River Algorithms, Models & Data Assimilation

SWOT Science Team Meeting, Pasadena, CA 13-16 June 2016

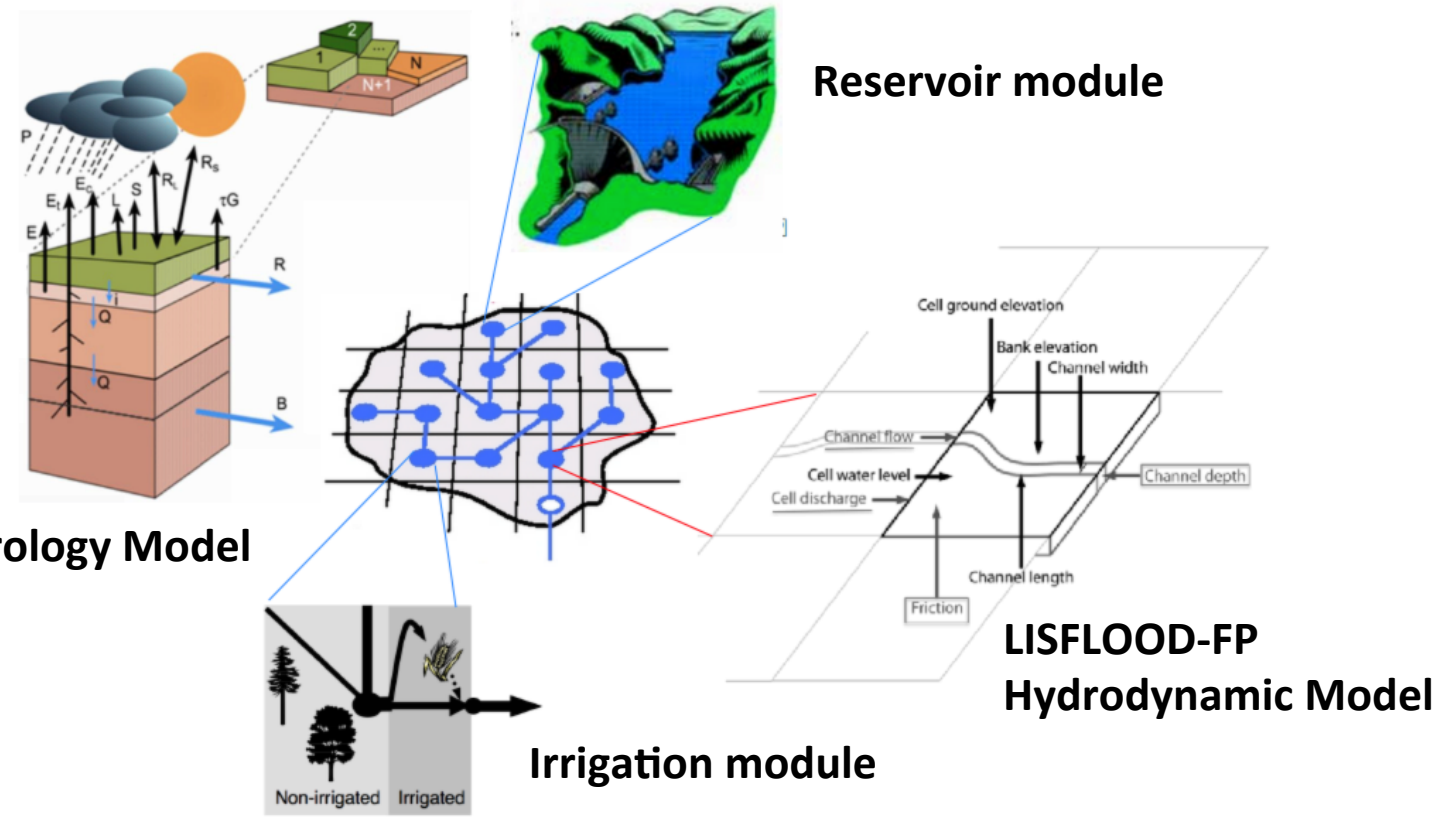
Project list

- Global assimilation & modeling framework (Andreadis/Lettenmaier/Margulis)
- Assimilation-based discharge algorithms (Pan/Wood/Fisher)
- River discharge algorithm development (Durand/Bjerklie/Gleason)
- River discharge algorithms (Monnier/Malaterre/Garambois/Biancamaria/Ricci/Roux/Gosset)
- Hydrologic & hydrodynamic modeling in S. America (Paiva/Bonnet)
- SWOT-GPM synergies (Villa/Gosset)

Assimilation & Modeling Framework for SWOT Data Products

Kostas Andreadis (JPL), Dennis Lettenmaier, Steve Margulis (UCLA)

- **Develop a framework for generating a Level 4 SWOT data**.
- Quantify errors in estimating water availability from using the Level 3 and 4 products.
- Evaluate whether SWOT observations can be used to estimate human impacts on the water cycle (e.g. reservoirs, diversions).
- Derive a dataset of runoff fields and demonstrate its value by calibrating a hydrology model against it.

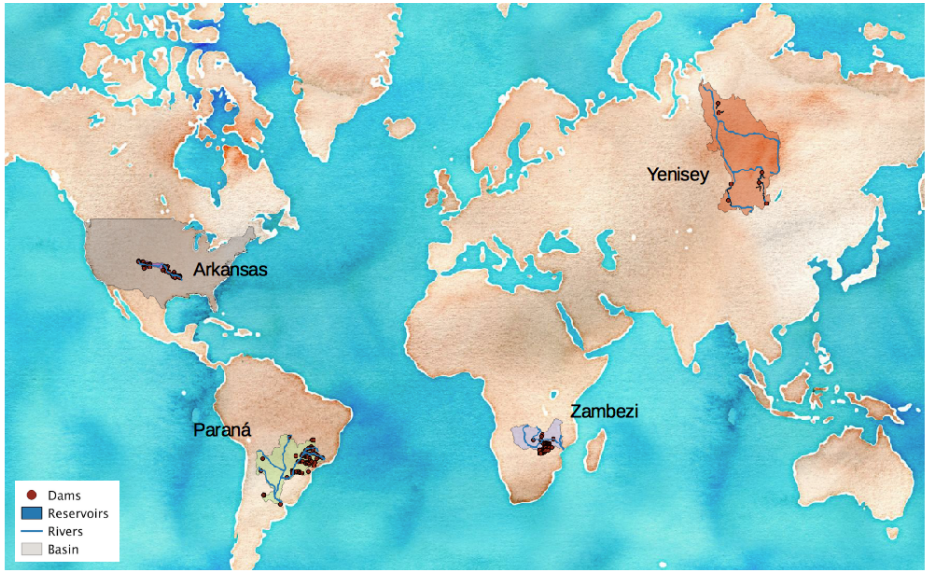


Assimilation & Modeling Framework for SWOT Data Products

Kostas Andreadis (JPL), Dennis Lettenmaier, Steve Margulis (UCLA)

- Level 4 product framework needs
  - Runoff generation and hydrodynamics
  - Water exchange between channel and floodplain
  - Land and wetland dynamics
  - Human impacts via reservoirs, irrigation, diversions

