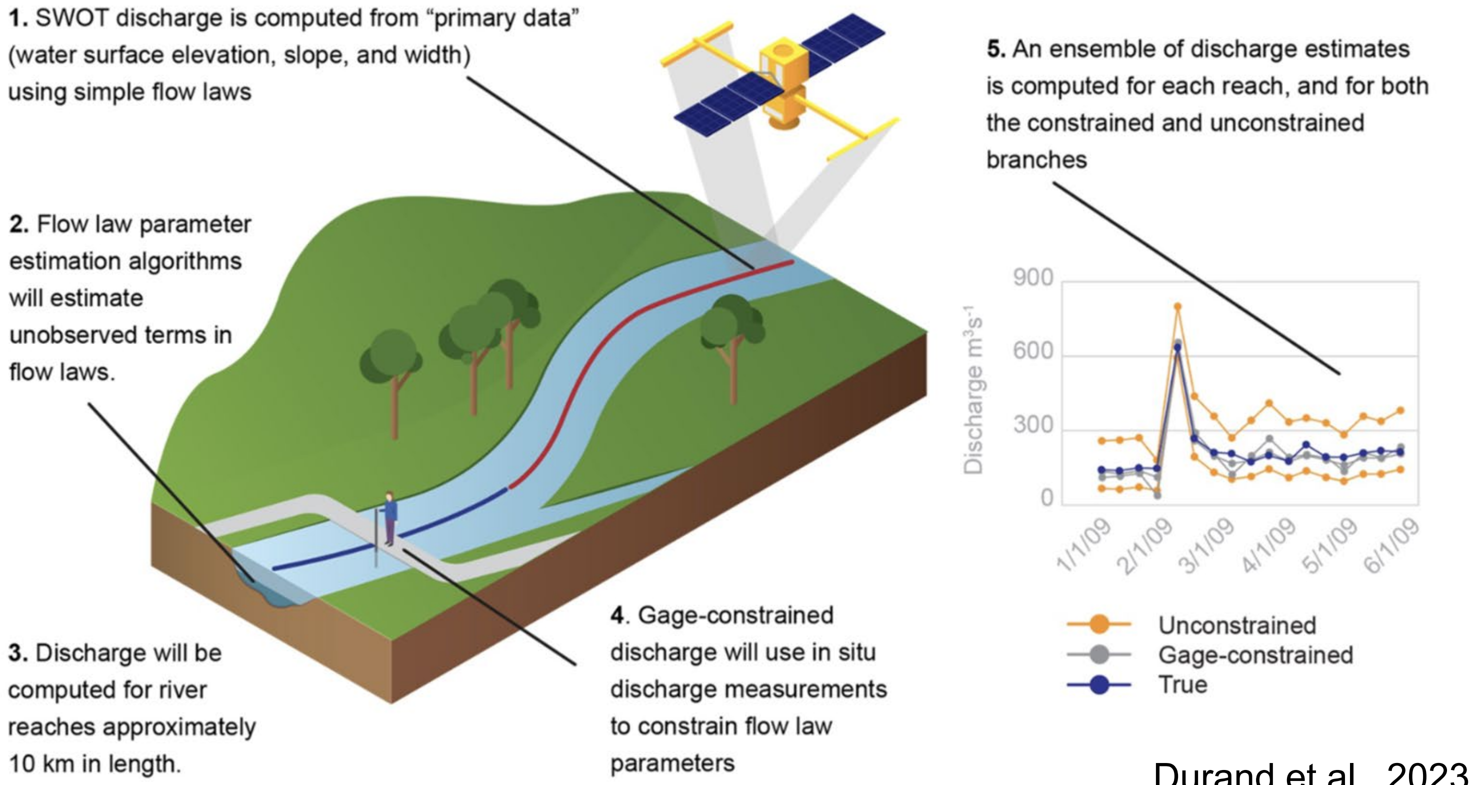
SWOT Discharge Accuracy: Current Status & Future Improvements

Mike Durand on behalf of the DAWG leads

SWOT Science Team Meeting, 2025, Arcachon
Thursday, October 16



Durand et al., 2023

SWOT discharge is derived from SWOT measurements of WSE, width and slope.
Expecation: discharge accurately tracks variations, with some timeseries bias.

Version 0 of SWOT discharge is public, though not global

SWOT tracks discharge variations, but less often and with more bias than expected

Data available at 827 river reaches

Paper describes this dataset in GRL, published March 2025

Geophysical Research Letters

RESEARCH LETTER
10.1029/2024GL114185

Special Collection:
Science from the Surface Water and Ocean Topography Satellite Mission

Key Points:

- The Surface Water and Ocean Topography (SWOT) satellite mission offers simultaneous and synoptic estimates of river discharge and other hydrological variables globally
- Results show that SWOT can track discharge dynamics without gauge information, with correct magnitude in some cases but with bias in others
- SWOT has the potential to provide valuable insights into global river discharge estimation, with implications for hydrologic science

A First Look at River Discharge Estimation From SWOT Satellite Observations

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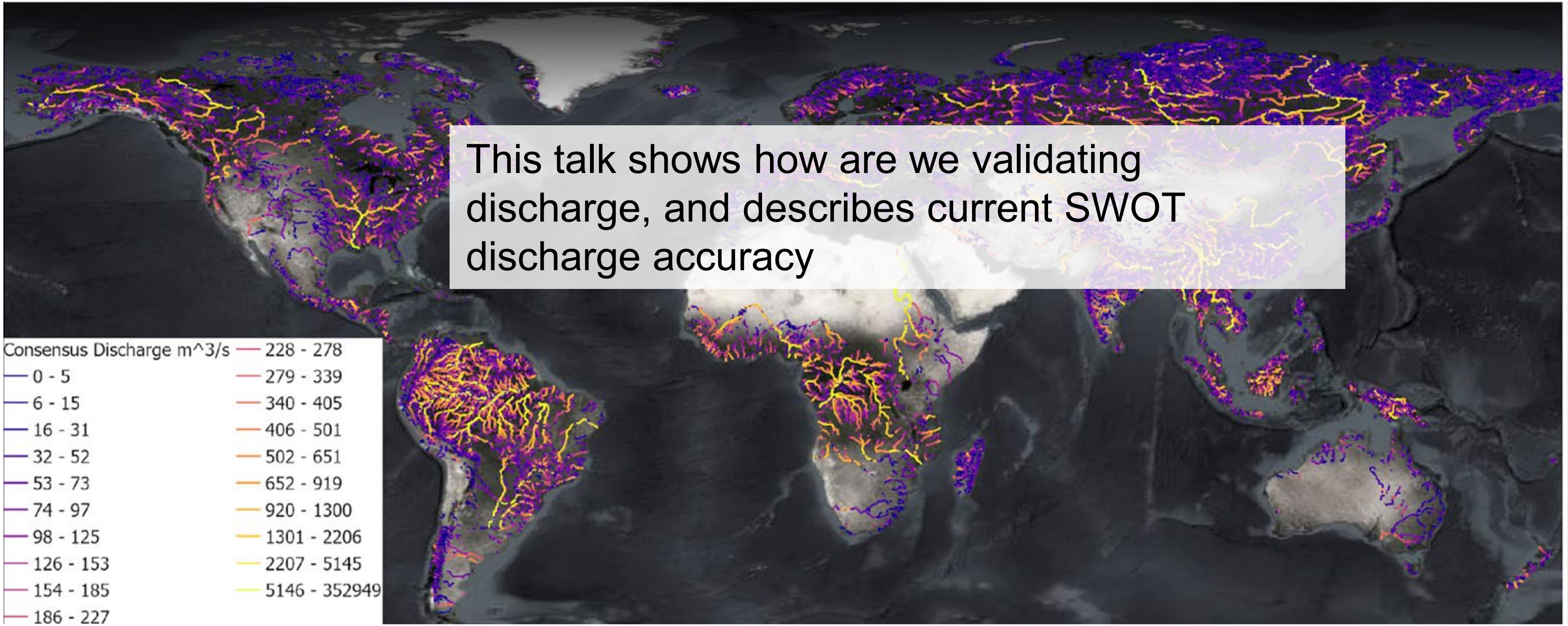
https://podaac.jpl.nasa.gov/dataset/SWOT_L4_DAWG_SOS_DISCHARGE

