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Towards a better understanding of the global hydrological cycle with SWOT

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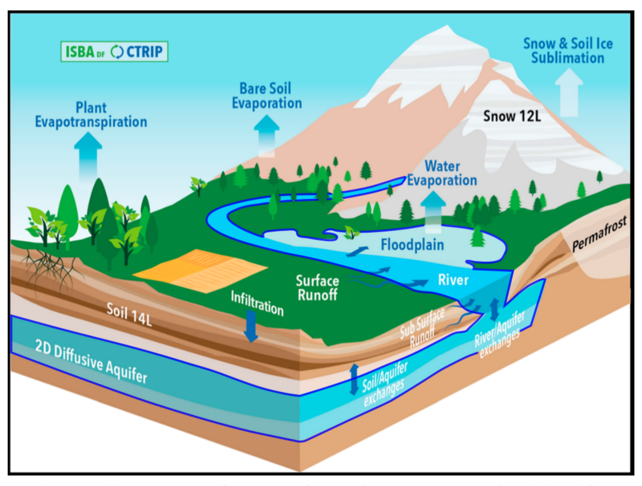
Introduction

There is an urgent need to be able to better predict the impacts of climate change on the planetary-scale fresh water resources. The interest of the SWOT mission on the continental / global scale is to be able to observe all major watersheds and lakes, especially those still poorly observed in situ, making SWOT a particularly good tool, suitable for the study of the continental and global hydrological cycle. Such information would go a long way in improving understanding of the role of the spatio-temporal variability of river flows and wetlands within the global water cycle. Currently, no model system exists which is able to produce reliable global estimates of discharge and river and lake water storage, mostly owing to a lack of data with sufficient spatial and temporal coverage. The main objective of this project, therefore, is to further refine methodologies (notably data assimilation) which have been developed over the past decade in preparation of the mission for using SWOT data to improve the input parameters and the physics of the hydrological and hydrodynamic parameterizations in Earth System Models (ESMs).

CTRIP-HyDAS: a global scale Hydrological Data Assimilation System based on the CTRIP river routing model at 1/12°

a. CTRIP river routing model

The CTRIP river routing model is designed to represent the dynamics of river and aquifer flows and their interactions. When coupled to the ISBA land surface model, it can be applied at the global scale to simulate the continental hydrological cycle.



ISBA-CTRIP scheme (Decharme et al., 2019)

A new river network and hydro-geomorphologcal parameters have been derived at the 1/12° spatial resolution. Such a resolution is particularly suited for the assimilation of SWOT observations, which spatial resolution is comparable. Hydro-geomorphological parameters are derived from existing global datasets when possible, and from empirical relationships otherwise: river length, slope, width, depth and roughness, aquifers delineation, porosity and transmissivity.

