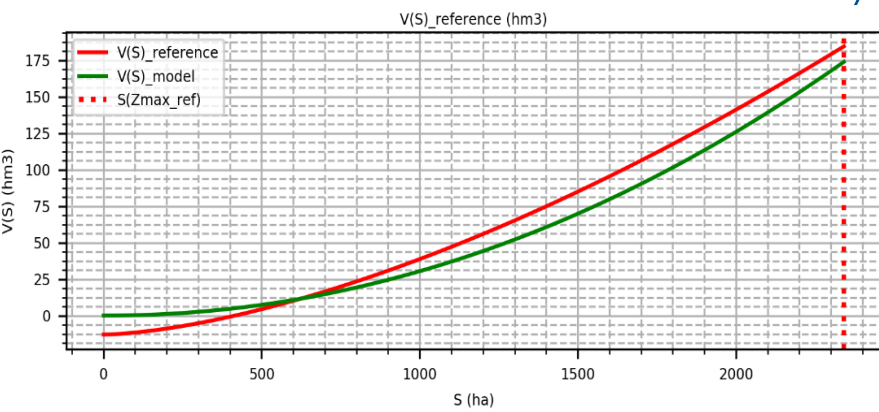
Results – Andalousie (Spain)

Barbate (231 Mm3; 2300 ha)



Ssat(t) : Satellite Reservoir surface vs Water manager surface (in-situ)