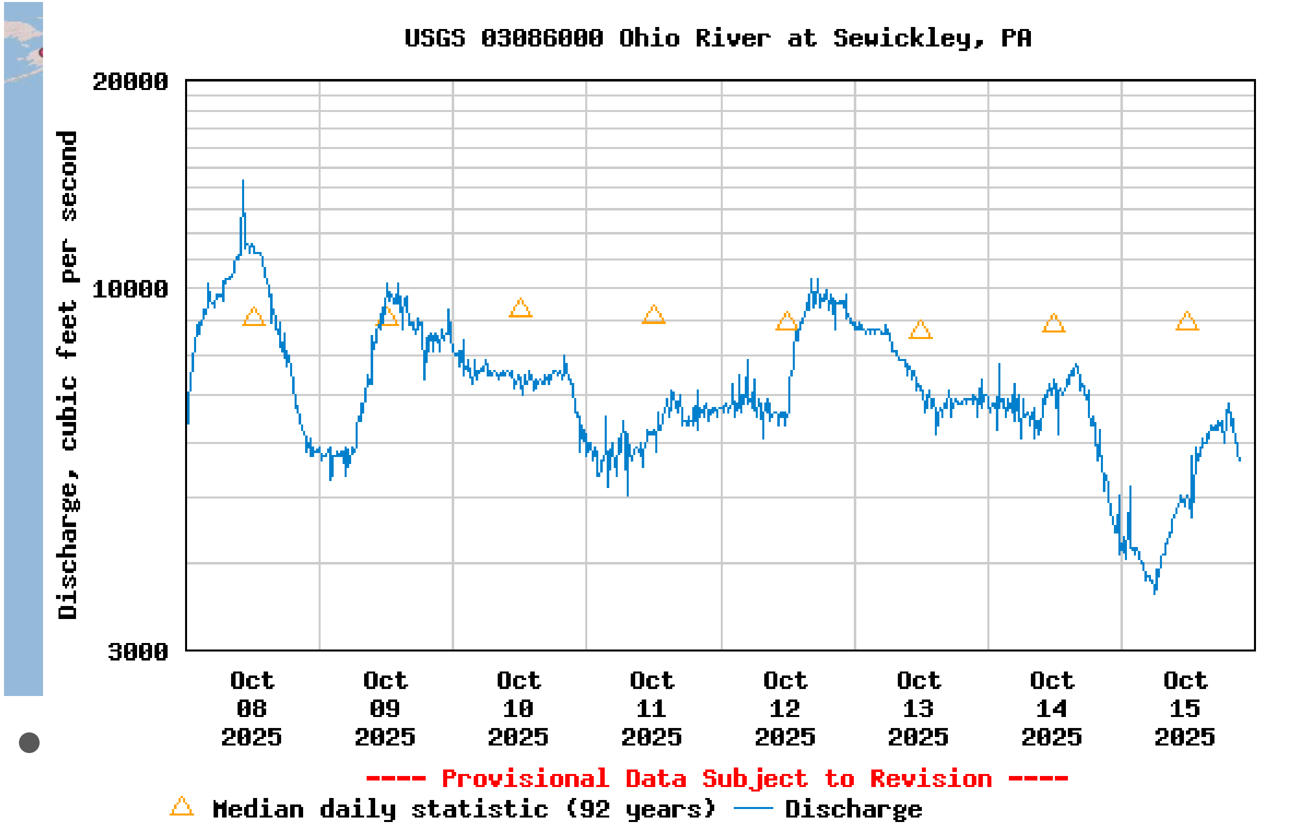
First global SWOT discharge is here!

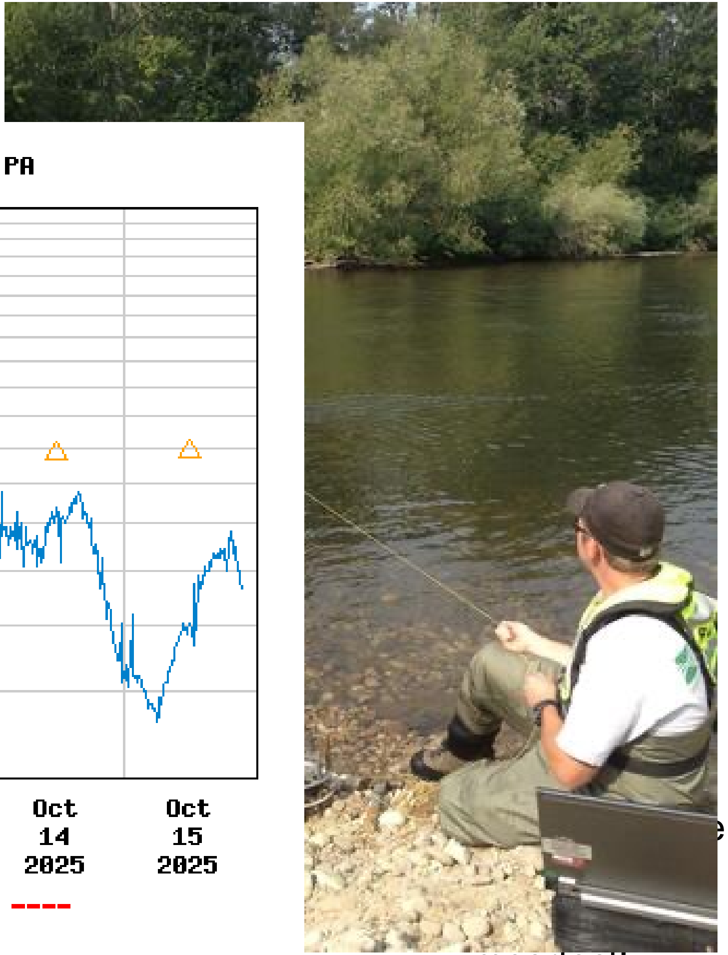


This talk shows how are we validating discharge, and describes current SWOT discharge accuracy

Data is a Level 4 product.

