Merits of Assimilating SWOT Altimetry & Sentinel-1 Flood Extent for Flood Forecasting - A Proof-of-Concept

T. H. Nguyen[1,2], S. Ricci[1], A. Piacentini[1], C. Emery[3], R. Rodriguez Suquet[4], and S. Peña Luque[4]

[1]CECI, CERFACS/CNRS UMR 5318, Toulouse, France - [2]LIST, Esch-sur-Alzette, Luxembourg - [3]CS-Group, Toulouse, France - [4]CNES, Toulouse, France

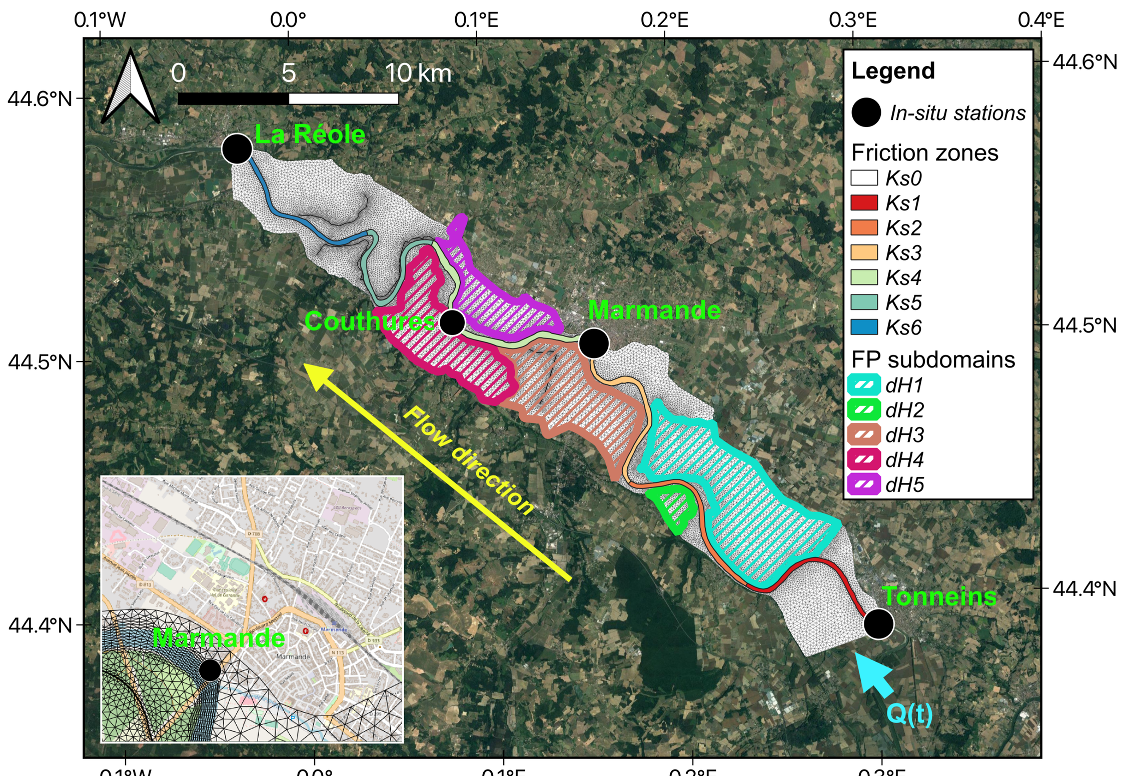
Abstract

Floods are one of the most common and devastating natural disasters worldwide. The recently launched **Surface Water and Ocean Topography (SWOT)** wide-swath altimetry satellite allows to measure with high precision the water surface elevation, including in floodplains. This work focuses on the assimilation of multi-source remote sensing (RS) data, namely 2D flood extent maps derived from Sentinel-1 C-SAR imagery data and SWOT data, in an **Observing System Simulation Experiment** (OSSE). An **Ensemble Kalman Filter** (EnKF) with a state-parameter dual analysis is implemented on top of a 2D hydrodynamic **TELEMAC-2D** (T2D) model. The proposed strategy is applied on the major 2021 flood event over the Garonne Marmandaise catchment.

