Jet Propulsion Laboratory
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Estimating river hydraulic variables from the assimilation of SWOT observations

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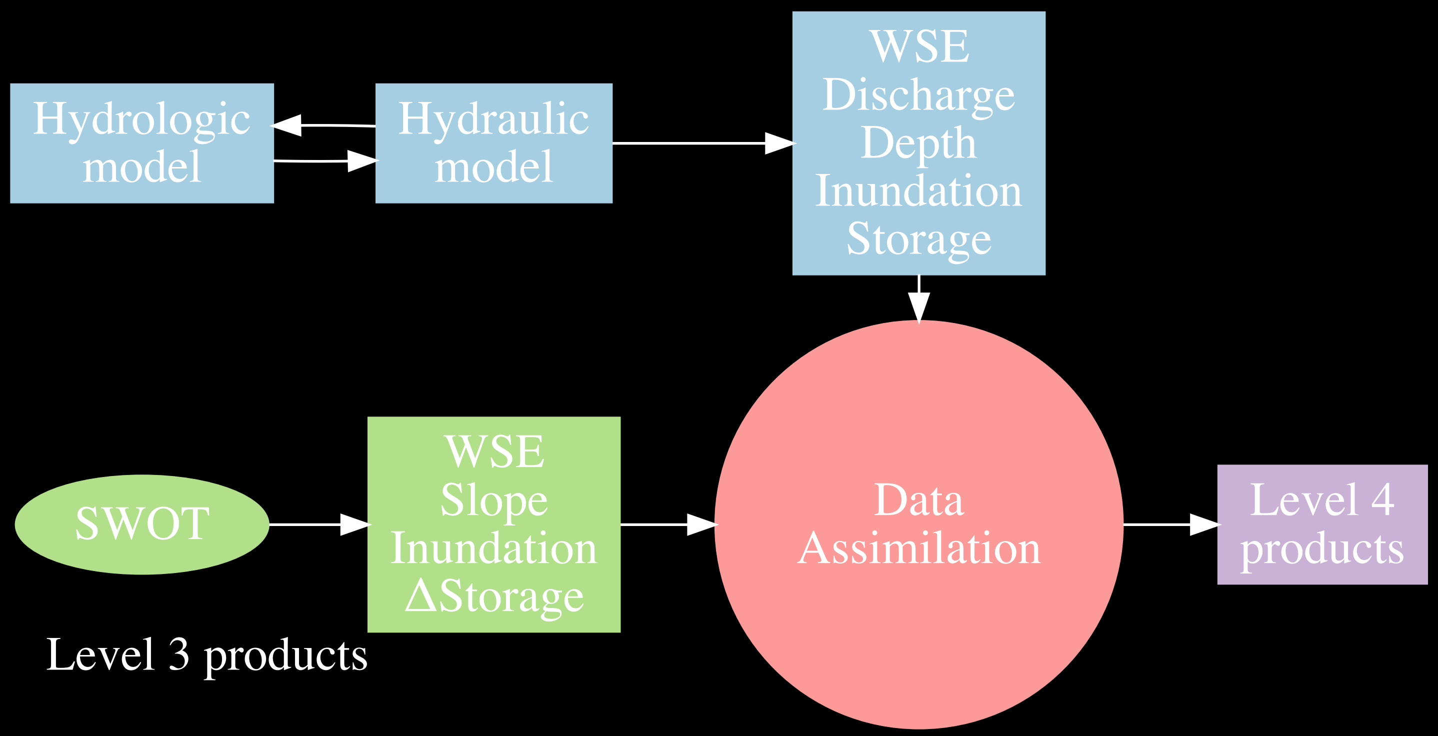
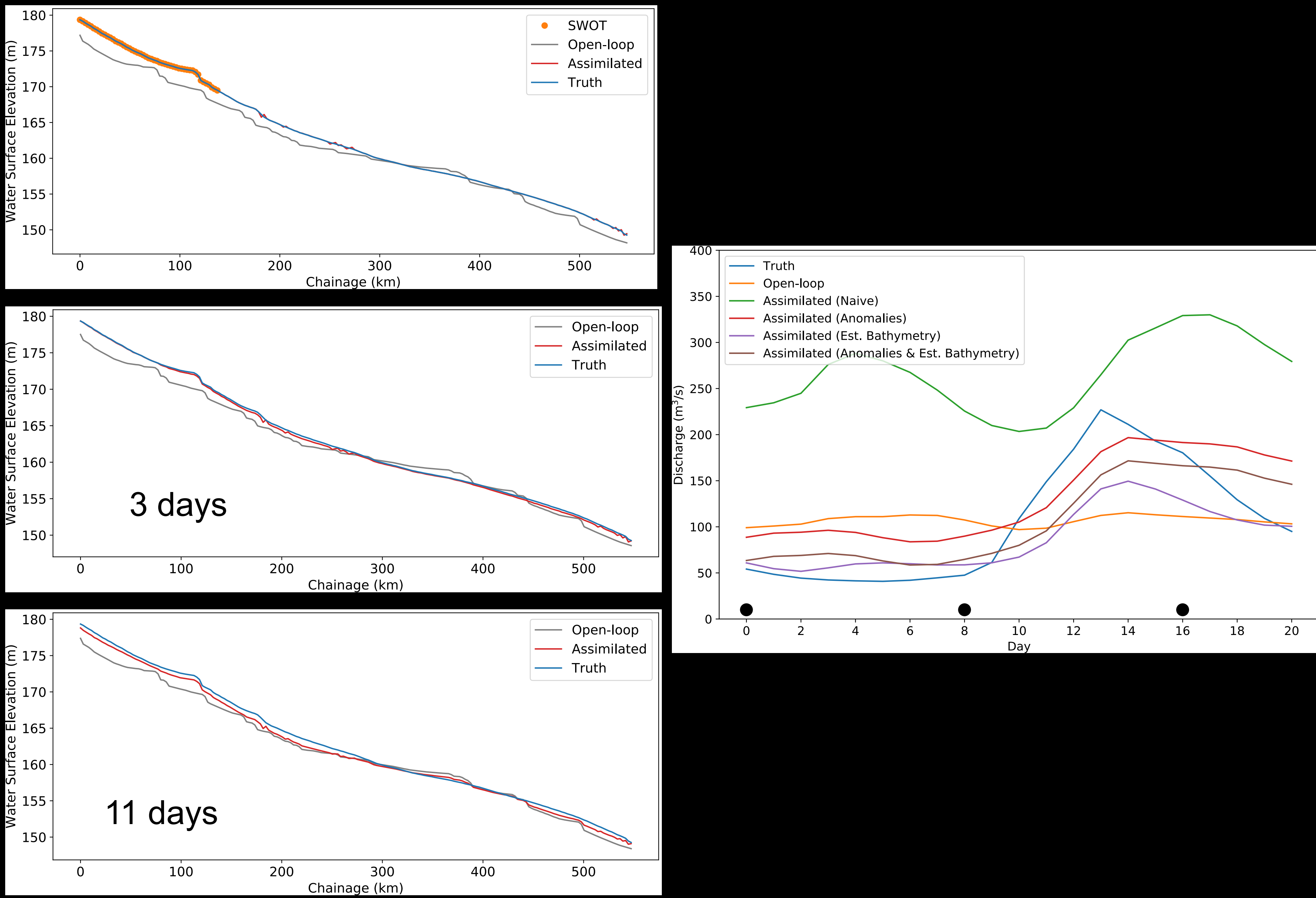
UCLA

