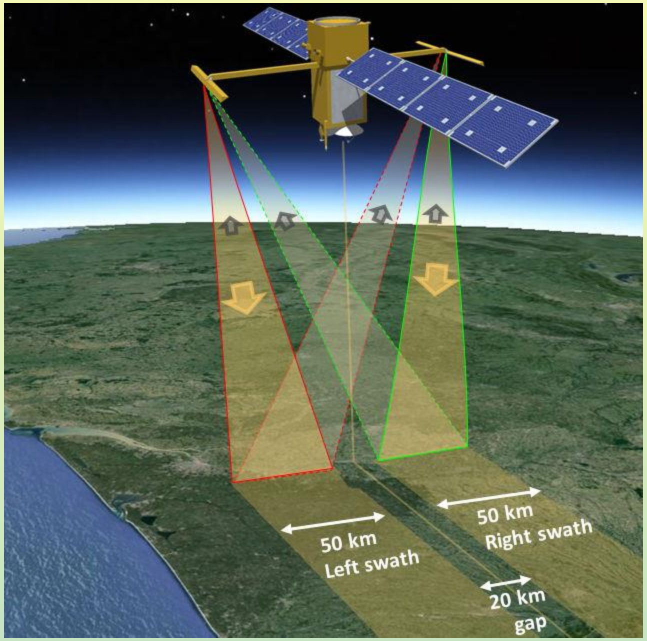
“Current status and future plans of non-DA discharge estimation”

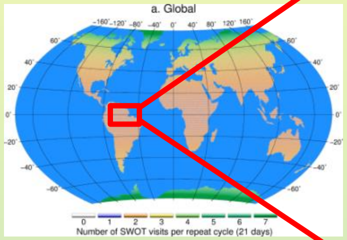
by

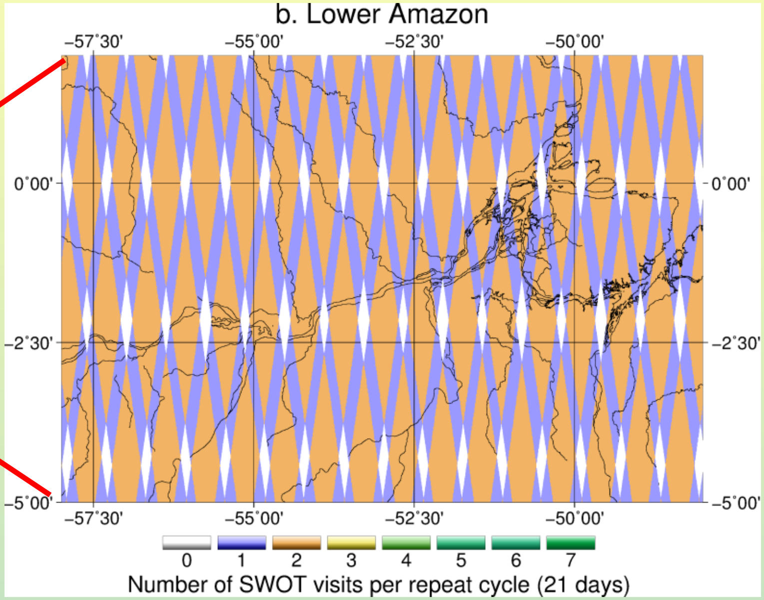
Bjerklie, D., Durand, M., Garambois, P.-A., Gleason, C., Monnier, J., Roux, H

June 15, 2016 – Hydrology splinter session - 11:10

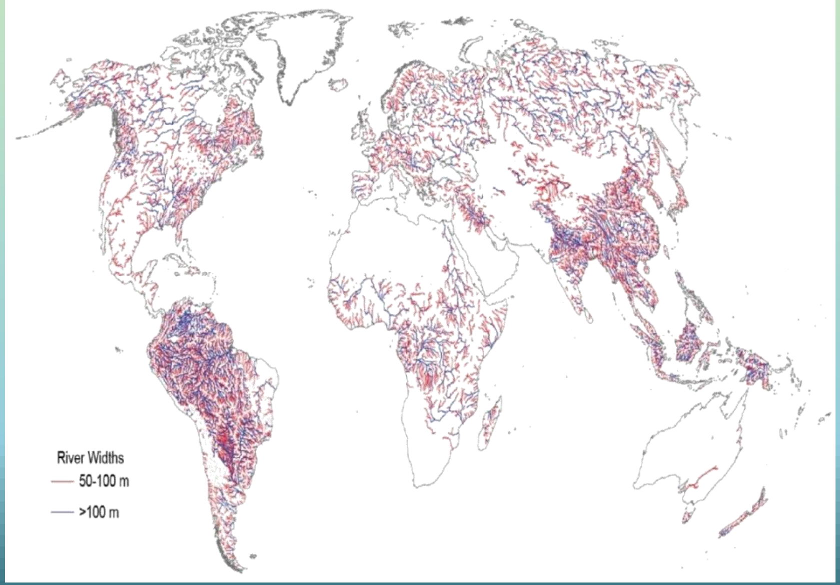
Context: SWOT data for continental hydrology







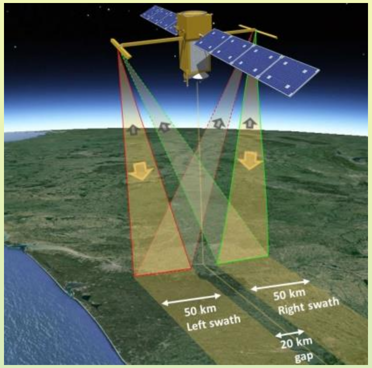
Courtesy: Sylvain Biancamaria (LEGOS)



« 100m width rivers » potentially seen by SWOT

Pavelsky et al. (2014)

How to best use SWOT data to infer river discharge at the global scale?