Keywords: Fluvial floods, Data assimilation, EnKF, TELEMAC-2D, Garonne, Sentinel-1, SWOT.

Study Area, Data, Model

a. Garonne Marmandaise catchment

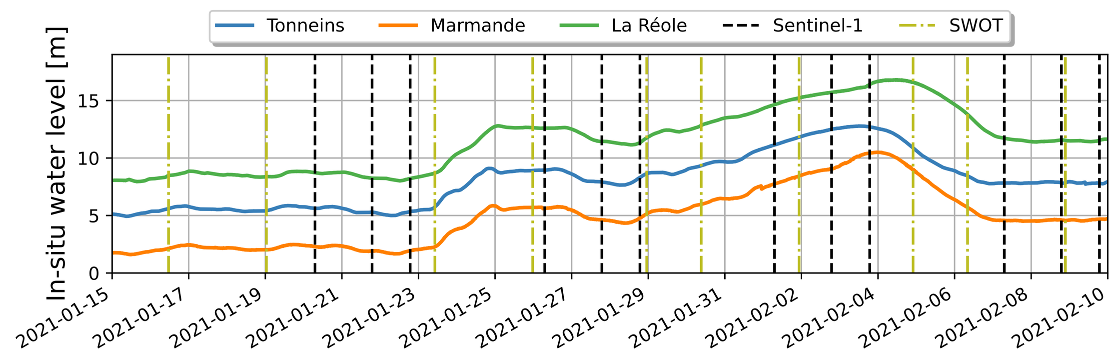


The hydrodynamic model, developed by EDF R&D, covers a 50-km catchment of the Garonne River (France). Its boundary conditions include the upstream hydrograph and the downstream rating curve.

b. In-situ observations from VigiCrue network

Three in-situ gauging stations are maintained by the VigiCrue network within this catchment, at Tonneins, Marmande, and La Réole, providing WSE time-series data.

Fig. 1: 2021 flood event observations



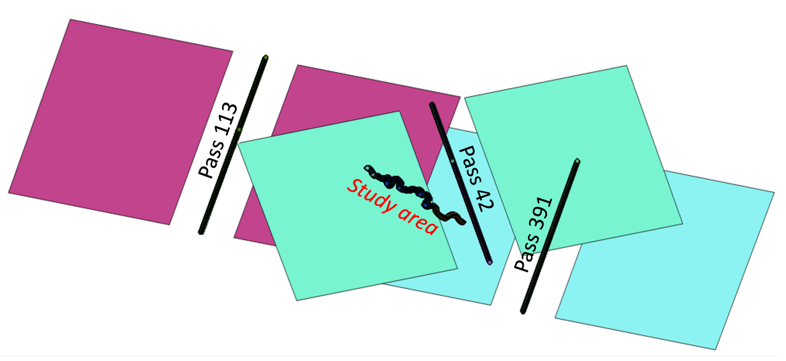
c. Copernicus Sentinel-1 observations

SAR is efficient at monitoring flood extents due to all-weather day-and-night imaging capabilities. Flood extents can be derived from C-band SAR S1 images (vertical dashed lines) using a Random Forest classifier.

d. Surface Water and Ocean Topography

Using a Ka-band Radar Interferometer (KaRIn), SWOT main river data products are delivered as pixel clouds (PIXC), river nodes, reaches, and rasters. They vary in resolution, level of uncertainty, and in content. Here we focus on high-rate (HR) river node products, from pass 42, 113 and 291, with an improved revisit frequency (x3 in OSSE only) to showcase its merits in a flooding context.

Fig. 2: SWOT passes over Garonne Marmandaise



References

1. T. H. Nguyen et al. (2022), Dual state-parameter assimilation of SAR-derived wet surface ratio for improving fluvial flood reanalysis, *Water Resources Research*, 58, e2022WR033155, doi.org/10.1029/2022WR033155.