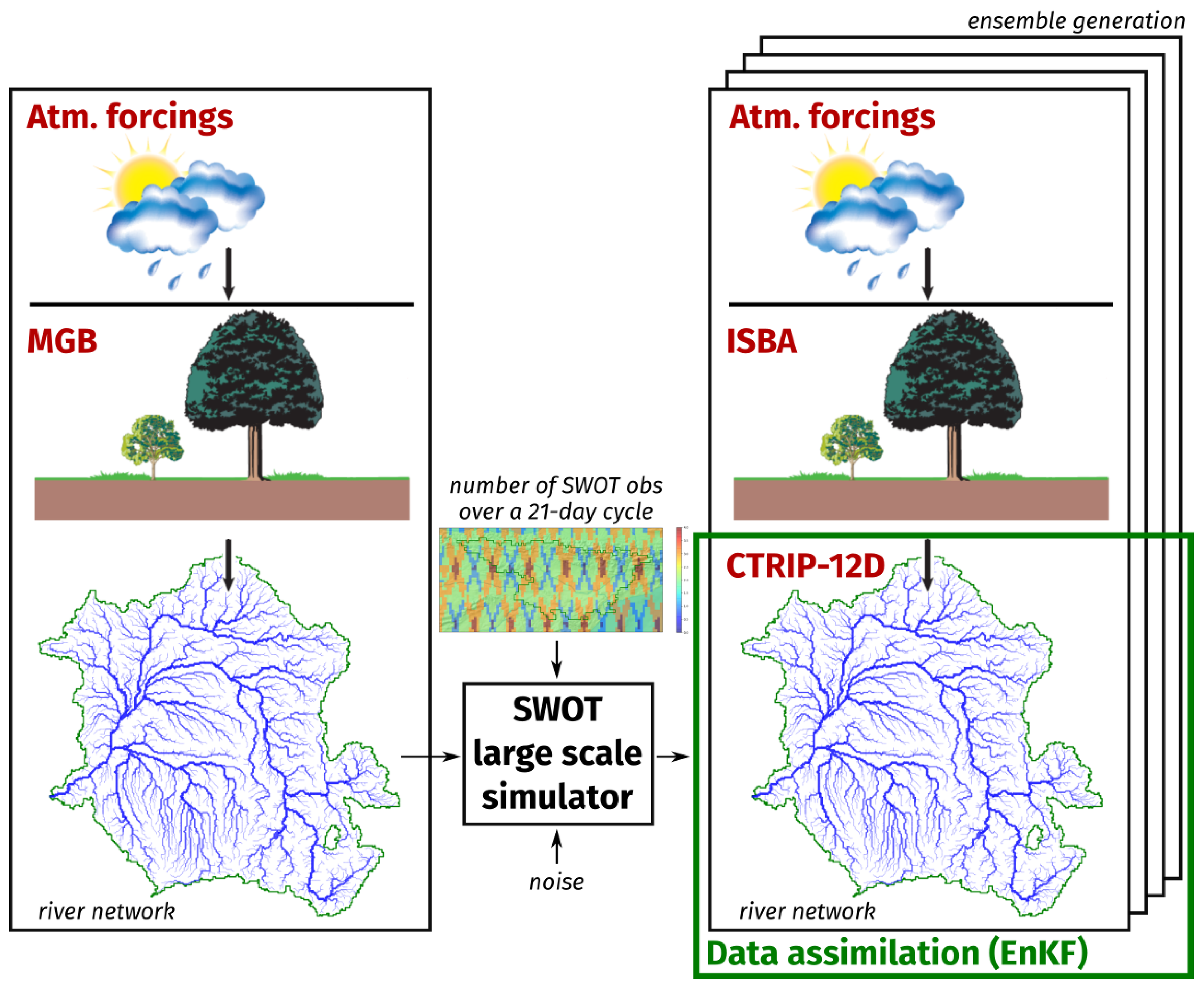
b. HyDAS: pseudo OSSE experiment

The Hydrological Data Assimilation System implemented in CTRIP is based on the Ensemble Kalman Filter.

The ensemble is generated by perturbing the atmospheric forcings using the method developed by Munier et al. (2015).

To prepare the assimilation of real SWOT observations, a twin experiment (OSSE) has been developed. Contrarily to classical OSSEs, a different hydrological model (namely MGB) is used to derive the "truth".

Simulated SWOT observations are obtained by perturbing this reference simulation with realistic SWOT errors, either on the water elevation or on the river discharge. The SWOT Large Scale simulation is used to derive the SWOT orbit passes.
Some improvements of the Kalman Filter are tested, and the algorithm is parallelized for a better computing efficiency.



