Global River Discharge from SWOT at Gauging Stations
A Complementary Perspective

SWOT Science Team Meeting
www.swot2025.org

Peyman Saemian[1]*, Siqi Ke[1], Omid Elmi[1], Benjamin M. Kitambo[1]
Fabrice Papa[2], and Mohammad J. Tourian[1]

[1] Institute of Geodesy, University of Stuttgart, Stuttgart, Germany
[2] Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Université de Toulouse, CNES/CNRS/IRD/UT3, Toulouse, France

ARCACHON · France
14-17 OCT. 2025

Contact: peyman.saemian@gis.uni-stuttgart.de

Background and Motivation

- River discharge is a key component of the global water cycle and an Essential Climate Variable (ECV).
- Accurate discharge data are critical for hydrological modeling, climate studies, and water resource management.
- In situ gauge networks are declining worldwide, leading to large spatial and temporal observation gaps.
- The SWOT mission delivers unprecedented high-resolution (~100 m) observations of surface water elevation across global rivers.
- Goal: Integrating SWOT WSE and gauge data to build better global discharge records. The new dataset is called SWOT-QQ.
- SWOT-QQ supports algorithm validation, model calibration, and data assimilation, helping to fully exploit SWOT's observational capabilities.

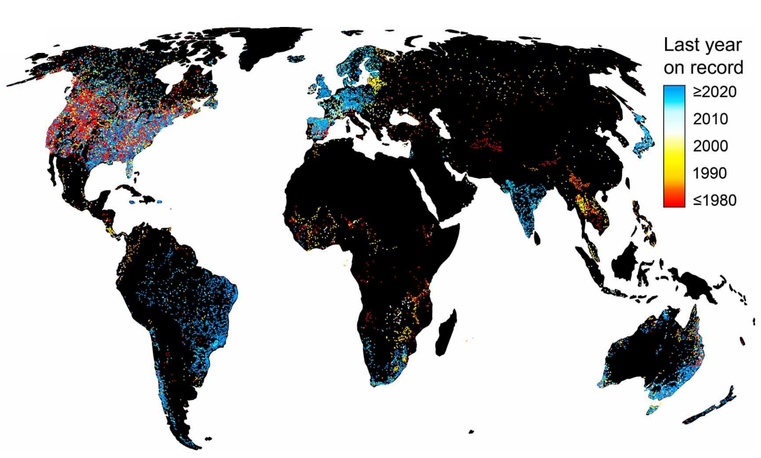

Figure 1. Distribution of the global river discharge gauges with their last record (Riggs et al. 2023).

Data Sets

In-situ river discharge

Daily gauge data (~60,000) from the global national and international Databases.

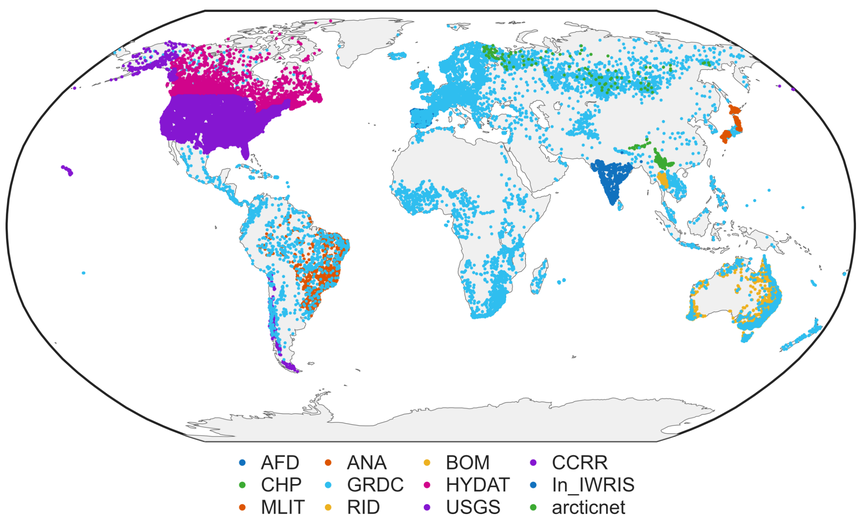

Figure 2. Distribution of gauges color-coded by their center.