SWOT Science Team Meeting, Montreal, 26-29 June 2018

CL#18-3600

Data Assimilation Framework




SWOT
Open-loop
Assimilated
Truth
Water Surface Elevation (m)
Chainage (km)
3 days
11 days
Truth
Open-loop
Assimilated (Naive)
Assimilated (Anomalies)
Assimilated (Est. Bathymetry)
Assimilated (Anomalies & Est. Bathymetry)
Discharge (m3/s)
Day

Getting discharge right
Is more than one reach, one time
hence, Missouri work

Flash talk

Mark Hagemann

June 28, 2018

Mass-conserved Manning's equation

$$Q_t = \frac{1}{n} W_{rt}^{-2/3} (A_{0,r} + \delta A_{rt})^{5/3} S_{rt}^{1/2}$$

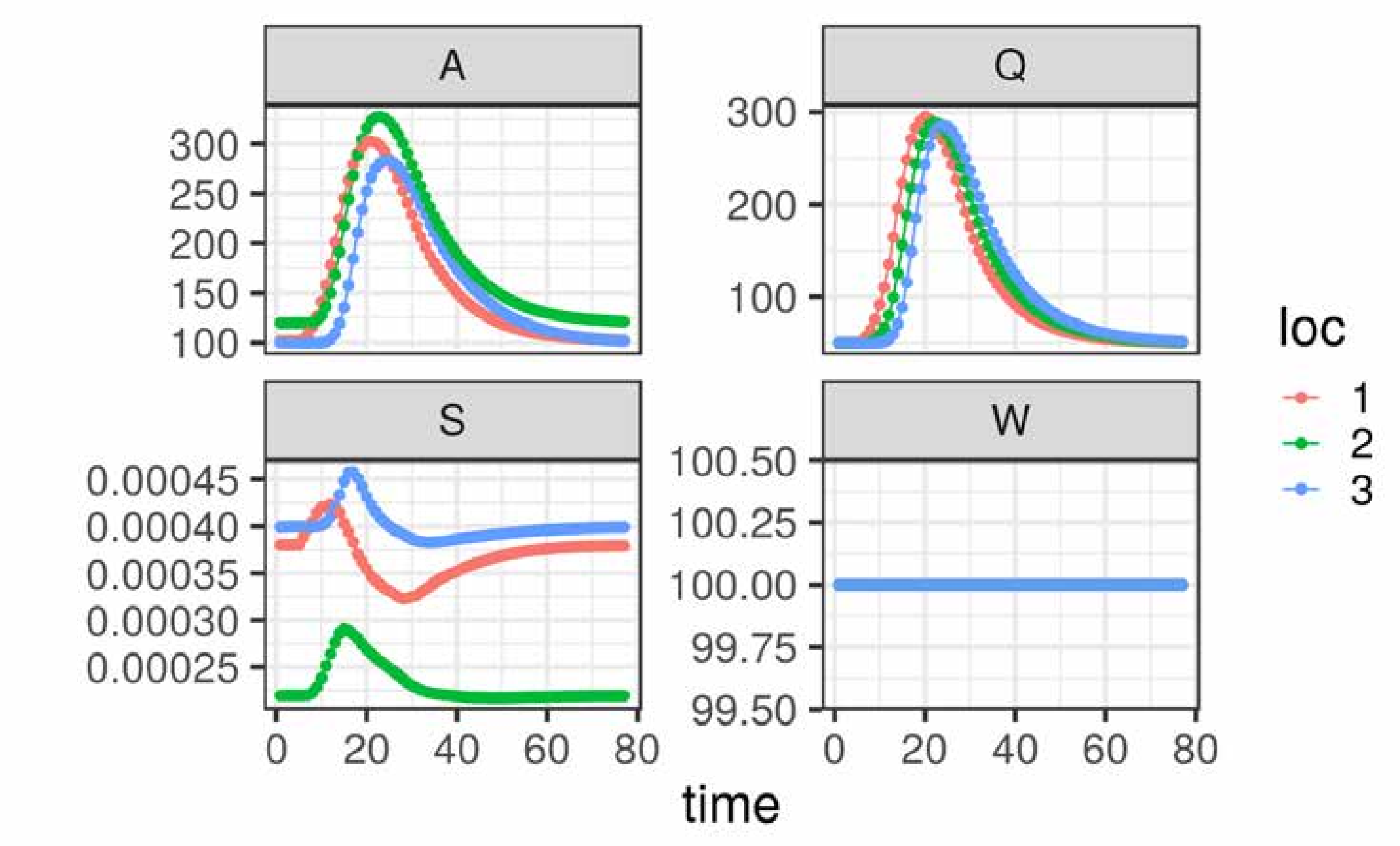
- Observed: $W_{rt}, \delta A_{rt}, S_{rt}$
- Unobserved: $Q_t, n, A_{0,r}$
- This model is nice, but does not hold perfectly.