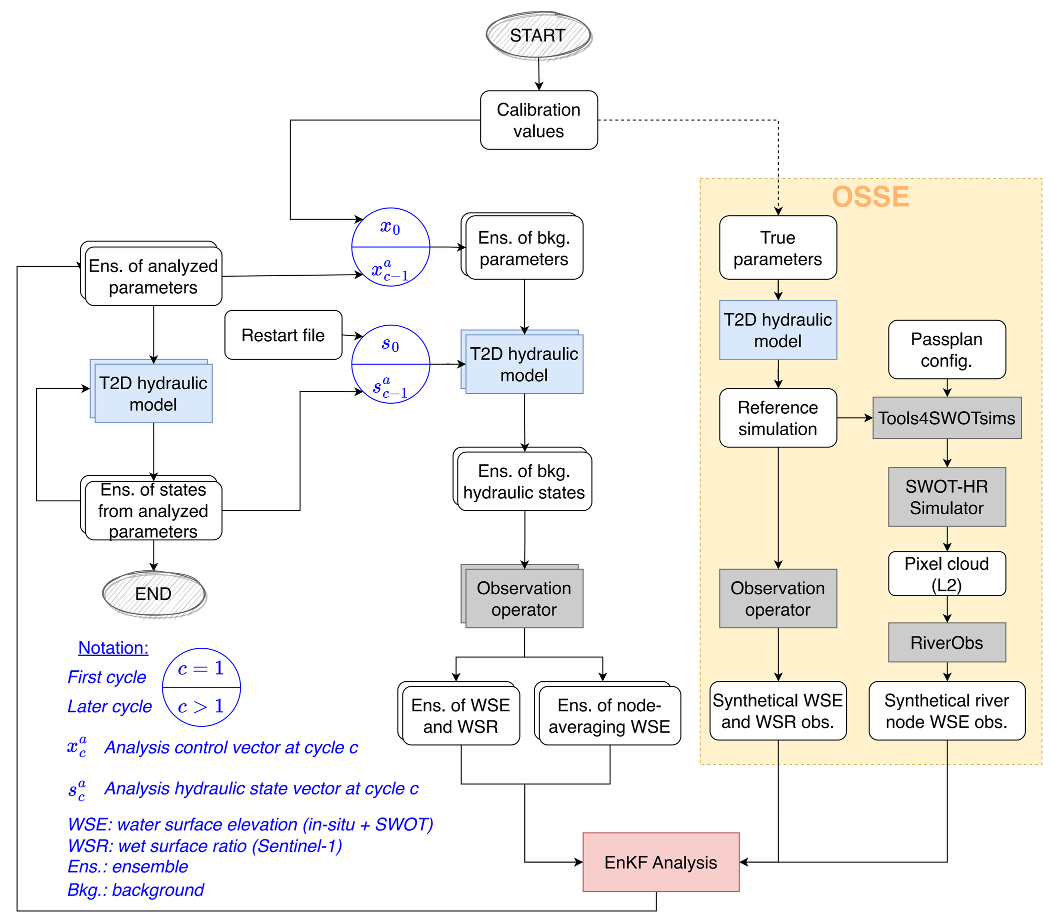
2. C. Emery et al. (2022), Tools4SWOTsims and SMURF, *AGU Fall Meeting 2022*, OS22A-21, Chicago, IL, 12-16 Dec 2022.

Acknowledgments: Thanks to EDF, SCHAPI and SPCs.

Contact: thanh-huy.nguyen@list.lu

Method and Experimental Results

Fig. 3: Proposed Workflow



Control vector: 7 Strickler friction coefficients Ks, 1 parameter μ to correct inflow discharge Q, and 5 floodplain corrective state variables dH. These corrections are implemented in the 5 floodplain zones in order to account for the evapotranspiration, ground infiltration and rainfall.

Random Forest-based flood extent detection:

- Inputs: Sentinel-1 VV-VH images and MERIT DEM
- Random Forest classifier trained on Copernicus EMSR samples having >90% water occurrence
- Test result: F_2-score averages 86.86% on 5 test sites

WSR is the ratio between the number of wet pixels and the total number of pixels within each of the 5 floodplain zones.
Tools4SWOTsims: a set of Python scripts to map 1D/2D hydrodynamic model outputs into 2D WSE rasters that is compatible with SWOT simulators.
SWOT-HR simulator to render the WSE rasters into PIXC.
RiverObs package to generate RiverTile products from PIXC.
Five experiments: 1 open-loop (OL) and 4 data assimilation (IDA, IGDA, FDA, RSDA) with 75 members.

