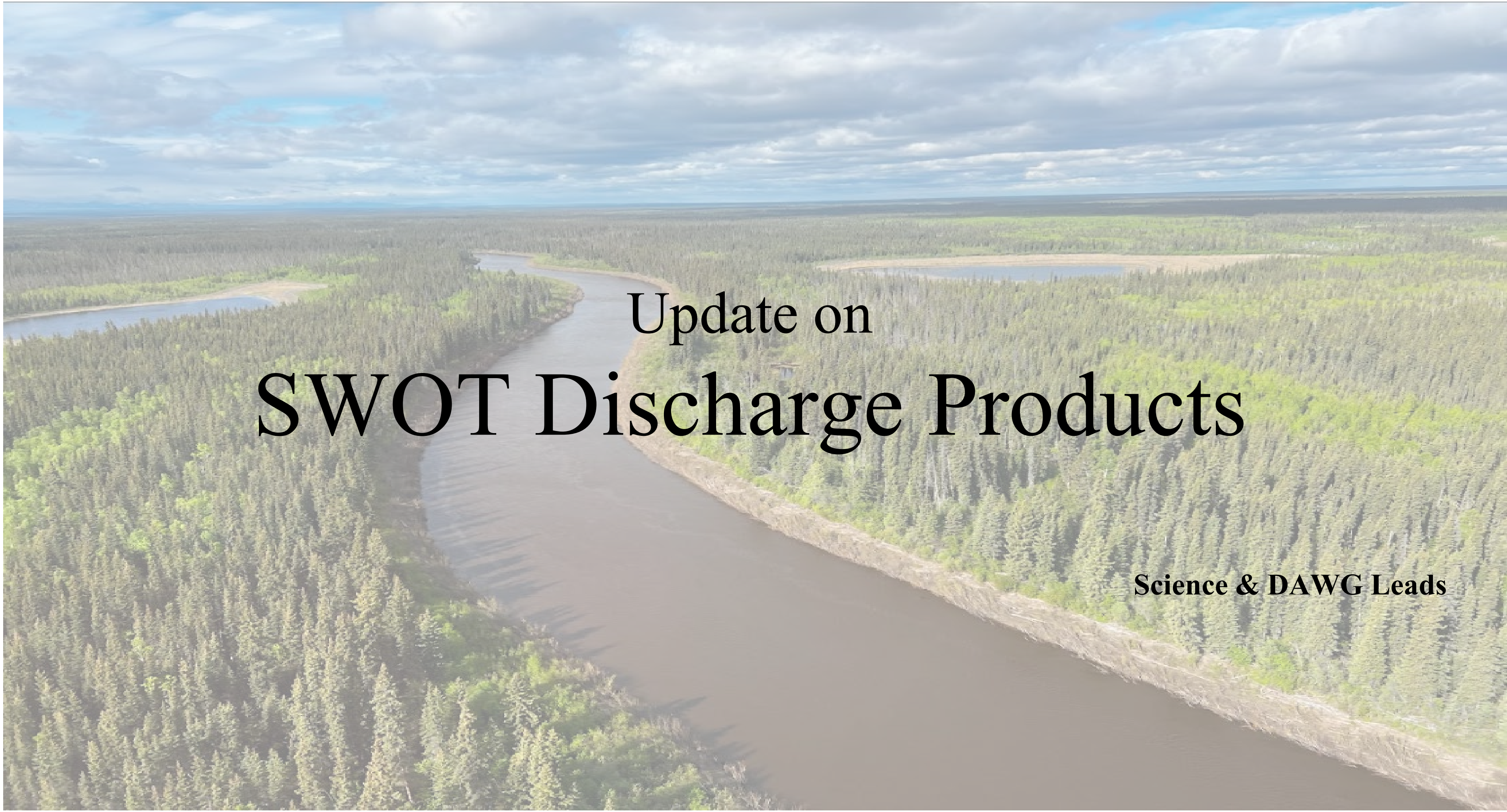

Update on
SWOT Discharge Products
Science & DAWG Leads

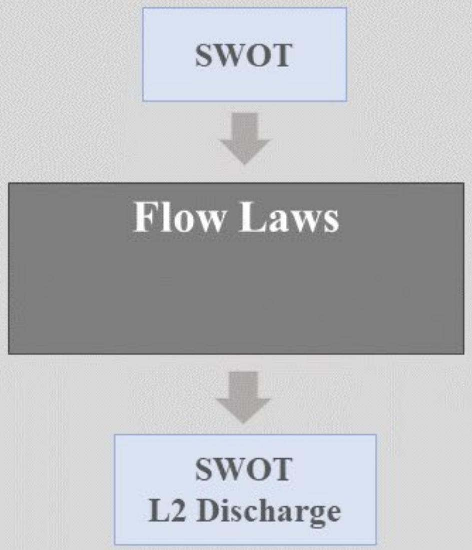
Presentation Overview

1. Plans for Release of SWOT Discharge Products
    a. Reminder of L2 vs. L4
    b. Timeline of product release
    c. Current L4 Results

1. Current status of Confluence
   (SWOT Discharge Processing Pipeline)

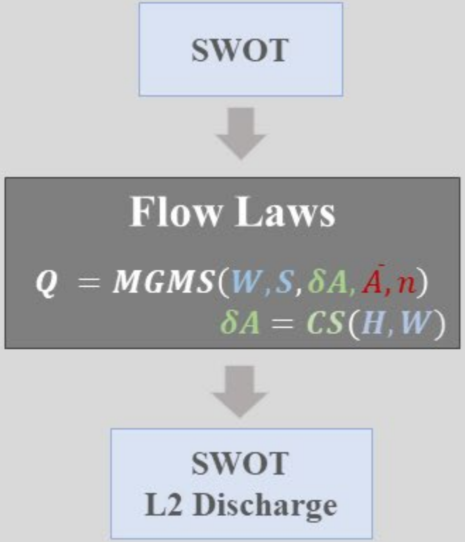
1. Overview of Current SWOT Discharge Accuracy

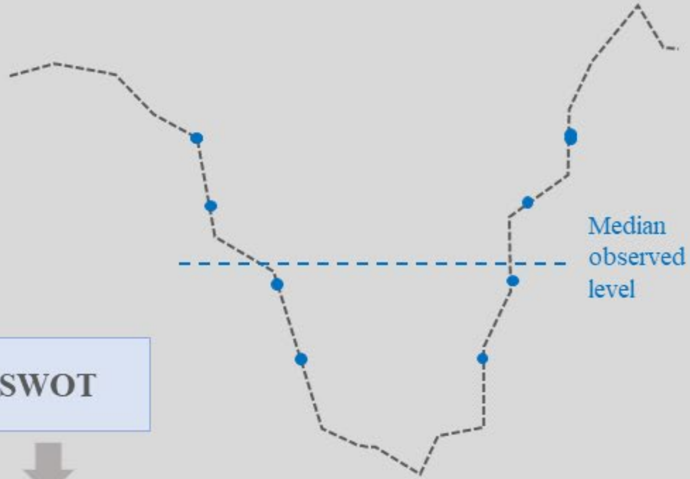
Reminder: L2 vs. L4 Discharge Products

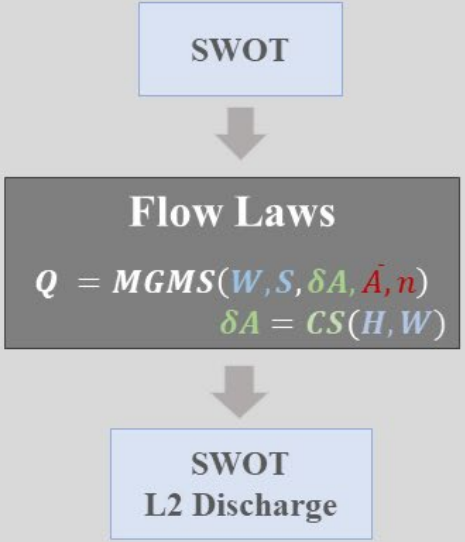


$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)







$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)

$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)

SWOT

↓

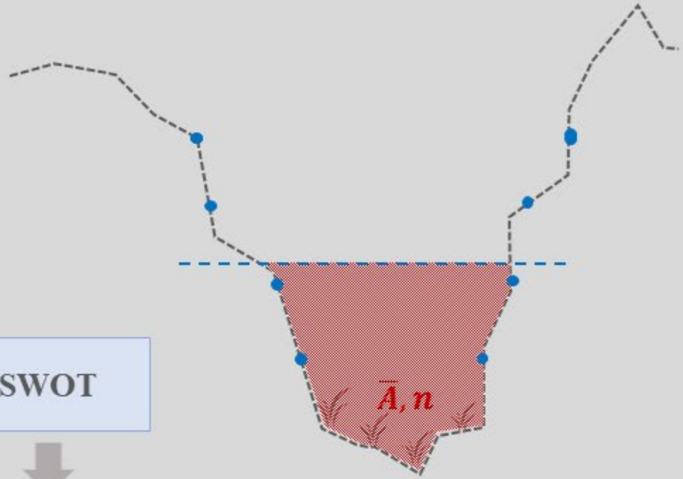
Flow Laws

$$Q = MGMS(W, S, \delta A, \bar{A}, n)$$

$$\delta A = CS(H, W)$$

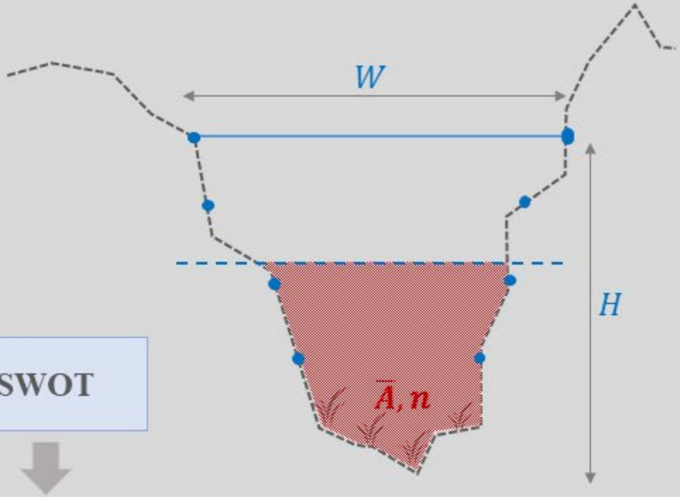
↓

SWOT
L2 Discharge



$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)



SWOT

↓

Flow Laws

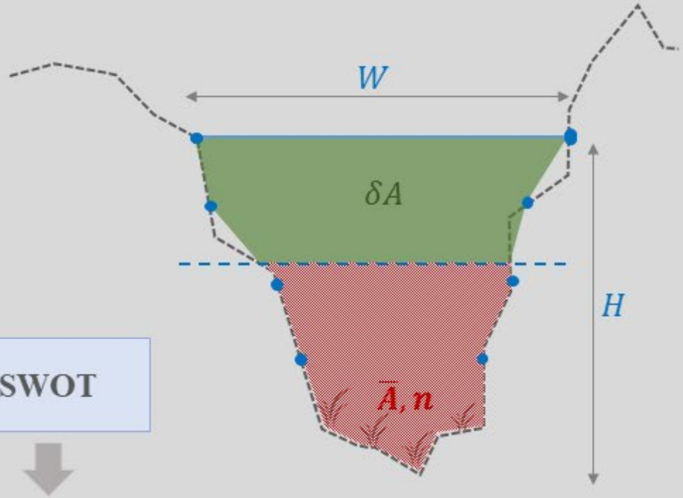
$$Q = MGMS(W, S, \delta A, \bar{A}, n)$$
$$\delta A = CS(H, W)$$