Getting closure

$$Q_t = \frac{1}{n_{rt}} W_{rt}^{-2/3} (A_{0,r} + \delta A_{rt})^{5/3} S_{rt}^{1/2}$$

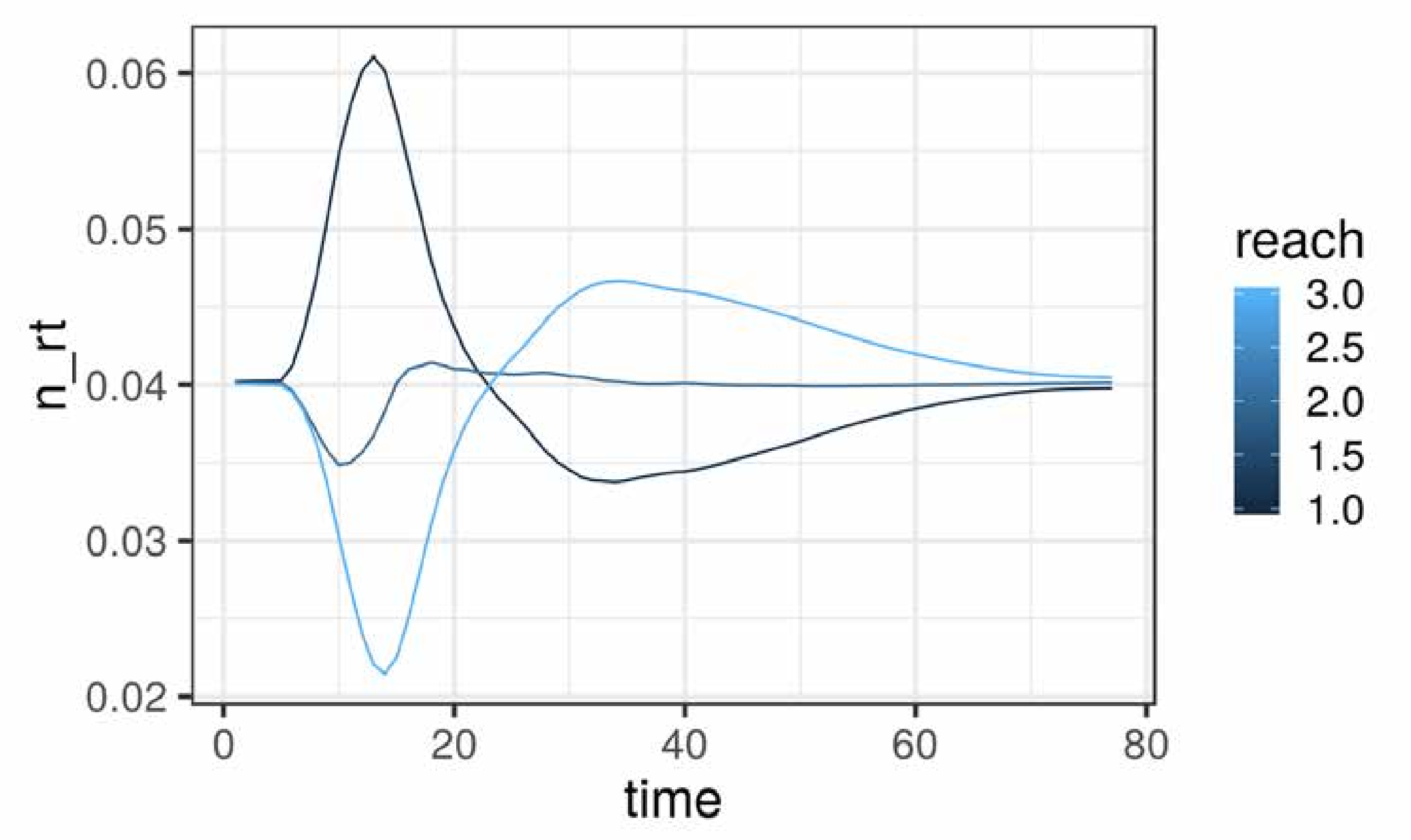
Treating n_{rt} as a closure term forces the equation to hold.