c. Recent results and future work

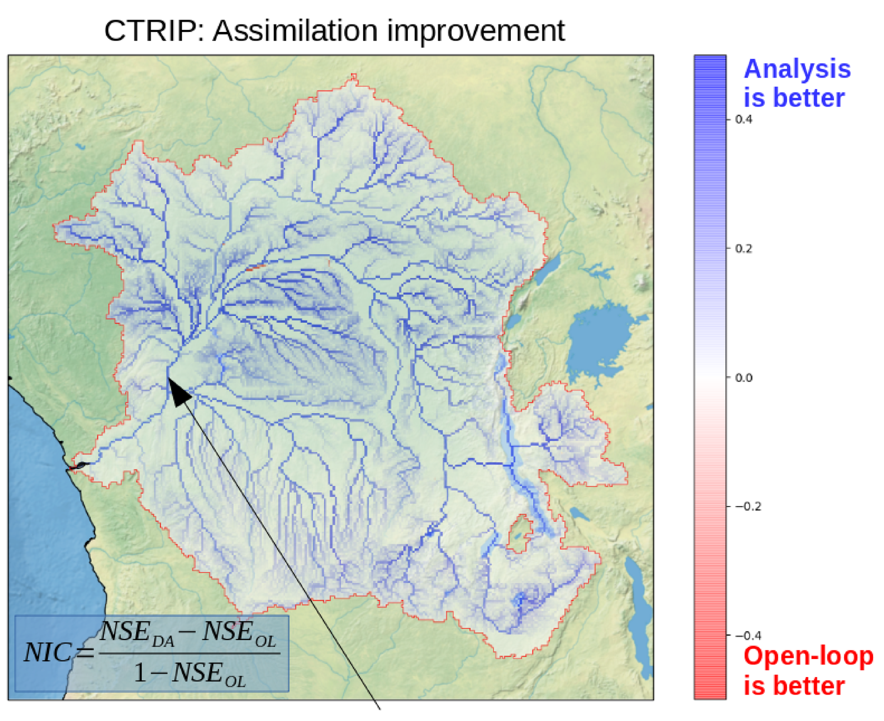
The CTRIP-HyDAS has been implemented over a few basins for testing different aspects of the Kalman Filter, including:

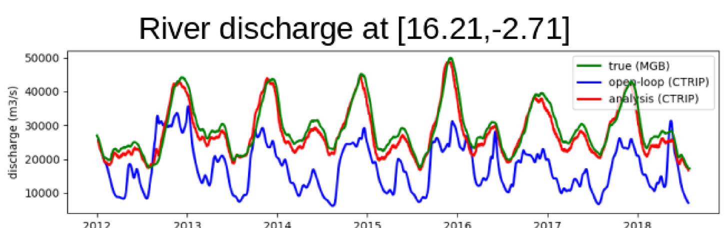
- different localization methods (e.g. Revel et al., 2019)
- temporal smoother
- assimilation of river depth or discharge
- robustness over basins with various hydroclimatic conditions

Future work will be dedicated to the set up of a global scale system able to ingest real SWOT observations, then focusing on:

- computing capabilities
- adequacy of CTRIP river network and SWOT river database

develop the assimilation of lake/reservoir volume variations





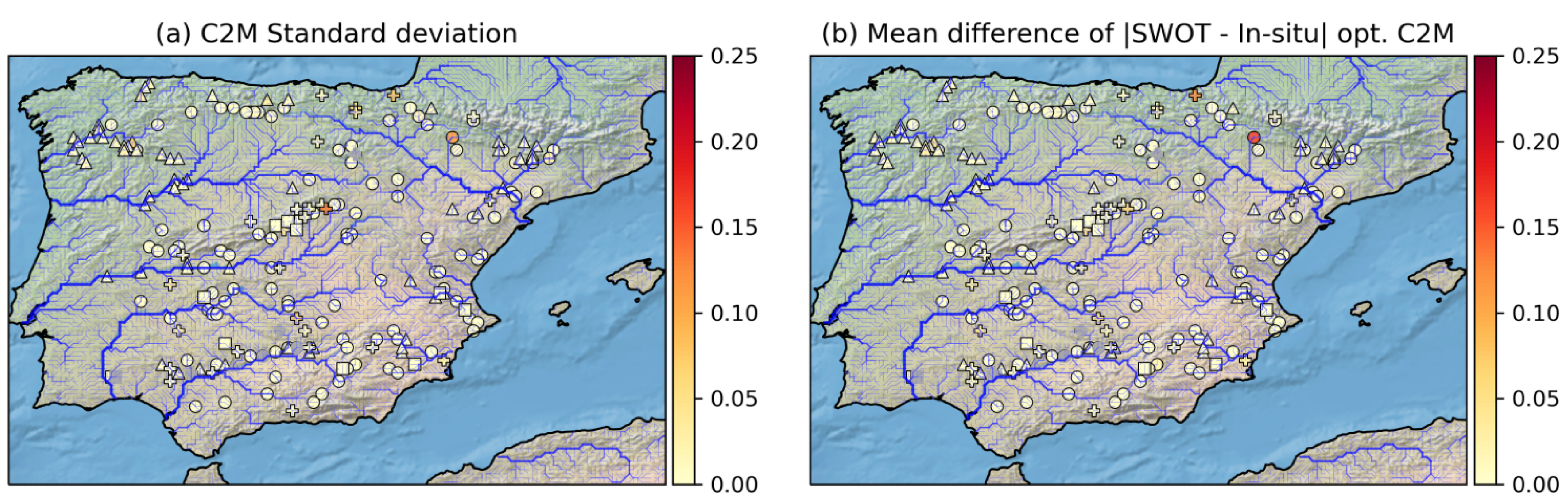
d. Using SWOT to calibrate the DROP reservoir model