↓

SWOT
L2 Discharge

$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)



SWOT

↓

Flow Laws

$Q = MGMS(W, S, \delta A, \bar{A}, n)$

$\delta A = CS(H, W)$

↓

SWOT L2 Discharge

$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)

SWOT

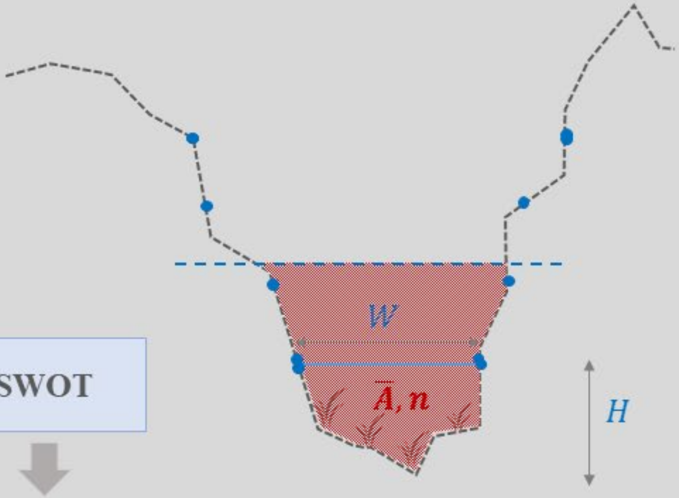
↓

Flow Laws

$$Q = MGMS(W, S, \delta A, \bar{A}, n)$$
$$\delta A = CS(H, W)$$

↓

SWOT
L2 Discharge



$$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$$

Flow Laws Parameters (FLPs)