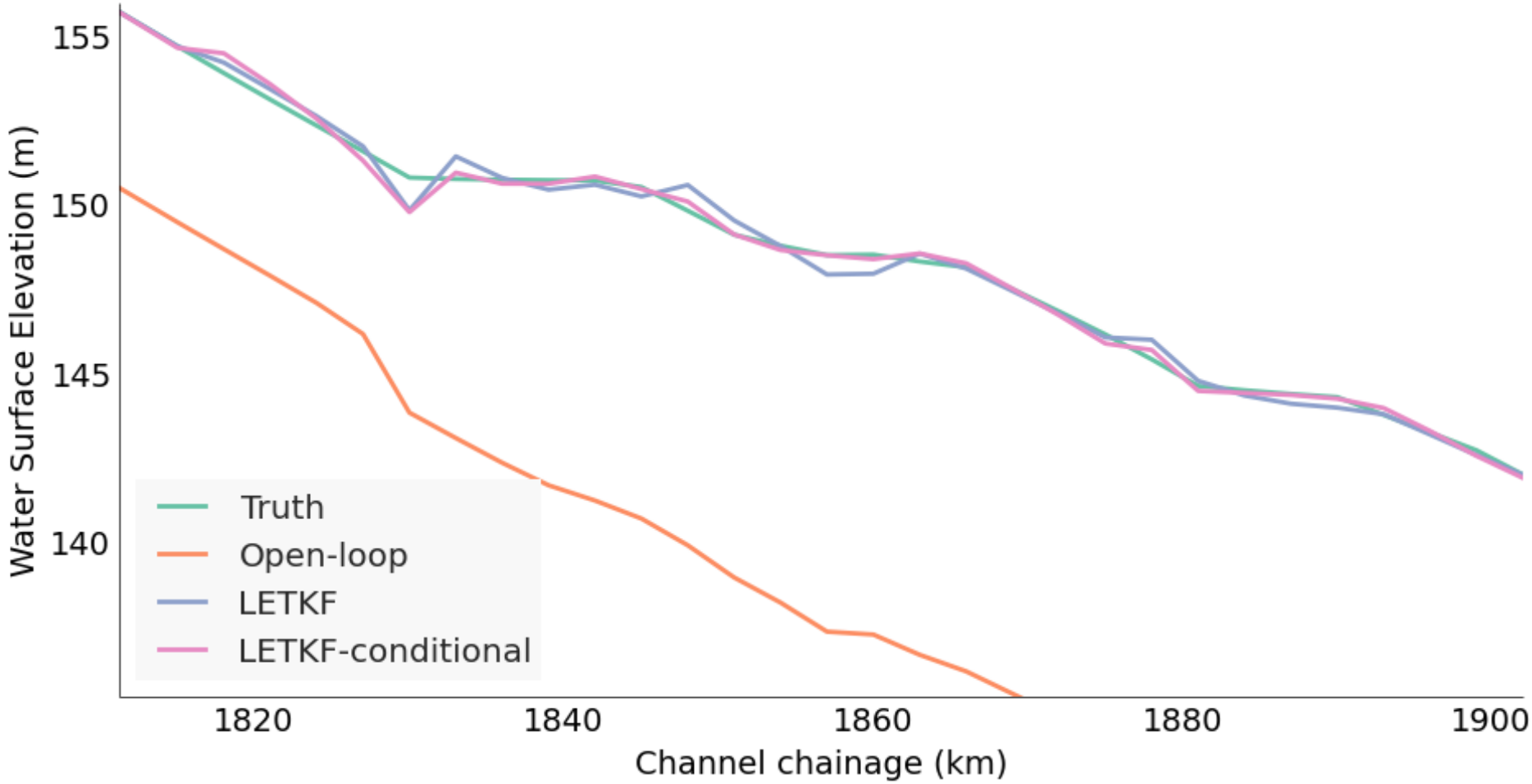
- Identical twin synthetic experiments
- Four case study basins
- Implementation over CONUS



Assimilation & Modeling Framework for SWOT Data Products

Kostas Andreadis (JPL), Dennis Lettenmaier, Steve Margulis (UCLA)

- Testing different assimilation configurations

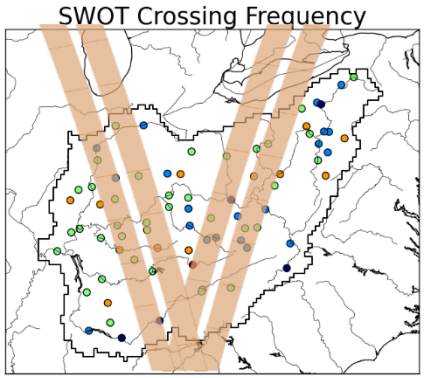


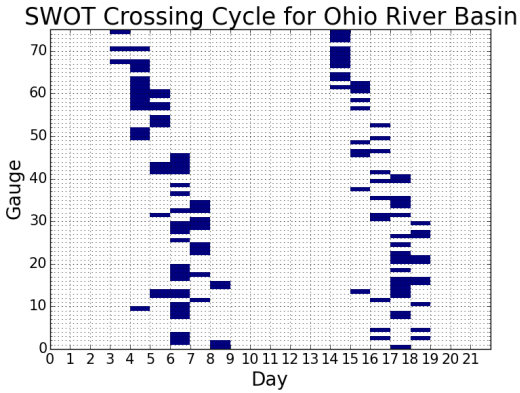
Algorithm Development for SWOT River Discharge Retrievals

Eric Wood, Ming Pan, and Colby Fisher [Princeton University]

Goals:

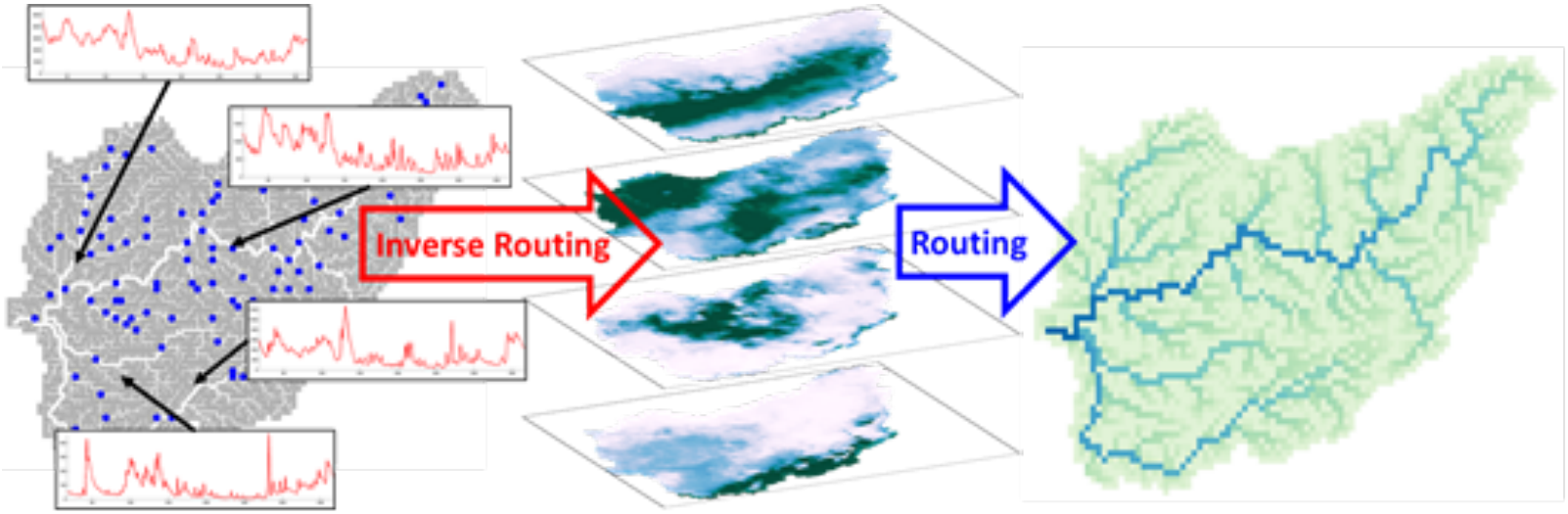
Create spatially/temporally complete river flow records from intermittent SWOT-derived discharge estimates.





Data Assimilation Approach:

Inverse Streamflow Routing: solving a 3-D (space-time) assimilation using a fix-interval smoother.