SWOT River Database (SWORD)

For the current version of SWOT-QQ, we have used SWORDv16.

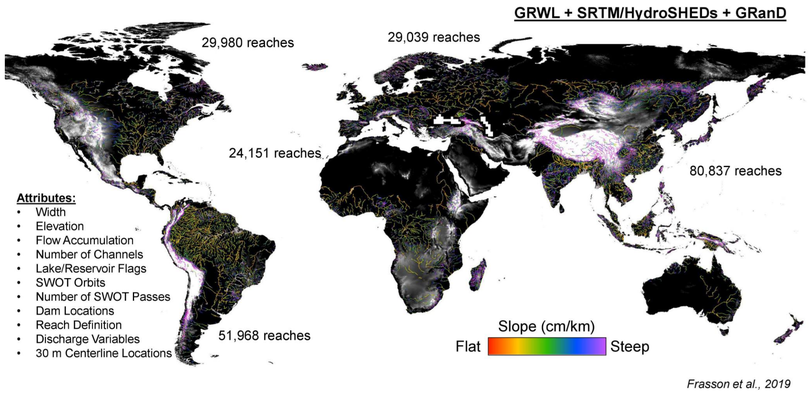

Figure 3. Global coverage of the Surface Water and Ocean Topography (SWOT) a priori River Database (SWORD) showing river reaches color-coded by slope (cm km^{-1}). The database integrates the Global River Widths from Landsat (GRWL), SRTM/HydroSHEDS, and GRanD datasets, providing attributes such as width, elevation, flow accumulation, number of channels, and SWOT orbit information. Regional reach counts are indicated. Source: Frasson et al., 2019.

WSE from SWOT L2 HR RiverSP

DOI: 10.5281/zenodo.11176233

For the current version, we have used KaRIn Version C products (April 2023-Present)

(some gauges have daily discharge during Cal/Val phase)

Method

Find the corresponding reach to each gauge

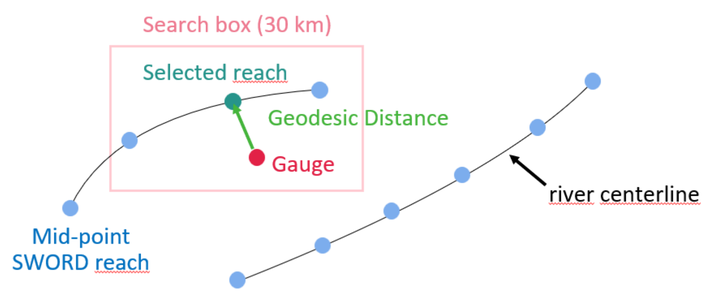

Figure 4. Schematic illustration of the procedure used to identify the nearest SWORD v16 reach to each in-situ gauge. For each gauge, the closest reach was determined based on the minimum geodesic distance between the gauge and the mid-point of SWORD reaches within a 30 km search box. The adjacent upstream and downstream reaches were also identified for subsequent analysis.

Nonparametric rating curve modeling

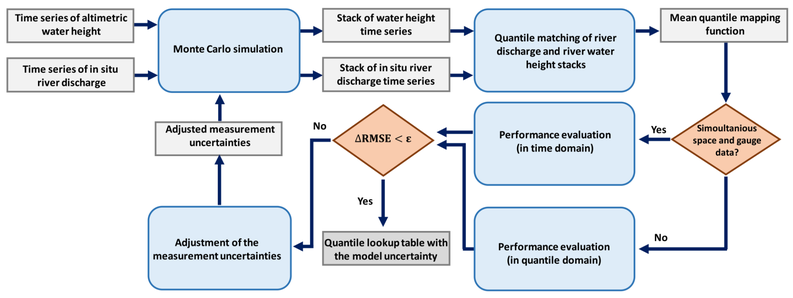

Figure 5. Flowchart of the stochastic quantile mapping function algorithm (adapted from Elmi et al., 2021, 2024).