SWOT

↓

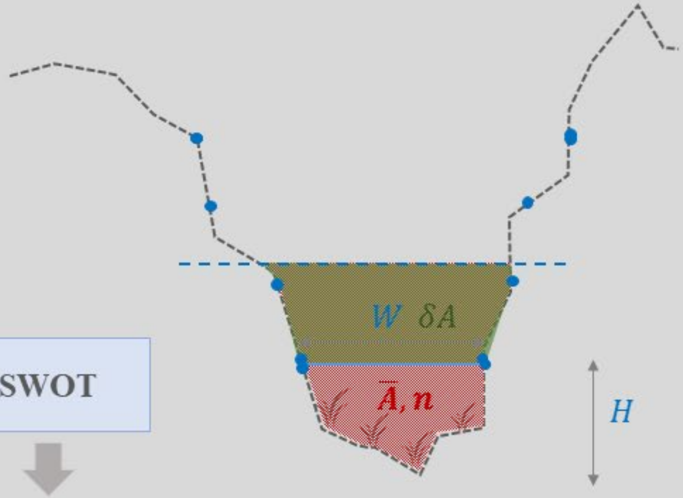
Flow Laws

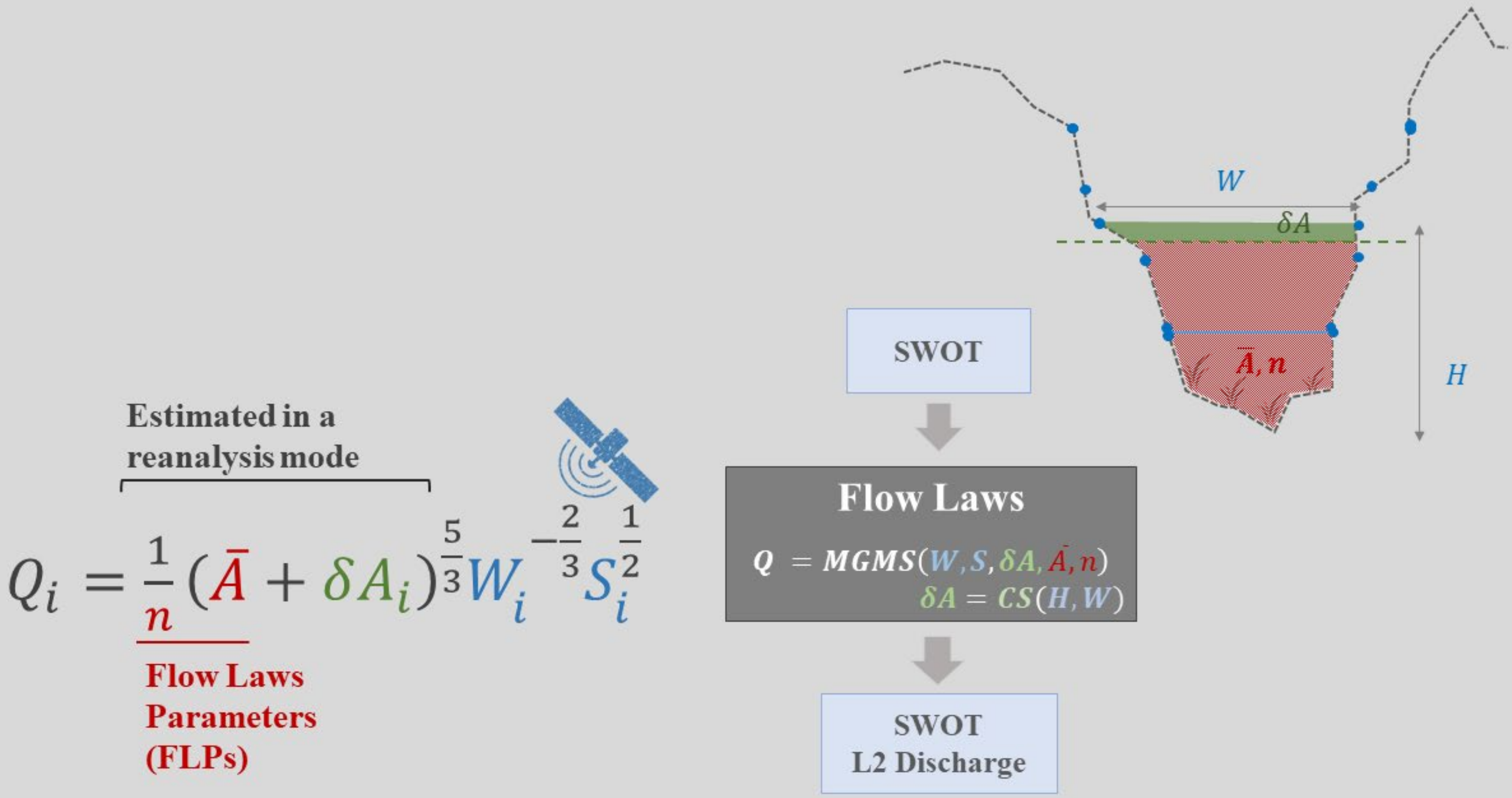
$Q = MGMS(W, S, \delta A, \bar{A}, n)$

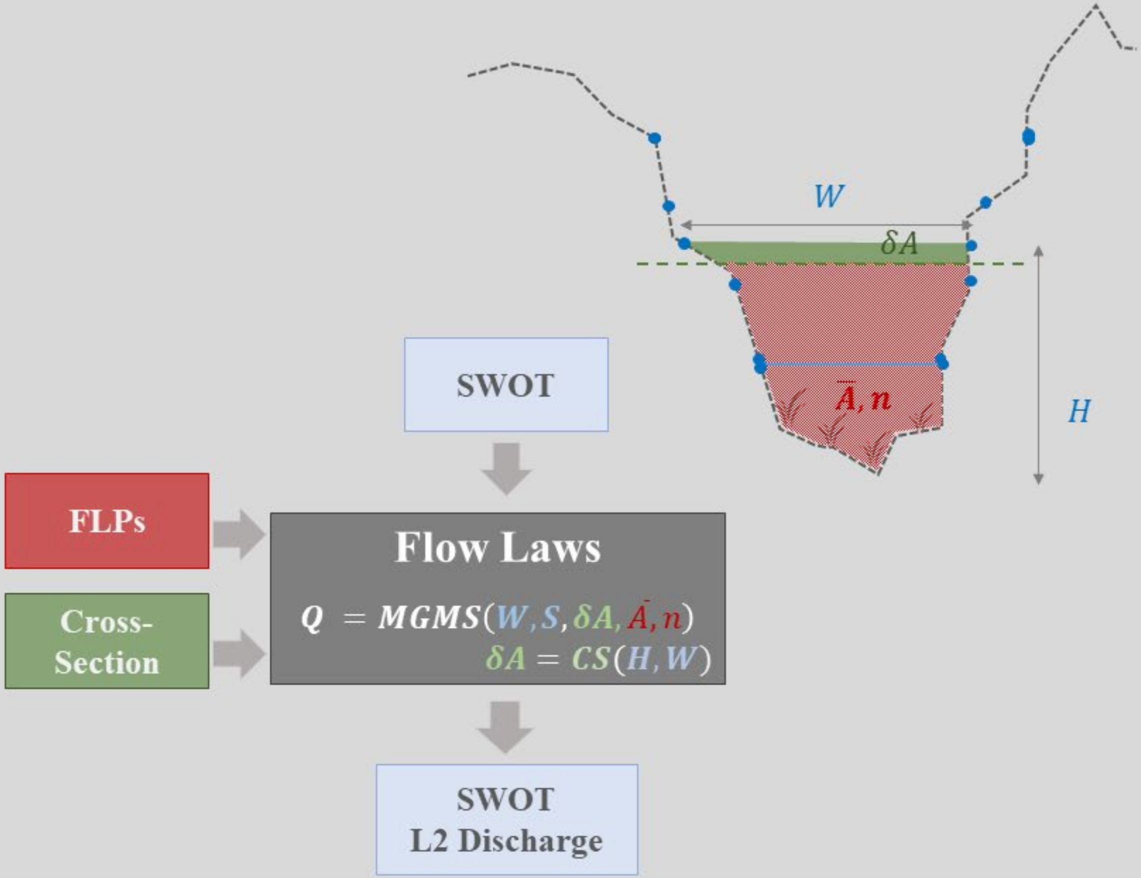
$\delta A = CS(H, W)$

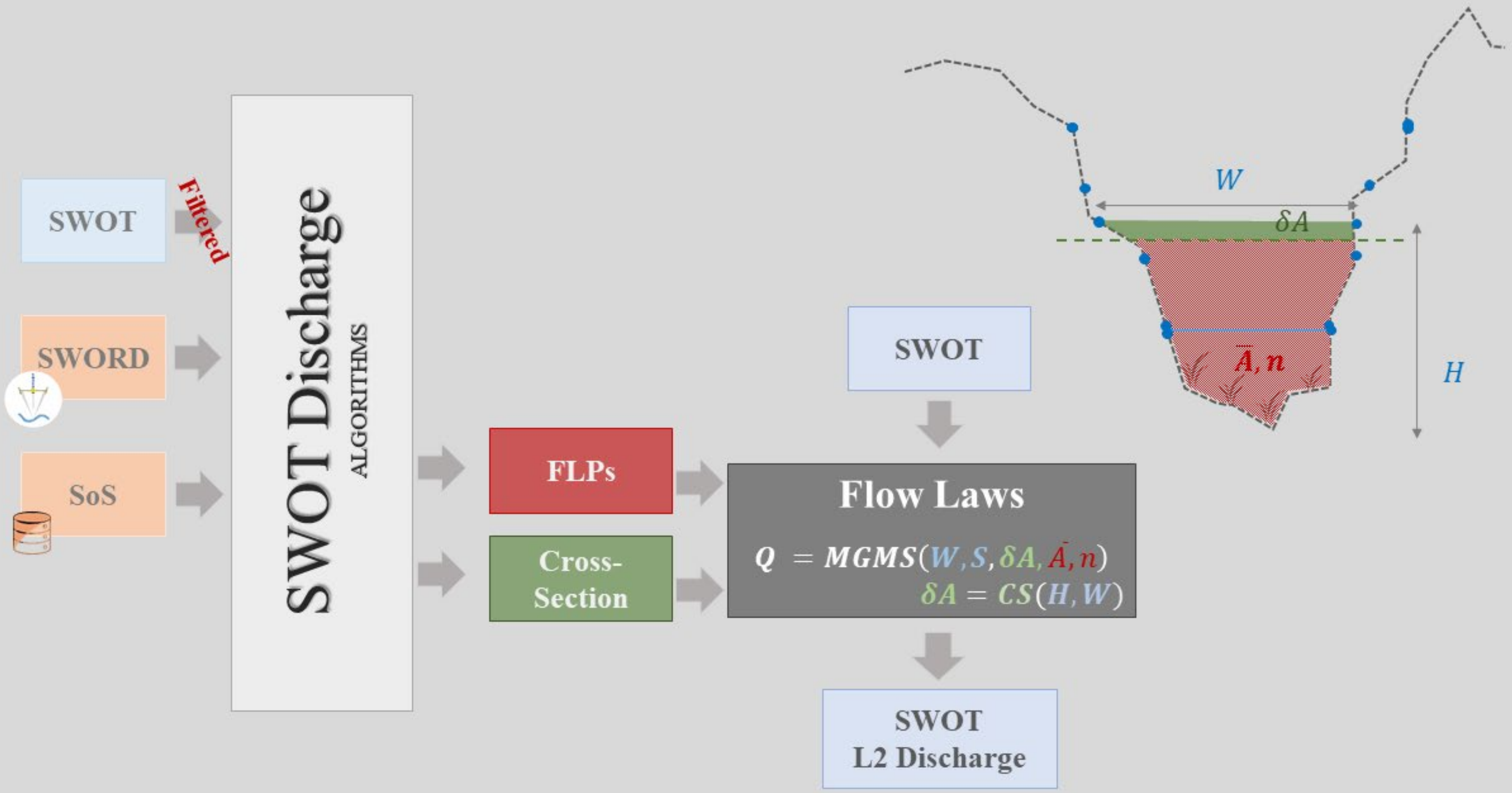
↓

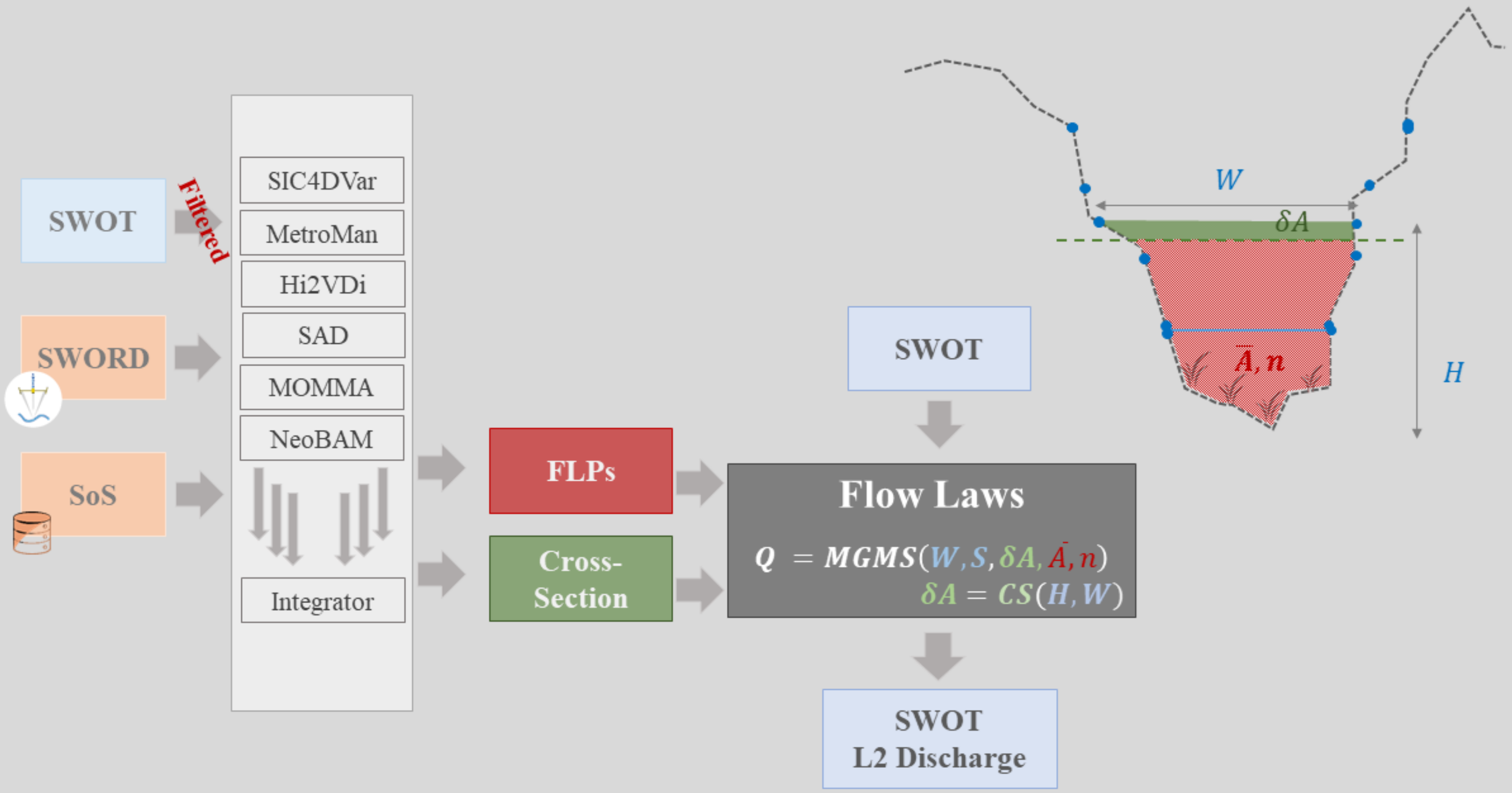
SWOT
L2 Discharge

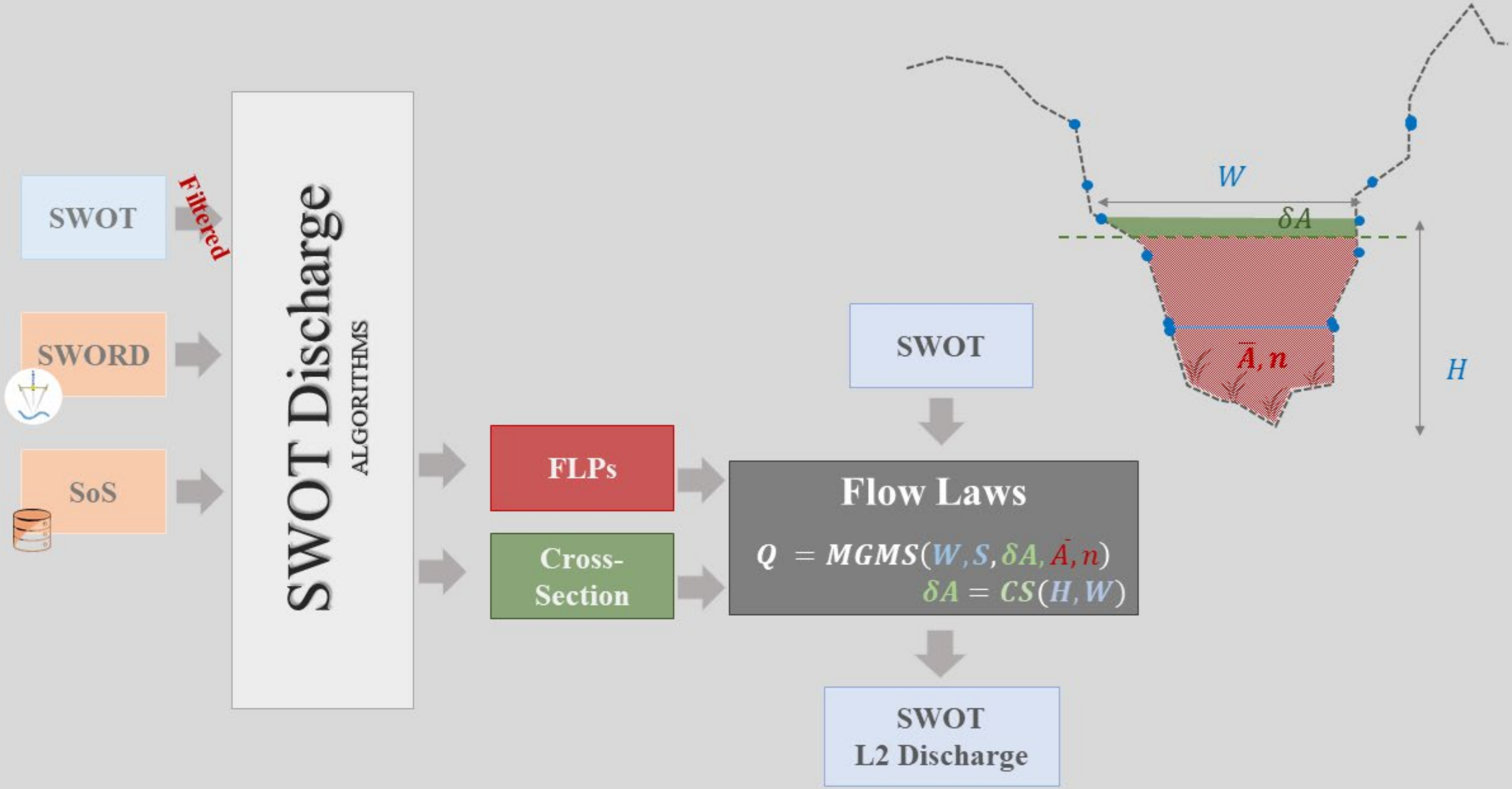



Estimated in a reanalysis mode
$Q_i = \frac{1}{n}(\bar{A} + \delta A_i)^{\frac{5}{3}} W_i^{-\frac{2}{3}} S_i^{\frac{1}{2}}$
Flow Laws Parameters (FLPs)
SWOT
Flow Laws
$Q = MGMS(W, S, \delta A, \bar{A}, n)$
$\delta A = CS(H, W)$
SWOT L2 Discharge
W
δA
$\bar{A}, n$
H