SWOT Discharge Validation Plan





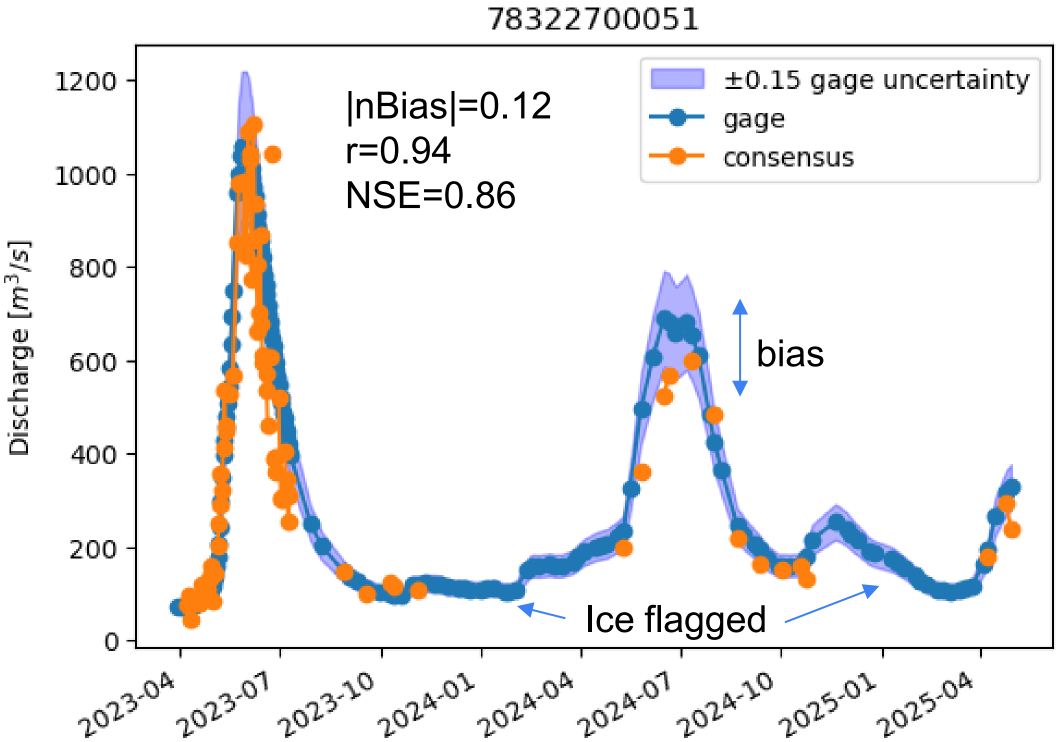
-
- We use gages from 8 agencies

e

imperfect!

How we measure discharge performance

SWOT discharge is good at tracking variations in discharge timeseries. We measure this skill with the Pearson correlation coefficient r



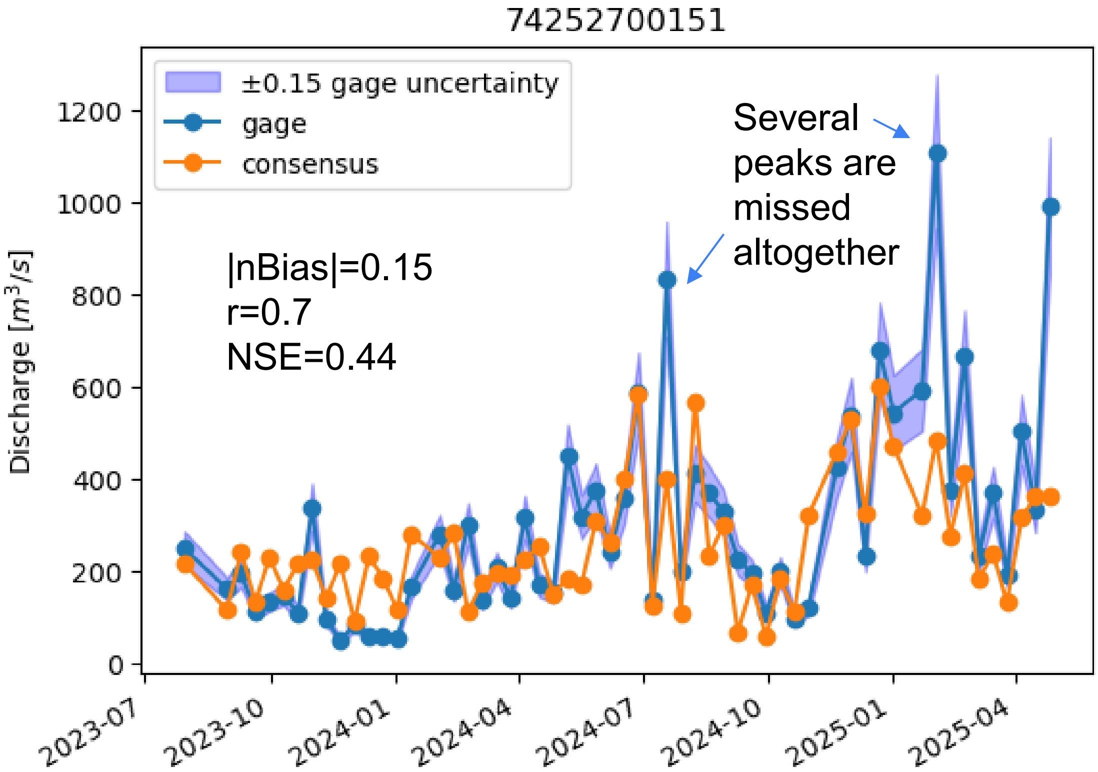
SWOT discharge is growing in its ability to measure timeseries mean discharge. We meaure this skill with the absolute value of the bias normalized by the true mean |nBias|

South Thompson River, British Columbia, Canada. Gage measurements by Water Survey Canada

Example discharge performance

In this reach, bias is still low, but correlation is not as good.

This may be due to differences between passes: note the up-and-down pattern, with error oscillating with alternating passes

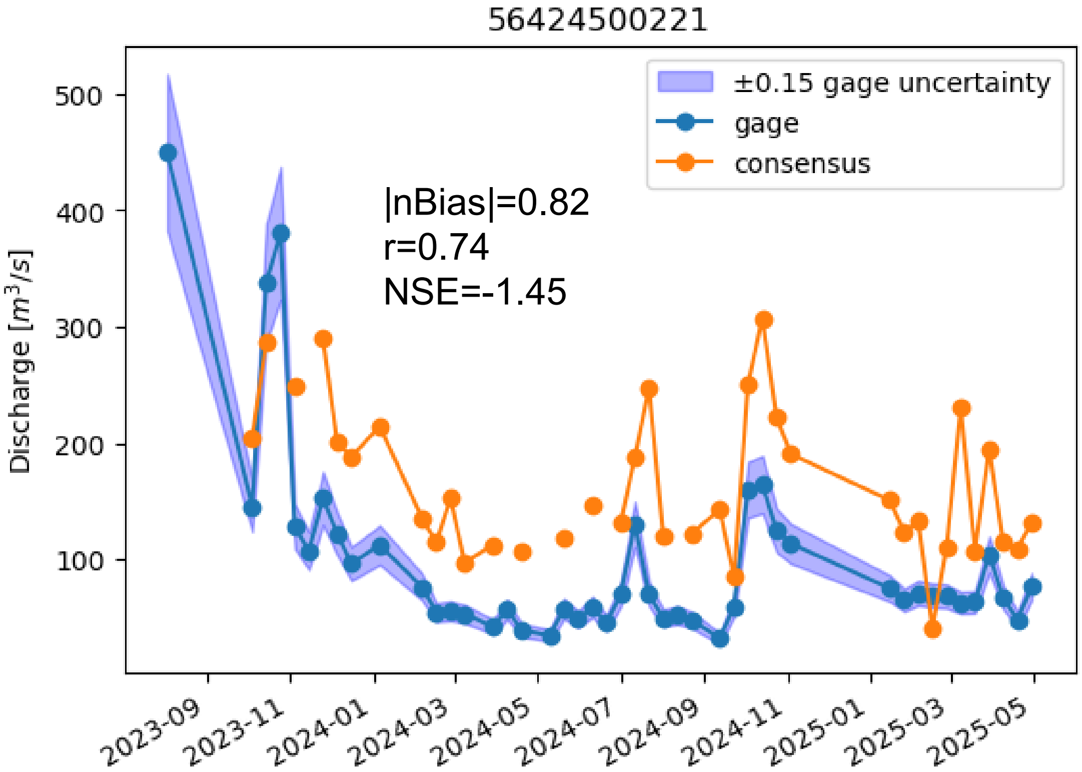


White River, Arkansas, US. Gage measurements by USGS

Example discharge performance

This reach has a larger bias, but its correlation with the gage demonstrates that the SWOT data still contain information