V(t) : Volume from satellite vs Volume rate in-situ data



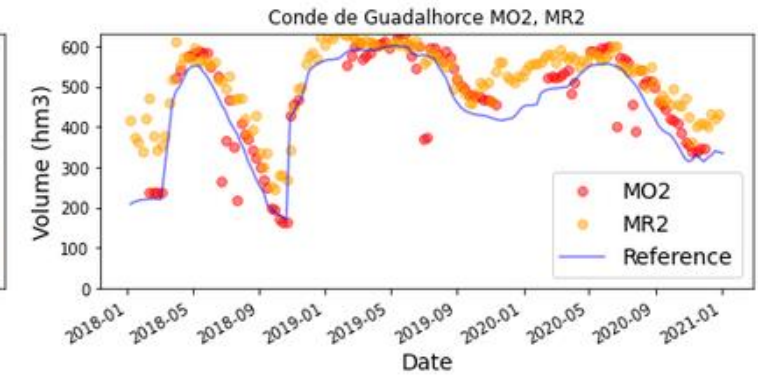
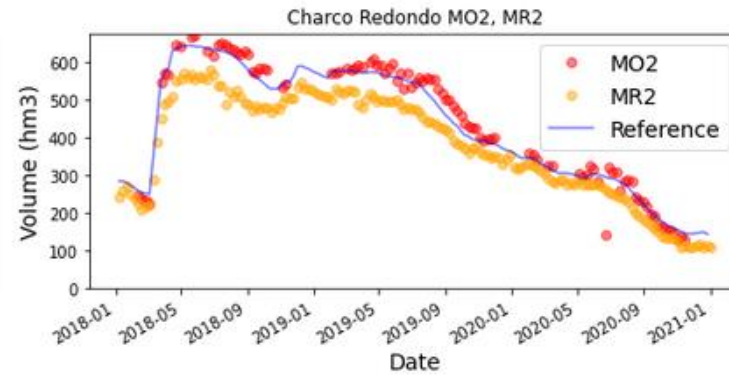
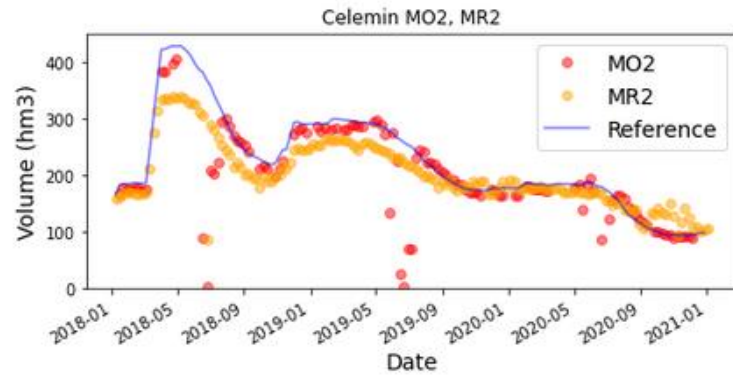
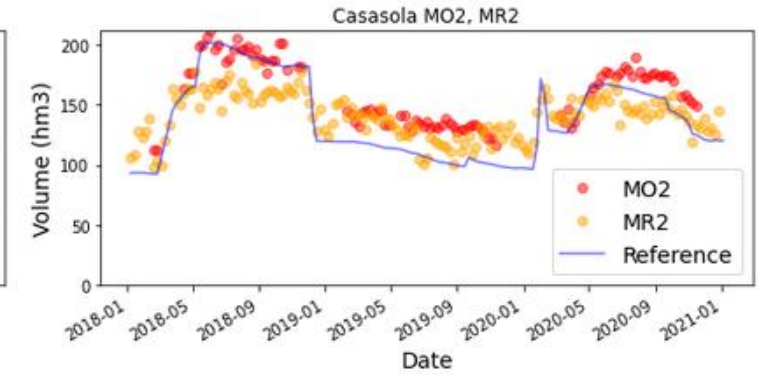
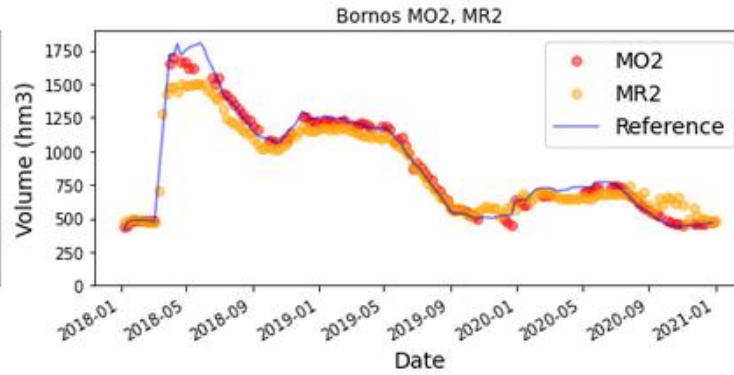
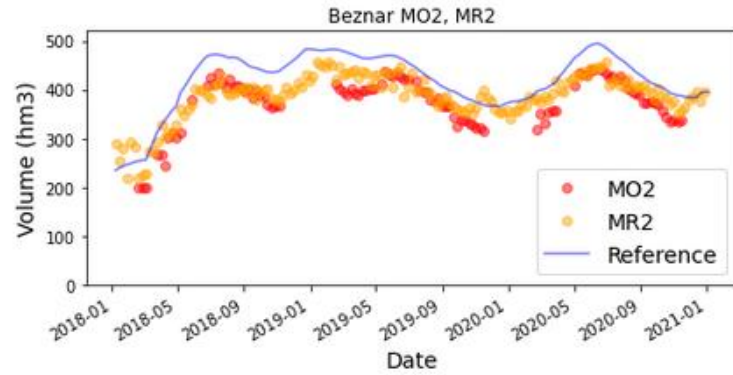
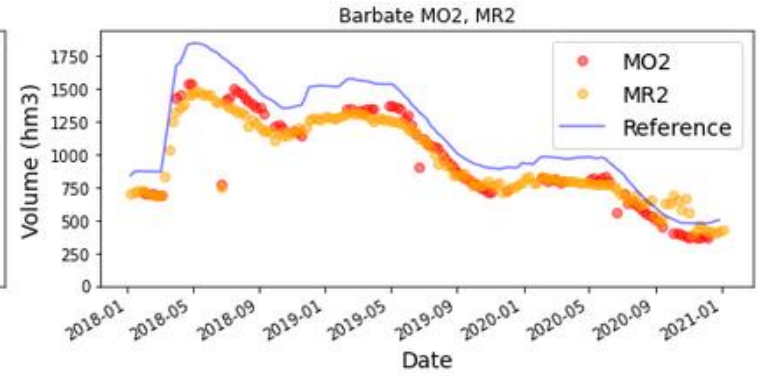
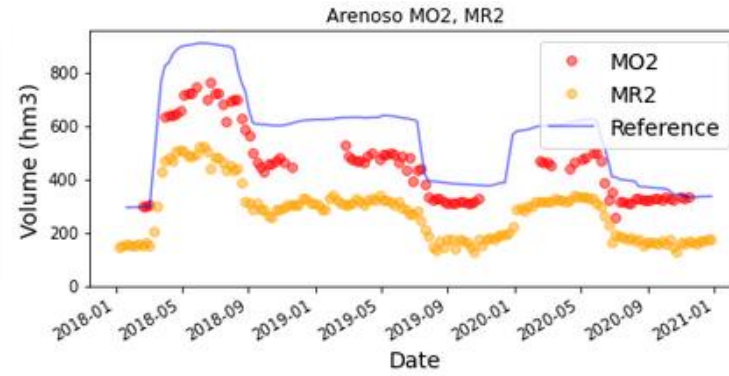
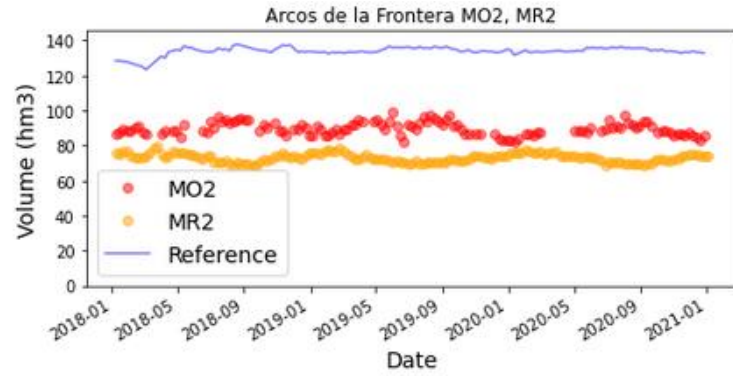
VR(t) : Volume rate from satellite vs Volume rate from in-situ data

Volume Relative error	Quantile 75% of absolute relative error
Optique_10 days	18 %
Radar_10 days	19 %