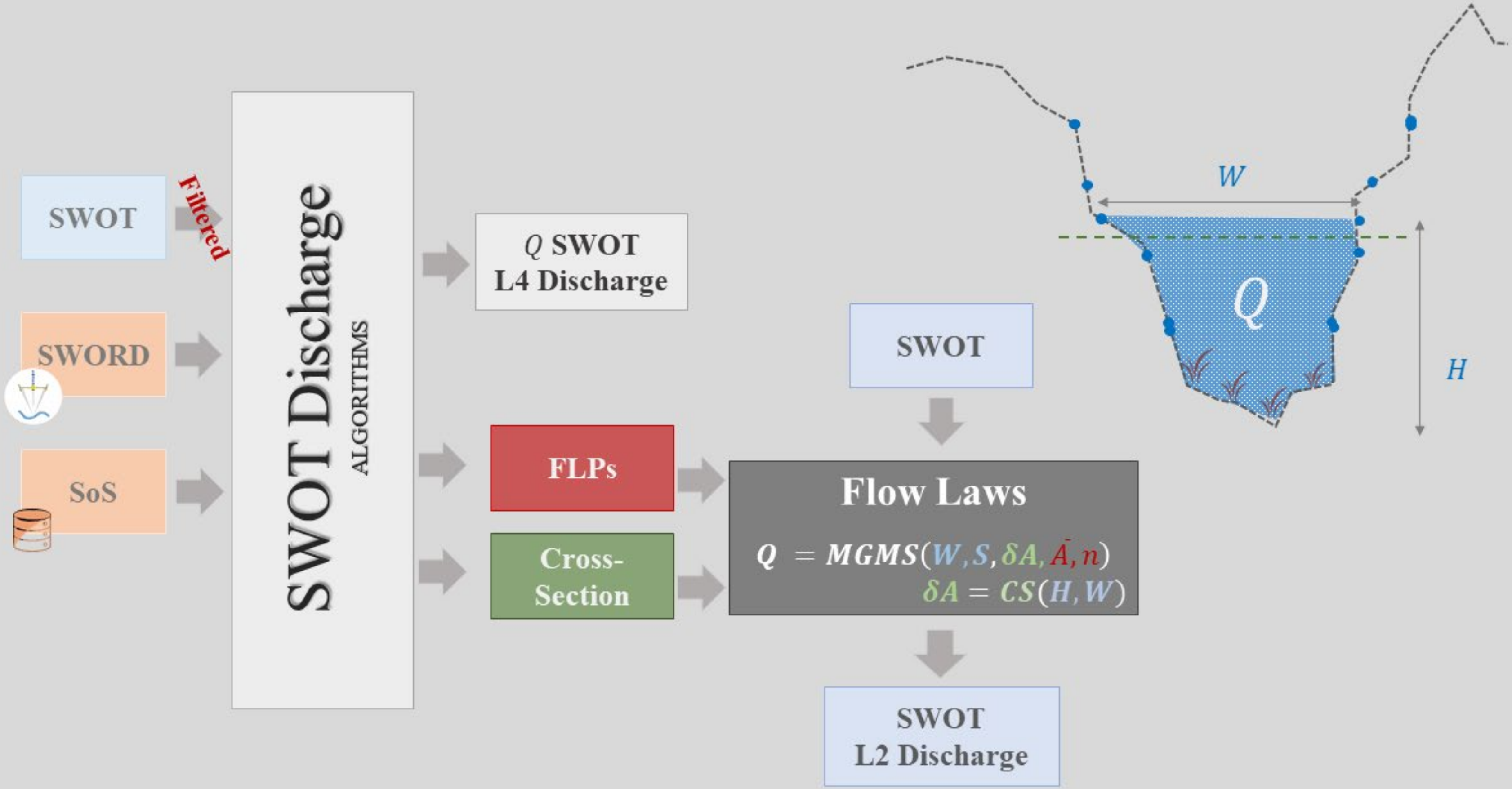

W
δA
Ā, n
H
SWOT
FLPs
Flow Laws
Q = MGMS(W, S, δA, Ā, n)
δA = CS(H, W)
Cross-Section
SWOT
L2 Discharge

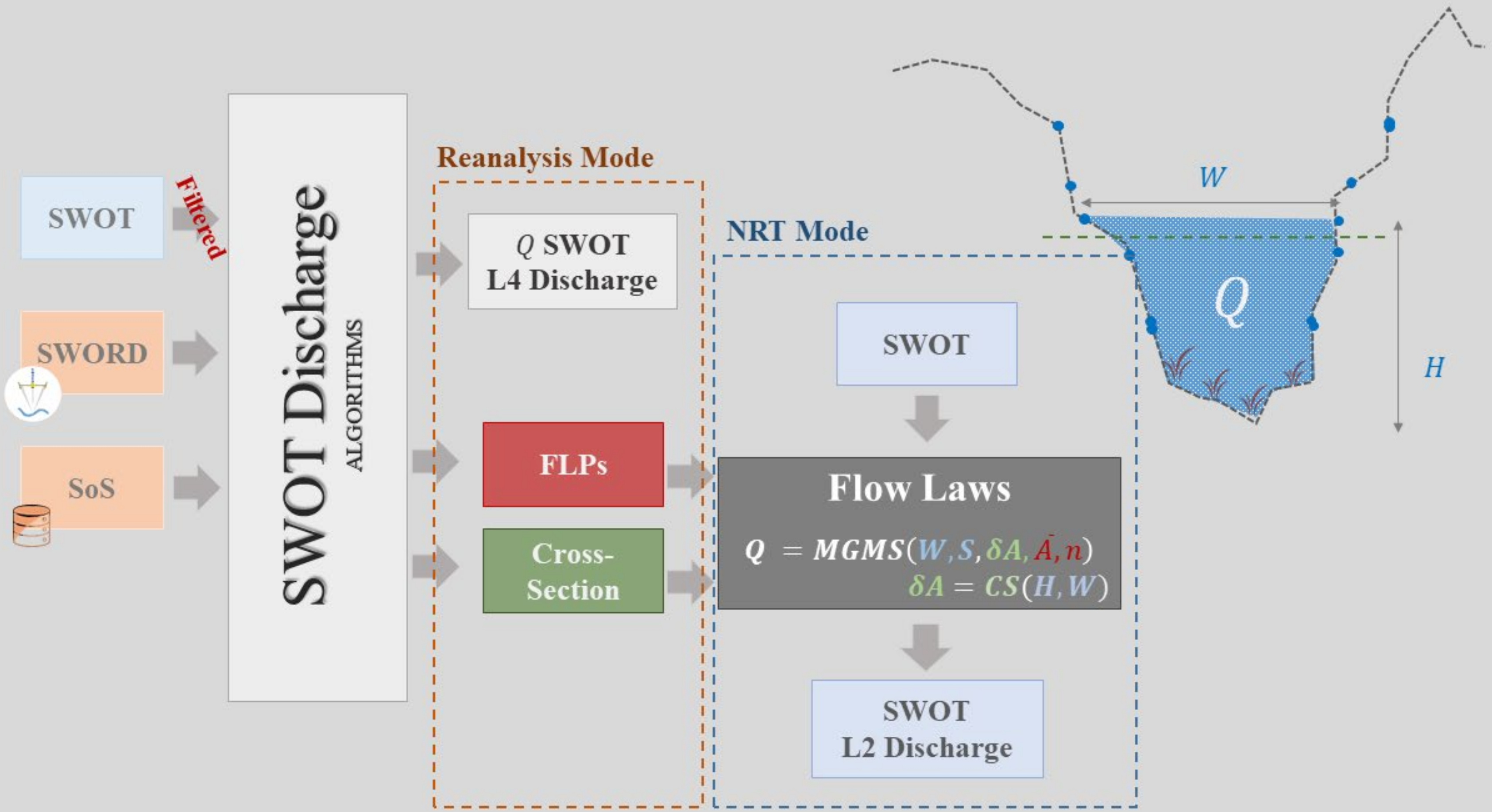

SWOT
Filtered
SWORD
SoS
SWOT Discharge
ALGORITHMS
FLPs
Cross-Section
SWOT
Flow Laws
$Q = MGMS(W, S, \delta A, \bar{A}, n)$
$\delta A = CS(H, W)$
SWOT
L2 Discharge
W
δA
$\bar{A}, n$
H


SWOT
Filtered
SWORD
SoS
SIC4DVar
MetroMan
Hi2VDi
SAD
MOMMA
NeoBAM
Integrator
FLPs
Cross-Section
SWOT
Flow Laws
$Q = MGMS(W, S, \delta A, \bar{A}, n)$
$\delta A = CS(H, W)$
SWOT L2 Discharge
W
δA
Ā, n
H

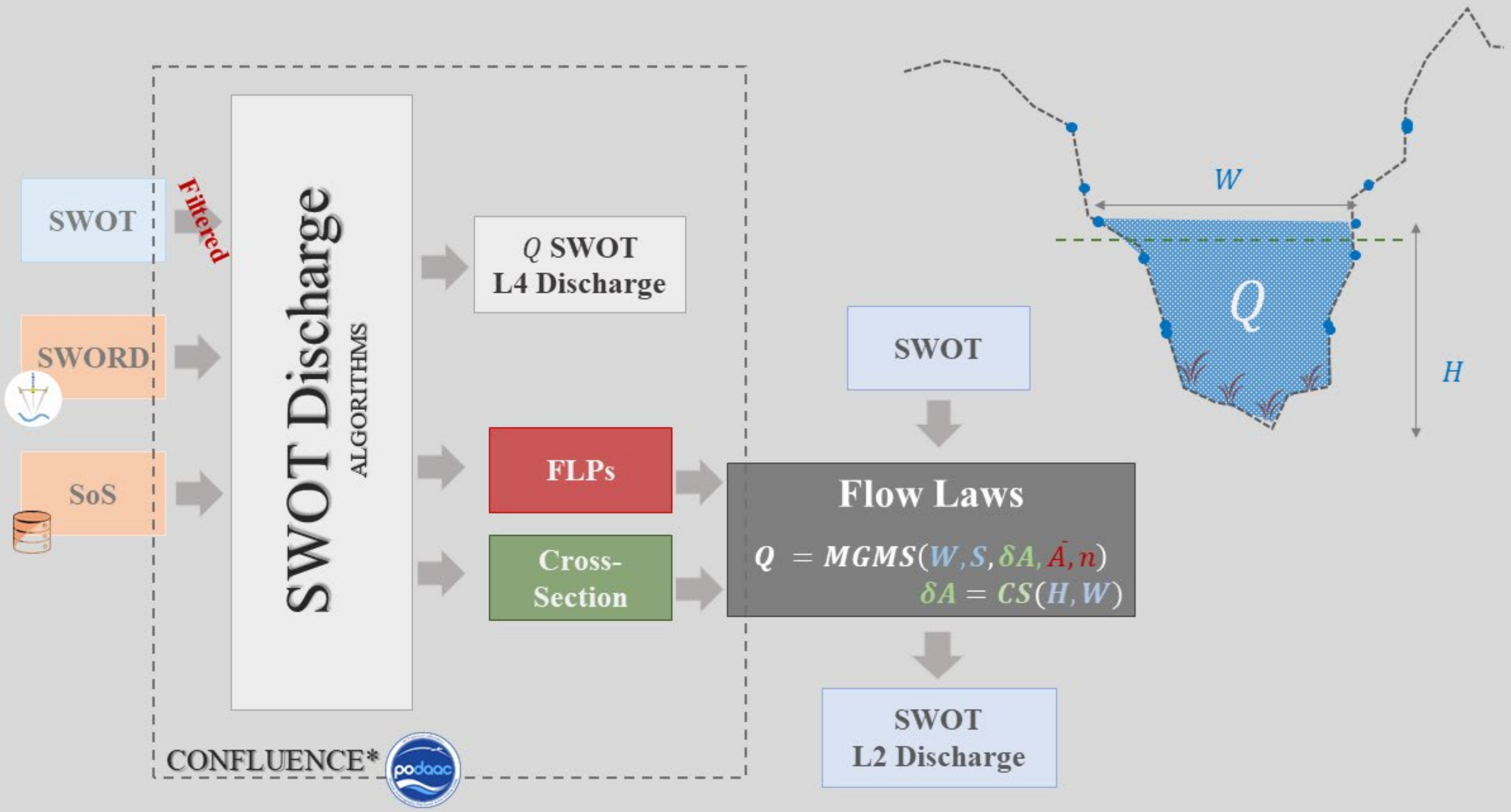


SWOT
Filtered
SWORD
SoS
SWOT Discharge
ALGORITHMS
FLPs
Cross-Section
SWOT
Flow Laws
$Q = MGMS(W, S, \delta A, \bar{A}, n)$
$\delta A = CS(H, W)$
SWOT
L2 Discharge
W
δA
$\bar{A}, n$
H


