Towards a global scale SWOT-CTRIP hydrological data assimilation system

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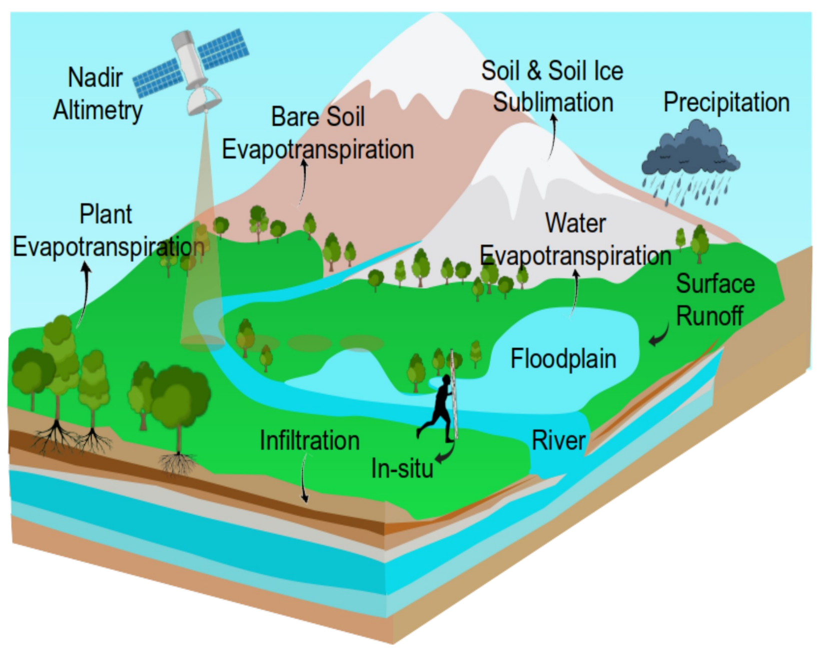
Challenge:

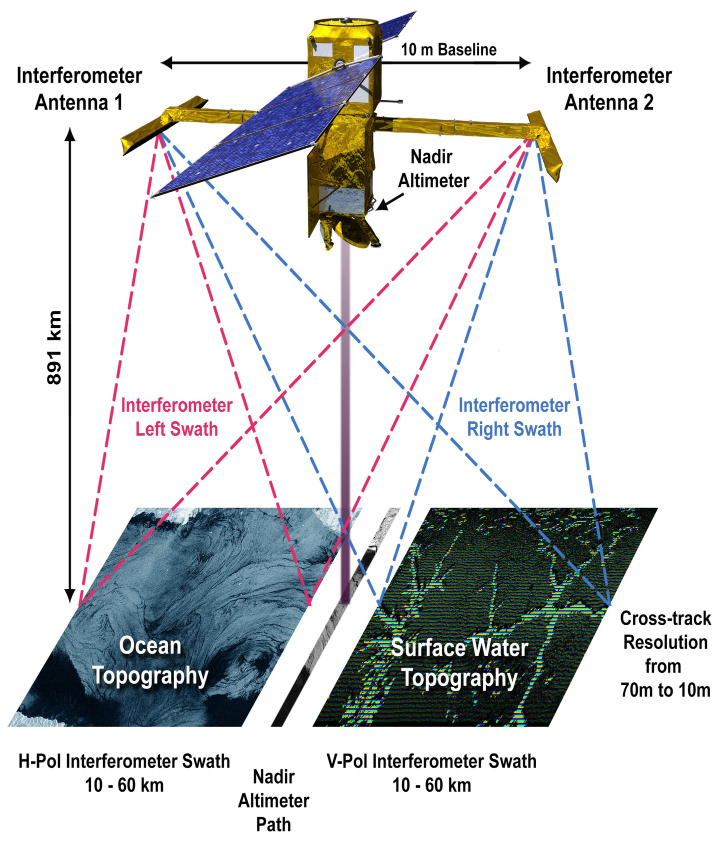


River system dynamics are pivotal in understanding the continental water cycle. Existing remote sensing tools, including nadir altimeters, have limitations in accurately assessing numerous continental water bodies.