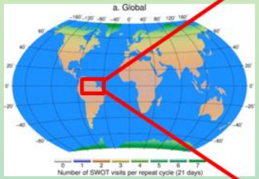


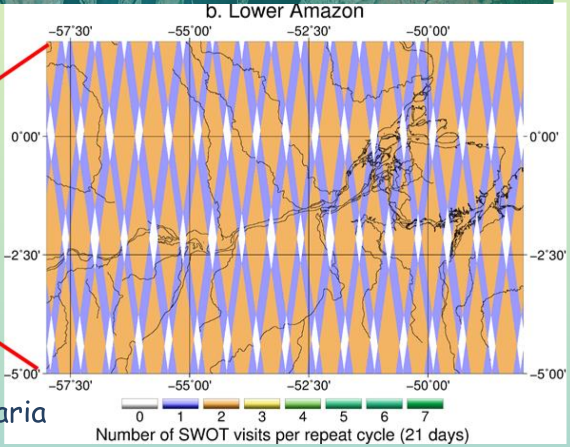
Garonne river (Toulouse, France)

Congo River (Border of Congo and RDC)

Challenging points:

- **Unobservable river bathymetry?**
- **Link between basal friction and topography?**





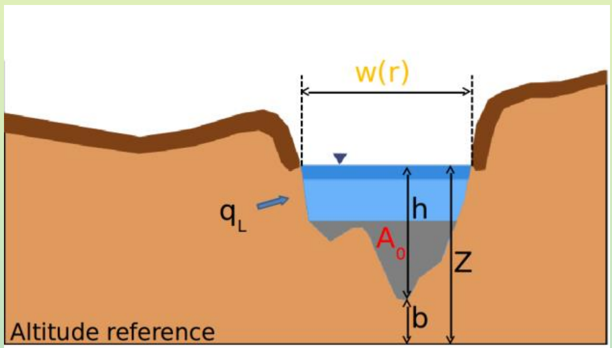
Courtesy: Biancamaria

SWOT data: elevation, width, slope

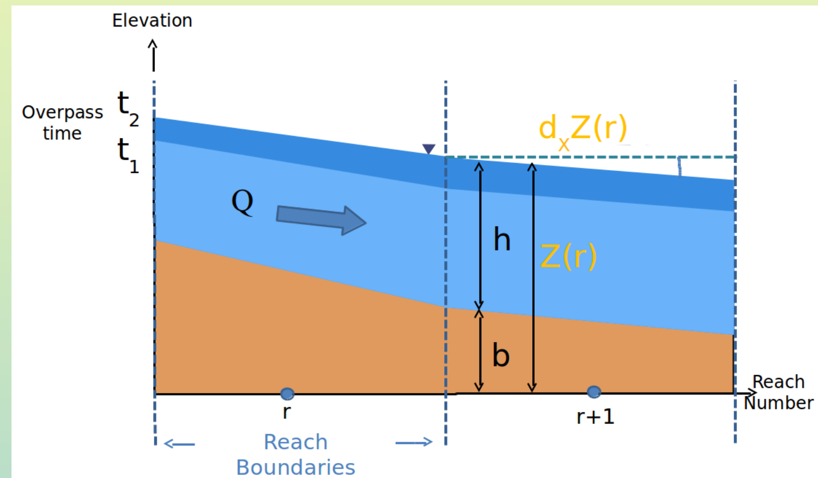
Tanana River (Alaska, US)

Position of river parameters inverse problems in a SWOT context

- Reach averaged SWOT obs. (Z, W, Slope) + temporal revisits
- No low flow bathymetry and friction observed

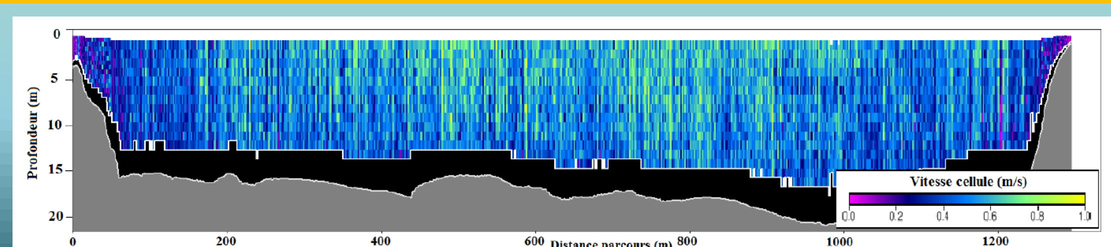


Case of single thread channels



→ Underconstrained inverse problems
→ Tiplet (Q, A0, K) Equifinality (e.g., Aronica et al. 1998, Roux and Dartus 2008, Garambois and Monnier 2015)

A real velocity profile, Rio Negro at Novo Airão in 12/15 (ADCP Measurement) – Source Paris 2015