Results and Validation

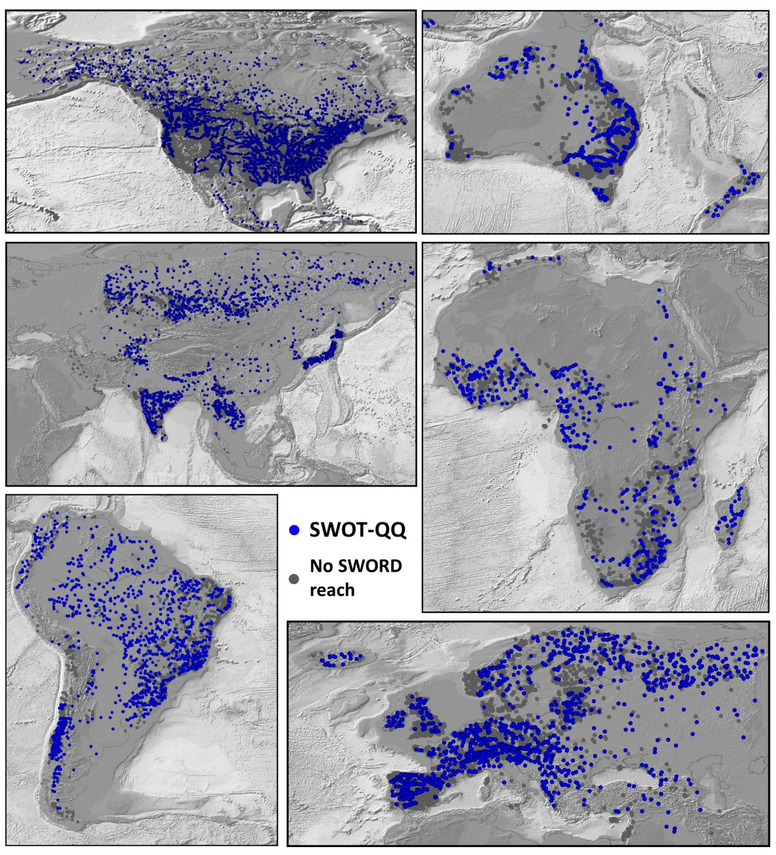

Figure 6. Distribution of discharge gauges across continents, grouped into (1) gauges with a SWOT reach within 10 km—where discharge was estimated using SWOT WSE (SWOT-QQ), and (2) gauges without a nearby reach, for which no SWOT WSE or SWOT-QQ estimate was available.