The Surface Water and Ocean Topography (SWOT) mission, launched on December 16, 2022, provides unprecedented two-dimensional water elevation measurements worldwide, which would be a great improvement in the future observations.

Building upon SWOT's capabilities, our research aimed to create a novel framework for globally estimating river discharge. This involved integrating SWOT data into the CTRIP-12D, utilizing the CTRIP-Hydrological Data Assimilation System (CTRIP-HyDAS) with the Local Ensemble Transform Kalman Smoother (LETKS) technique. The integration represents an innovative approach to comprehensively assess river discharge on a global scale.

Solution:



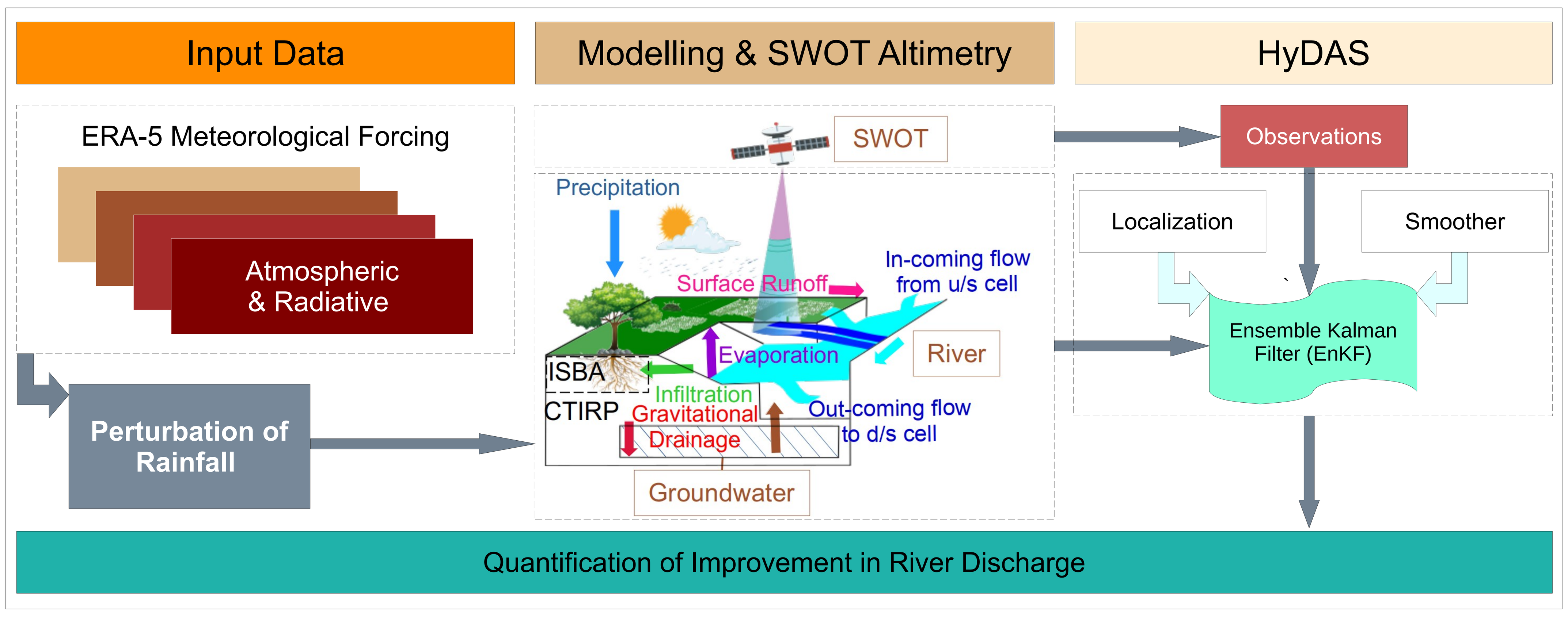
SWOT represents a collaborative satellite altimetry mission jointly undertaken by the French and US space agencies, officially launched in December 2023.