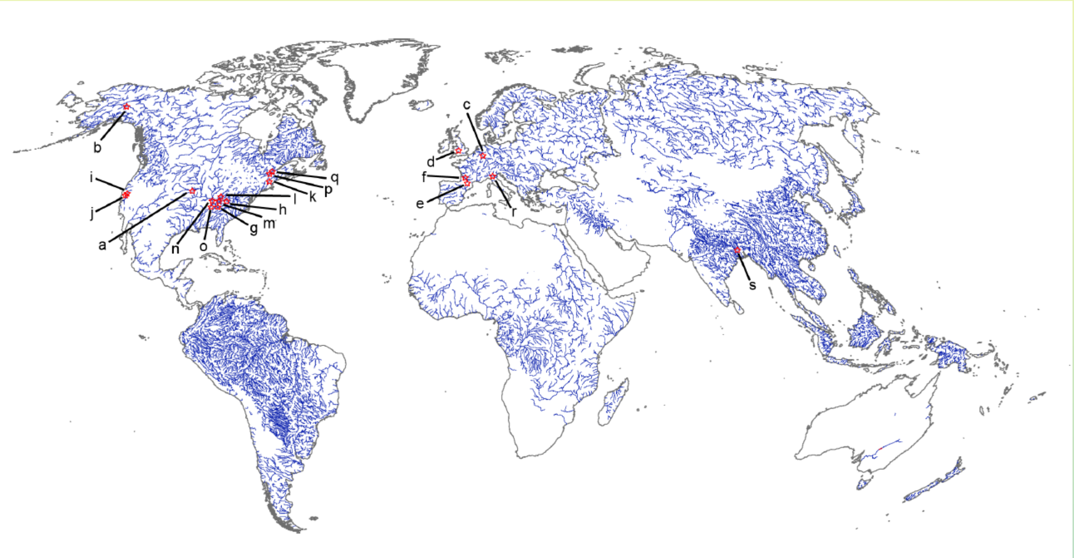


Four primary methods for discharge inversion

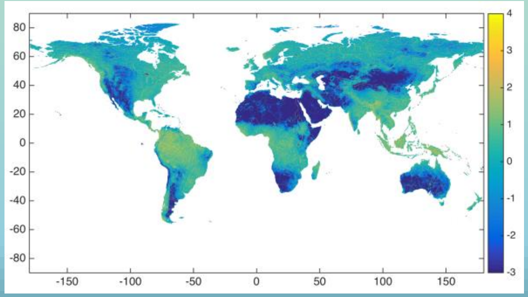
Author(s)	Algo Basis	Identified variables	Data required	Comments
MFG D. Bjerklie	Mannning	K, A, hence Q	In situ Q + W, S and H	Assumes mean annual flow is known
Metroman [Durand et al 2014] JoH [Yoon et al. 2016] JoH	Temporal mass+manning $\begin{cases} \partial_x Q + \partial_t A = 0 \\ Q = K A R_h^{2/3} \sqrt{S} \end{cases}$ + Bayesian MCMC	K, A_0, hence Q	W, Z, S	Requires a first guess, mass conservation integrated in time
AMHG [Gleason and Smith 2014] PNAS, [Gleason et al. 2014] [Gleason and Wang 2015] GRL	$w=aQ^b \rightarrow Q=(w/a)^{1/b}$ a,b Estimate from width obs at Nr*Nt sections qith dxQ=0 + Genetic Algorithm	a,b, hence Q	W	Statistical method requiring time varying w at several locations
GaMo [Garambois and Monnier 2015] AdWR	mass+manning $\begin{cases} \partial_x Q = 0 \\ Q = K A R_h^{2/3} \sqrt{S} \end{cases}$ + Levenberg-Marquardt algorithm	K, A_0, and Q	W, Z, S	Effective (topography,roughness) Requires a first guess

The PEPSI Challenge

« an experiment without ancillary data and river specific assumptions»