The DROP (Dam-Reservoir Operation model) has been recently developed and integrated to the CTRIP model to represent the effect of dam-reservoirs on the river flow dynamics (Sadki et al., 2022).

The model has been implemented and validated over 215 dam-reservoirs in Spain.

Simulated SWOT-derived volume variations with various types of error have been used to calibrate the DROP model.

The efficiency of the calibration is compared to the best calibration results that could be obtained from daily observed data (volume variations and reservoir release).



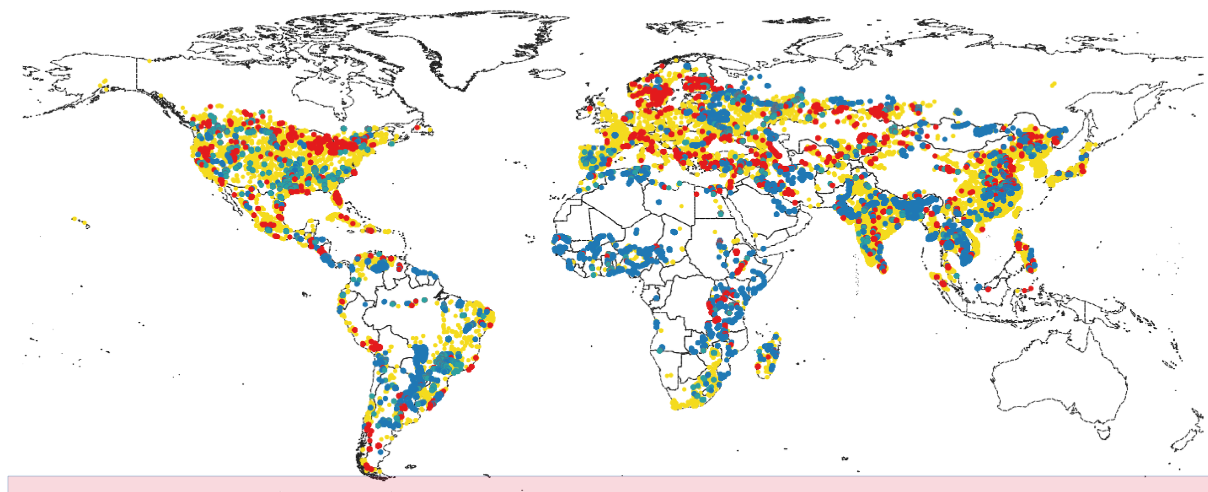
(a) For each reservoir, standard deviation of the optimal C2M score with varying random errors on SWOT observations of water elevation and surface area. (b) Average of absolute biases between the calibration efficiency of the reference (daily in situ data) and the calibration efficiency with varying errors on SWOT observations.

Results show that despite errors in SWOT observations and coarser time sampling, the calibration efficiency using SWOT data is almost as good as the one using real daily data.

This demonstrates the huge potential of SWOT to calibrate the DROP model for all dam-reservoirs of the globe observed by SWOT.