SWOT
Filtered
SWORD
SoS
SWOT Discharge
ALGORITHMS
Q SWOT
L4 Discharge
FLPs
Cross-Section
SWOT
Flow Laws
$Q = MGMS(W, S, \delta A, \bar{A}, n)$
$\delta A = CS(H, W)$
SWOT
L2 Discharge
W
Q
H



SWOT
Filtered
SWORD
SoS
SWOT Discharge
ALGORITHMS
Reanalysis Mode
Q SWOT
L4 Discharge
FLPs
Cross-
Section
NRT Mode
SWOT
Flow Laws
$Q = MGMS(W, S, \delta A, \bar{A}, n)$
$\delta A = CS(H, W)$
SWOT
L2 Discharge
W
Q
H



* Add a few more layers

Discharge Products L2/L4

Discharge Product	Level 4	Level 2
SWOT Data	WSE, width, slope	WSE, Width, Slope
Input Data Level	River SP Node/Reach	RiverSP Reach
Output Level	Reach	Reach
Filtering	ON	OFF
Coverage	Global	Global
Production	Reanalysis	Near Real Time
Output Format	SoS	RiverSP
Algorithms	Discharge Algos	Flow Laws
Status	Available Version C on Dec. 1st	To be Produced Version D

Plan for Discharge Product Availability

December 2022 :
SWOT Launch

Adapting Discharge
Algorithms and Confluence to
real SWOT data and errors

May 2024 :
Release of the full
reprocessed Version C

December 2024 :
First global Level 4
product
Unconstrained Run
Definition of Filtering
Configuration
« Permissive »

February 2025 :
DAWG Workshop Montpellier
Product Validation
Investigation of Filtering
Configurations

July 2025 :
Global Level 4 product
Constrained Run
Product Validation

October 2025 :
Definition of
Discharge Quality
Flags
Product Validation

Plan for Discharge Product Availability

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SWOT Launch

Adapting Discharge Algorithms and Confluence to real SWOT data and errors

May 2024 :
Release of the full reprocessed Version C

December 2024 :
First global Level 4 product
Unconstrained Run
Definition of Filtering Configuration
« Permissive »

February 2025 :
DAWG Workshop Montpellier
Product Validation
Investigation of Filtering Configurations

July 2025 :
Global Level 4 product
Constrained Run
Product Validation

October 2025 :
Definition of Discharge Quality Flags
Product Validation

December 1st, 2025 :
Release of the Global Level 4 product with quality flags
Version C, SWORD v16
Updated Release every month

Early 2026 (TBD):
Release of the full reprocessed Version D

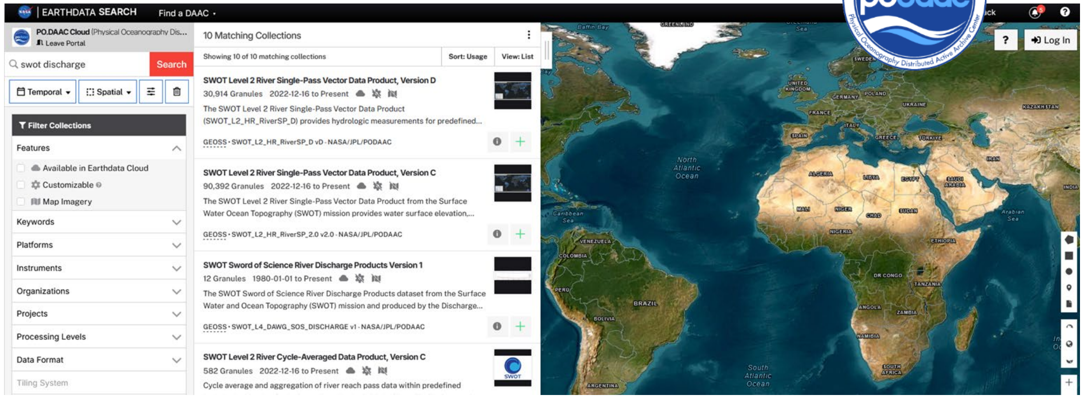
Spring 2026 (TDB):
Release of the Global **Level 2 and Level 4** products with quality flags
Version D, SWORD v17

How to Access Discharge Products

Level 2 Eventually

- River SP Reach Products

Level 4 Starting December 1st, 2025



Confluence (L4) production status

Funded by NASA ESTO AIST:

Colin Gleason, Subhransu Maji, Nikki Tebaldi,

Mike Gangl, John Gardner, Tamlin Pavelsky

Funded by SWOT ST 2020:

Colin Gleason,Travis Simmons, Nikki Tebaldi

With DAWG contributors:

Mike Durand, Steve Coss

SWOT ST Meeting

Arcachon, France, 2025

Goals of Confluence:

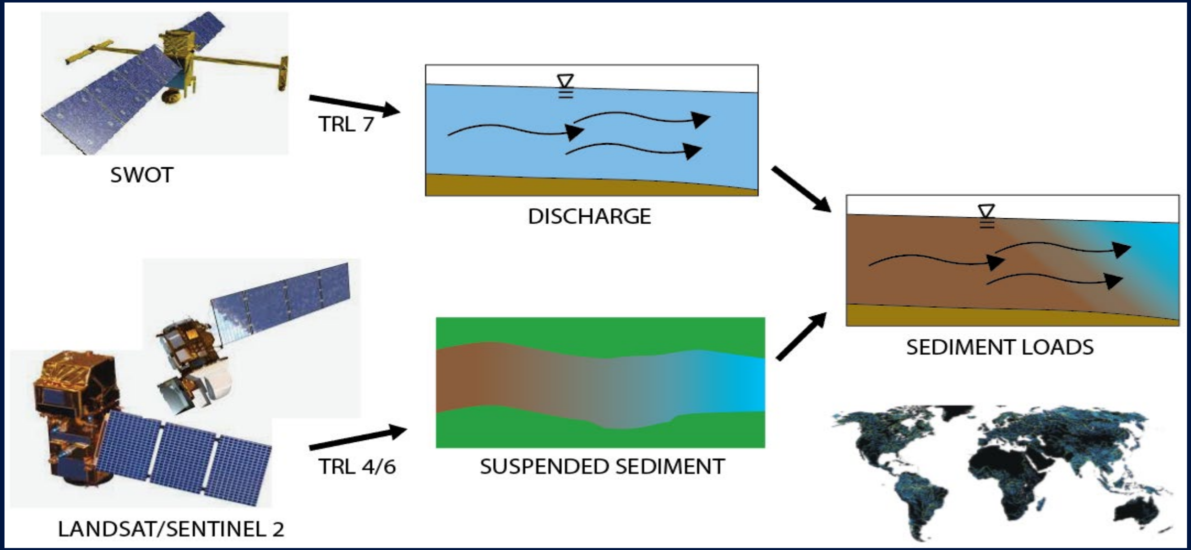
A software

Create L4 discharge and parameters for L2 discharge, as overseen by the DAWG (SWOT ST funding)

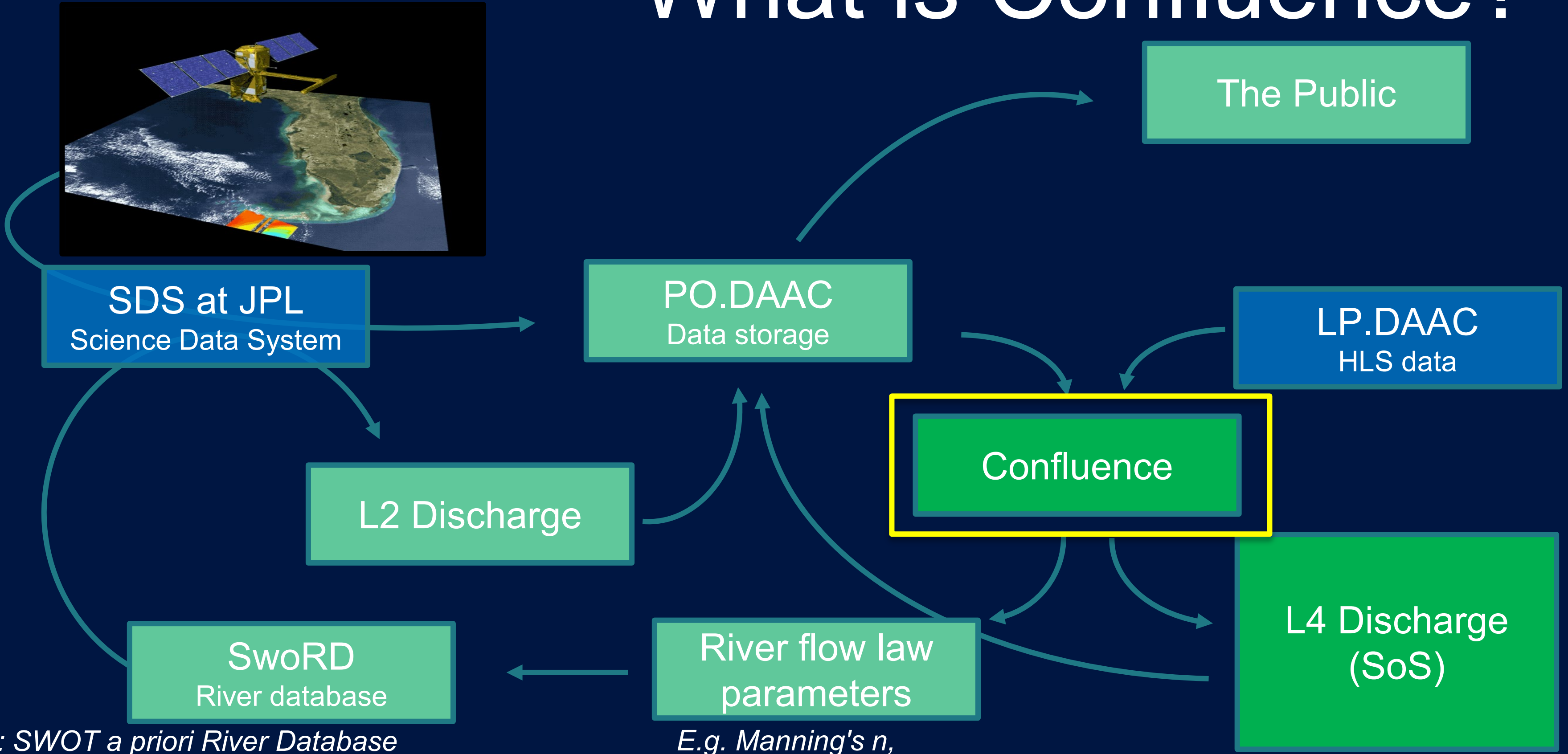
Co-estimate SSC from HLS (ESTO funding)

Fully cloud based

Transition to PO.DAAC (ESTO funding)