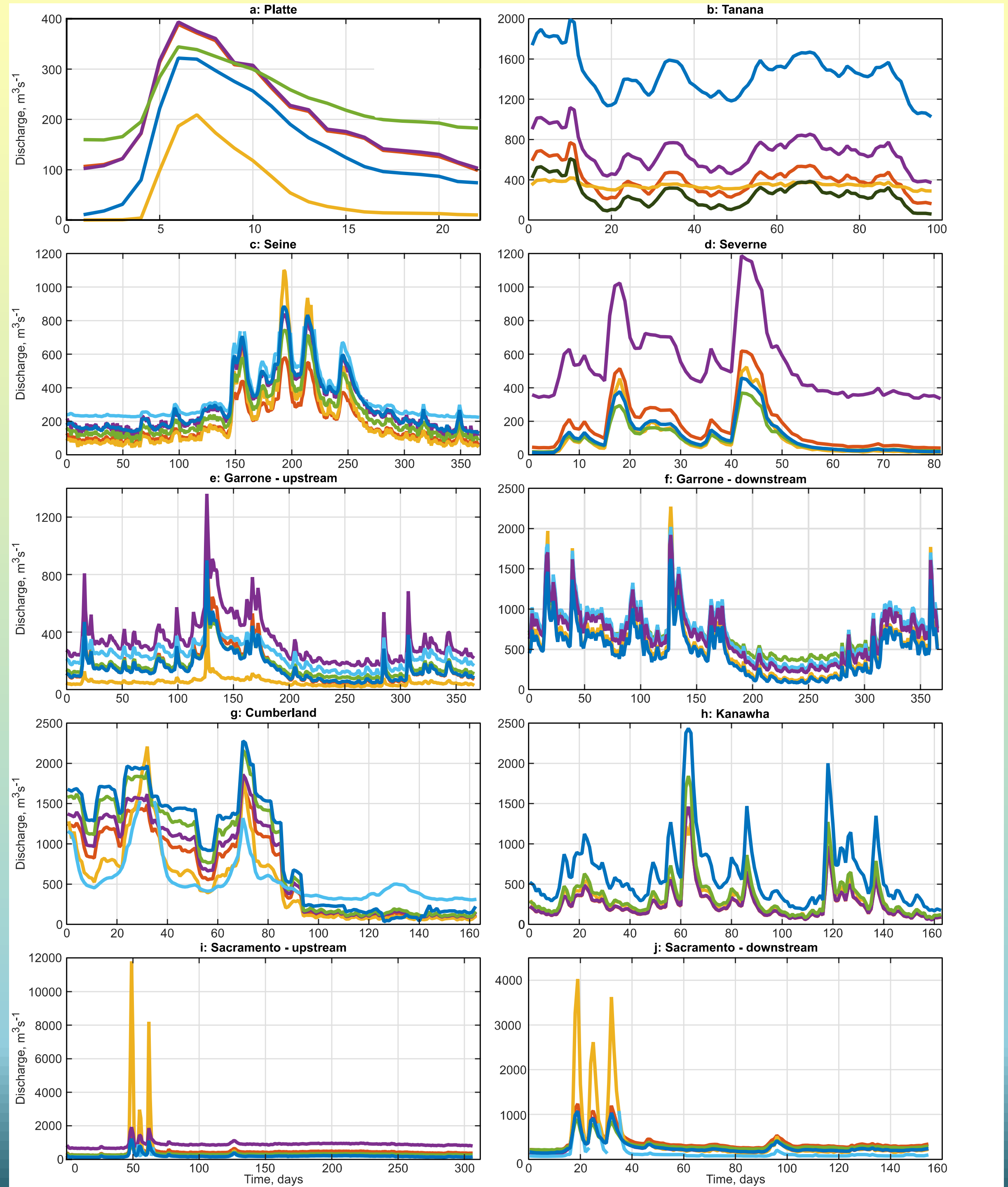


- 19 rivers with contrasted geomorphological properties and flow regimes – braided rivers, dam (Ohio). (Model outputs)
- Prior information (WBM discharge)
- Twin experiments with reach averaged observables



WBM model: Rawlins et al., Hydrol. Proc., 2003

Results (1/2)



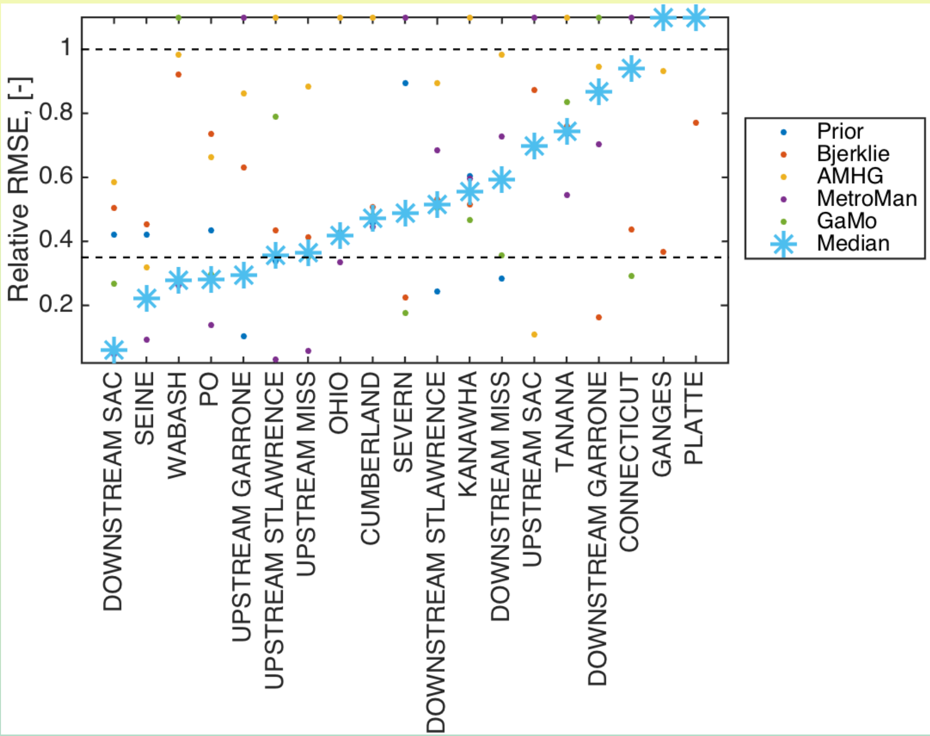
- True
- Prior
- MFG
- MetroMan
- GaMo
- AMHG

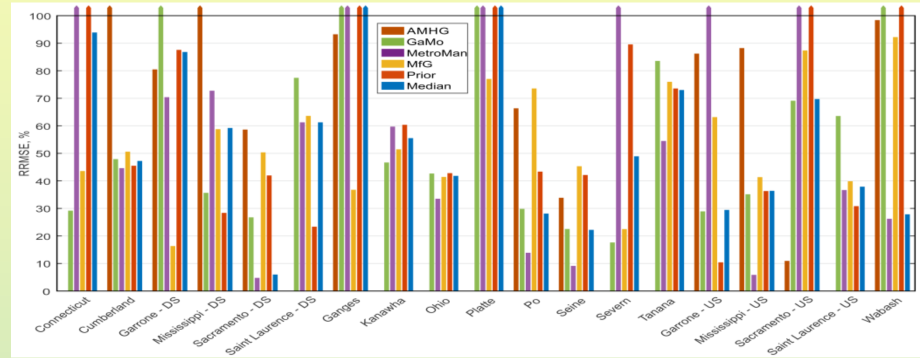
Results (2/2)