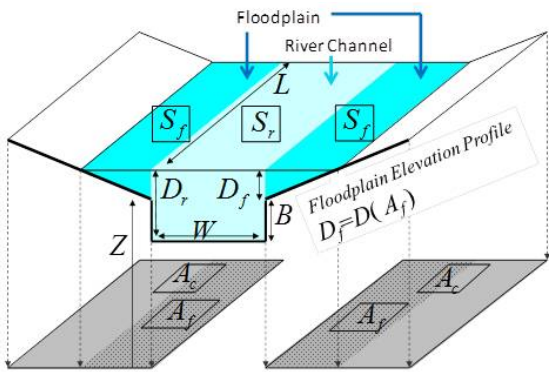


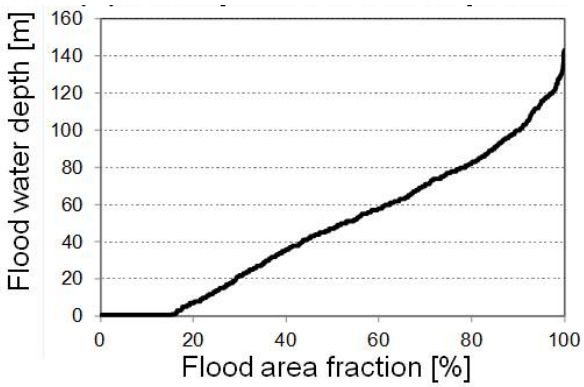
Discrete Discharge Estimates **Inverted Runoff Fields** **Complete Discharge Maps**

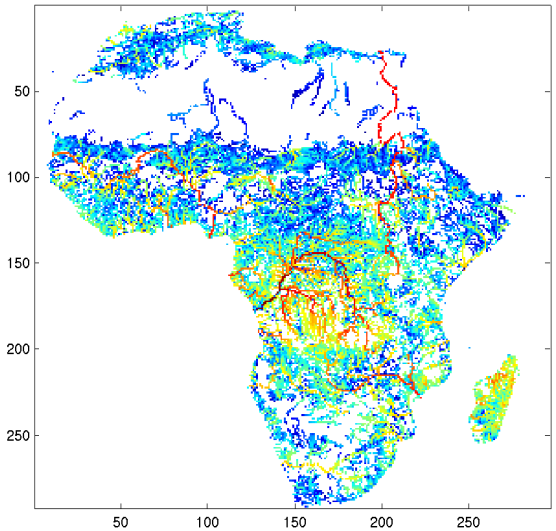
Algorithm Development for SWOT River Discharge Retrievals

Forward River Discharge/Depth/Storage/Inundation Modeling

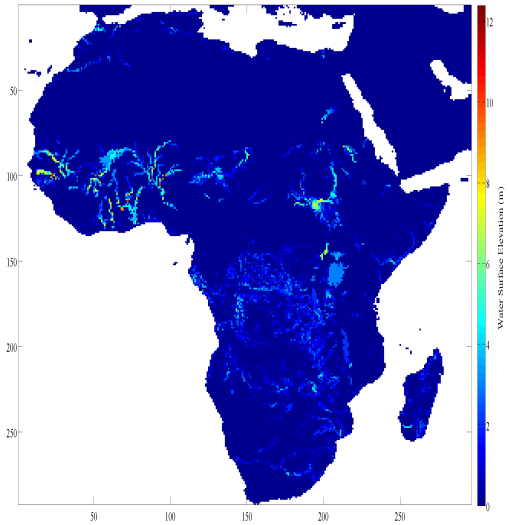
- Distributed global routing model (Catchment-based Macro-scale Floodplain model) that is capable of calculating river and floodplain values of:
  - Water Storage
  - Water Depth
  - Discharge
  - Inundated Area