Preparing surface water types for LSMs

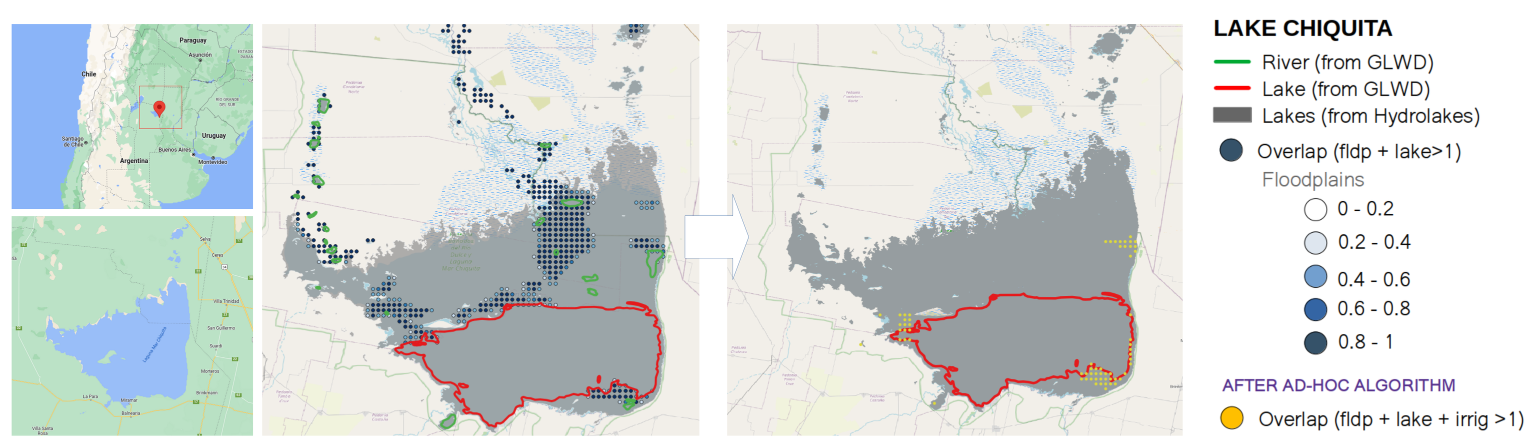
Datasets of the different surface water types (lakes, floodplains or irrigation) are merged onto one grid for usage in a land surface model (LSM).



Inconsistencies are found as the data are not taken at the same time or have different assumptions

An ad-hoc algorithm can fix most of the issues :
- Frac. Floodplains + Frac. Lakes < 1
- Frac. Irrigation + Frac. Lakes < 1
- Irrigation and floodplains can co-exist

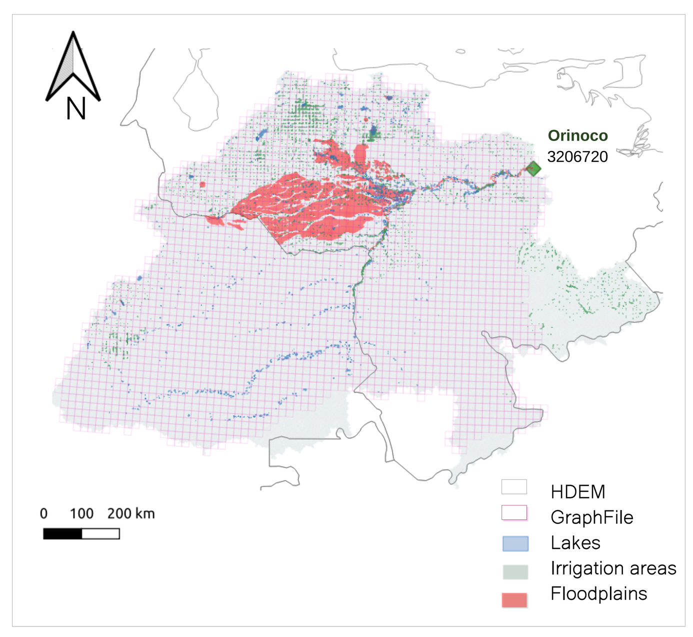
Lakes and reservoirs can be discriminated by the presence of a dam downstream.



The methodology produces a map which co-locates the routing network with a consistent description of surface water types.

The perspective of ORCHIDEE on the Orinoco catchment on a 20km atmospheric grid using 15 HTU is displayed :

- The river network of the Orinico is represented through a graph.
- Lakes are placed along the river.
- The central floodplain and its drainage network is visible.
- Irrigated areas within the catchment can also be identified.



The inconsistencies between lake and floodplain fractions begs a modelling question : When predicting lake volumes, should we not also predict the transition to flooded areas ?

As the hydrological cycle changes so will the fractions of flooded and lake areas.

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