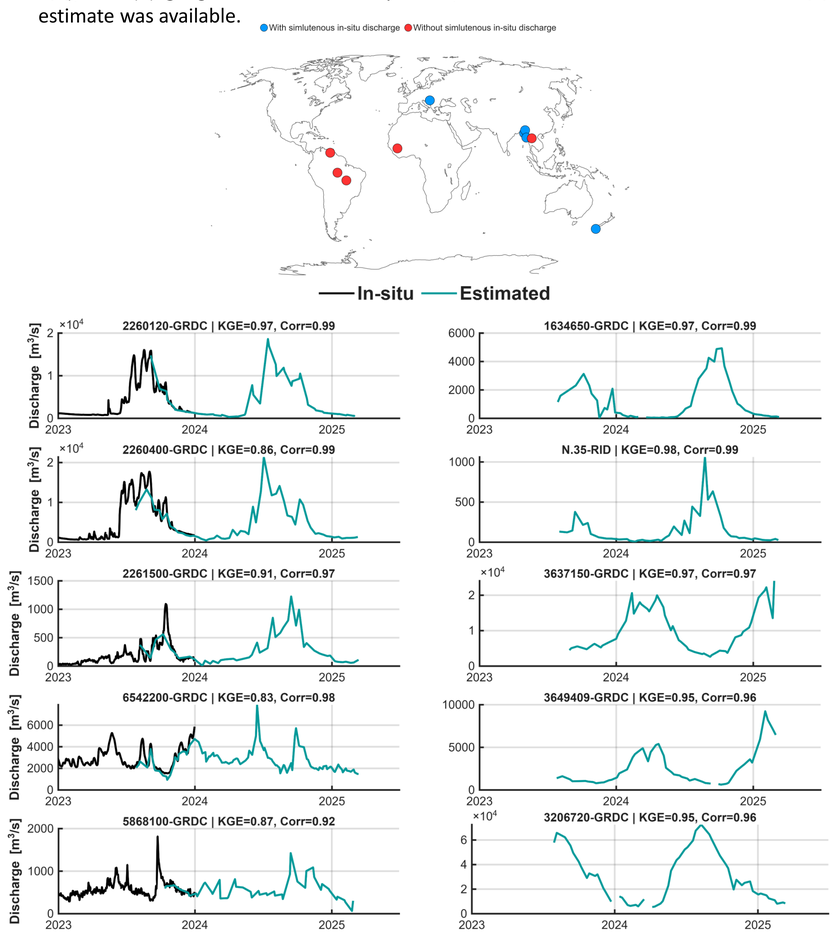

Figure 7. Comparison of in-situ and SWOT-QQ estimated discharge at selected stations. The left column shows cases with overlapping observation periods between in-situ and SWOT-QQ data, while the right column shows stations without temporal overlap. Reported values include Kling–Gupta Efficiency (KGE) and correlation coefficients. The distribution of the gauges is shown in the above figure.

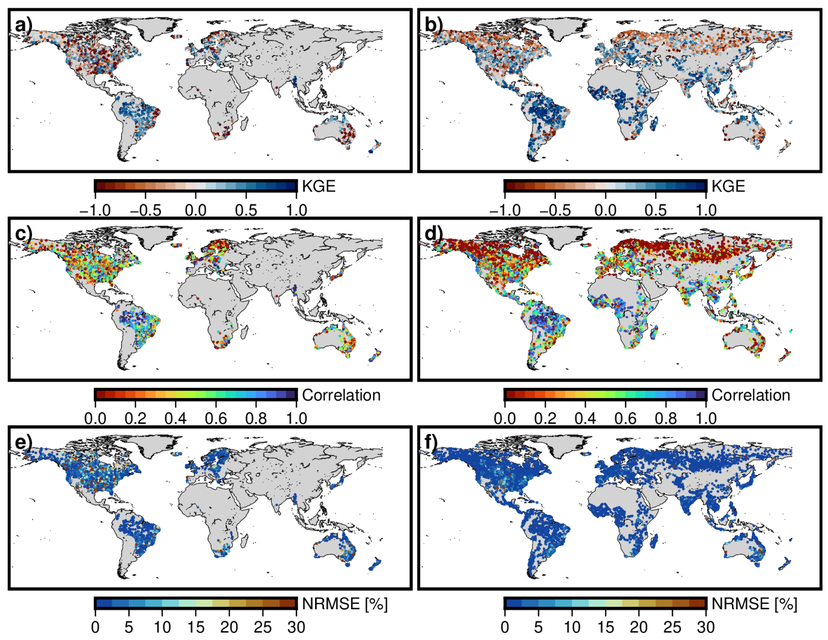

Figure 8. Global performance of SWOT-QQ discharge estimates compared to in-situ observations using three evaluation metrics: Kling–Gupta Efficiency (KGE), correlation, and normalized root mean square error (NRMSE). Panels (a), (c), and (e) show results for stations with overlapping observation periods between SWOT-QQ and in-situ discharge, while panels (b), (d), and (f) present results for stations without temporal overlap, where the comparison was based on mean monthly discharge values.