Distinguishing itself from its predecessors in nadir-looking altimetry, SWOT boasts a wide swath coverage of approximately 100 kilometers. This expanded coverage enables the measurement of both surface water elevation and slope.

SWOT facilitates the precise determination of water surface elevation for rivers wider than 100 meters, achieving a remarkable accuracy within a 10-centimeter uncertainty range over a 10-kilometer reach.

Significantly, SWOT introduces a novel capability by estimating discharge information for the monitored rivers. However, it is important to note that this discharge measurement comes with an associated uncertainty of up to 40%, which represents a considerable level of variability as shown in previous studies.

Methodology:



Data assimilation is performed using an Ensemble Kalman Filter (EnKF). The ensemble generation process involved perturbing the dominant modes derived from a Principal Component Analysis of precipitation data.

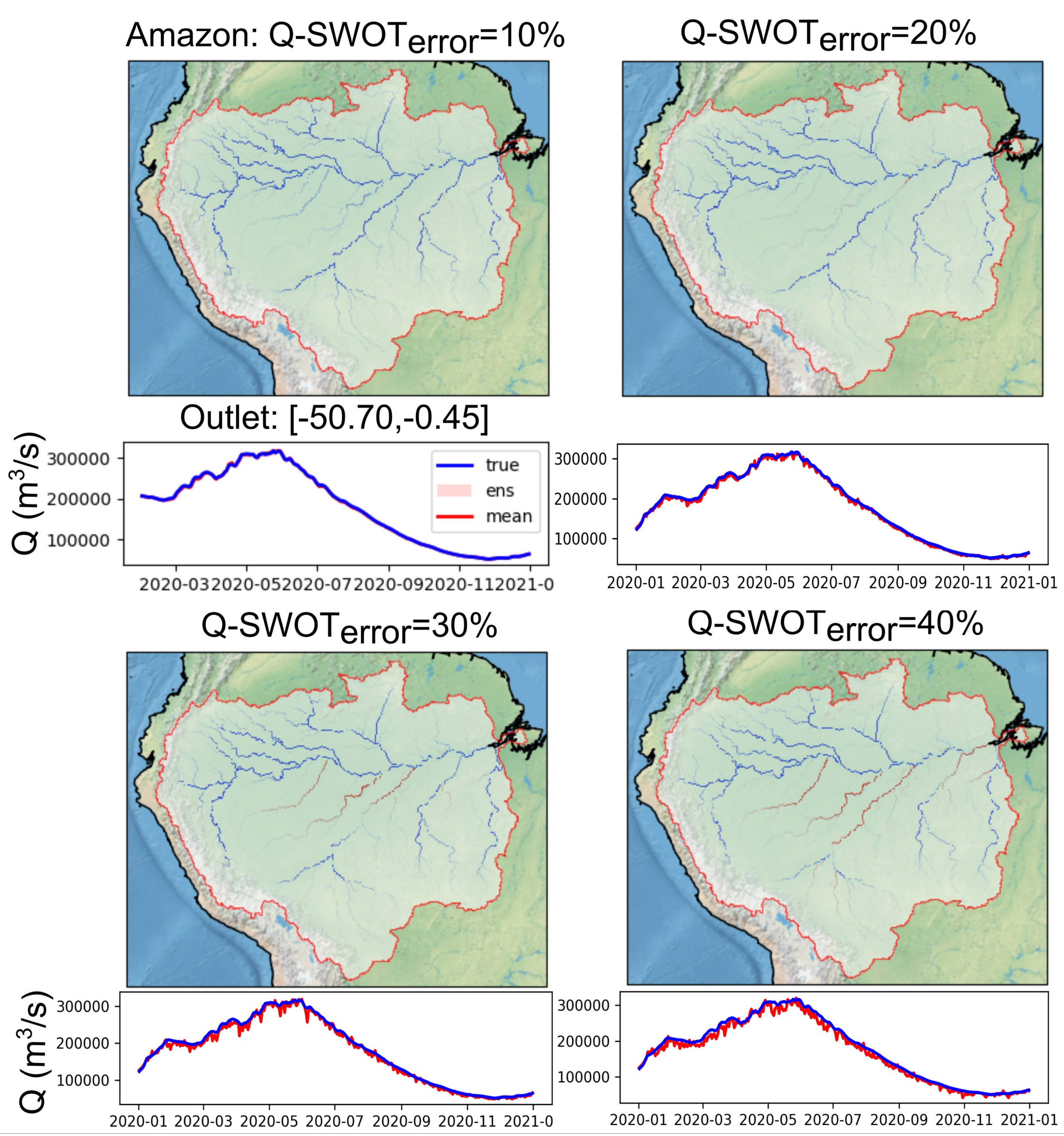
Proxy SWOT-based river discharge has been derived incorporating realistic orbit masks and the addition of noise. Further, the methodology was applied across various river basins, with varied sizes and locations globally.