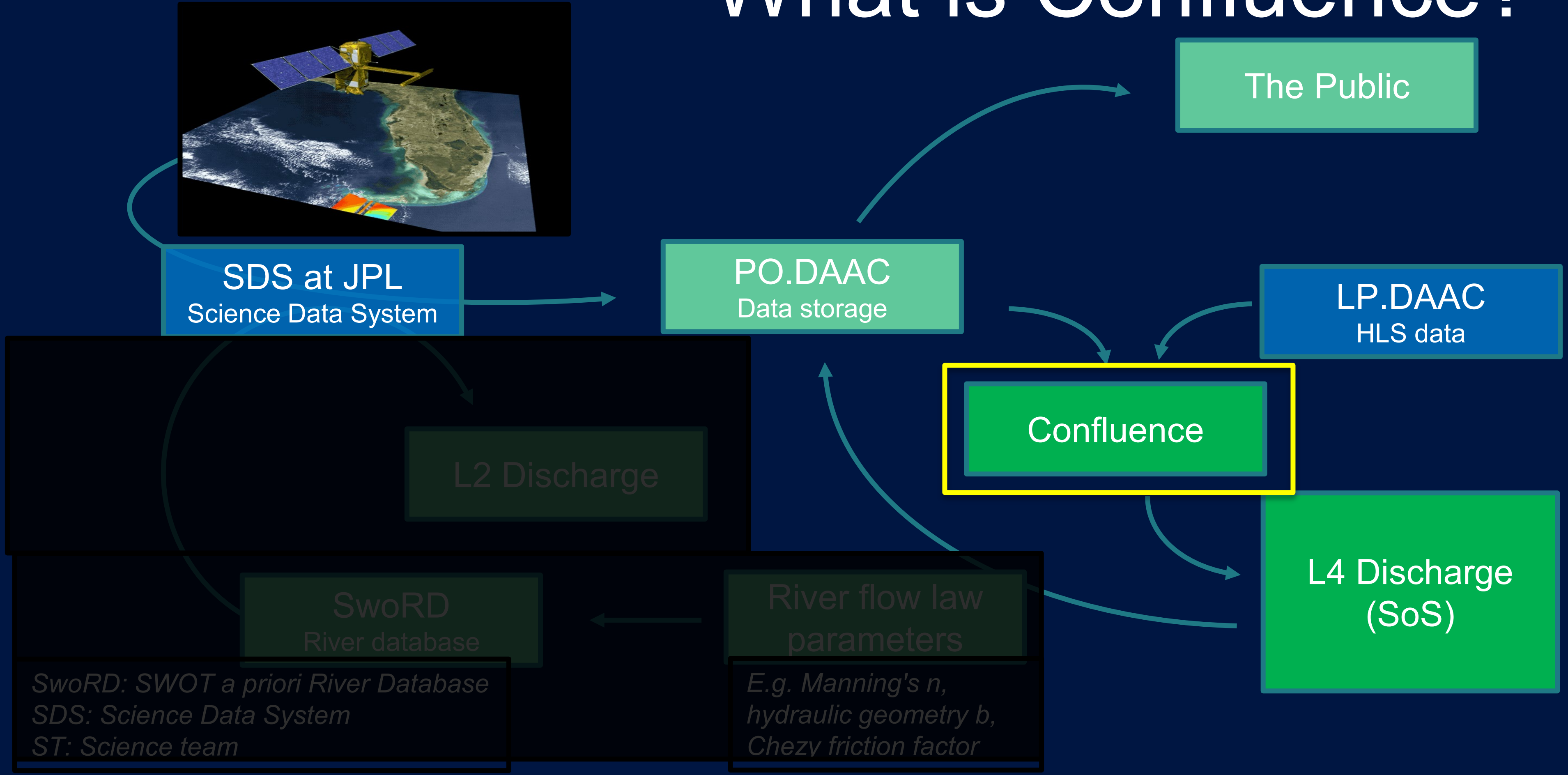
What is Confluence?



SwoRD: SWOT a priori River Database
SDS: Science Data System
ST: Science team

E.g. Manning's n,
hydraulic geometry b,
Chezy friction factor

What is Confluence?

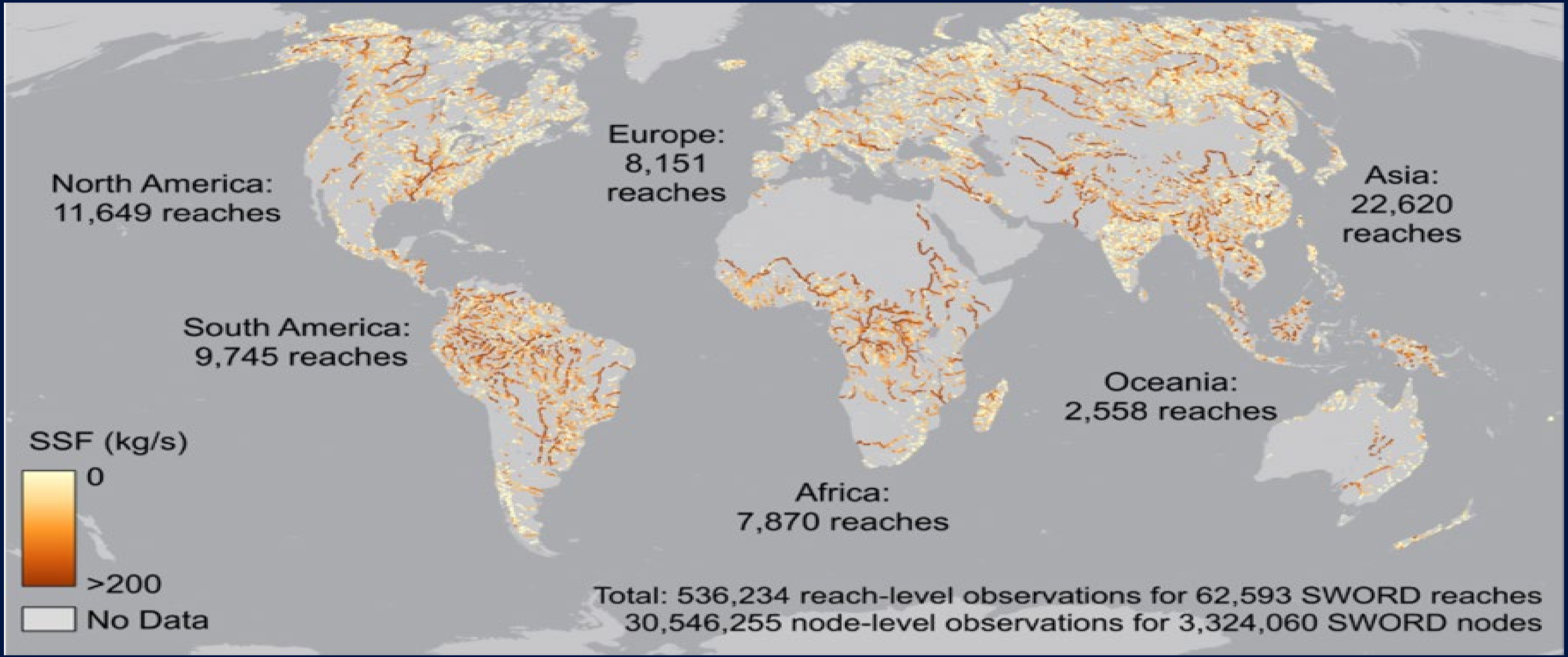


Everything is working, fully automated

Module	Maximum Execution Time	Minimum Execution Time	Average Execution Time	Total Execution Time	Cost	Number of Jobs	Number of Failures	Number CPUs Used	Memory Used (MB)
Init Workflow	00:10:42	00:10:42	00:10:42	00:10:42	$0.00	1	0	0.25	512
Setfinder	07:31:25	00:07:44	01:58:14	14:58:46	$1.16	12	0	1	2048
Combine Data	00:01:31	00:01:08	00:01:19	00:02:39	$0.00	2	0	1	2048
Input	01:11:33	00:01:14	00:18:01	05:22:36	$1,114.85	158,942	1,566	0.5	1024
Prediagnostics	00:22:12	00:01:15	00:08:06	02:23:02	$64.97	157,376	0	0.5	1024
Priors	21:12:48	00:38:23	05:42:38	21:12:50	$7.98	6	0	4	16384
MetroMan	00:51:26	00:01:12	00:07:17	01:04:51	$117.75	33,706	91	4	8192
Momma	01:00:39	00:01:22	00:08:06	02:45:25	$130.31	157,376	48	1	2048
geoBAM	12:00:43	00:01:35	00:10:34	13:43:46	$1,101.45	157,376	67	4	8192
Sad	00:26:22	00:02:10	00:08:21	02:26:52	$278.13	157,376	0	1	2048
Sic4Dvar	00:23:46	00:01:18	00:07:50	01:06:53	$63.63	72,437	0	1	2048
MetroMan Consolidation	01:11:59	00:17:14	00:40:33	01:12:01	$0.61	6	0	2	16384
Postdiagnostics FLPE	01:07:32	00:02:18	00:08:23	02:31:05	$230.97	157,376	0	0.5	1024
Moi	11:35:34	00:01:12	00:05:46	11:35:47	$4.36	880	0	1	2048
Postdiagnostics MOI	01:14:30	00:02:19	00:08:25	02:30:59	$235.09	157,376	0	0.5	1024
Offline	00:24:53	00:01:13	00:08:05	02:21:04	$129.79	157,376	1	1	2048
Validation	01:01:19	00:01:14	00:08:06	02:45:04	$130.04	157,376	49	1	2048
Output	21:52:07	02:02:59	07:43:42	21:52:08	$43.15	6	0	16	65536
			Totals	14:06:30	$3,654.24	1,525,006	1,822		

Everything is working, fully automated

Everything is working… including sediment!



Lucchese et al, in review

Everything is working… including sediment!

Operational status updates

Original plan: PO.DAAC runs confluence ~ 1x/mo under a data accession request: L4 discharges produced ~12x/year

Fact: Data accession request was denied

Consequence: There is no support to actually run the thing we've built

Solution: SWOT mission immediately stepped in. Run in the SDS instead of PO.DAAC environment. L4 discharges still produced ~12x/year

Operational status updates

Original plan: Nikki would support 2x/yr updates to the codebase from the community

Fact: Nikki is now at the University of Chicago with no scope to work on Confluence. Travis' contract is complete

Consequence: PO.DAAC can run Confluence, but no one in the DAWG has the skills / PO.DAAC has no budget to update it. We are at risk of Confluence ossifying.

Solution: UMass' local cluster (Unity) agreed to partner with us to provide this service.