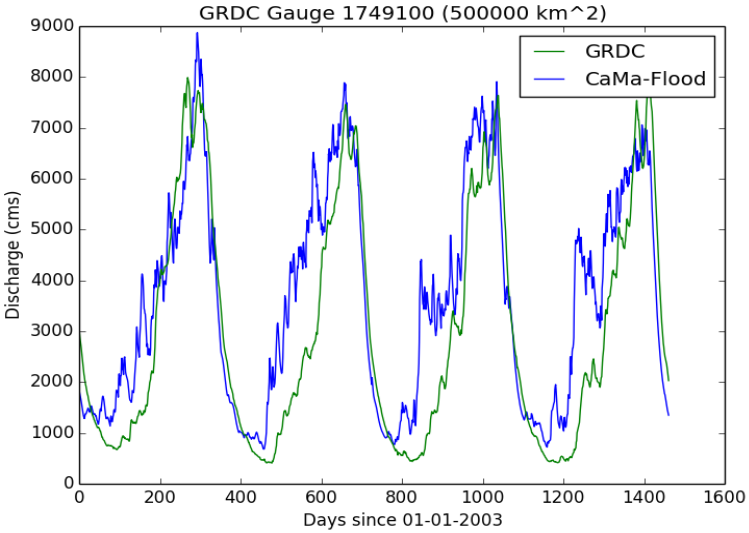




Discharge



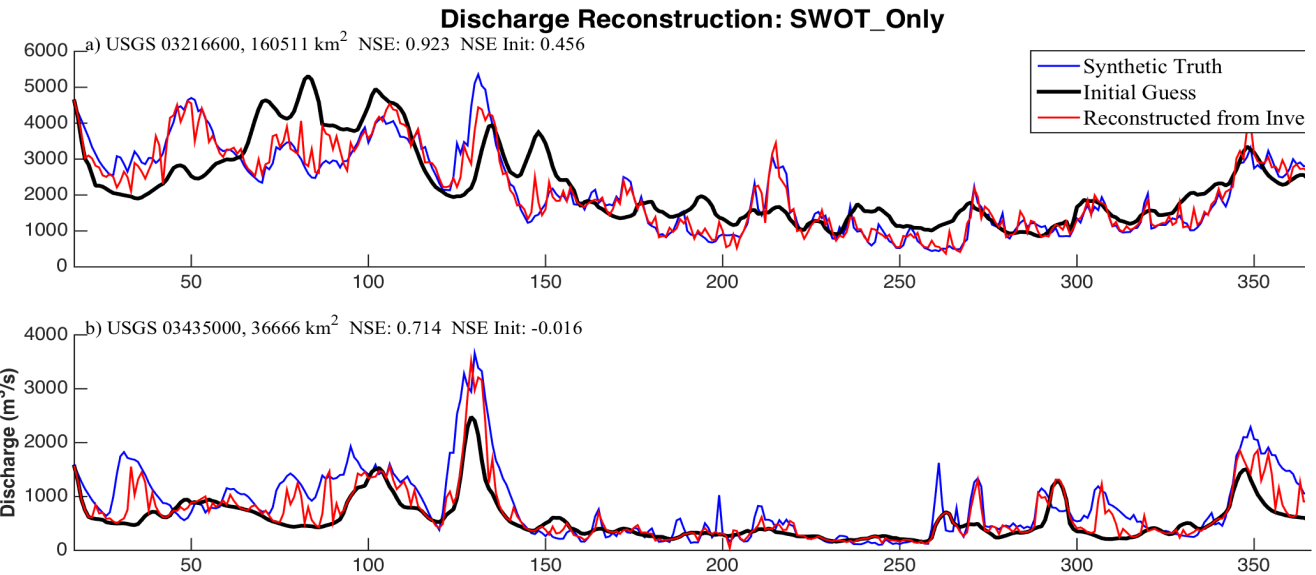
Inundation

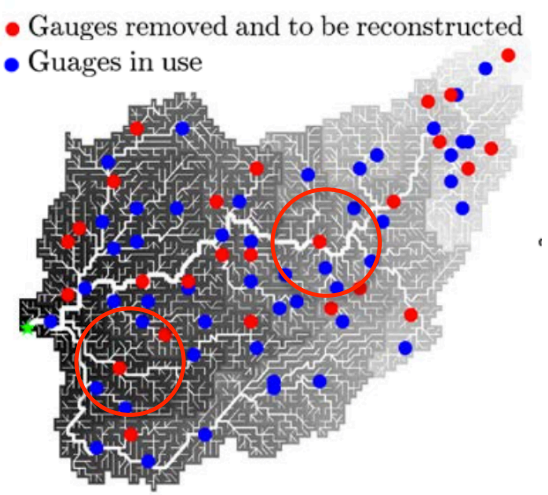


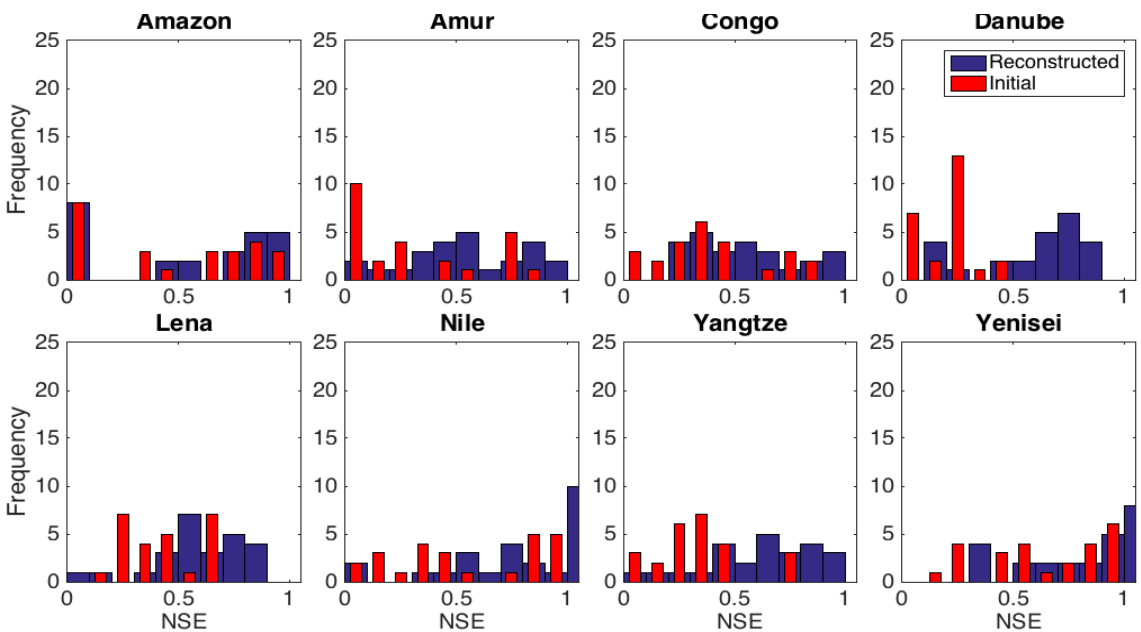
Validation at GRDC Stations

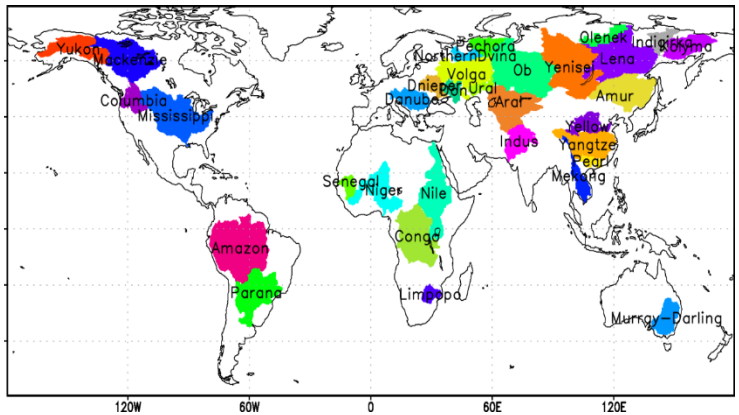
Algorithm Development for SWOT River Discharge Retrievals

Eric Wood, Ming Pan, and Colby Fisher [Princeton University]







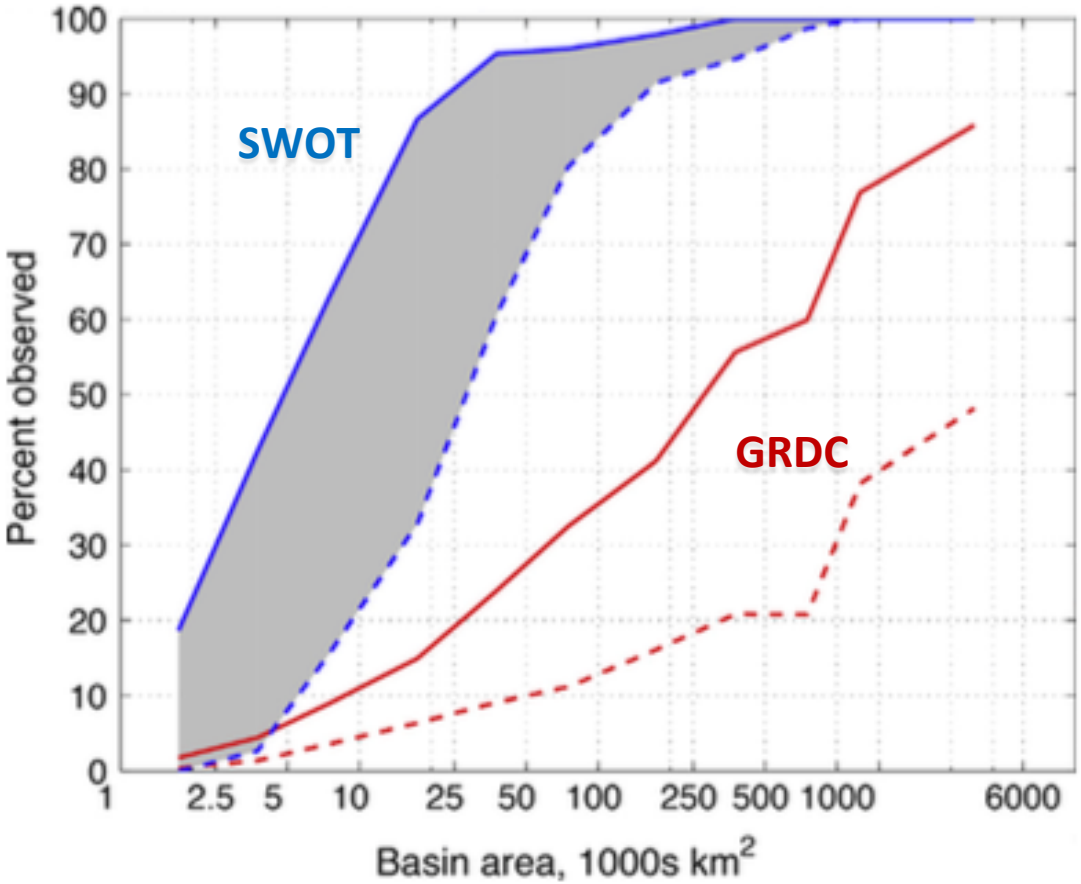


Development and comprehensive validation of discharge algorithms

Michael Durand (Ohio State), Colin Gleason (Umass-Amherst), David Bjerklie (USGS)

- Focus: Mass-Conserved Flow Inverse (McFLI) discharge algorithms

- Initial rounds of McFLI development and validation are complete (Pepsi Challenge, numerous papers)
- Grand challenge: Accurate discharge estimation for ungauged rivers. McFLI algorithms provide a way forward



Development and comprehensive validation of discharge algorithms

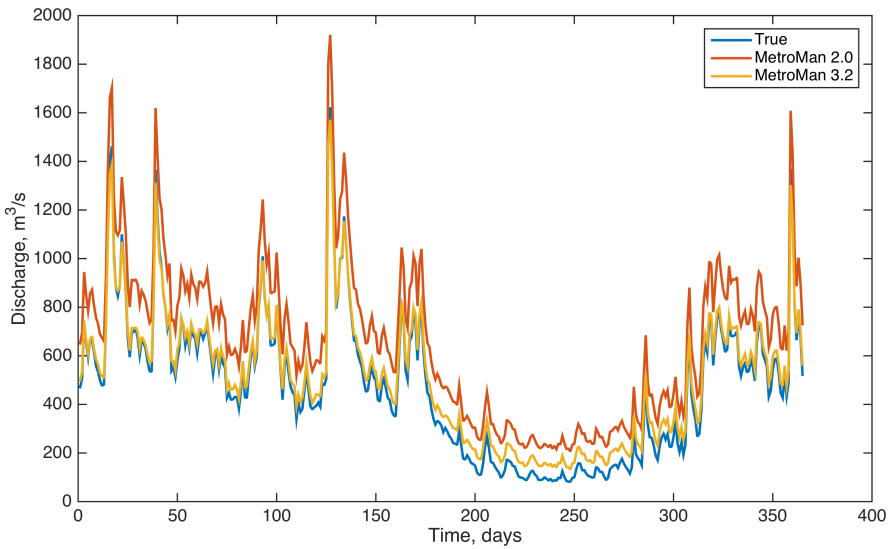
Michael Durand (Ohio State), Colin Gleason (Umass-Amherst), David Bjerklie (USGS)

Algorithm development: Need to combine theory behind various algorithms, as well as to develop new algorithms

Algorithm validation: Need to test against:

1. Hydraulic model output
2. SWOT Instrument simulator data
3. In situ SWOT-like datasets
4. AirSWOT measurements

Downstream Garonne

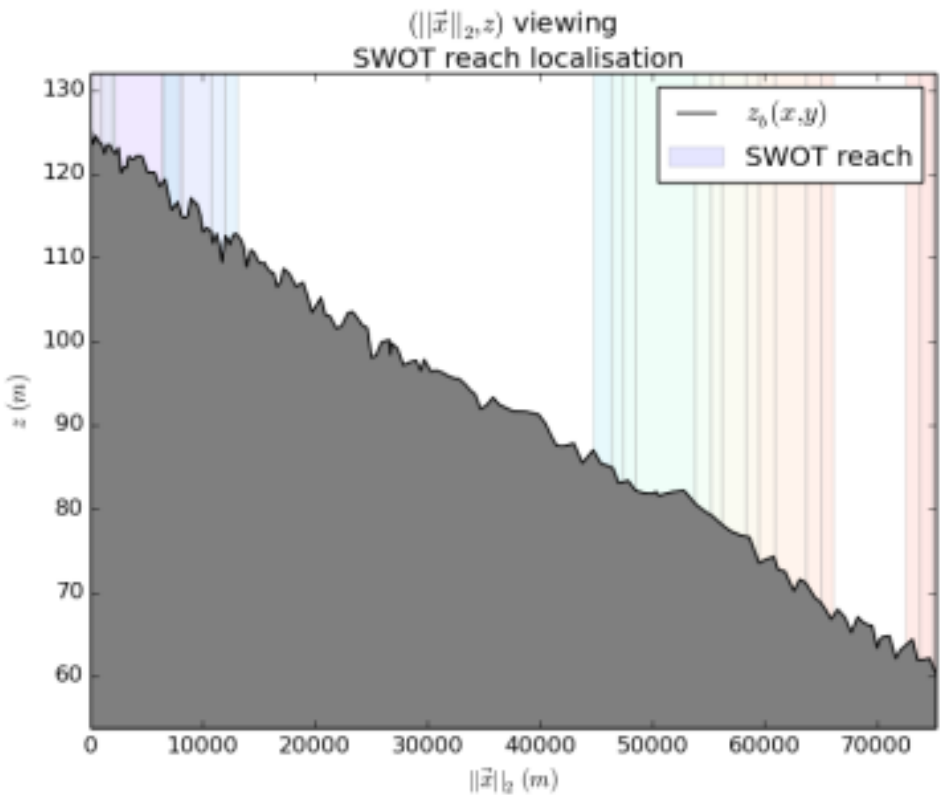


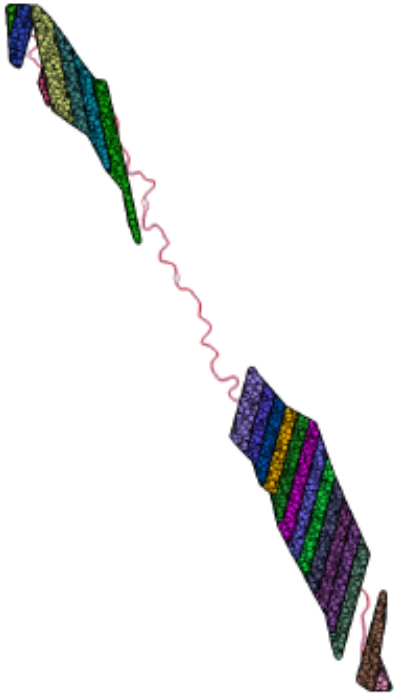
Preliminary Result: combining two McFLI algorithms leads to improved discharge retrieval. *Continuing to obtain new validation datasets is critical!*

SWOT river discharge algorithms

Jerome Monnier, Pierre-Olivier Malaterre, Pierre-Andre Garambois, Sylvain Biancamaria, Sophie Ricci, Helene Roux, Marielle Gosset

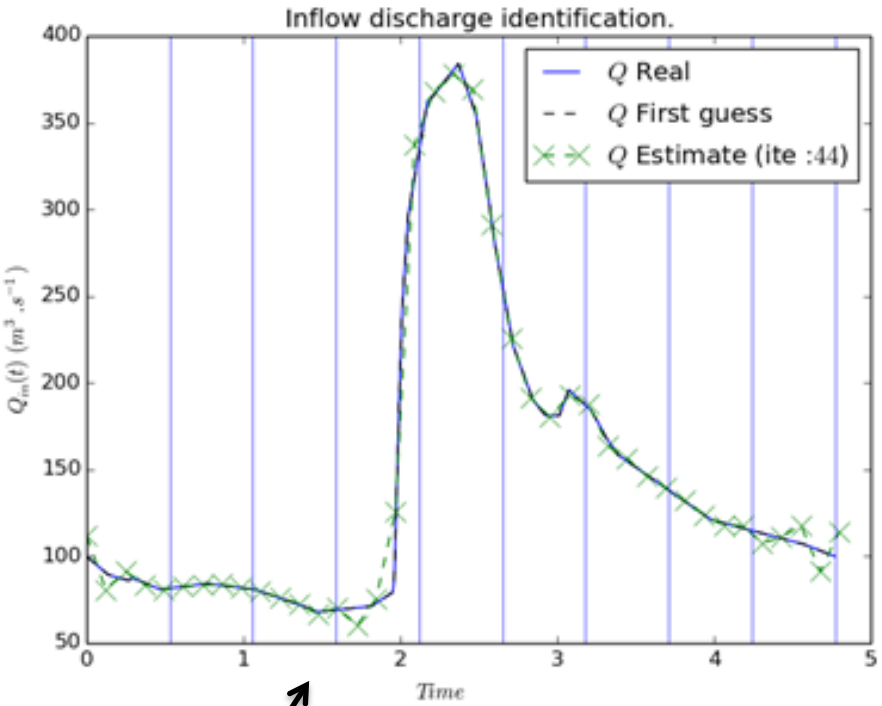
- **Comparison of hydrodynamic model formulations**
- **0.5D reach averaged - 1D full Saint Venant and 2D Shallow Water**
- **Variational sensitivities & DA with SWOT-like observation operators**
- **Estimation of river discharge and inflows**
- **Test cases: Garonne (hierarchical model), Xingu (0.5D-1D) etc**