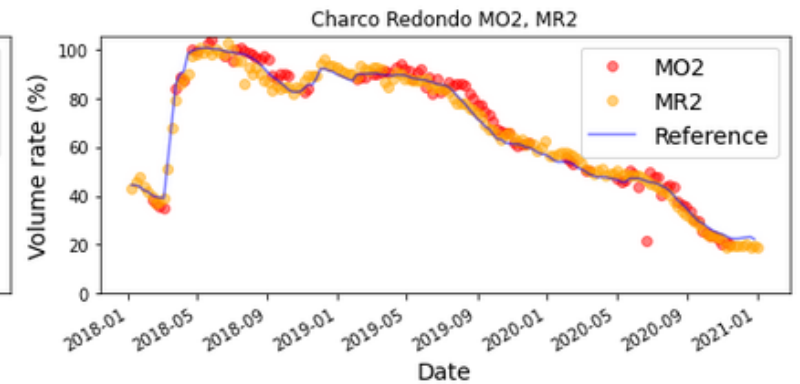
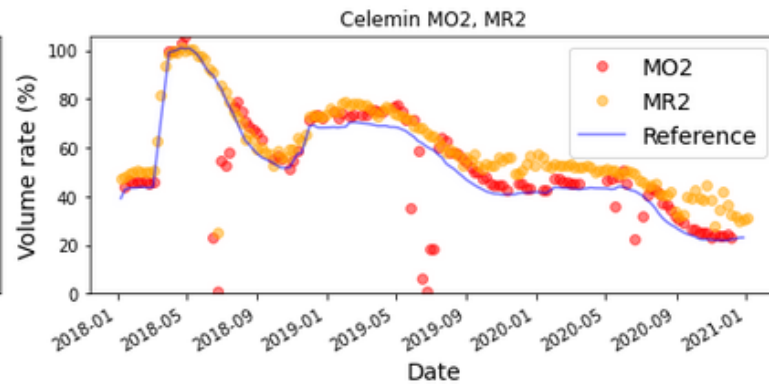
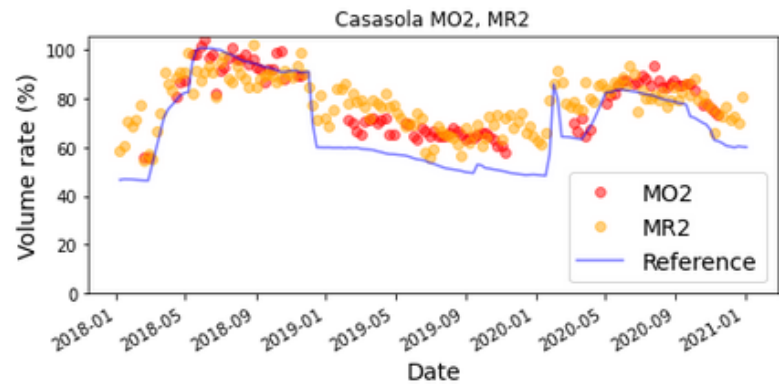
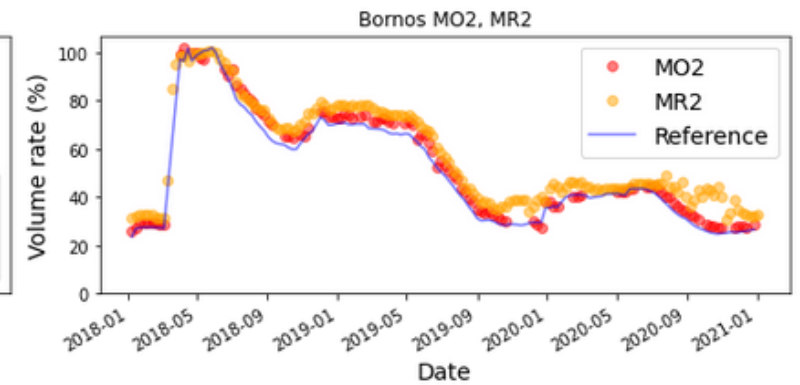
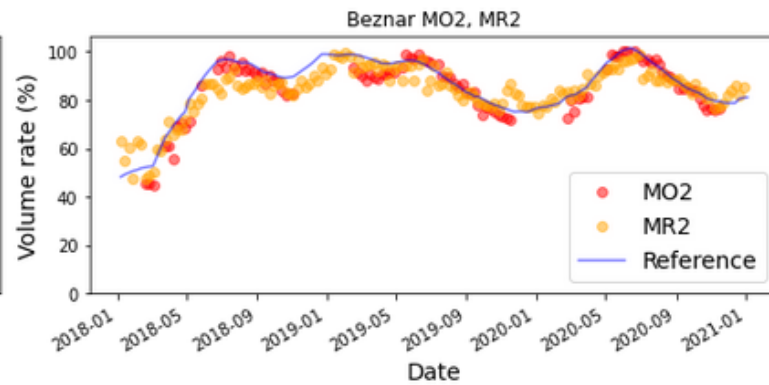
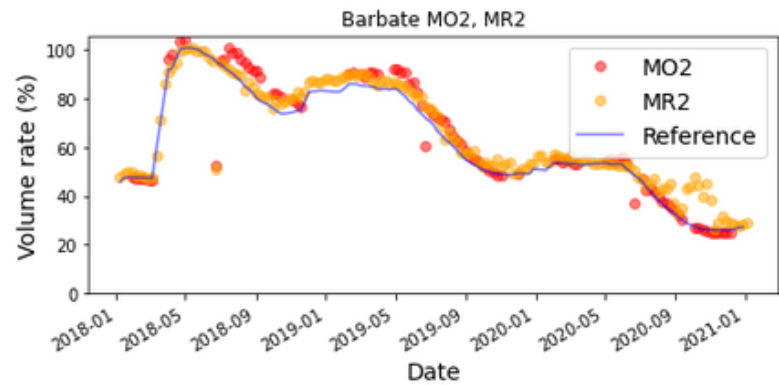
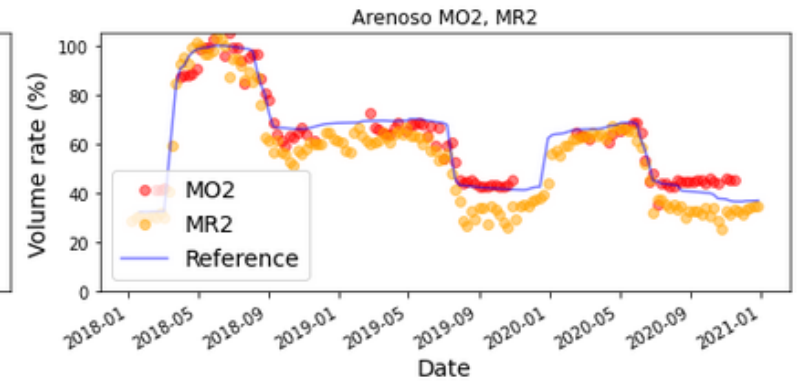
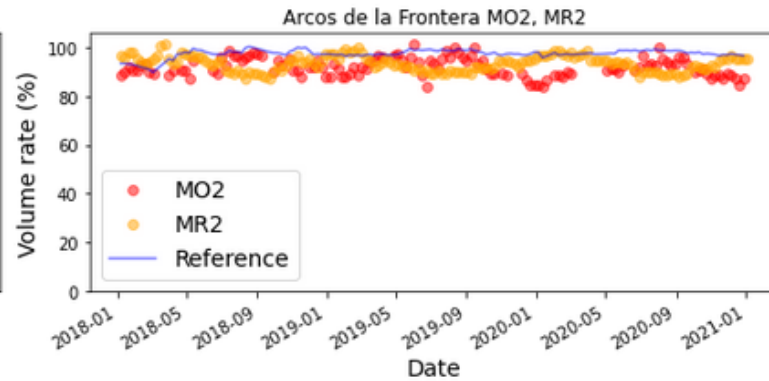
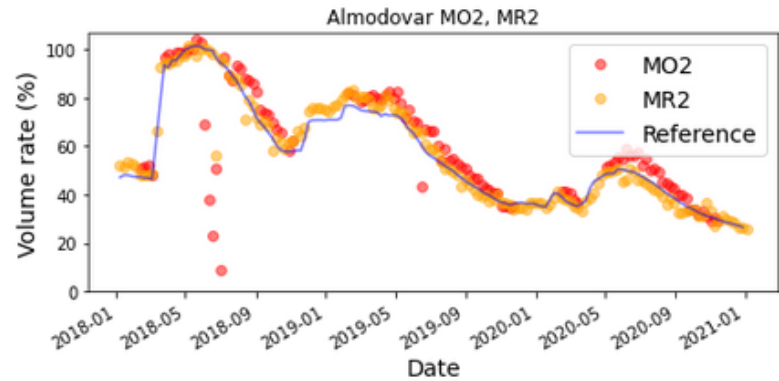
Volume Rate Relative error	Quantile 75% of absolute relative error
Optique_10 days	8,3 %
Radar_10 days	7,5 %