An open-loop simulation was conducted to examine the ensemble's dispersion, consisting of 25 members generated from perturbed meteorological inputs.

To evaluate the assimilated discharge's performance against true run, Twin Experiments or Observing System Simulation Experiments (OSSEs) were executed.

Results:

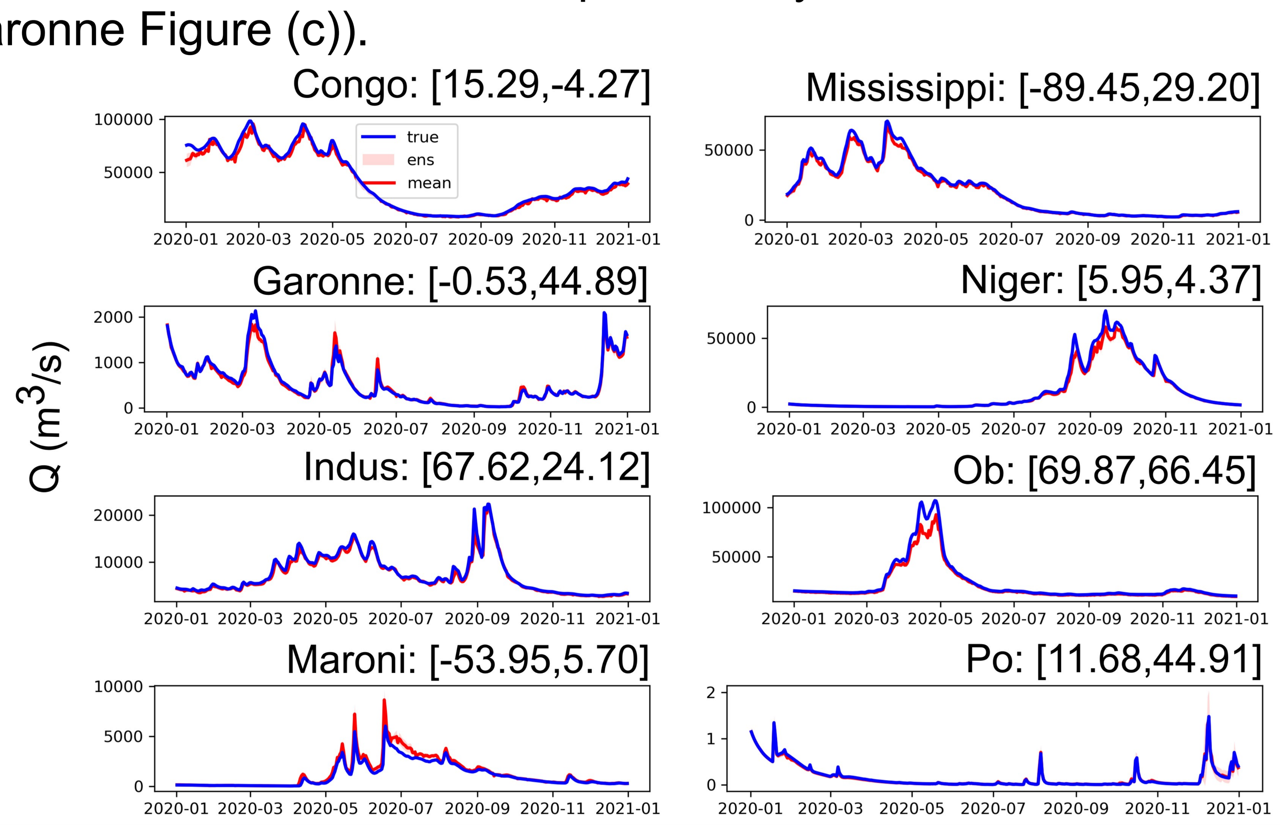
a)