Lisflood toy model



Getting closure

$$Q_t = \frac{1}{n_{rt}} W_{rt}^{-2/3} (A_{0,r} + \delta A_{rt})^{5/3} S_{rt}^{1/2}$$



USGS POSTER - *Operational Remote Sensing of River Discharge*

Near-term Goal: Establish 2 Virtual Stream Gages (VSG) in Alaska

Objectives

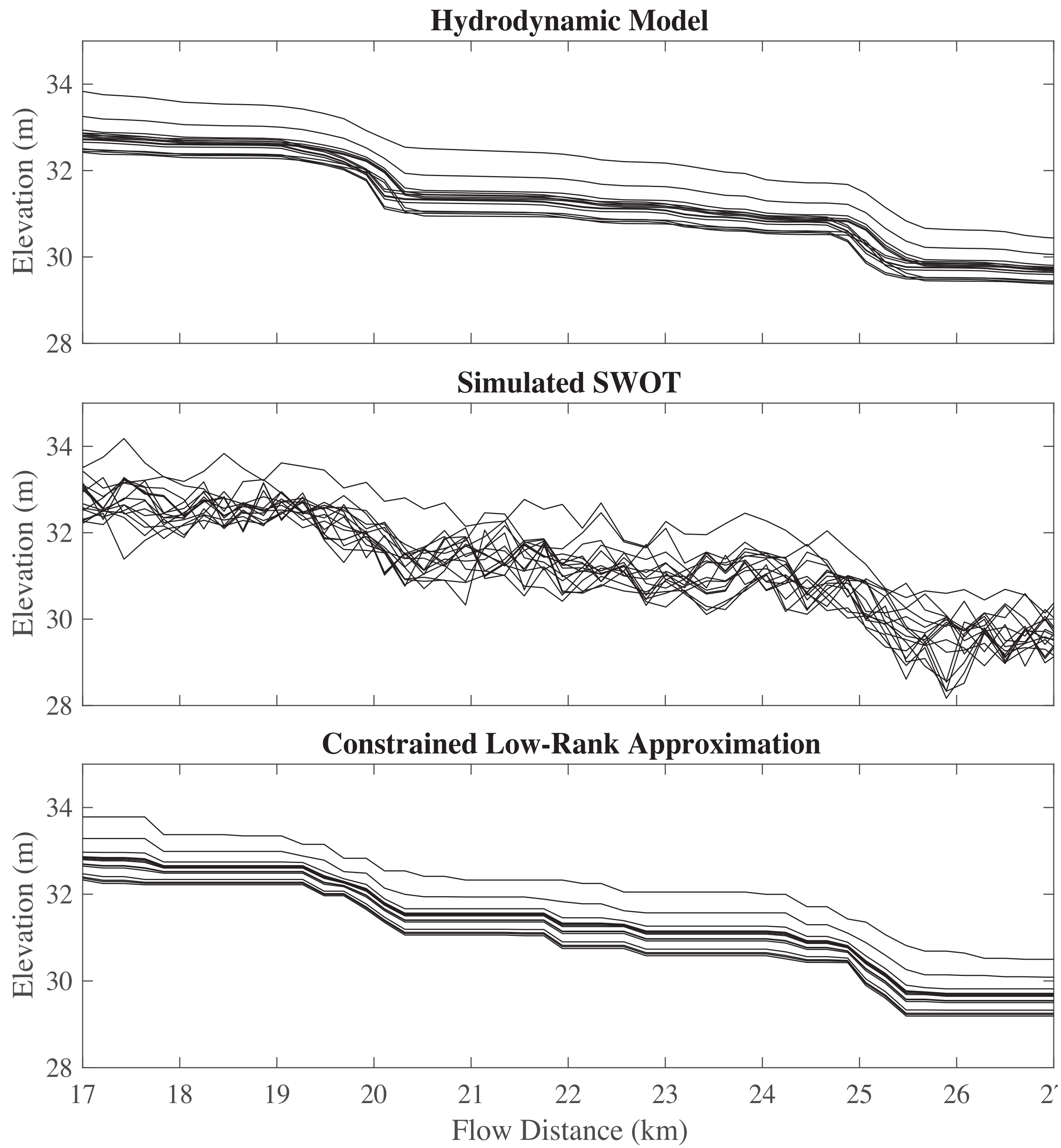
- Independent Q estimate for each width, height, slope observation (max 10% error)
- Operational assessment of width-stage data quality and relation to understand expected error
- Lengthy time series through multi-satellite approach (DSWE, ERS, JASON, Sentinel)
- Safe, fast, cost-effective calibration through drone technology
- Publish/distribute generated data
- Increase Q information in remote environments/build USGS VSG capacity