Vdem(S) : V(S) law from DEM vs V(S) law from Water manager

EXEMPLES VOLUME

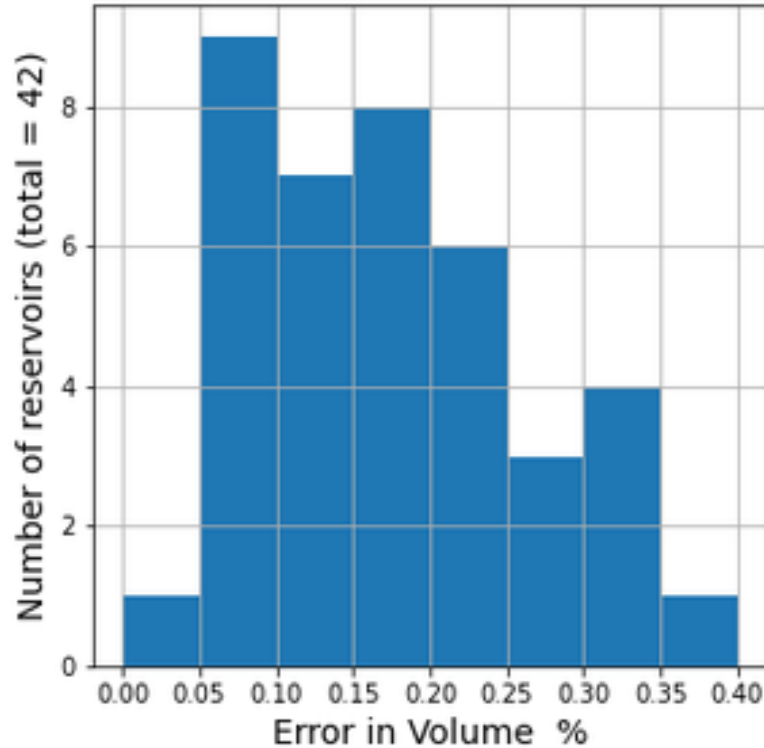


EXEMPLES VOLUME RATE



RESULTS (BASED ON OPTICAL – S2)