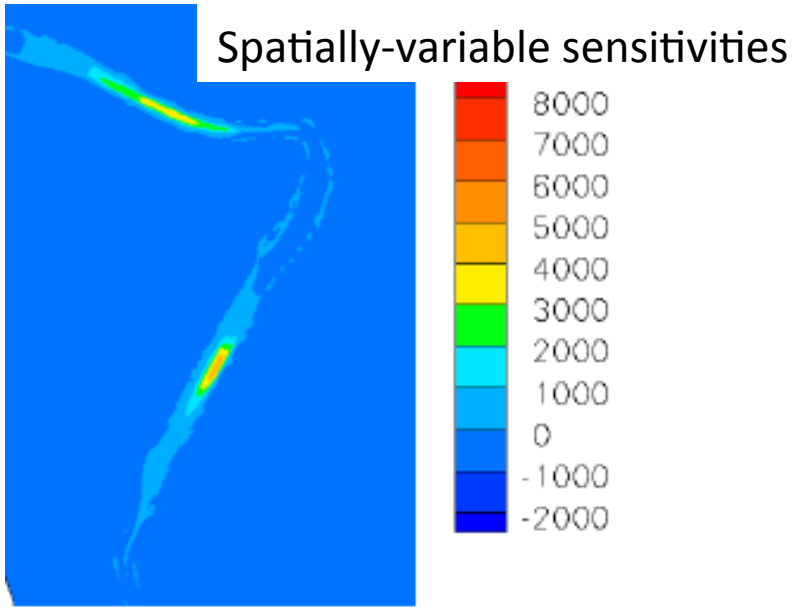


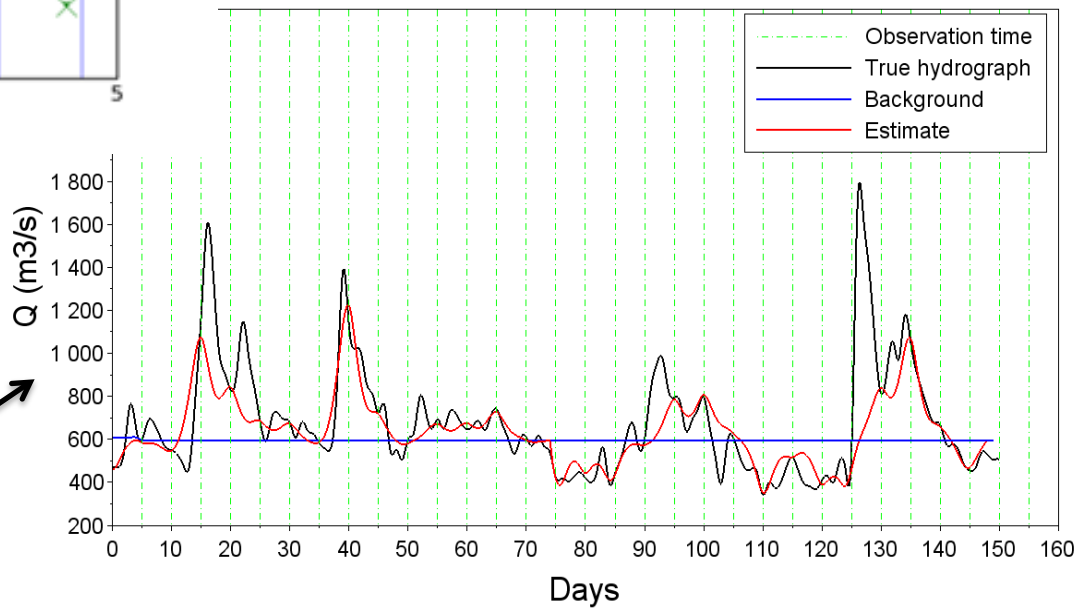
SWOT river discharge algorithms

Jerome Monnier, Pierre-Olivier Malaterre, Pierre-Andre Garambois, Sylvain Biancamaria, Sophie Ricci, Helene Roux, Marielle Gosset



Estimation of inflows

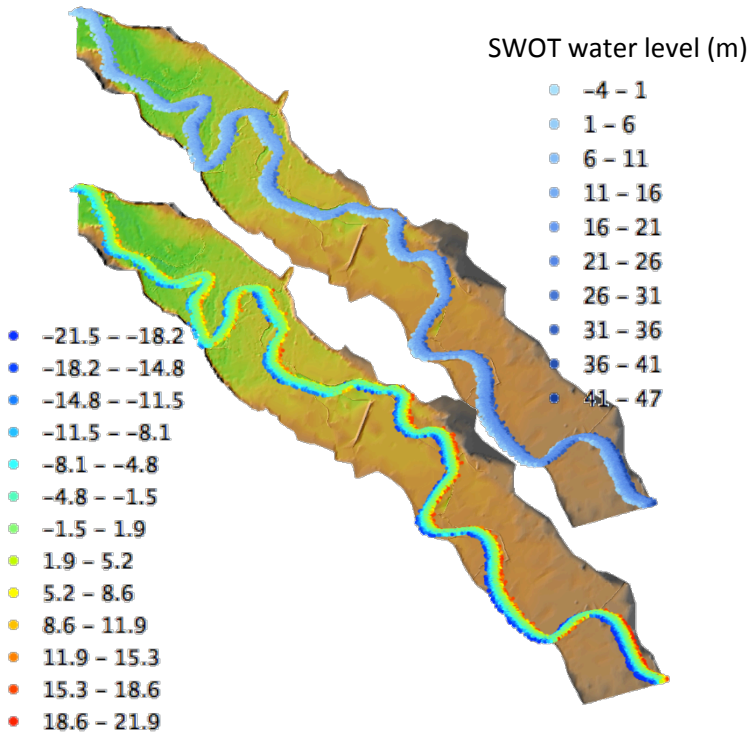




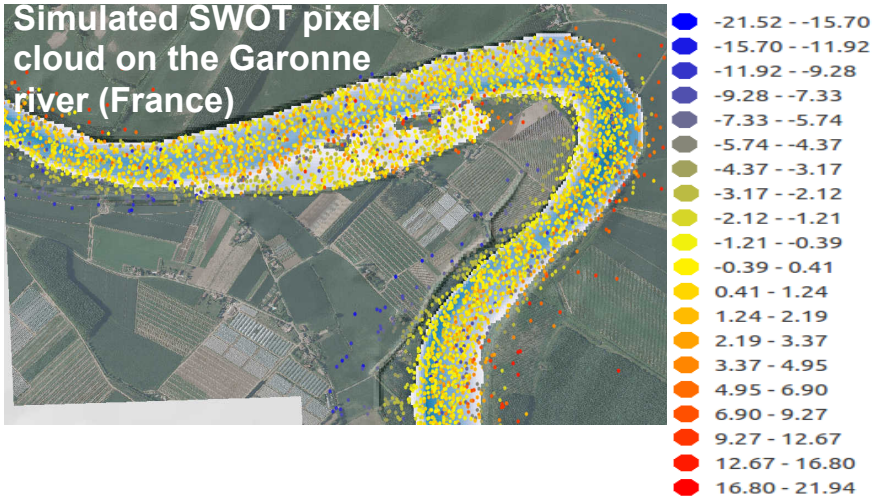
Estimation of river discharge

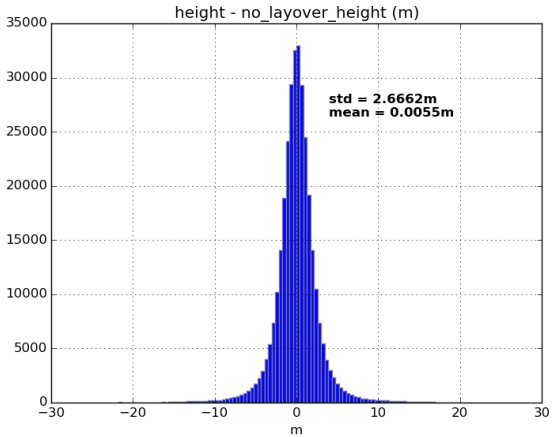
SWOT river discharge algorithms

Jerome Monnier, Pierre-Olivier Malaterre, Pierre-Andre Garambois, Sylvain Biancamaria, Sophie Ricci, Helene Roux, Marielle Gosset

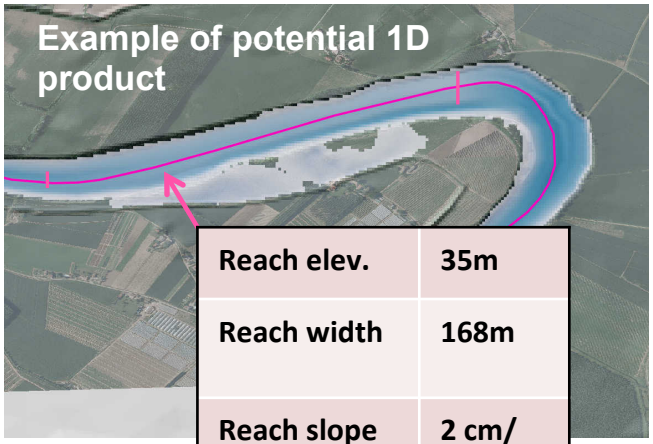


SWOT error:





SWOT total error Q = 600 m³/s



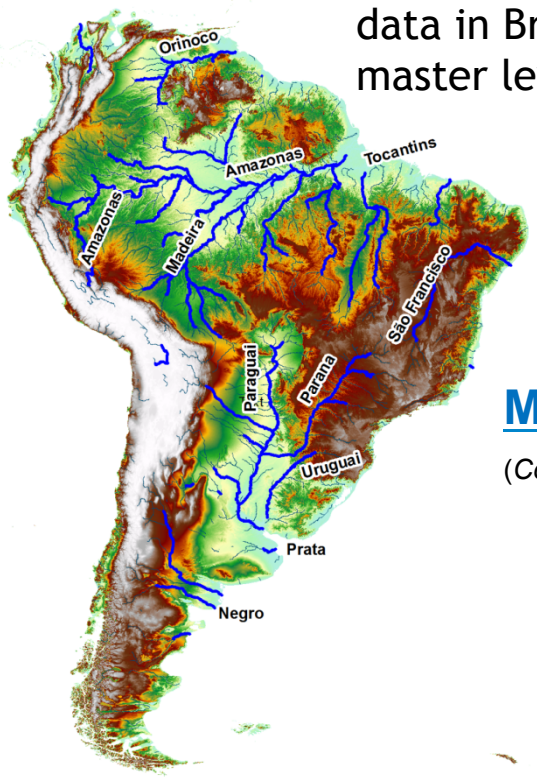
Reach elev.	**35m**
Reach width	**168m**
Reach slope	**2 cm/ km**
Elev. error	**…**