- True
- Prior
- MFG
- MetroMan
- GaMo
- AMHG

PEPSI challenge summary

« an experiment without ancillary data and river specific assumptions»





Median RMSE is 55%
(4 algorithms + Prior + median)

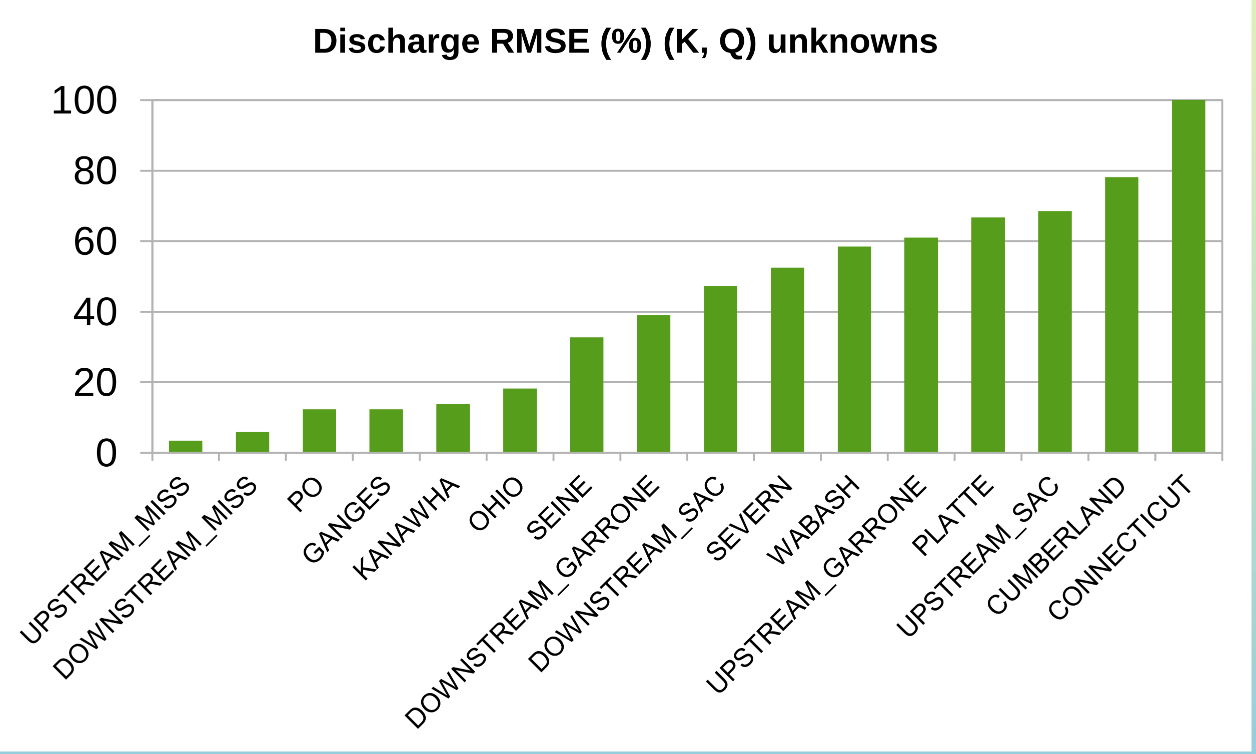
- One algorithm <35% RRMSE for 14/16 non-braided rivers
- Some rivers contain low head dams,

- **Manning based estimations: Equifinality between topography and roughness remains**

- **Geomorphology and hydrology:**
  - Influence on inversions
  - Benefit of using physical bounds on unknowns

Adding more in situ information?

- GaMo algorithm with explicit bathymetry inversion (requiring one in situ measurement) on Pepsi dataset

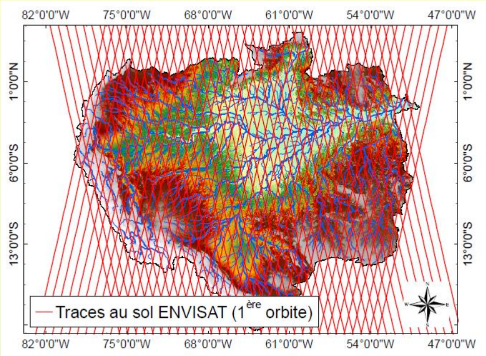


Rating curves based on Altimetry/Rainfall-Runoff

[Leon 2006], [Getirana 2009], [Paris 2015] phD, [Paris et al. 2016] WRR

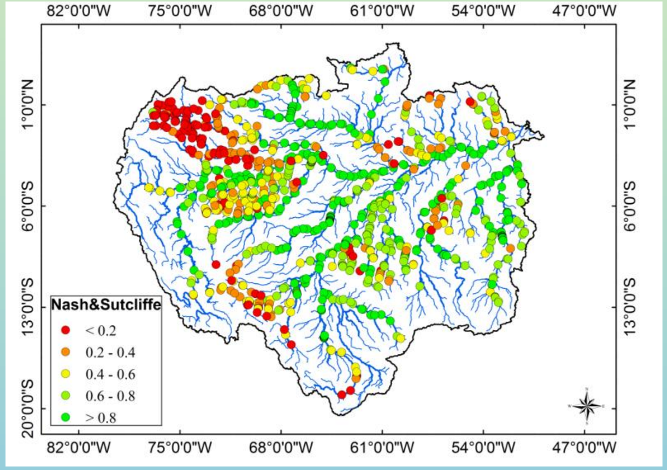
$$Q = a(Z - Z_0)^b$$

Calibration :
Q from rainfall runoff model
Z from sat. altimetry (multimission)
→ SCEM-UA algorithm to infer a, b, and Z0