Absolute Volume Error

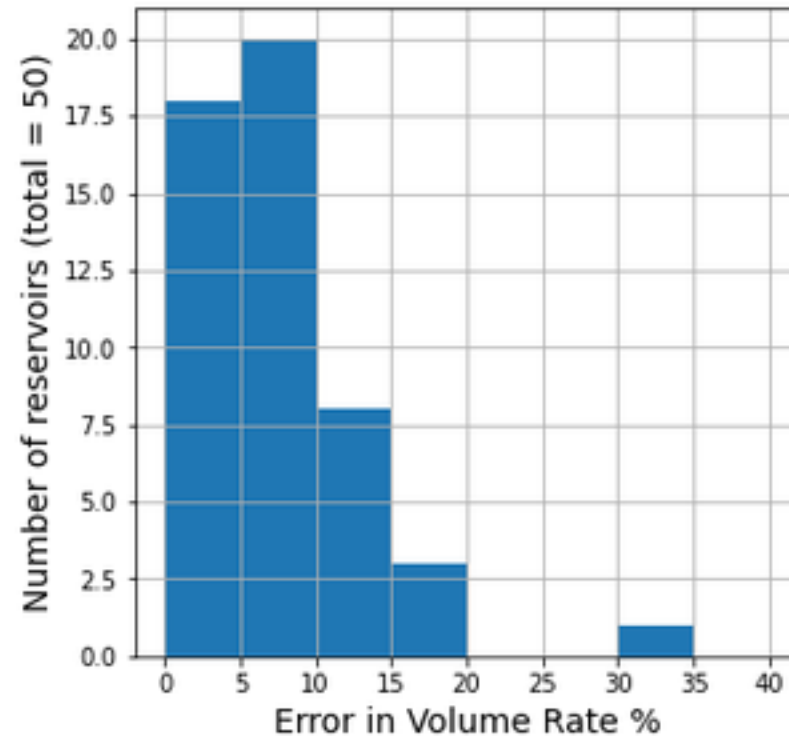


All measurements
Mean = 17%
Q(75%) = 23%

- 17 over 42 Reservoirs have an uncertainty < 15%
- Absolute volume estimation is hard:
 - Surface + Bathy estimation uncertainty
 - Insitu data – not always reliable