Table 1: Experimental Settings - OSSE

Exp. name	Assimilated obs. In-situ WSE	S1 WSR	SWOT WSE	Control vector
OL	☐	☐	☐	-
IDA	☑	☐	☐	Ks, Q
IGDA	☑	☑	☐	Ks, Q, dH
FDA	☑	☑	☑	Ks, Q, dH
RSDA	☐	☑	☑	Ks, Q, dH

Fig. 4: SWOT river products on 2021-01-16

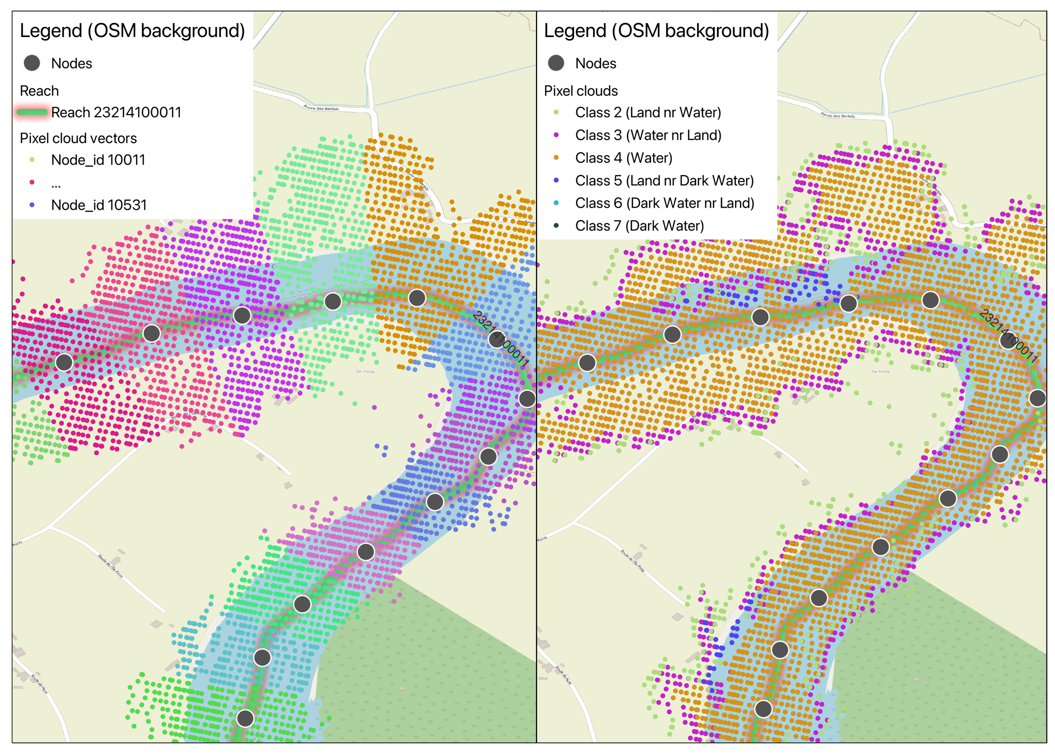


Fig. 5: Taylor's diagram of node-based WSE

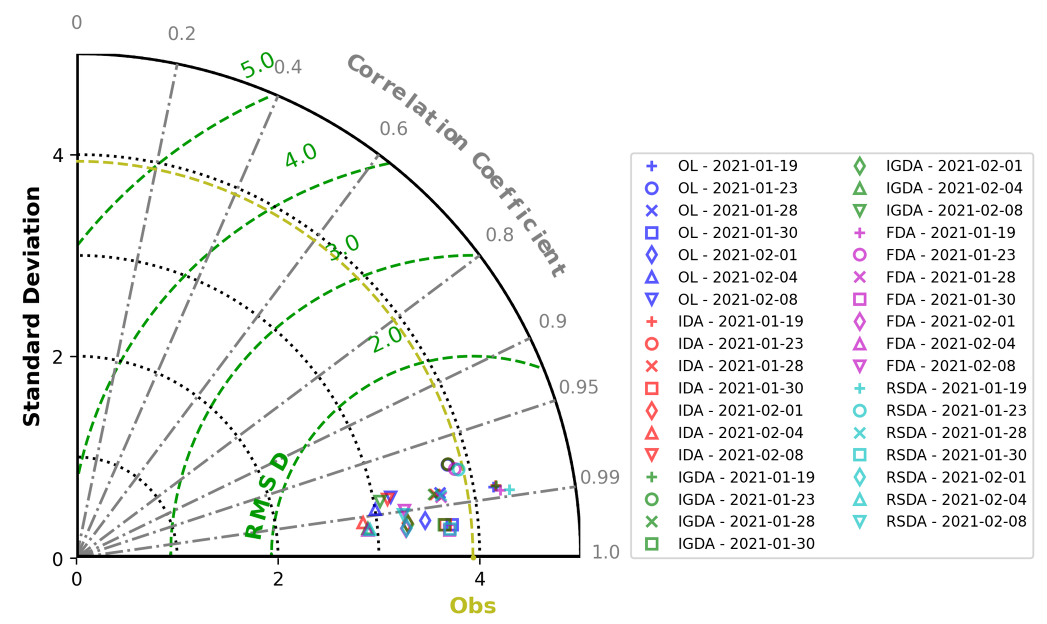


Fig. 6: Simulated WSE at Tonneins

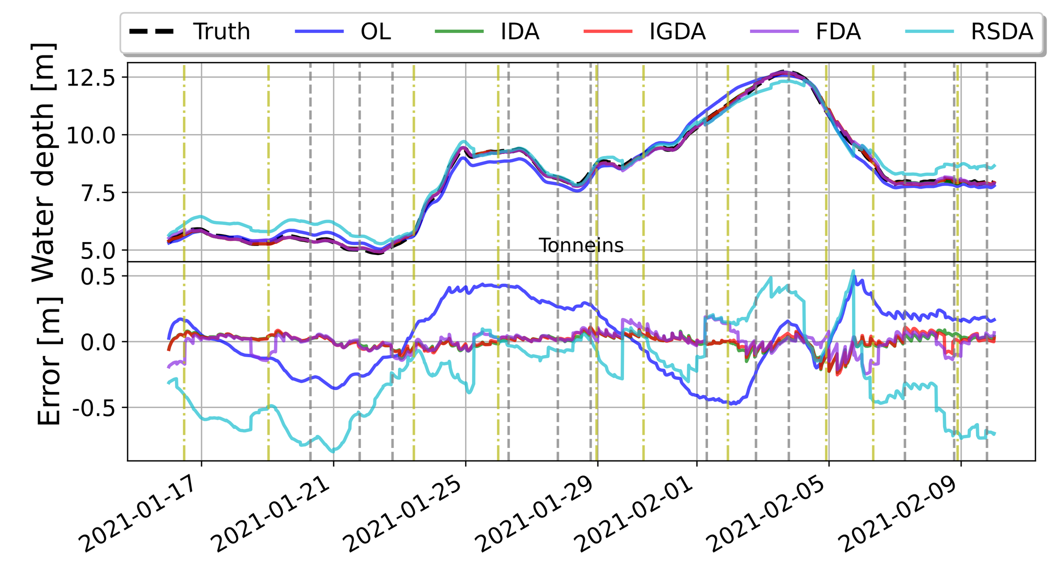