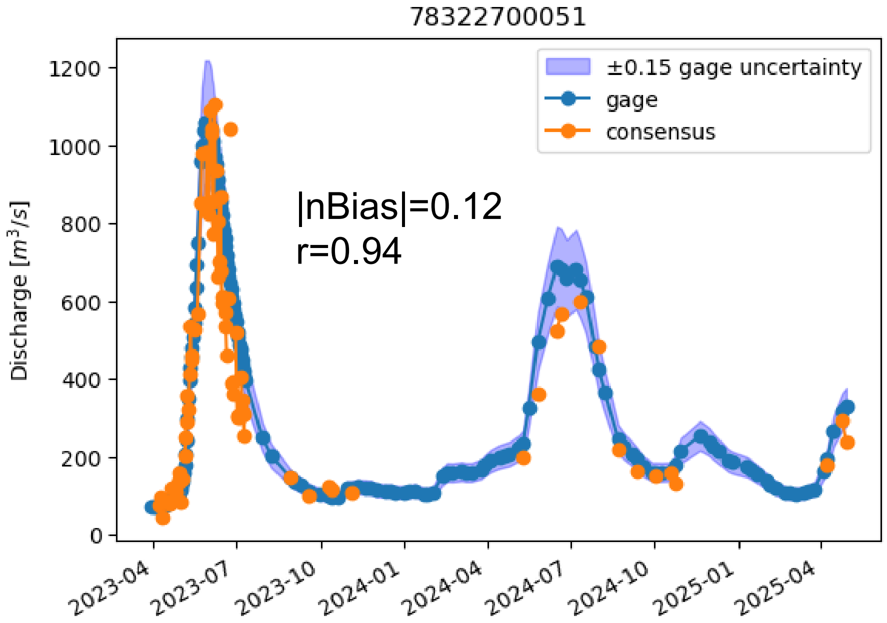
This river is 84 m wide (in SWORD), under the SWOT science requirement (100 m)



Murray River, Australia. Gage measurements by ABOM

Target Accuracies

- Bias: Average difference between SWOT and gages*
  - Global hydrologic models subject to biases:45-55 %**
  - SWOT target: 30%. We use these global models as a prior.
- Correlation: Tracking discharge variations in time
  - Given SWOT observation error levels, correlations of 0.9+ should be achievable
- Note that there are no accuracy requirements for discharge



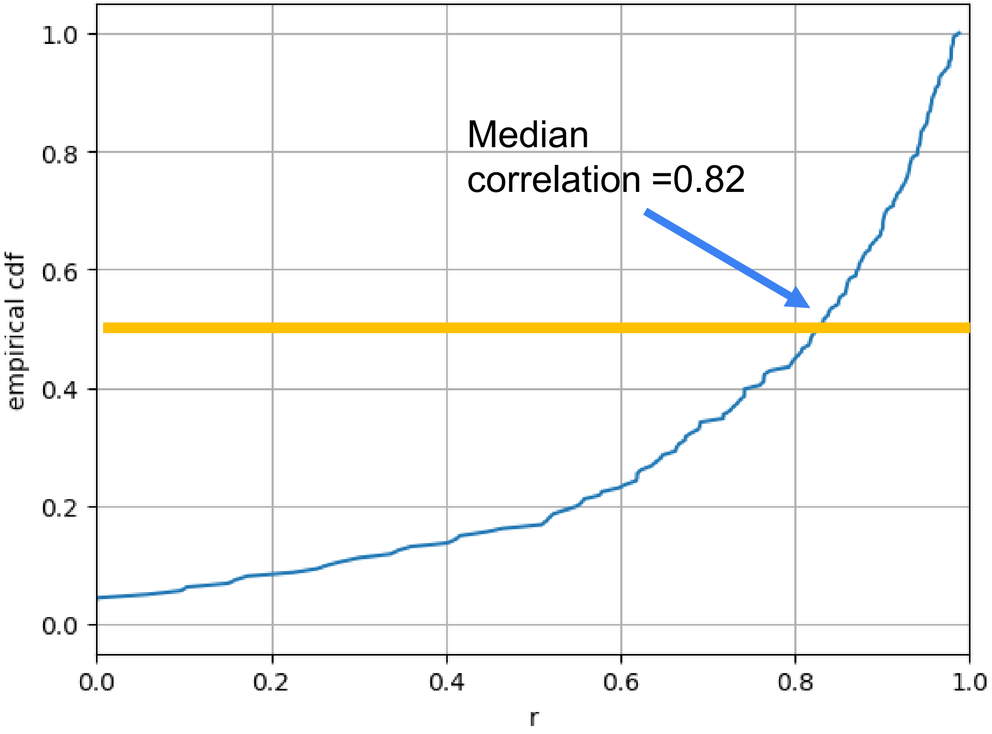
* Note that gages themselves are imperfect! Assume 10-20% error in gages is reasonable.
** Based on assessing our own prior datasets. Global ML models are rapidly improving.

SWOT discharge accurately tracks discharge variations

Median correlation indicates that typically, SWOTaccurately tracks discharge variations

The interquartile range [0.62-0.93] indicates performance is robust across a significant majority of reaches

SWOT is meeting expectations! Future work will aim to exceed the target value of 0.9 more for the top two thirds of reaches



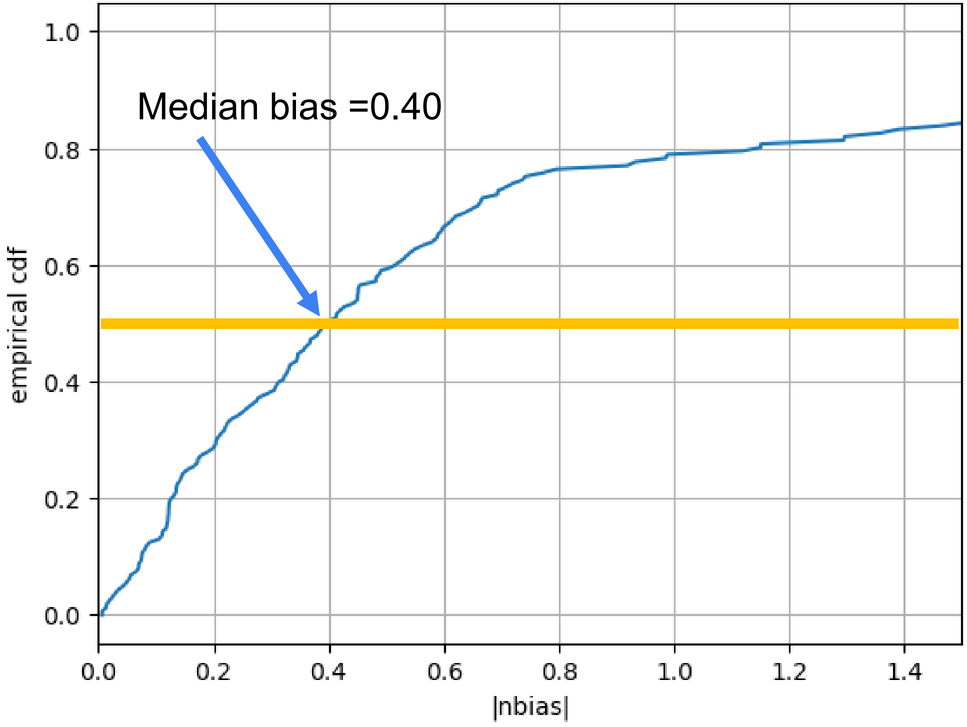
Evaluation across SWOT validation gages globally

SWOT Q is achieving lower bias as algorithms mature

Median bias indicates that typically, SWOT is a bit below pre-launch expectations

The interquartile range [0.25-1.24] indicates a need for improvement.