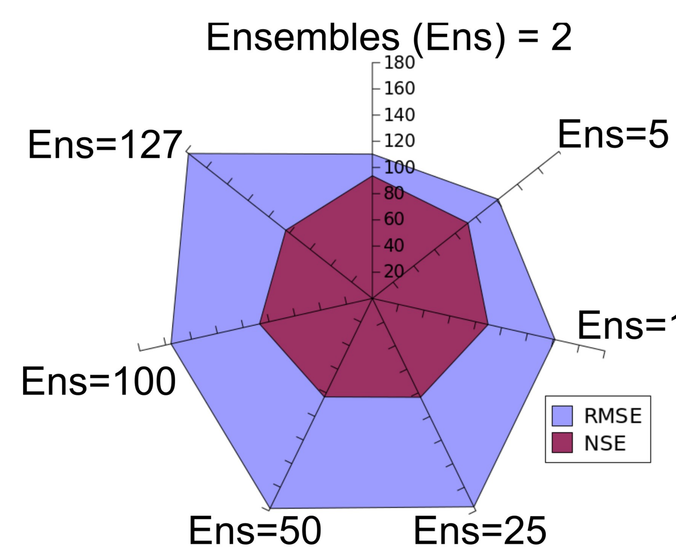


It's important to anticipate potential significant errors in SWOT-derived discharge and assess their influence in the assimilation process. To replicate SWOT-induced errors in discharge, we introduced variability into outputs from the true run by multiplying them with white noise characterized by a mean of unity and varying standard deviations (0.1, 0.2, 0.3, and 0.4). As depicted, the introduction of error in discharge data has a minimal impact on simulation performance, remaining inconsequential until reaching error levels exceeding 20% (Figure (a)). Beyond this threshold, with errors surpassing 30%, noticeable degradation in simulation results becomes evident (Figure (a)). Further, the discharge has been estimated at the downstream point of the various basin to evaluate the performance of assimilation (Figure (b)).

In addition to implementing localization, the ideal ensemble size was examined for integrating global-scale SWOT-based observations while maintaining reasonable computational efficiency. Findings indicate that an ensemble size of 25 is computationally efficient without compromising the quality of simulations (e.g. Garonne Figure (c)).

b)





c)

Conclusions:

Our results demonstrate that the assimilation of virtual SWOT observations led to a remarkable enhancement in river discharge estimates over a several basins under various hydro-climatic conditions (Amazon, Congo, Garonne, Indus, Maroni, Mississippi, Niger, Ob and Po basins). The next step is the extension of the CTRIP-HyDAS to the global scale. These findings indicate that SWOT products hold significant potential for substantially improving hydrological simulations on both a global and continental scale. By harnessing the power of the SWOT altimetry mission and employing our innovative framework, we can advance our understanding of the complex dynamics of river systems and their role in the broader continental water cycle.

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