Key issues:

- First order stage-width relation (linear) and quality control
- Selection of gage-reach: geomorphologic and width-stage quality control considerations.
- Methods to calibrate manning flow resistance parameter and how many calibration points are needed to derive ratings

Opportunities:

- USGS gage data as "ground truth"
- Test USGS and SWOT discharge algorithms



Hydrodynamic Model
Elevation (m)
34
32
30
28
Simulated SWOT
Elevation (m)
34
32
30
28
Constrained Low-Rank Approximation
Elevation (m)
34
32
30
28
17
18
19
20
21
22
23
24
25
26
Flow Distance (km)

The use of HAND for large-scale SWOT discharge estimation

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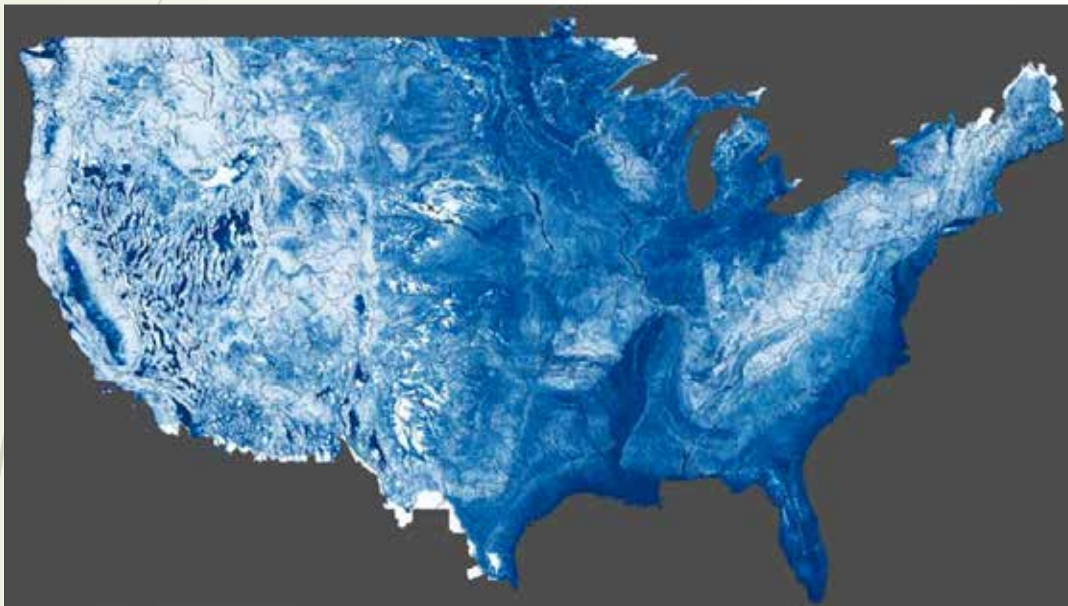
Civil and Environmental Engineering