Combining SWOT obs. and modeling for S. America rivers

Rodrigo Paiva (UFRGS), Marie-Paule Bonnet (GET)

Explore the potential of the combination of SWOT-like observation and modelling for the study of large to medium size water systems in South America

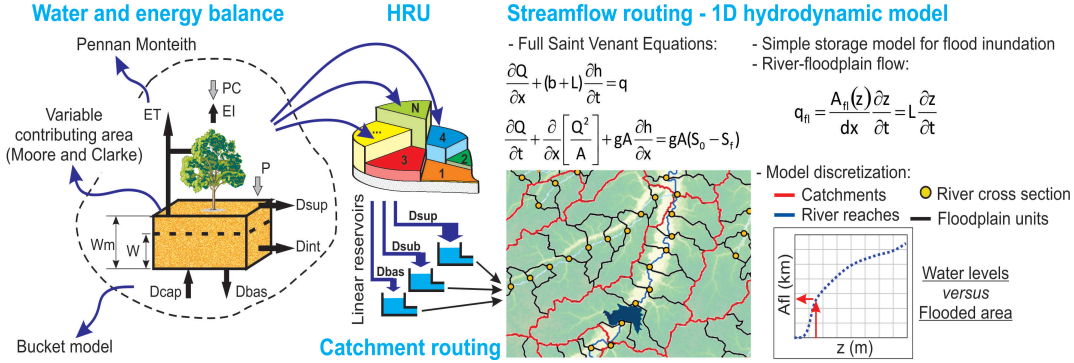
Promote the use of models, SWOT and other surface water remote sensing data in Brazil: training courses and training new researchers (PhD and master level).



Regional scale hydrologic-hydrodynamic model

MGB-IPH: ***M**odelo de **G**randes **B**acias – **I**nstituto de **P**esquisas **H**idráulicas*

(*Collischonn, 2007*; *Paiva, 2011, Paiva et al., 2013*). Several applications over South American basins

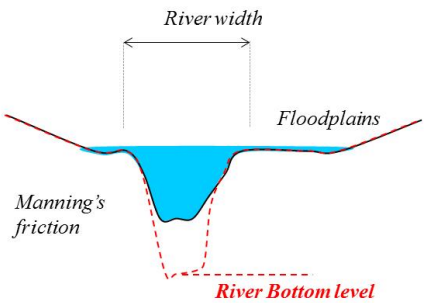


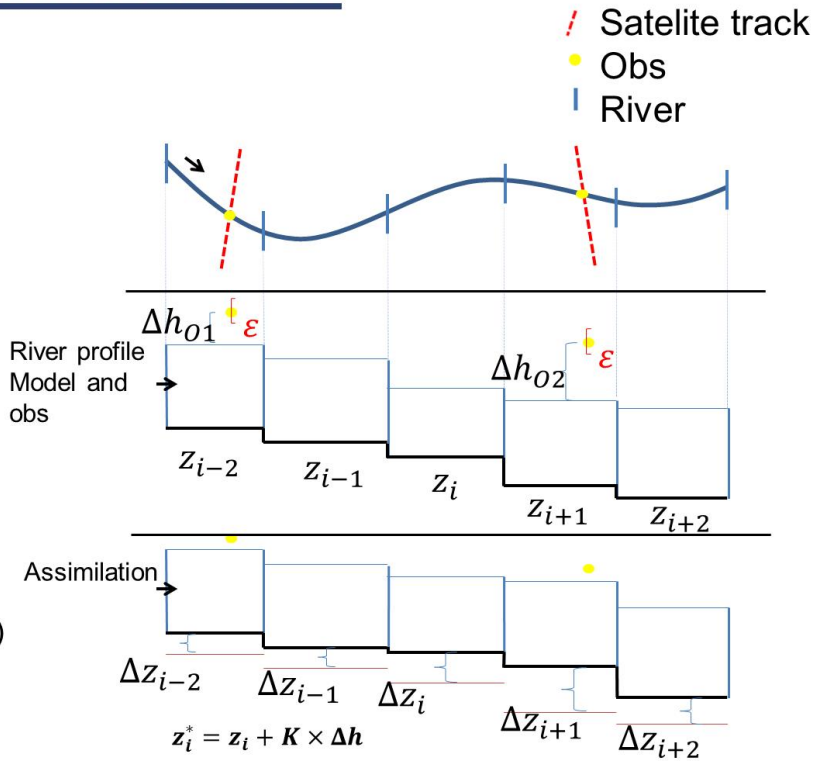
Combining SWOT obs. and modeling for S. America rivers

Rodrigo Paiva (UFRGS), Marie-Paule Bonnet (GET)

Integration of SWOT and regional scale hydrologic-hydrodynamic model MGB-IPH:

- Assimilation of SWOT data to improve model parameters as river bathymetry





- Test Kalman Filters and simple methods
- SWOT and other altimeters (e.g. IceSAT, Envisat)

- Assimilate SWOT-like data to create continuous hydrology fields (discharge, water height, inundation)

e.g. Assimilation of ENVISAT altimetry into MGB-IPH in the Amazon (Paiva et al., 2013) using EnKF

- SWOT discharge or water height
- current altimeters: (e.g. ENVISAT, JASON, ICESAT, ICESAT2, Altika)
- current flood inundation extent estimeates (e.g. Papa et al., SMOS)

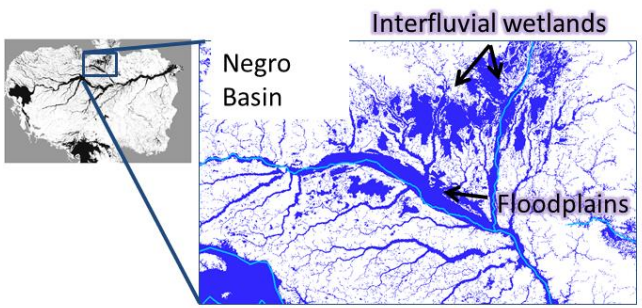
Combining SWOT obs. and modeling for S. America rivers

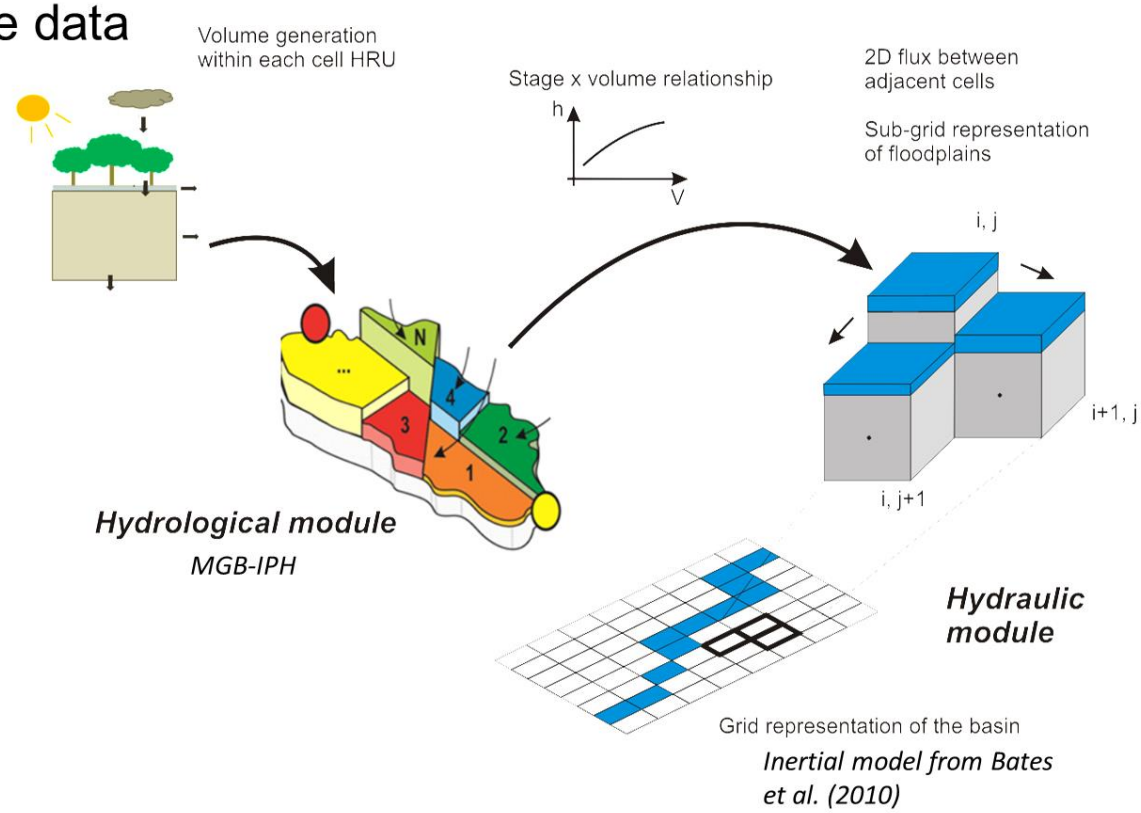
Rodrigo Paiva (UFRGS), Marie-Paule Bonnet (GET)