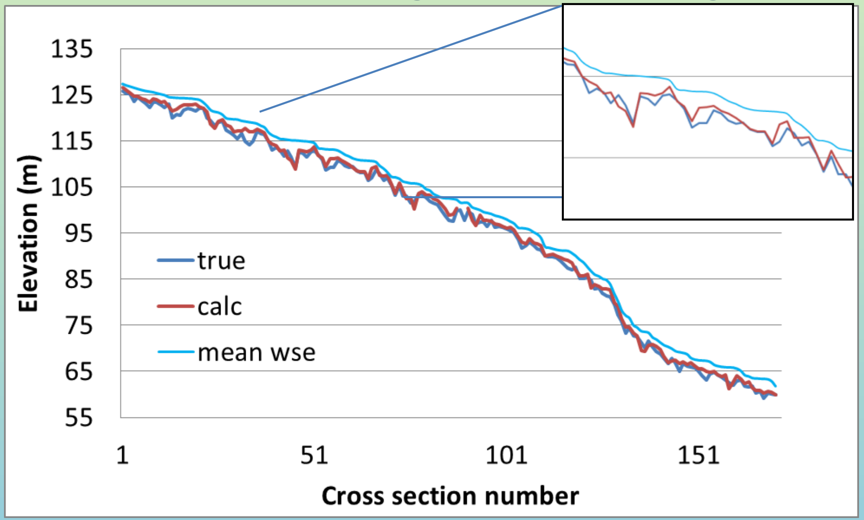
Envisat tracks over the Amazone basin

Validation of Q estimation (Amazone Basin)



$$Q = \alpha(Z - Z_0)^{\beta} S^{0,5}$$

Bathymetry estimation test (Garonne River) - true discharge, reach averaged Z



- **Simple and potentially robust Q=f(Z)**
- **Possible batymetry inversion (sensitivity study in progress)**

USGS Discharge Algorithm Experiments Using Existing Satellite Information

$$Q = \frac{\left[W*\left((h-B)*(1-(\frac{1}{1+r}))\right)^{1.67}*S^{0.5}\right]}{n}$$

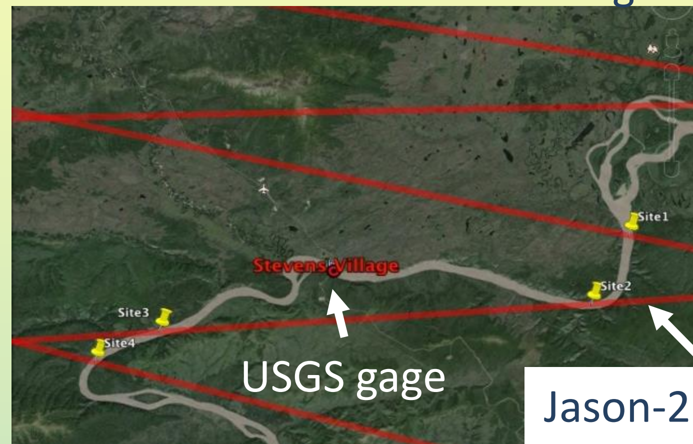
logarithmic modifier for change in resistance with depth (Limerinos, 1970; Jarrett. 1984)

$$n = n_b*(1+\log(\frac{H-B}{h-B}))$$

Prandtl-von Karman (PVK) Equation with base flow resistance estimated from channel characteristics and various options for calibration

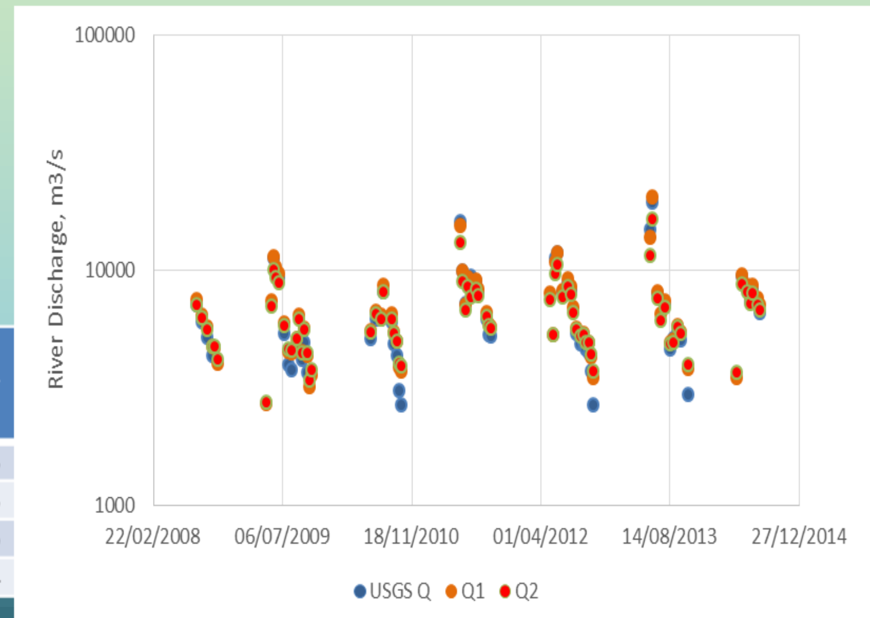
$$Q = 2.5 * W * Y * (g * Y * S)^{0.5} * (ln\left(\frac{Y}{y_0}\right) - 1)$$