SWOT is close to meeting expectations: at least two algorithm changes will improve bias (stay tuned!)

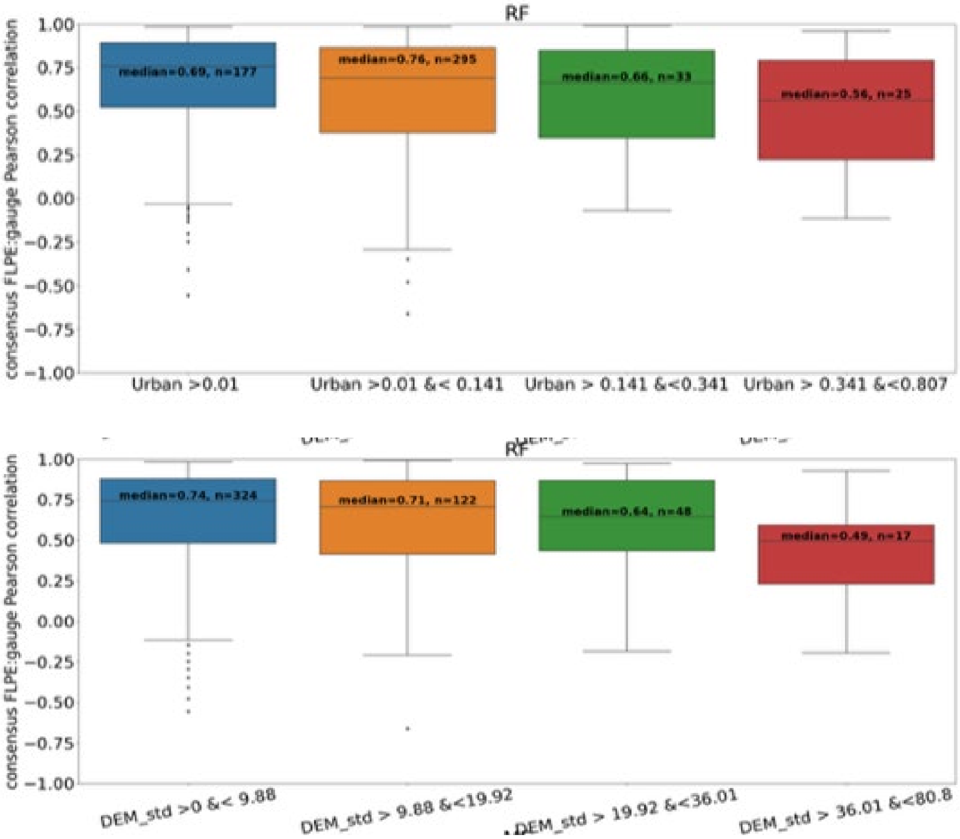


Evaluation across SWOT validation gages globally

Understanding SWOT accuracy: Land cover & topography

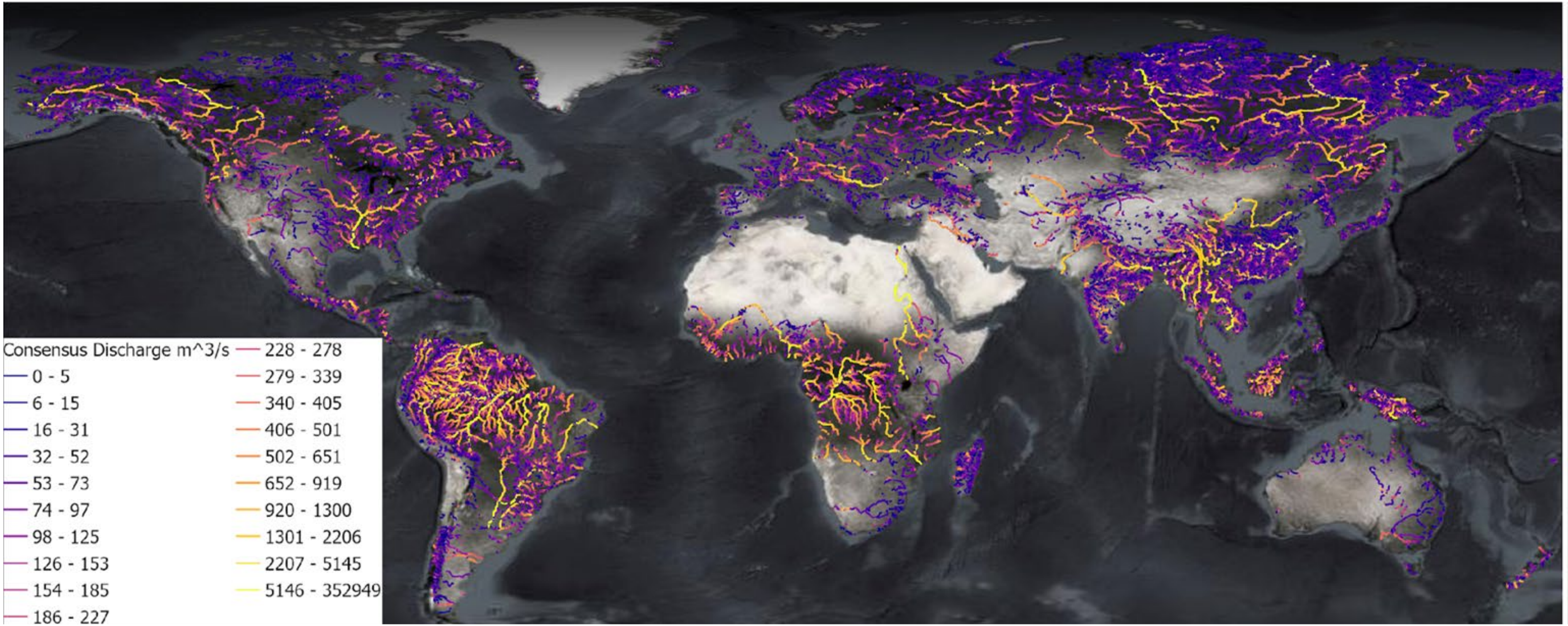
We found that performance degrades significantly where there is significant urban land cover near the reach

Performance also degrades when there is significant topographic variations near the reach



Coss et al., in prep.

First version of global SWOT discharge captures spatial and temporal patterns



Version 1 Discharge will be released by December 1

Plan B: Release existing dataset. Version 1 will be NO WORSE than this!

- Global run produced summer 2025 has been shown
- Uses Version C SWOT data
- Reach-scale flow law parameter estimation algorithms are running, but algorithm to “integrate” gage information across basin scale will be run next version
- We filter less data out than in Andreadis et al. 2025:

Plan A: The latest & greatest

- Improved algorithms and priors
- Runs are nearly complete
- A decision taken on Oct 24 which run will become version 1
- Global runs done and checked in November.
- Release improved documentation

Plan A: New configuration is being tested and run!

- Cécile Cazals (INRAE) has created a new set of filters that allows significantly more data into the Confluence run, with only a small loss of accuracy “permissive + relaxed”. Huzzah!
- Heejin An (U Mass) has mapped new machine-learning derived prior discharge estimates and done a Confluence run with these, improving accuracy. Huzzah!
- Ellie Friedman (U Mass) has created a new “Consensus algorithm” that improves accuracy by discarding aphysical discharge timeseries. Huzzah!

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Algorithm changes for Version 2 (2026) include:

Version D SWOT data

Version 17 SWORD

New Machine-Learning priors that overlap in time with the SWOT period

More permissive data filters

Better consensus algorithm

River hypsometry constraint

Integrator algorithm

Constraint to more in situ data

Continued bug fixes

We fully expect these changes should significantly improve discharge skill!