Volume Rate Error

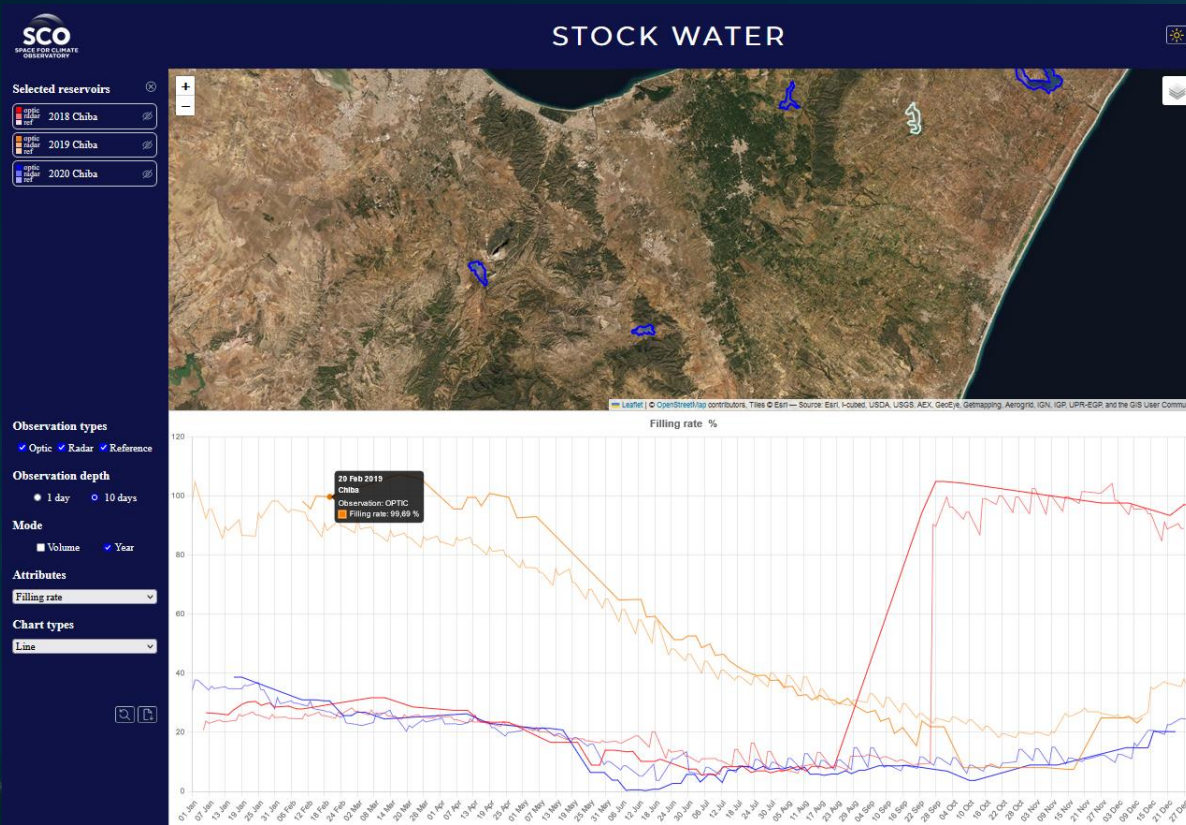


All measurements
Mean = 6.4%
Q(75%) = 7.7%

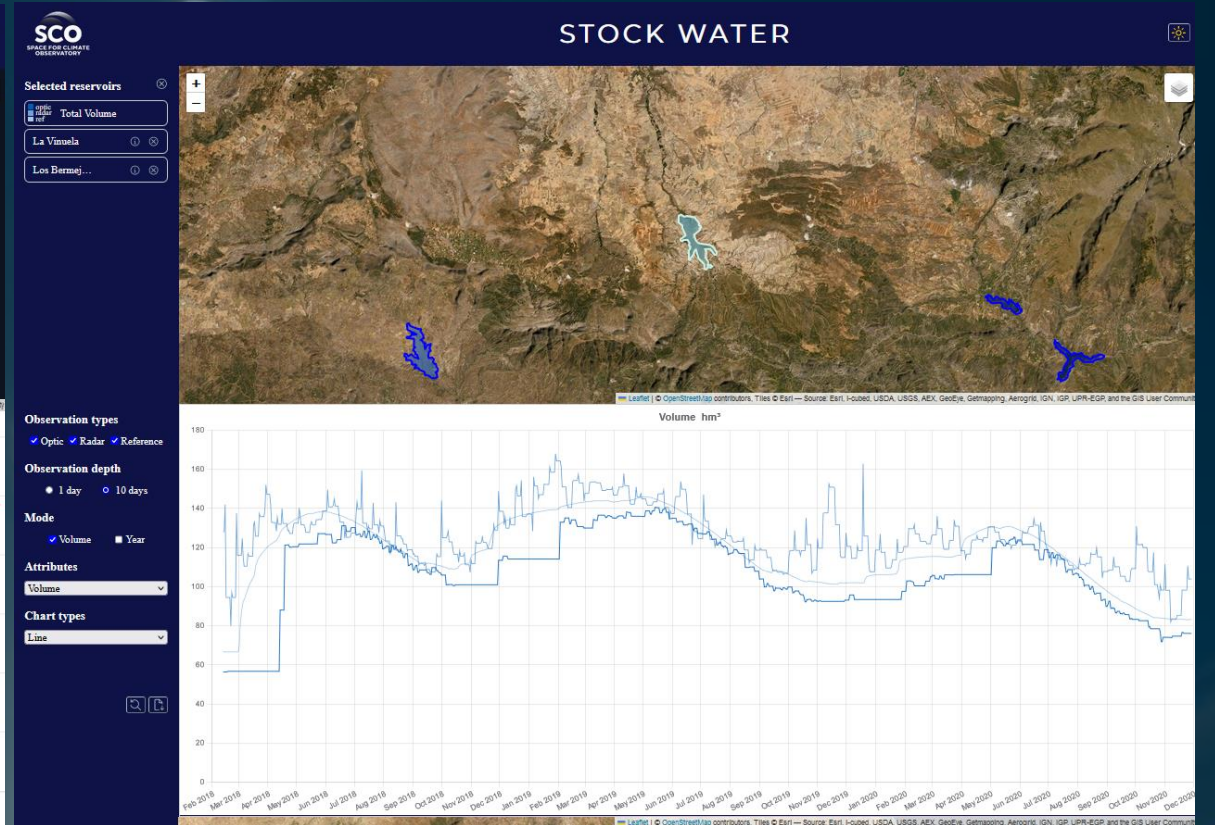
- 46 over 50 Reservoirs have an uncertainty < 15%
- Volume rate is easy but:
 - Maximum Volume rates must be observed during the experiment (3 or more years)



STOCKWATER PORTAL



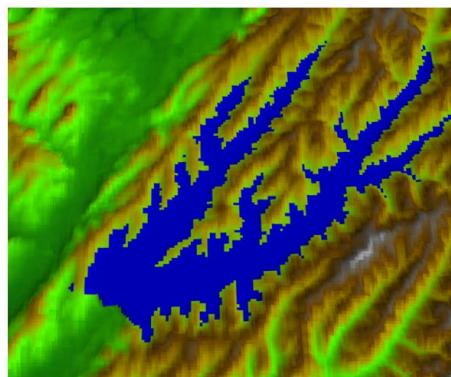
Yearly comparison



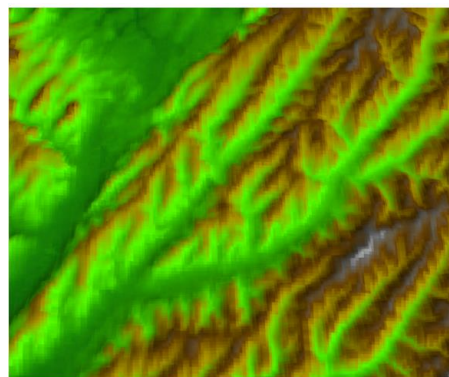
Total volume contained in several reservoirs