Yukon River at Stevens Village

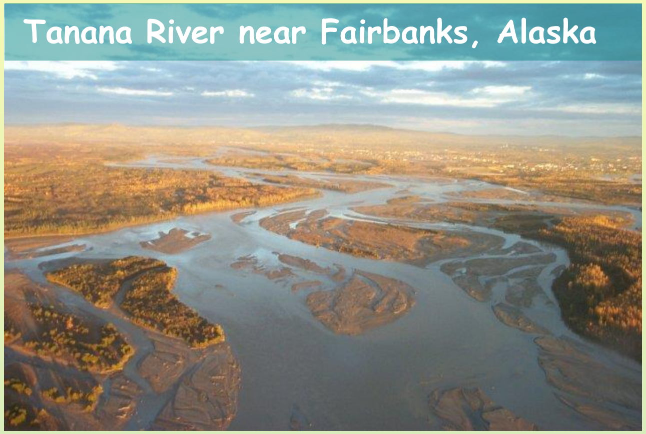


Jason-2 flight line used for calculations

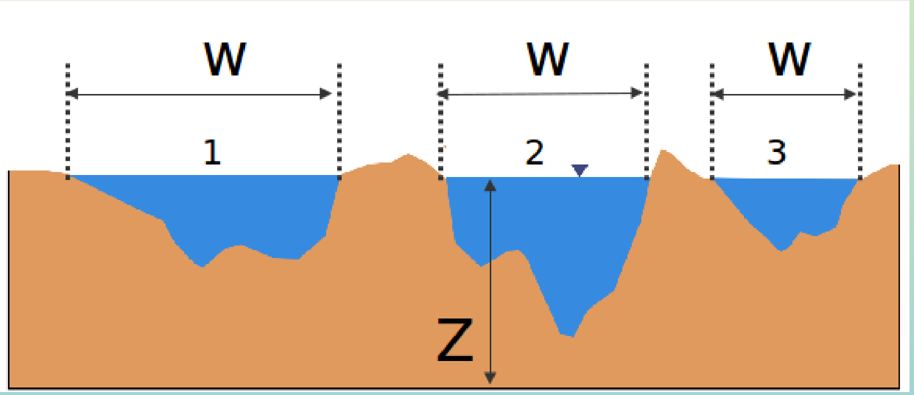
	USGS Measured m3/s	MAN Estimated m3/s	PVK Estimated m3/s	MAN absolute Error m3/s	PVK absolute error m3/s	MAN log error
Mean	6882.21	6879.65	6495.97	338.29	-104.52	0.03
Stdev	3231.48	2967.81	2333.60	385.21	919.71	0.03
Max	19370.90	20473.45	16545.09	1102.55	1233.51	0.15
Min	2648.45	2682.86	2727.98	-1013.64	-3220.00	-0.04



Perspectives for braided rivers



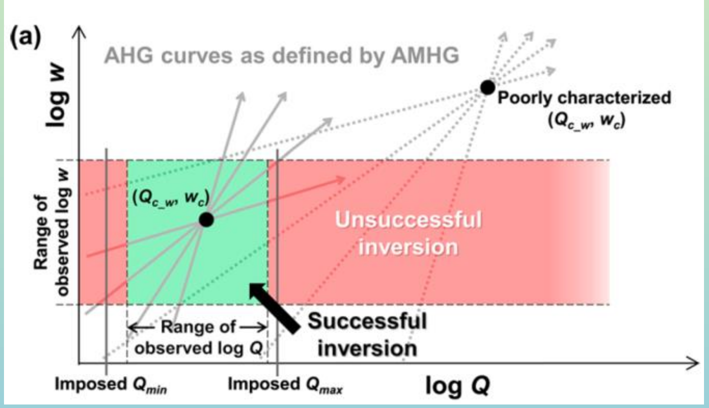
Idealized view of multi thread channels



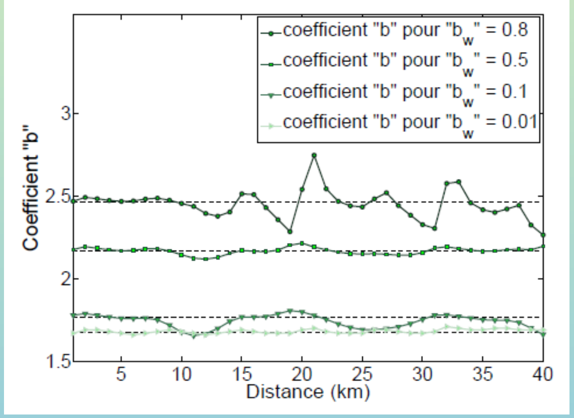
- **Hydraulic visibility of braided rivers [Garambois et al.] revised**
- **Identifiability of hydraulic parameters from SWOT like observables?**
- **Discharge inversion test on Ganges river system [Bonnema et al. 2016] WRR**