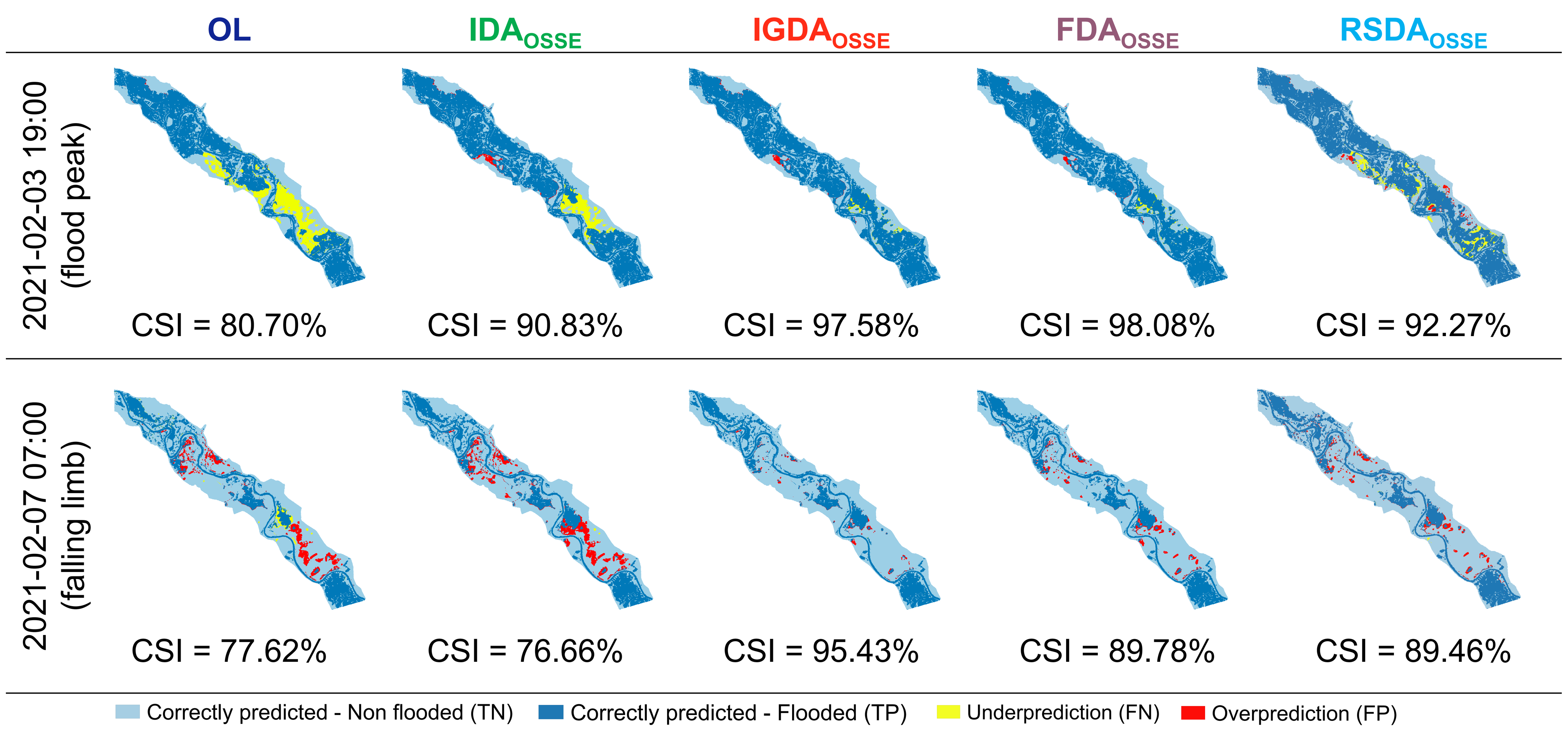


Table 2: RMSE of simulated WSE at observing stations

RMSE [m]	Tonneins	Marmande	La Réole
OL	0.260	0.398	0.578
IDA	0.052	0.042	0.053
IGDA	0.054	0.044	0.049
FDA	0.075	0.056	0.053
RSDA	0.410	0.435	0.413

Fig. 7: Contingency maps w.r.t Sentinel-1 flood extents at flood peak and recess



→ The assimilation of SWOT WSE improves slightly flood extend representation at flood peak.

Conclusions

- ☑ Merits of leveraging heterogeneous observations from Sentinel-1 SAR data and SWOT data;
- ☑ Ensemble-based DA allows improving reanalysis and forecast in the riverbed and floodplain;
- ☑ Several limitations regarding potential information conflicts between data sources.

Perspectives

- ☐ Assimilating other observations, e.g. water (surface) velocity, SWOT, S-/L-band SAR;
- ☐ Applying on real flood event with SWOT data;
- ☐ Exploiting RS flood observations as front-type data.