Princeton University

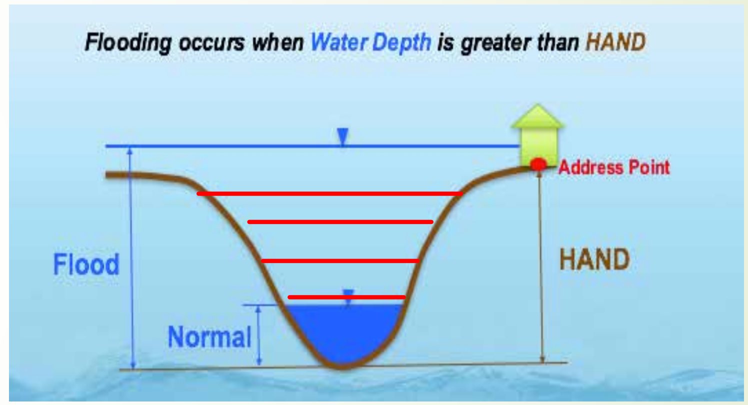
HAND – Height Above Nearest Drainage

River

- A seamless terrain analysis method to assess flood risk;
- Recently further developed to estimate "active channel geometry"



Normalized topography above its local drainage; pre-computed for 2.7 million NHDPlus reaches in CONUS



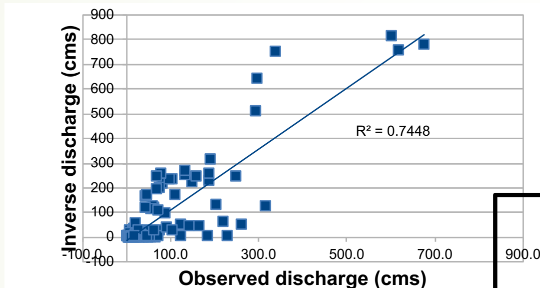
D (ft)	W (m)	HR (m)	A (m^2)	…
0	46.45	0	0	…
1	87.38	0.256	22.36	…
2	101.36	0.5	51.25	…
…	…	…	…	…
83	500.12	3.2	200.25	

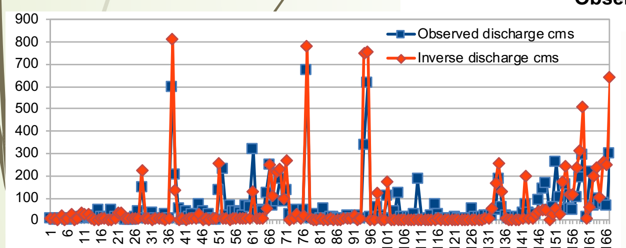
(Liu et al. 2018; Zheng et al. 2018)

Simple test cases

USGS 06879100
Kansas River at Fort Riley, Kansas

- ~60 m wide, no significant baseflow



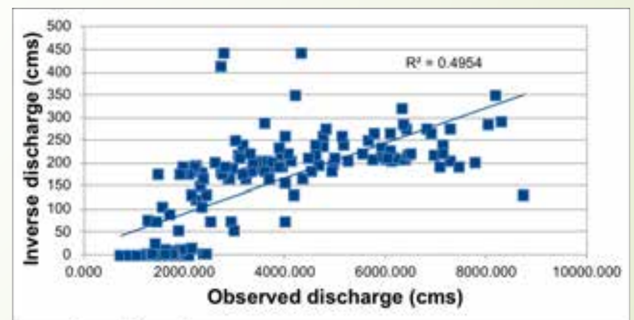


Bottom width in HAND ≈ actual channel bottom width

W (m)	HR (m)	A (m²)
46.4551	0	0
87.3881	0.256	22.368
101.3685	0.5056	51.257
...	...	...