Current advances in understanding the inverse problem

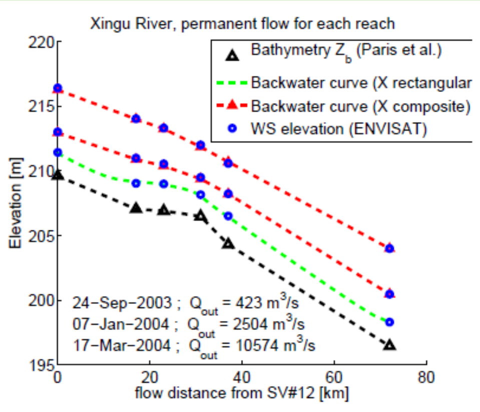
- Towards improved model formulation for inversions
  - Use of hydraulic geometrie(s) + physical model(s)
  - Explicit quantification of reach averaging effects
- Studies about within reach variabilities
  - Effective roughness
  - Proxys for control sections detection
  - Variabilities of hydraulic geometries coefficients



NEcessary: « AHG crossing » vs (w,Q) bounds definition for inversibility of AMHG [Gleason and Wang 2015]



Identifiability of power law coefficients [Paris et al.]



Validation of Effective multiregime roughness and X section for a braided river [Garambois et al.] rev.

Conclusions (1/2)

- Prepare a synergistic approach able to benefit from flow equations, parcimony and physical meaning of power laws and statistical approaches

- Extended study of discharge inverse problems to:
  - Different unknowns and obs amounts and uncertainties
  - Reach averaging
  - Identification(s) time window(s), time sampling sensitivity

- Better constrain discharge inversion problem:
  - Investigate Q inversion(s) response surface for various contexts
  - Use ancillary data (« SWOT + limited field campains »)

Conclusions (2/2)

- Towards Interactions/coupling with data assimilation methods and hydraulic models:
  - 19 rivers of PEPSI challenge for DA experiments (design?)
  - Other river cases

- Data aspects:
  - SWOT simulator data
  - Towards a World river (hydrosystems) database? (bathymetry, hydro-geomorphological classes…)
  - new river cases

- Discussion of next steps from a fluvial perspective Thursday at 10:00

DAWG and RAMADA need you!

If you have the following for any river....

- A calibrated channel hydraulic model
- A floodplain DEM + channel bathymetry
- Distributed in situ measurements of height, width, and slope
- Simulator outputs
- Secret AirSWOT data

WE NEED IT! Contacts:

Colin Gleason at cjgleason@umass.edu
Mike Durand at durand.8@osu.edu
Pierre-andre.garambois@insa-strasbourg.fr
Helene.roux@imft.fr

References

Durand, M., E. Rodriguez, D. E. Alsdorf, and M. Trigg (2010), Estimating River Depth From Remote Sensing Swath Interferometry Measurements of River Height, Slope, and Width, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 3(1), 20–31.

M. Durand, C. J. Gleason, P. A. Garambois, D. Bjerklie, L. C. Smith, H. Roux, E. Rodriguez, P. D. Bates, T. M. Pavelsky, J. Monnier, X. Chen, G. Di Baldassarre, J.-M. Fiset, N. Flipo, R. P. M. Frasson, J. Fulton, N. Goutal, F. Hossain, E. Humphries, J. T. Minear, M. M. Mukolwe, J. C. Neal, S. Ricci, B. F. Sanders, G. Schumann, J. E. Schubert, and L. Vilmin. (2016) An intercomparison of remote sensing river discharge 1 estimation algorithms from measurements of river height, width, and slope. Water Resources Research

Durand, M., J. Neal, E. Rodríguez, K. M. Andreadis, L. C. Smith, and Y. Yoon (2014), Estimating reach-averaged discharge for the River Severn from measurements of river water surface elevation and slope, Journal of Hydrology, 511(C), 92–104, doi:10.1016/j.jhydrol.2013.12.050.

Garambois, P. A., and J. Monnier (2015), Inference of effective river properties from remotely sensed observations of water surface, Advances in Water Resources, 79(C), 103–120, doi:10.1016/j.advwatres.2015.02.007.

Garambois, P. -A., Calmant, S., Paris, A., Roux, H., Monnier, J., Silva, J., Biancamaria, S. Towards effective cross section for ungauged rivers retrieved by hydrodynamical modeling of flow lines gained by satellite altimetry. (revised)

Gleason, C. J., and L. C. Smith (2014), Toward global mapping of river discharge using satellite images and at-many-stations hydraulic geometry, Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1317606111.

Gleason, C. J., and J. Wang (2015), Theoretical basis for at-many-stations hydraulic geometry, Geophys. Res. Lett., 42(17), 7107–7114, doi:10.1002/2015GL064935.

Gleason, C. J., L. C. Smith, and J. Lee (2014), Retrieval of river discharge solely from satellite imagery and at-many-stations hydraulic geometry: Sensitivity to river form and optimization parameters, Water Resources Research, 50(12), 9604–9619, doi:10.1002/2014WR016109.

Yoon, Y., P.-A. Garambois, R. C. D. Paiva, M. Durand, H. Roux, and E. Beighley (2016), Improved error estimates of a discharge algorithm for remotely sensed river measurements: Test cases on Sacramento and Garonne Rivers, Water Resources Research, 52(1), 278–294, doi:10.1002/2015WR017319.