Summary

The first look at SWOT discharge is published: Andreadis et al. GRL 2025

The first global SWOT discharge products (Version 1) will be online by December 1: discharge timeseries variations are tracked well, with some bias. SWOT discharge meets expectations qualitatively; quantitative accuracy is improving!

SWOT Discharge Version 2 will be out next year. We expect significant improvement in accuracy, from new algorithms, and new priors

Space Agency Level 2 discharge products will accompany Discharge Version 2 next year

Extra Slides

SWOT discharge flavors have both quality and quantity!

The RF data has ten or more observations for 50,048 of the 58,433 reach-observable reaches (86%) - 5x more than Andreadis et al. 2025! There are a total of 1.2 M such observations in all.

Further filtering to the MF data (requires height-width correlation), you lose only 17% of the reaches

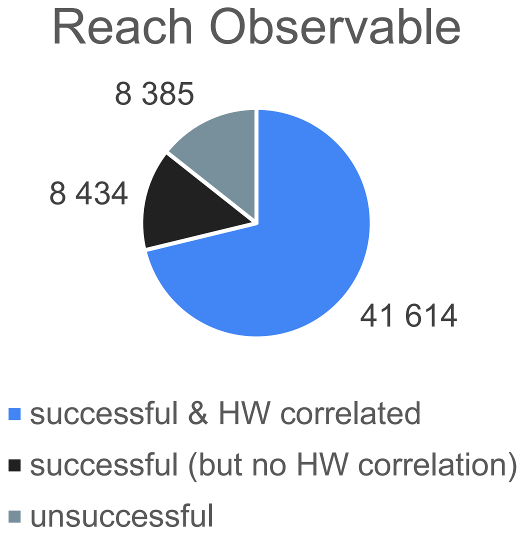
The LF data (does not require reach observations) has more data, but at somewhat lower quality: data on XX reaches, and YY in all.

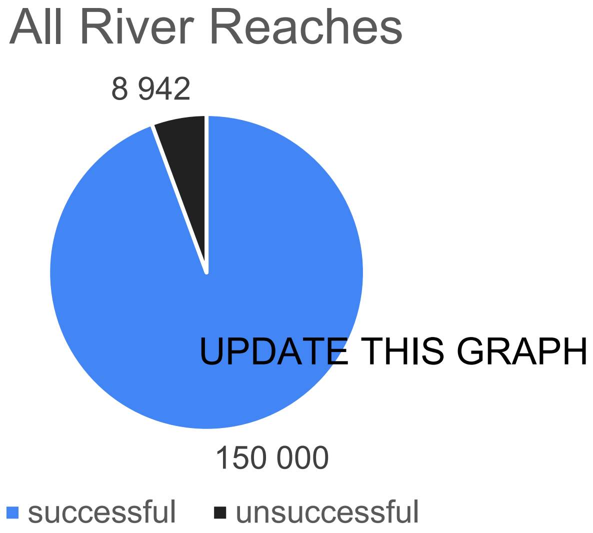
On which reaches do we expect SWOT discharge? On which do we attempt to exceed expectations?

- It is not expected to have SWOT discharge everywhere
- There are a total of 58,433 reaches that are “reach observable”, in-line with pre-launch expectations:
  - Rivers (type 1) rather than reservoirs or dams
  - Reach width > 80 m
  - Reach slope > 3.4 cm/km
  - Reach length > 7 km
- FLPE algorithms based on node data rather than reach data increase spatial and temporal coverage: there are potentially up to 158,942 “node observable” reaches: an ambitious effort to improve coverage

Expected data quality and quantity varies by ~~ice cream~~ SWOT discharge flavor

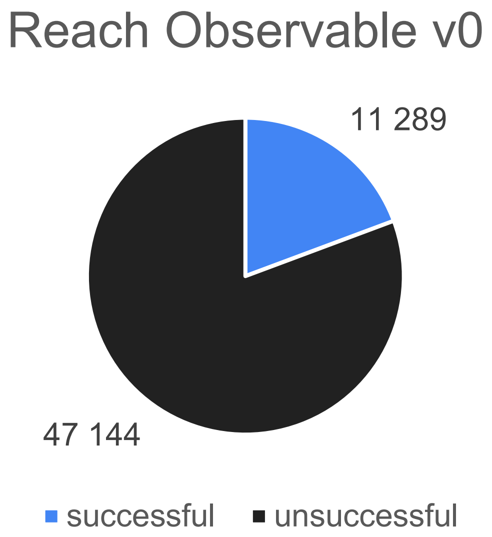
Most of the reach observable reaches have height width correlation and thus have the highest accuracy timeseries

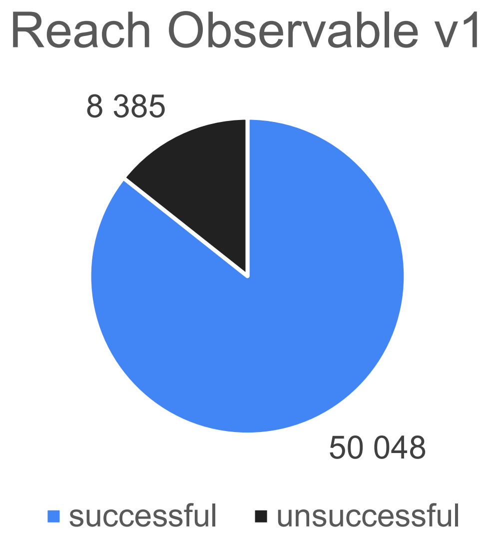




On reaches where we expect it, we have discharge 86% of the time. In most of these reaches, we believe we are accurately tracking discharge variations!

We have far more high quality data in v1 than we did in v0





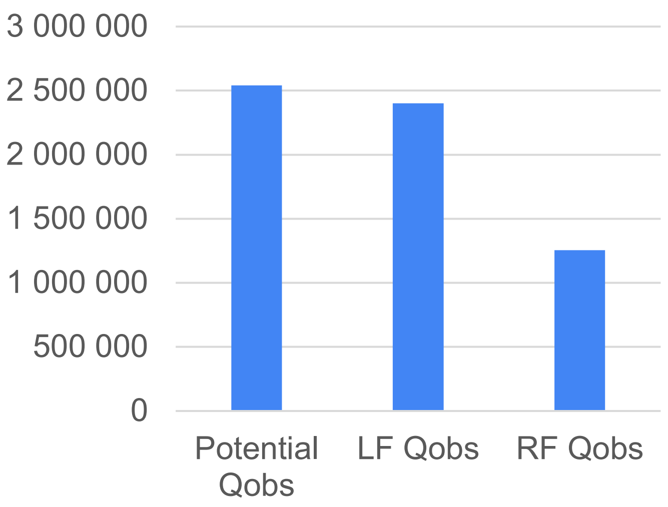
Compared with v0 (Andreadis et al. 2025), we now have successful discharge timeseries in 5x more reaches!

Leveraging diversity among algorithms improves SWOT discharge timeseries data volume

There are ~2.5M “potential” discharge observations, after accounting for ice, data downlink issues,

We have nearly 2.4M actual Q observations, when you do not require concurrent reach observations

We have 1.25 M RF Q observations.