Operational status updates

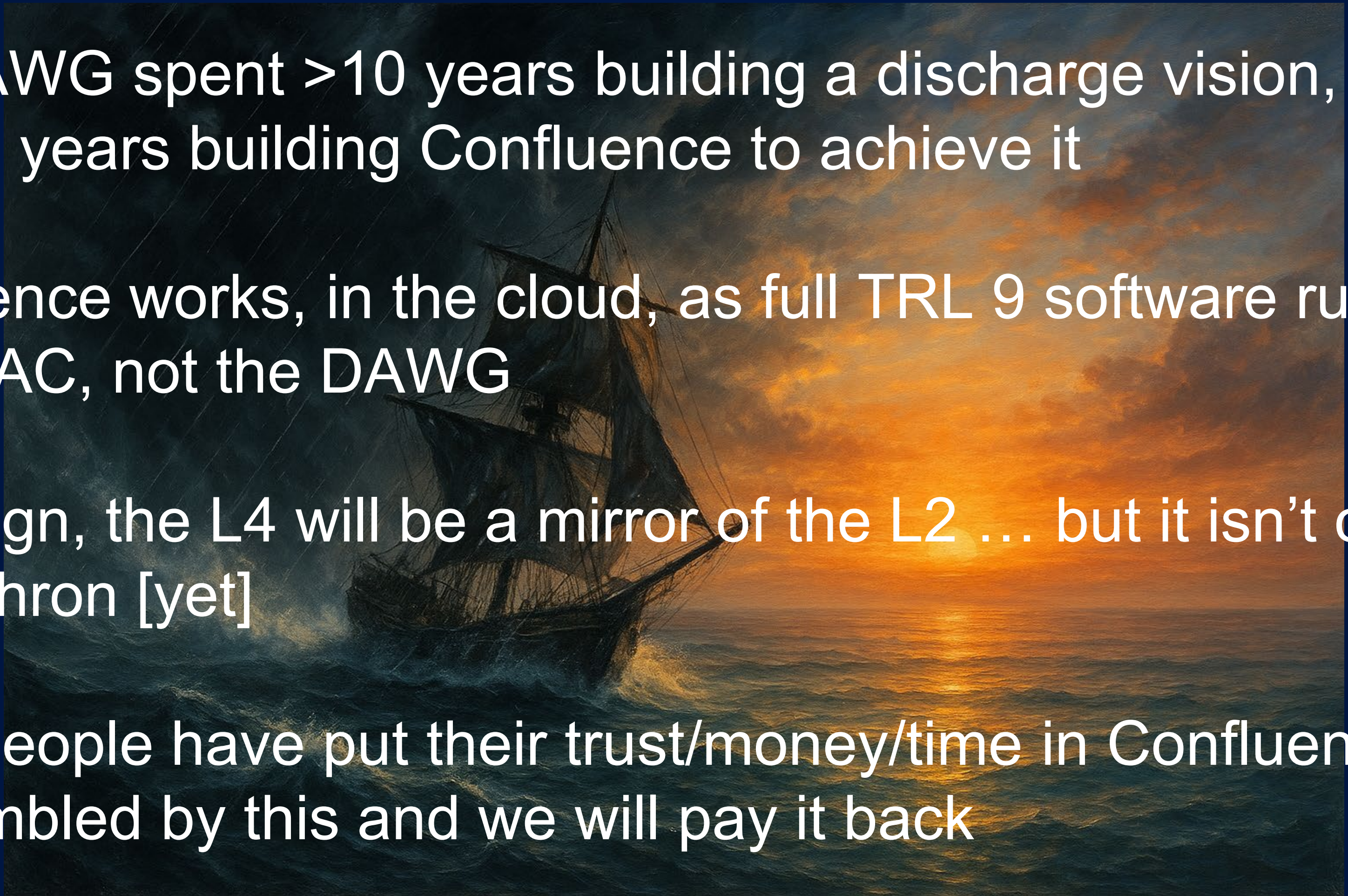
Original plan: Confluence runs 1x/mo and we provide parameters to the SDS to generate the L2 NRT discharge product 1x/yr.

Fact: Confluence's L4 output will become public before the L2

Consequence: This week, the DAWG will finalize the details of priors, flags, and production runs

Solution: We will provide a L4 discharge product (together with sediment!) on December 1.

Conclusions

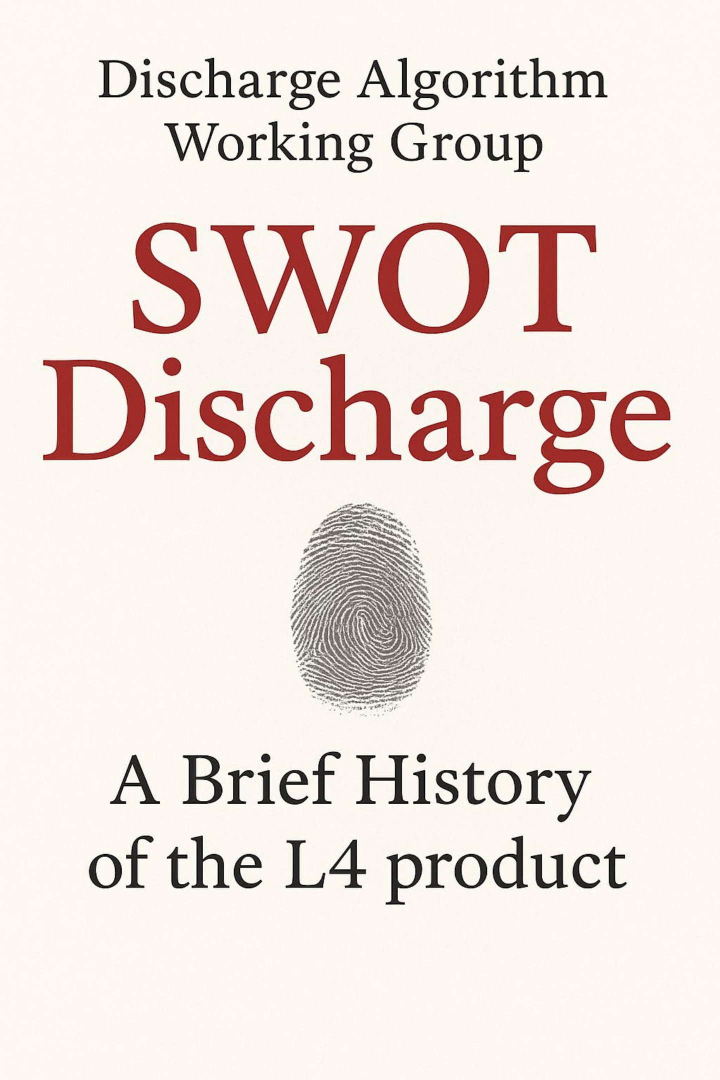


The DAWG spent >10 years building a discharge vision, we spent 5 years building Confluence to achieve it

Confluence works, in the cloud, as full TRL 9 software run by PO.DAAC, not the DAWG

By design, the L4 will be a mirror of the L2 … but it isn’t on Hydrochron [yet]

Many people have put their trust/money/time in Confluence: we are humbled by this and we will pay it back



Once upon a time …
After crafting our own tools …
And getting data from space
…
a new journey could start!

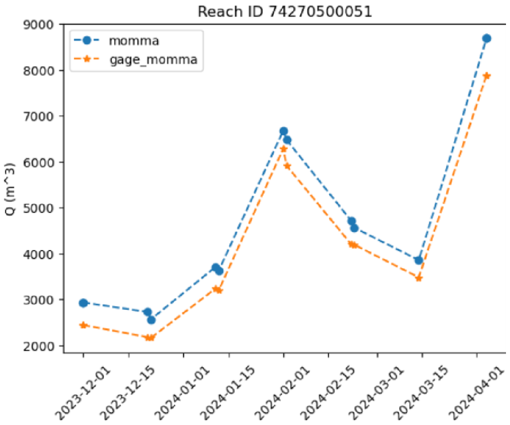
Evolutions of the L4 Q(t) product runs and performance analysis since the ST 2024

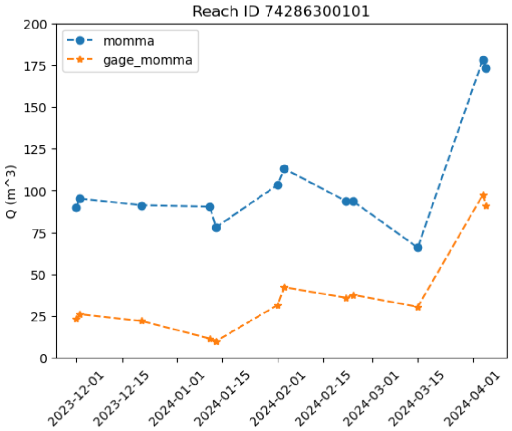
- **ST 2024 at Chapel Hill (First run)**
- **Kostas et al paper (First paper, December 2024 - March 2025)**
- *Montpellier DAWG Workshop (February 2025)*
- **ST 2025 at Arcachon (cf. Poster Steve Coss et al)**

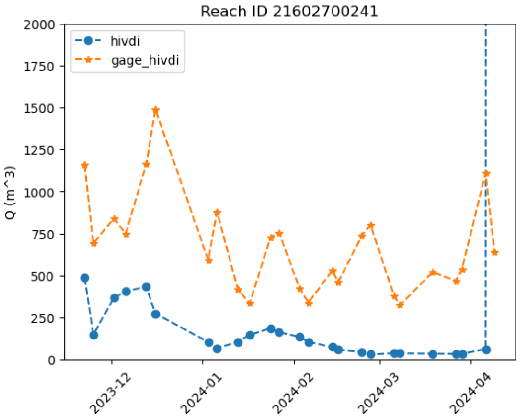
<u>Other very interesting runs and analysis (Workshop Bordeaux on Monday), but not presented here:</u>

  - Filtering strategies (pre-processing, June 2025 (Slides Cécile Cazals et al))
  - Filtering strategies (post-processing, October 2025 (Slides Ellie Friedmann et al))
  - ML LSTM for a new prior (Slides Heejin An et al)
  - Validation over GRDC gages (cf. MJ Tourian, Peyman Saemian et al)

ST Chapel Hill, June 2024
The good, the bad, the ugly!





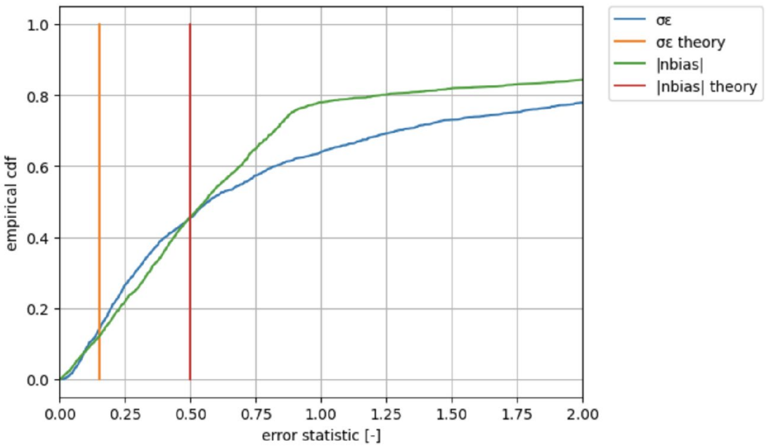


<u>The good:</u>
R^2=0.99
NSE=0.93
KGE=0.87
RMSE=531.01
nRMSE=0.12
nBIAS =0.12
n=13

<u>The bad:</u>
R^2=0.88
NSE=-5.53
KGE=-0.77
RMSE=68.37
nRMSE=1.78
nBIAS =1.75
n=12

<u>The ugly:</u>
R^2=0.0006
NSE=-3824.33
KGE=-59.08
RMSE=18142.90
nRMSE=26.56
nBIAS =4.56
n=25

CDF over the set (Consensus)



- σε tracks error in dynamics (standard deviation of the unnormalized discharge error, divided by the mean flow)
- |nbias| (gage mean normalized)
- Both error in dynamics and bias are exceeding expectations (parenthetical):
  - 68%tile of σε at 100% (15%)
  - 68%tile nBIAS at 75% (50%)

Lessons from this (First run)

- We successfully ran on large dataset (1500 reaches)
- Results are below expectations
- Widths are a major source of error
- Difficult to understand why and where good, bad or ugly (no obvious spatial patterns, nor correlation with width, slope, channels)
- We must understand this!
- We must find good filters and preprocessing. Strict (Cassie's) filter is too strict!