- MGB-IPH 2 D coupled hydrologic and hydrodynamic modelling for future SWOT era

- Improve MGB-IPH model towards 2D hydrodynamic simulations to take advantage of SWOT-like data

Test over major wetlands e.g. Amazon





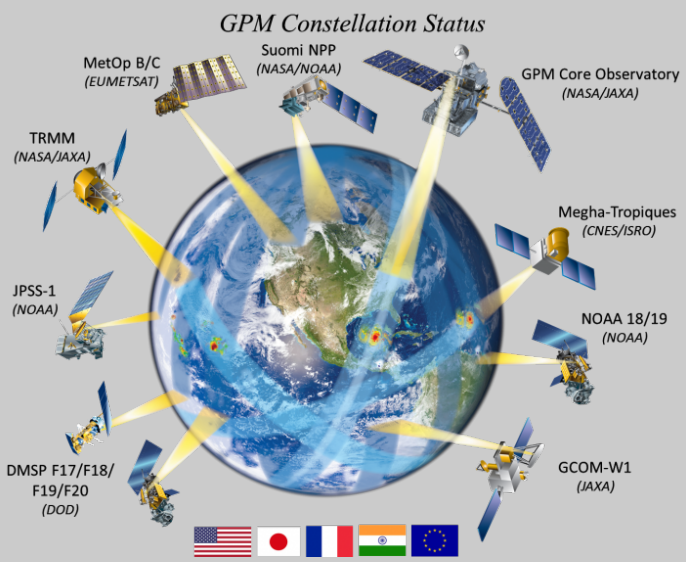
Validations using current satellite altimeters (e.g. ENVISAT, JASON, ICESAT, ICESAT2, Altika) and imagery satellites (e.g. LandSat, JERS-1, Alos Palsar)

SWOT-GPM synergies

Marielle Gosset, Daniel Villa (INPE)

- Different 'boxes' – Rainfall = an output of the 'atmospheric WC'- An entry to the Surface Water Cycle

- The 2 are coupled by the hydrological/land surface processes
  - The observed Rainfall/discharge relationship tells us about the hydrological/LS processes



Active (GPM-DPR radar Ka-Ku)
passive microwave constellation
+
Geostationnary satellite (IR)

-> combined rainfall products on regular grid – regular time steps

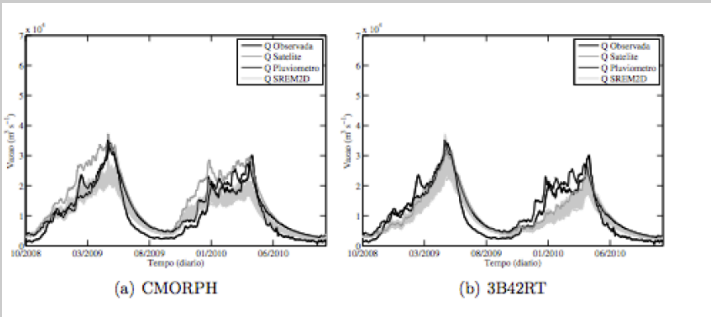
IMERG (10 km / 1h)
TAPEER – (50 km/6 h)

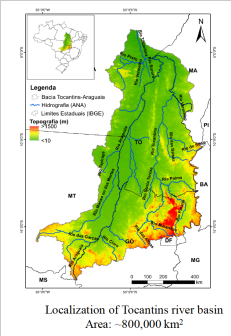
SWOT-GPM synergies

Marielle Gosset, Daniel Villa (INPE)

- The differences between observed/predicted relationship between discharge variability and rainfall variability is an indicator of :

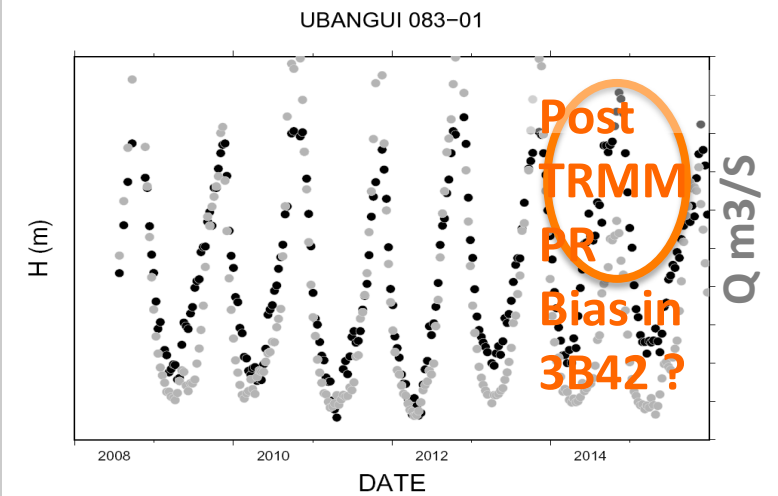
SRE error model and uncertainty propagagation in hydrological modeling
(here Tocantins basin Brazil) :





- Measurement errors/ uncertainties in rain? In water levels?

- Wrong representation/ understanding of hydrological processes?.

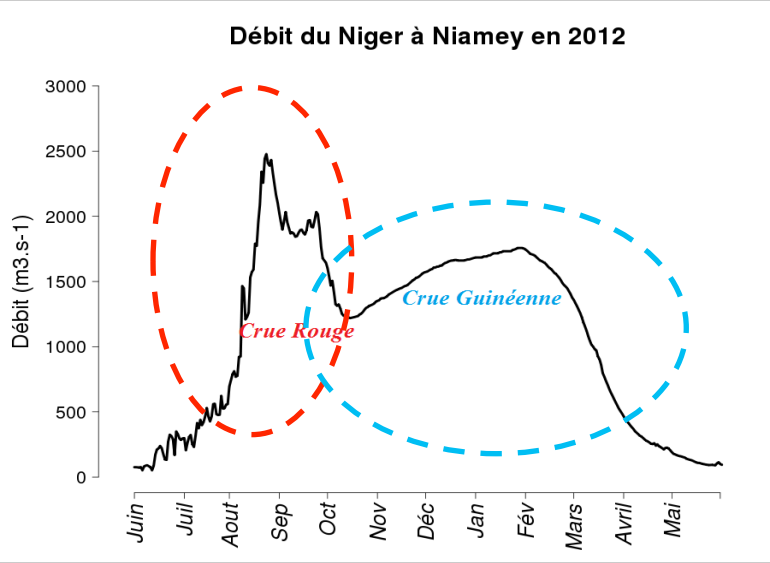


Congo River

SWOT-GPM synergies

Marielle Gosset, Daniel Villa (INPE)

- Different time-space scales :
  - River outflow = basin integrator
  - Rainfall variability explains some of the discharge variability
    - Rainfall observation + hydrol. Model can help ' fill the gap between SWOT water level sampling'

Niger River in Niamey

High frequency variability due to local convective rainfall superimposed to main flow :