Note: A naïve expectation is that we would have ~6M total discharge observations in this run

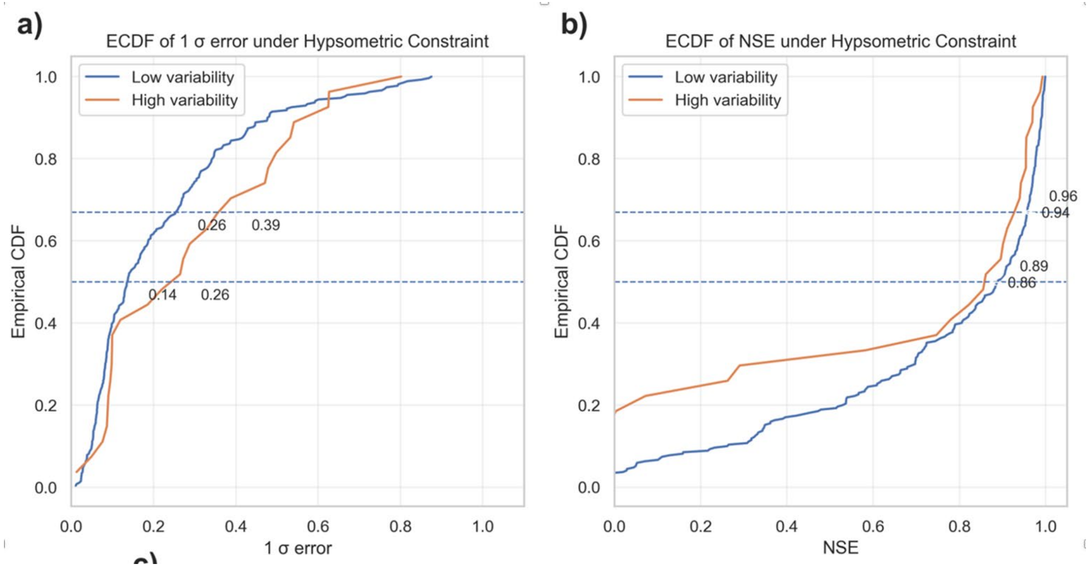
Review of Update Part 1 (Wednesday) Talking Points

- Science Team (Level 4) discharge products are now available
  - v0 (Andreadis et al. 2025) is available now, over a subset of reaches
  - v1 will be available [to be decided on at Bordeaux, insert update]
  - v2 will be available in 2026
  - Accuracy qualitatively in line with pre-launch expectations: we track temporal variations, but observations have timeseries bias
    - New algorithms are expected to improve accuracy
  - Fraction of observations that pass quality filters is far lower than expected pre-launch
    - Version D data products are expected to improve usable data volume
- Space Agency (Level 2) discharge products will be available in 2026

More Technical Summary

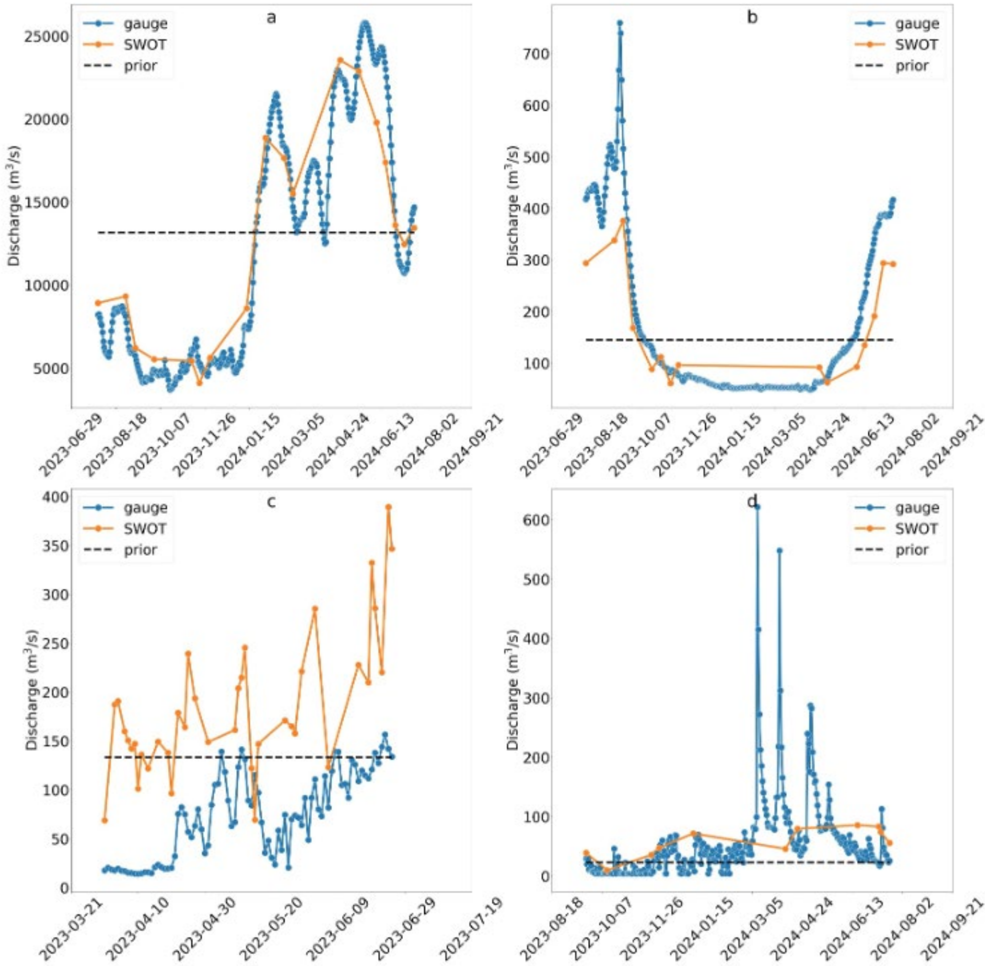
- Version 1 has a 5x increase (over v0) in SWOT discharge that accurately tracks (RF) river discharge temporal variations: ~50k reaches of ~58k reaches.
- On these reaches, median correlation is ~0.75
- Our filters discard ~half of expected reach observations
- Nearly all of the remaining ~101,000 reaches have discharge timeseries of slightly lower skill
- Flagging is being added to indicate skill difference, prior to release
- Discharge v1 will be released publicly by December 1, 2025

New algorithms for v2: hypsometric constraint



Example Reach Timeseries

- Some reaches (a) have high skill: low bias and high correlation
- Other reaches (b) have bias but track variations
- In version 1 there are more reaches with high skill: Progress!