Kostas et al paper, 2025

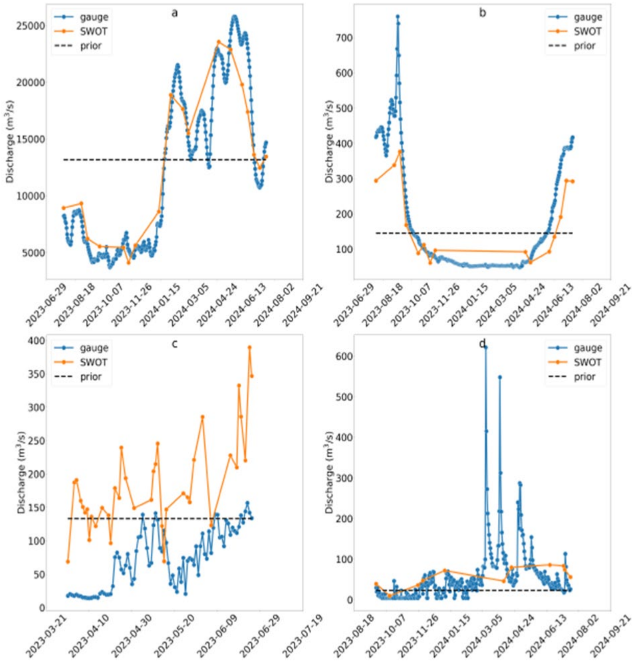


Figure (a): *Mississippi River near Baton Rouge*. SWOT accurately captures both river discharge dynamics and magnitude (**r=0.965**, normalized bias **nBias=1.9%**)

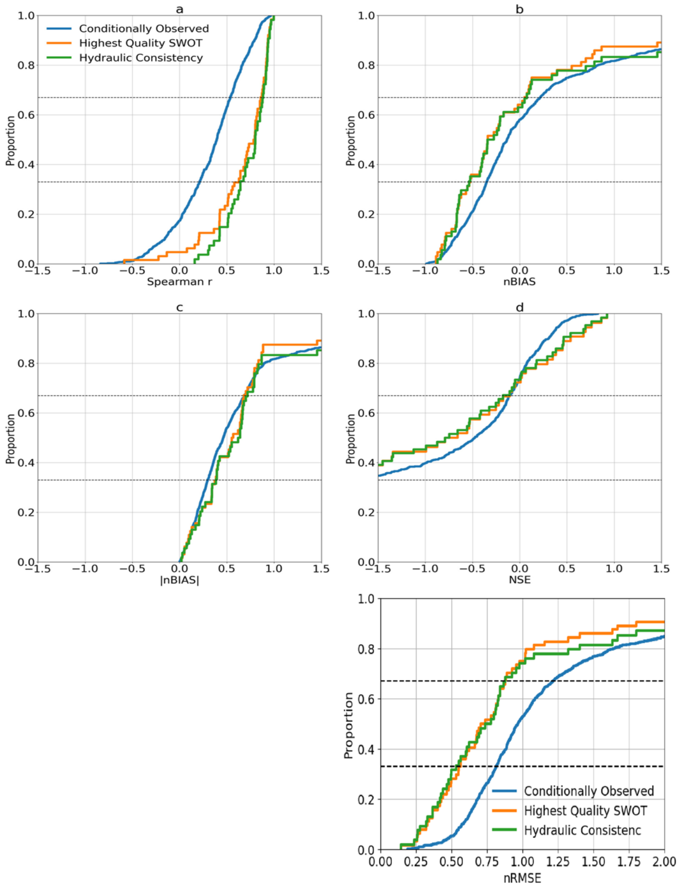
Figure (b): *Kenai River near Sodotna*. SWOT resolves discharge variations (**r=0.97**), but with a bias of **nBias=27%**. Pre-launch studies found that bias is most often due to bias in the prior, which was -41% for this reach

Figure (c): *Le Drac River near Grenoble*. SWOT captures discharge variations (**r=0.65**) but SWOT estimates are much larger (**nBias=162%**) than the gauge.

Figure (d): *Loire River near Saint-Victor sur Loire*. SWOT discharge does not meaningfully track the gauge (**r=0.2**), and bias is substantial (**nBias=87%**)

Andreadis, K. M., Coss, S. P., Durand, M., Gleason, C. J., Simmons, T. T., Tebaldi, N., et al. (2025). A First look at river discharge estimation from SWOT satellite observations. *Geophysical Research Letters*, *52*, e2024GL114185. https://doi.org/10.1029/2024GL114185

Andreadis et al paper



(a) the "Conditionally Observed reaches" (n=827)
(b) the "Highest Quality SWOT data" = completely observed reaches (n=65)
(c) the "Hydraulic Consistency" & "Highest Quality SWOT data" (n=54)

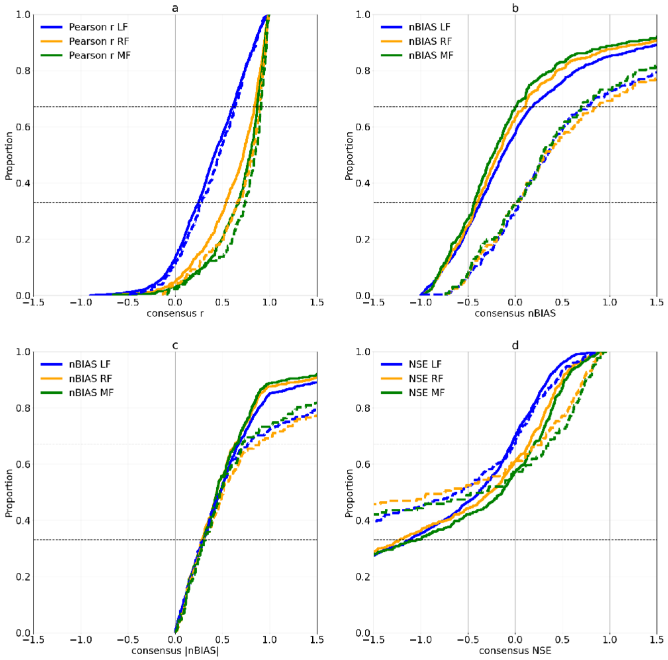
Spearman correlation (median): 0.39 for the Conditionally Observed reaches, approximately half the value of Completely Observed reaches (0.73) or hydraulic consistency reaches (0.8)
Absolute value of the bias (median): 56% for the Completely Observed reaches, which is larger than predicted in pre-launch studies (but prior bias in this study is also large: 62%)
Median bias is reduced from 0.72 to 0.64, and 0.34 for river widths less than 100 m, between 100 and 200 m, and above 200 m, respectively, for the hydraulically consistent reaches => **bias is reduced a lot for large Rivers**

Andreadis, K. M., Coss, S. P., Durand, M., Gleason, C. J., Simmons, T. T., Tebaldi, N., et al. (2025). A First look at river discharge estimation from SWOT satellite observations. *Geophysical Research Letters*, *52*, e2024GL114185. https://doi.org/10.1029/2024GL114185

Lessons from this (Kostas paper)

- At 65 gauged reaches shows results consistent with pre-launch expectations
- SWOT estimates track discharge dynamics without relying on any gauge information: median correlation is 0.73 (for Completely Observed Reaches), with a correlation interquartile range of 0.51–0.89.
- SWOT estimates capture discharge magnitude correctly in some cases but are biased (median bias is 50%) in others
- There are already a total of 11274 ungauged global locations with highest quality SWOT measurements (& 115 gauged) (24/10/2024)

Status October 2025 (cf Poster Steve Coss)

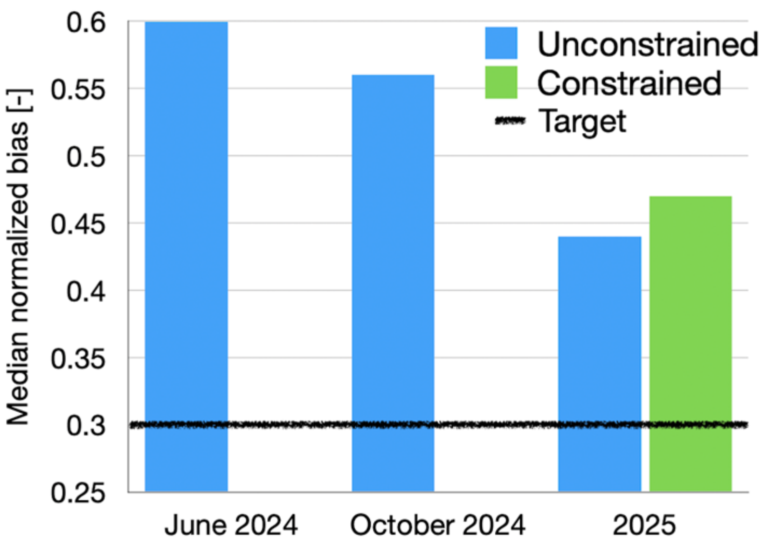


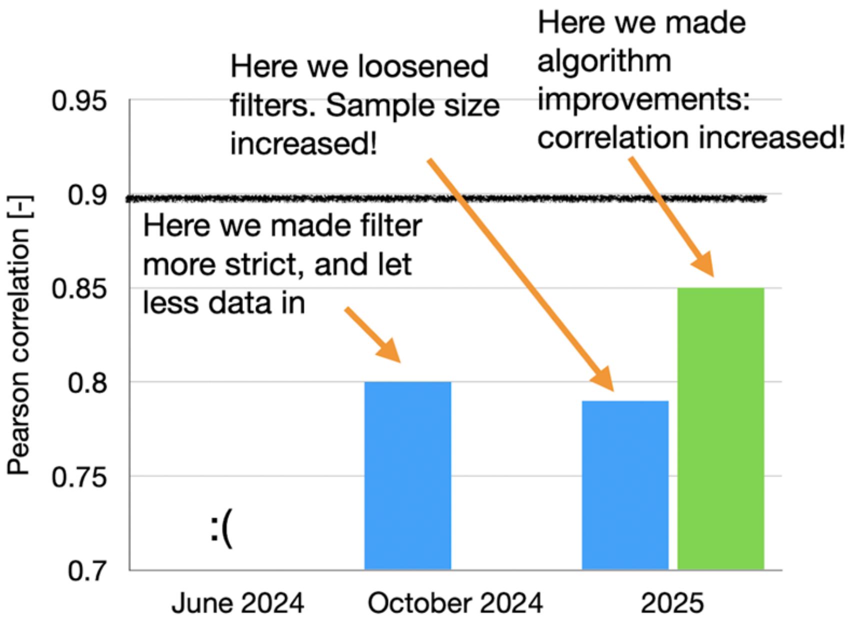
Discharge Accuracy has improved substantially since Kostas et, al. 2025

- LeastF/ReachF/MostF are identical to the categories in the Kostas paper
- Discharge is WAY better than what we showed in that paper
- Bias in both run types appears to be a direct product of the prior
- Median r shifted up in the LeastF (0.39 to 0.42), and MostF groups (0.8 to 0.84), and lowered slightly in the ReachF group (0.73 to 0.72)
- Absolute normalized bias is significantly reduced. While the RF data had ~56% median |nBIAS| in the previous run, it's been reduced to 44%.
- Some typological drivers have significant impacts on the performance (urban landcover and steep topography)

Cf Poster « Typological Drivers of SWOT discharge Accuracy" from Steve Coss & Mike Durand

Summary of the metrics over time ...





Conclusion

- A lot of runs, improvements, tests and analysis have been made during the last 15 months
- Confluence Offline version is very useful to make these tests
- Knowledge about the triggers of the performance is increasing
- Filtering aspects have also given very interesting results, increasing the number of reaches where we get results, still providing good performance indicators (“the relaxed permissive filter”)
- On going works are promising (new priors, post-filters, validation over other datasets, etc.)
- We test a new combo of filters and priors that will provide the L4 Q(t) product by December 2025 with better results than what we showed here

Thanks! Question?

DAWG Workshop, Bordeaux, Monday Octobre 13th, 2025