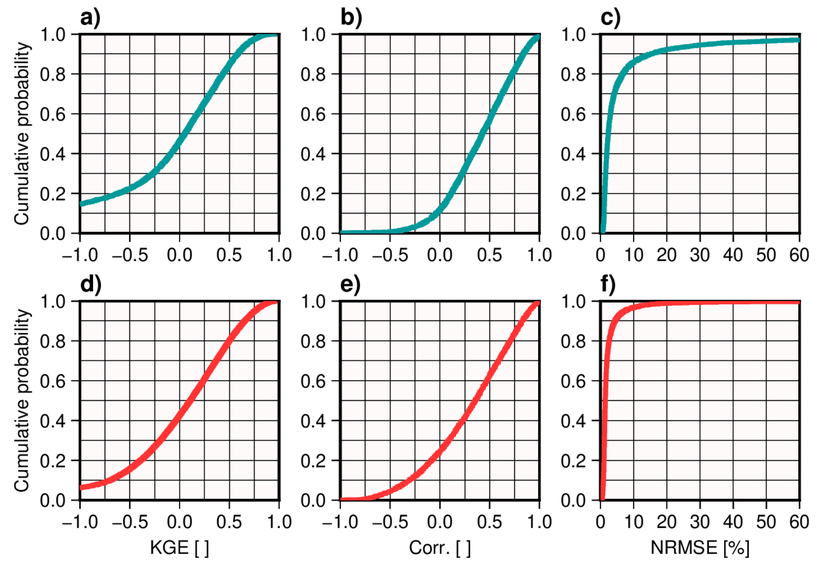

Figure 9. Cumulative distribution functions (CDFs) of the Kling–Gupta Efficiency (KGE), correlation, and normalized root mean square error (NRMSE) for SWOT-QQ discharge estimates compared to in-situ observations. Panels (a–c) show results for stations with overlapping observation periods, while panels (d–f) show results for stations without temporal overlap, where comparisons were made using mean monthly discharge values.

Comparison With SWOT SoS discharge

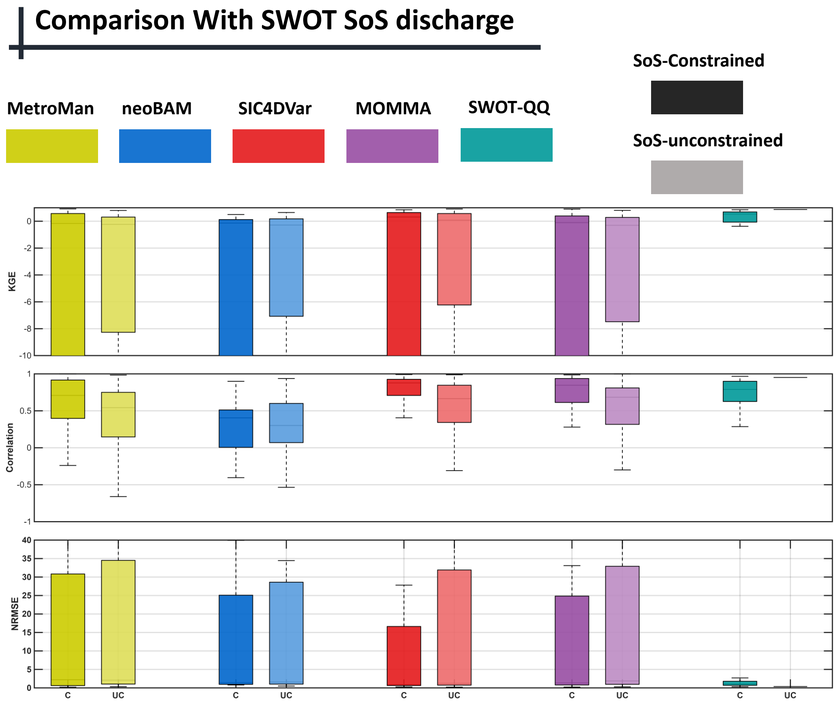

Figure 10. Comparison of discharge estimation performance between the SWOT-SoS algorithms (constrained and unconstrained) and the SWOT-QQ approach. Boxplots show the distribution of Kling–Gupta Efficiency (KGE), correlation, and normalized root mean square error (NRMSE) across all stations. The constrained (C) and unconstrained (UC) versions of each SWOT-SoS method (MetroMan, neoBAM, SIC4DVAR, MOMMA) are shown alongside the SWOT-QQ results.

Outlook

- Improve the reach–gauge matching approach (e.g., river name check, flow accumulation analysis, visual inspection).
- Update to SWORD v17b.
- Integrate SWOT Version D discharge results.
- Expand the analysis to include more in-situ gauges.
- Develop an online platform to share results and interactive visualization.

References

•Elmi, et al. "Spaceborne river discharge from a nonparametric stochastic quantile mapping function." *Water Resources Research* 57.12 (2021): e2021WR030277.

•Elmi, et al. "Remote sensing-based extension of GRDC Discharge time series-a monthly product with uncertainty estimates." *Scientific Data* 11.1 (2024): 240.

• Frasson, et al. "Global Relationships Between River Width, Slope, Catchment Area, Meander Wavelength, Sinuosity, and Discharge." Geophysical Research Letters, 46 (2019), 3252-3262. https://doi.org/10.1029/2019GL082027

• Riggs, et al. "Extending global river gauge records using satellite observations." *Environmental Research Letters* 18.6 (2023): 064027.