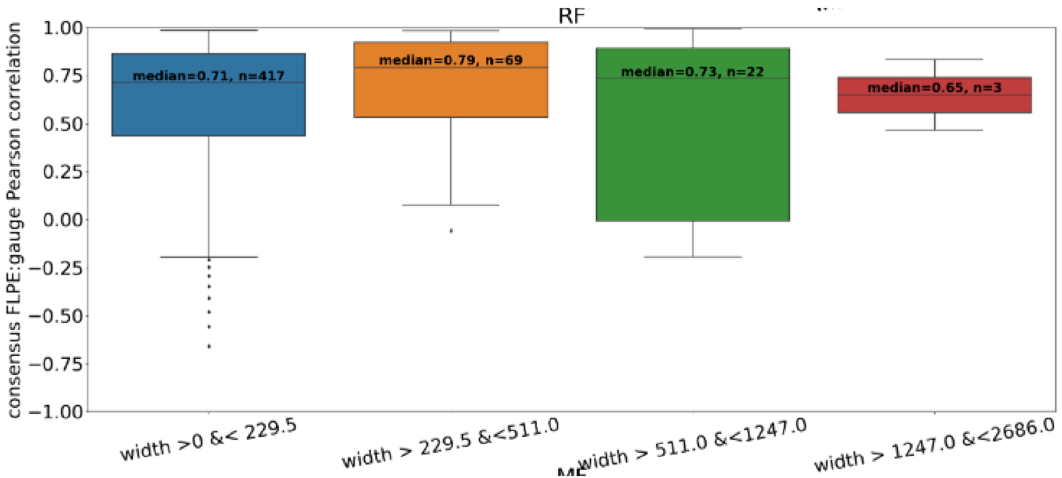


Andreadis et al. 2025

Understanding SWOT accuracy: Bigger is not always better

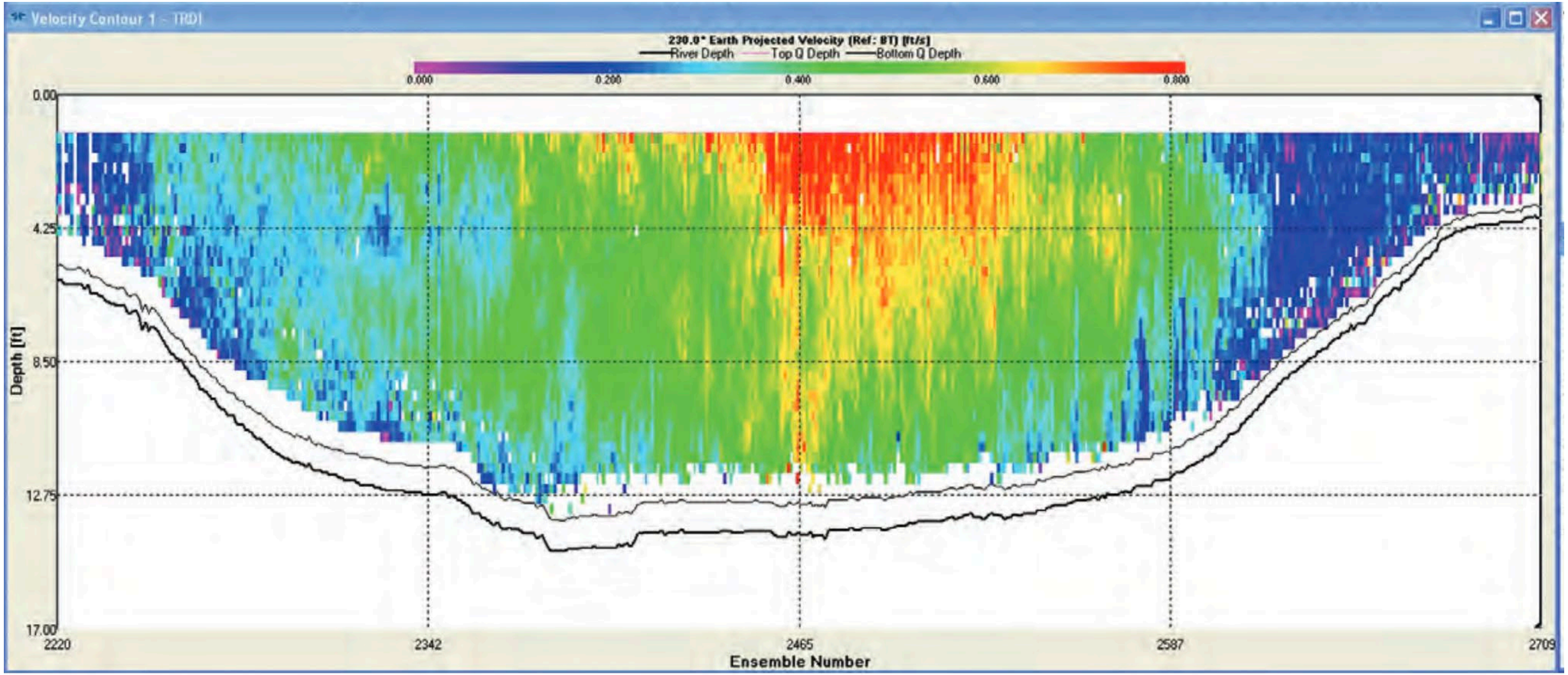
Rivers between ~200 and ~500 m wide perform better than smaller rivers

However, contrary to expectations, the biggest rivers (>500 m) show more varied performance, tracking



Unconstrained, reach-filtered…widths 230-500 m are better than 0-230. But bigger rivers (>500 m) are not better than the smaller ones

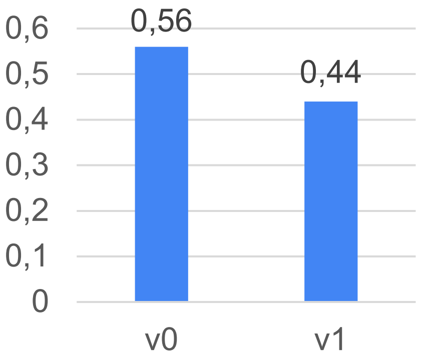
Coss et al., in prep.

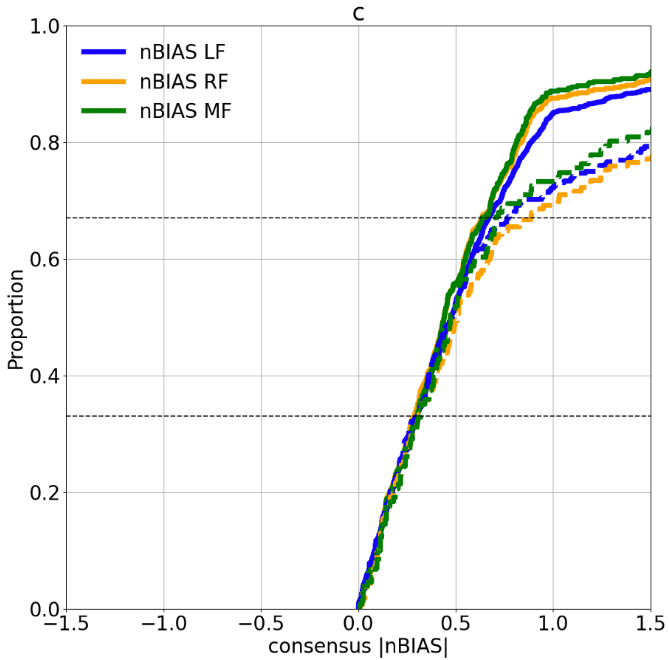


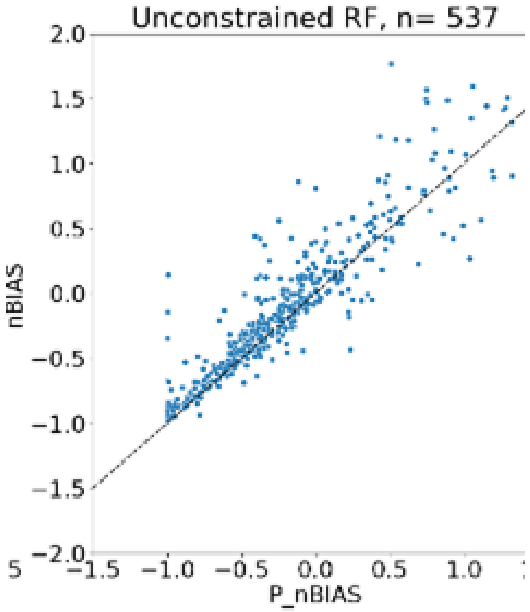
Velocity Contour 1 - TRDI
230.0° Earth Projected Velocity (Ref: BT) [ft/s]
River Depth
Top Q Depth
Bottom Q Depth
0.000
0.200
0.400
0.600
0.800
0.00
4.25
8.50
12.75
17.00
Depth [ft]
2220
2342
2465
2587
2709
Ensemble Number

SWOT discharge mean flow accuracy has improved

However, accuracy on average is not improving compared with the prior mean flow, as they did in pre-launch studies.







For the Level 4 products, constrained does not “spread” gage information across basins, and bias is expectedly unimproved over unconstrained. This will change for v2.

Coss et al., in prep