BATHYMETRY - NEW METHODS

Estimating reservoir bathymetry from DEM with deep learning



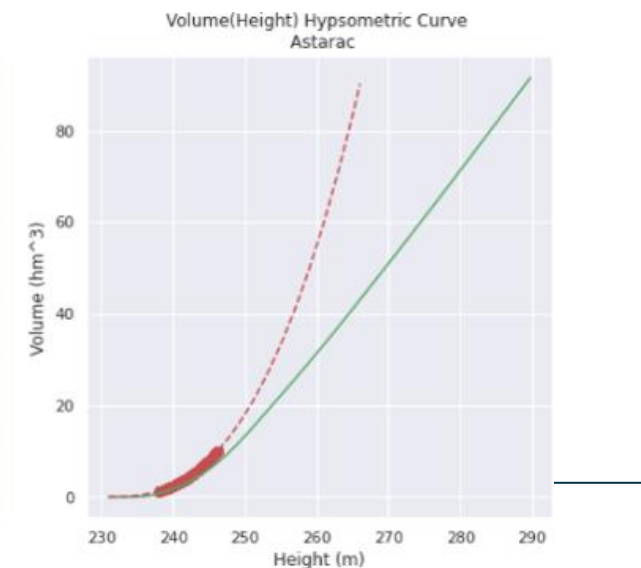
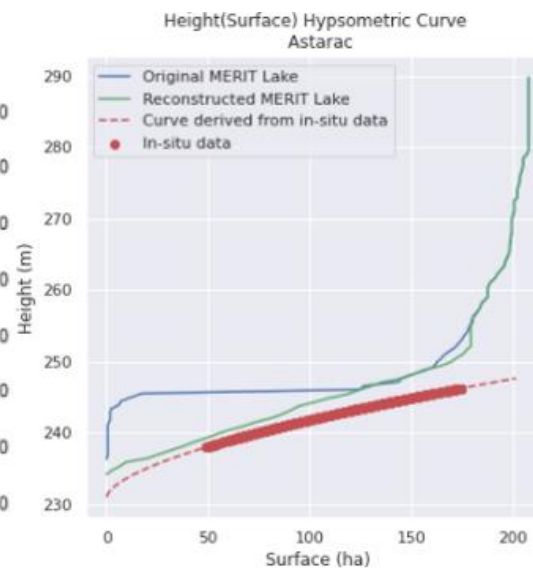
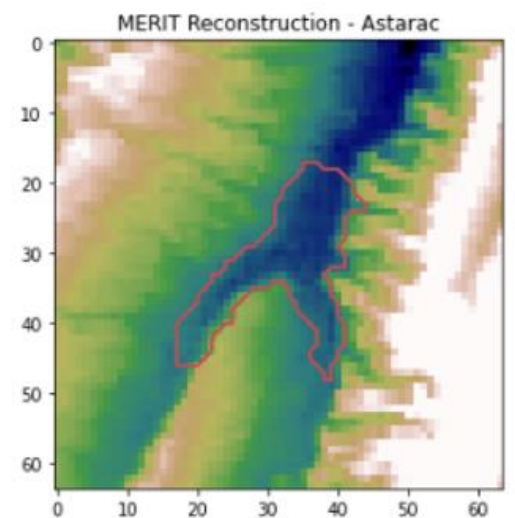
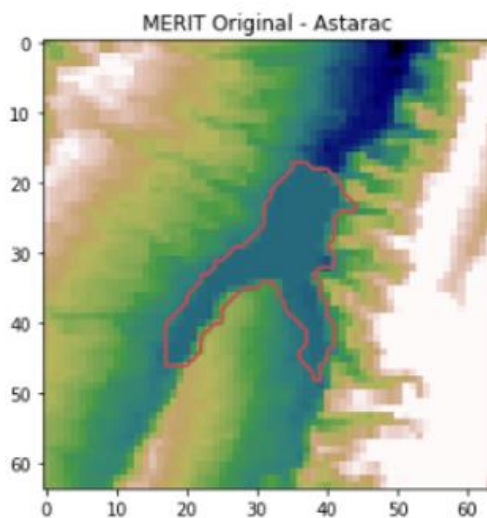
In Painting technique



Artificial Reservoirs
– Dataset synthesis
+ Training

Total volume error
on evaluation
dataset : 17%
(median)

Results



TAKE HOME MESSAGE

Conclusions

- **Quality** - Reservoirs monitoring by satellite : F(Area, Bathymetric law from DEM)
 - hard to estimate absolute volumes (17% mean)
 - good performance on volume rates (6% mean)
- **StockWater** - Phase 2 on-going :
 - 50 new reservoirs to be analyzed (Brazil, Burkina, Tunisia, Laos)
 - Data sharing on web portal « Space Climate Observatory »



Perspective

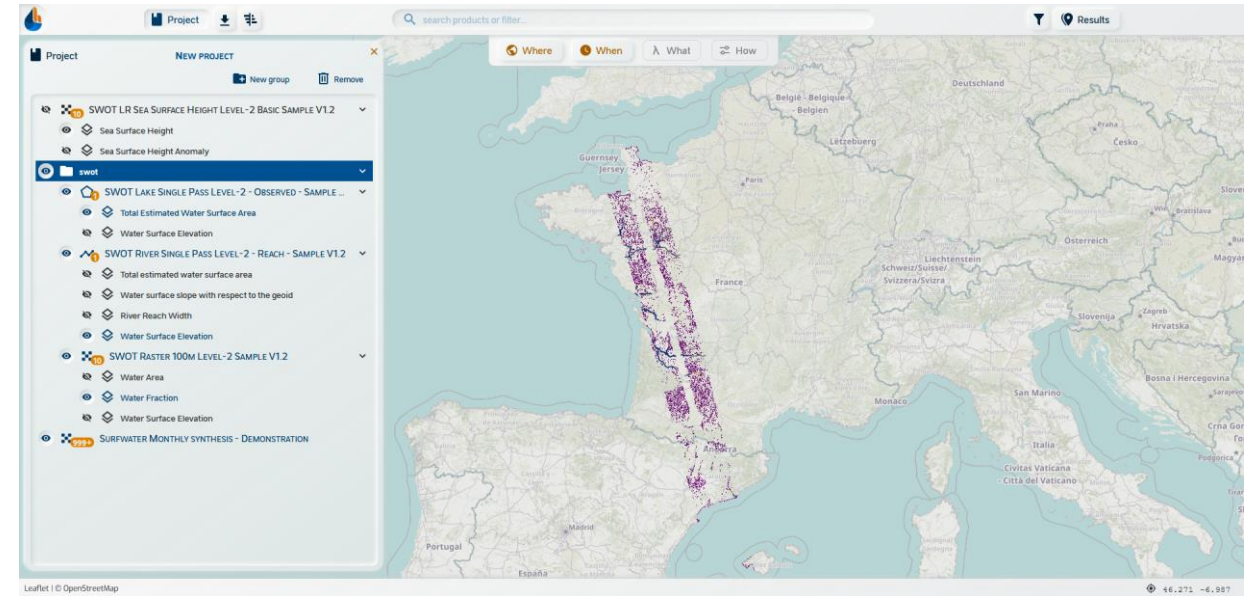
- Working on technical improvements:
 - DEM processing (multiple dams management, huge reservoirs)
 - Water detection (glint removal, huge reservoirs between tiles)
- Working on demonstration service for France Government for 80 & 500 reservoirs (future 20 000)
- Data in new hydro portal :  hydroweb.next
 - **Completeness & Synergy with SWOT Data**



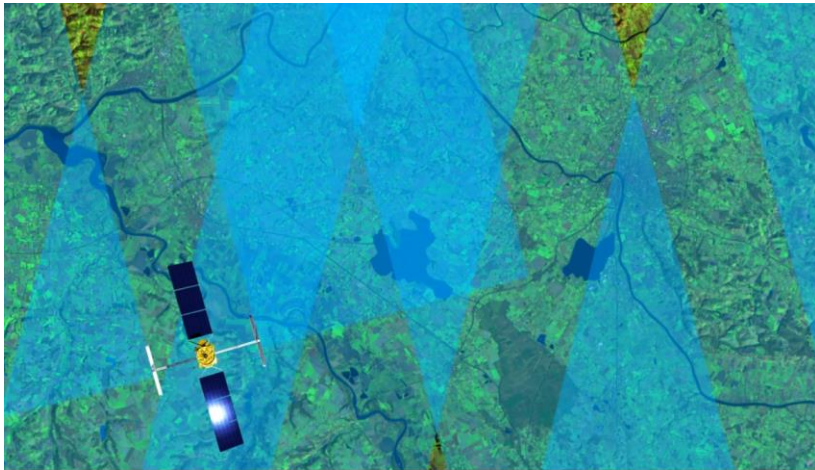
THANKS FOR YOUR ATTENTION

QUESTIONS?

santiago.penaluque@cnes.fr



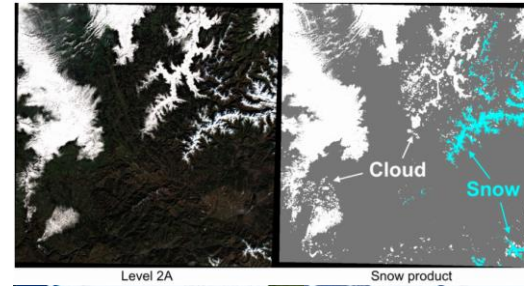
• Données SWOT



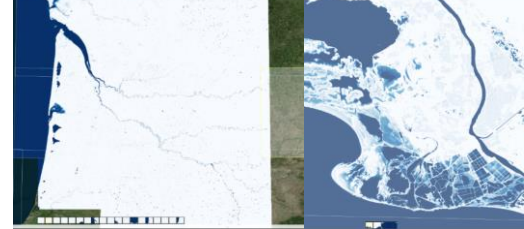
- Lancement fin 2022
- Hauteur/Surfaces lacs et rivières (global)
- Produit Lac - **Variation stocks eau**
 - Min : lac > 6ha
 - Optimal : lac > 100ha
- Produit Rivières - **débit** (largeur > 100m, possiblement 50m)

• Produits hydrologie spatiale

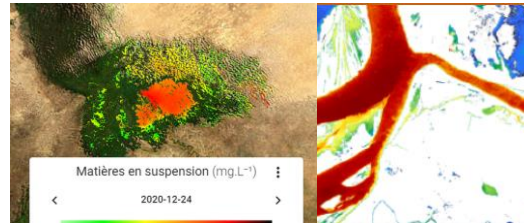
- Neige (LIS)



- Surfaces eau (Surfwater)



- Qualité eau (Obs2co)



- Produits THEIA
 - Occ Sols (OSO), Altimétrie (Hydroweb), Humidité sols (SMOS)

• Portail Hydrologie

- Lancement 2022
- Production au fil de l'eau
- Couverture: x10 France (2022), 1/3 monde (2023)
- Perspectives:
 - **Insitu + Modélisation**
 - **Volumes Stockwater (+SWOT)**