Station Number 06934500
Missouri River at Hermann, Missouri

- > 300 m wide, with significant baseflow

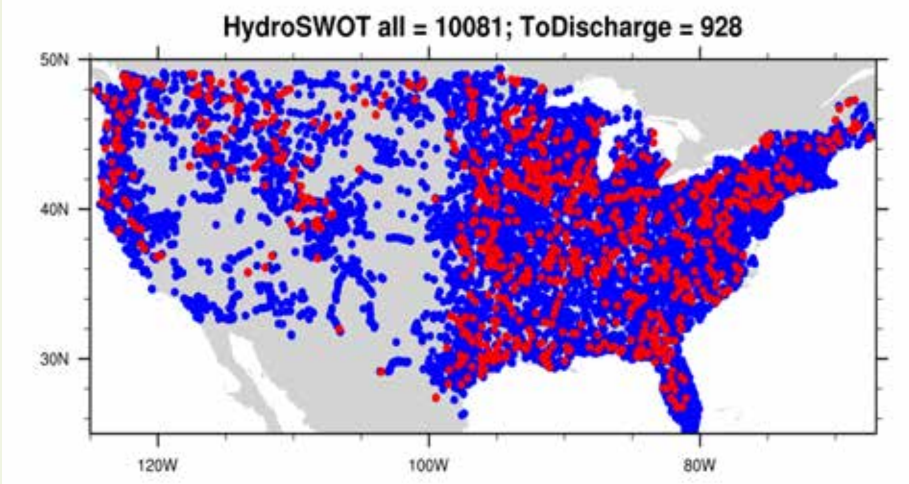


- R^2 not too bad, but significant underestimation
- Reason: bottom width in HAND-derived geometry is baseflow width (DEM bottom), instead of channel bottom

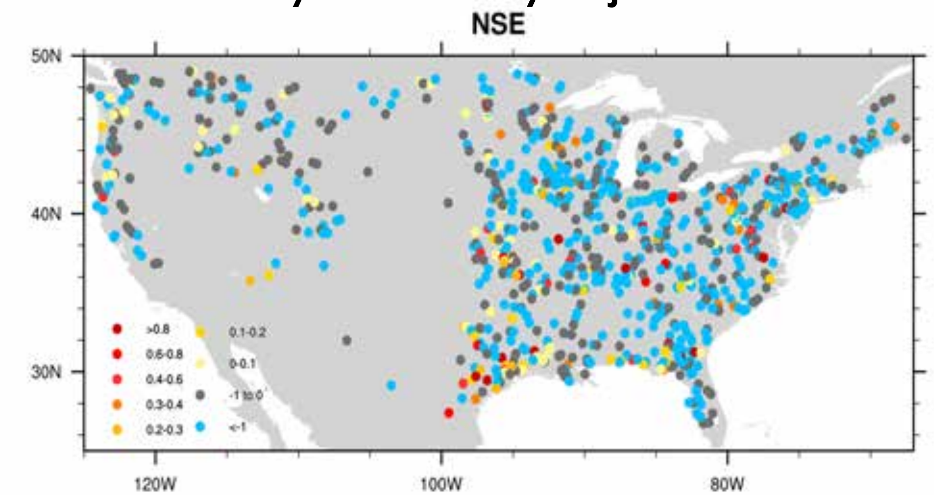
HAND geometry table

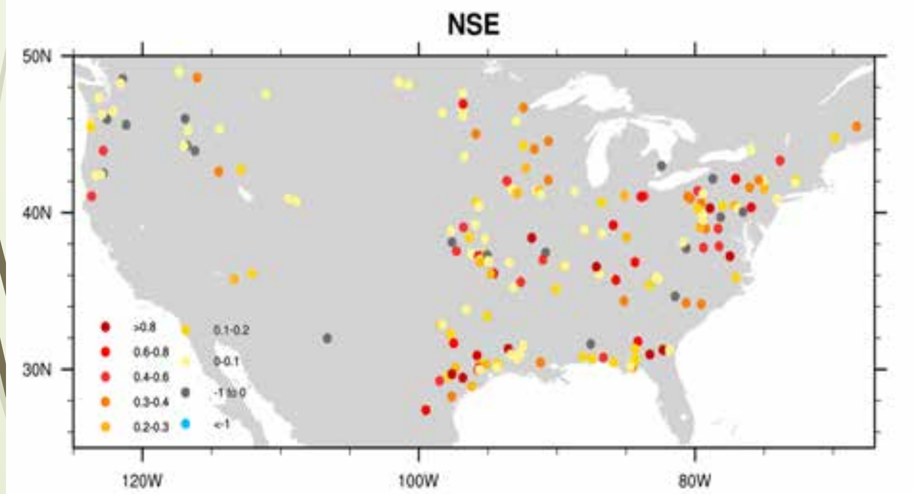
W (m)	HR (m)	A (m²)
248.4641	0	0
379.9939	0.2711	103.0283
389.4982	0.5663	220.5603
...	...	...

Large-scale discharge estimation
– HydroSWOT as "SWOT observations"

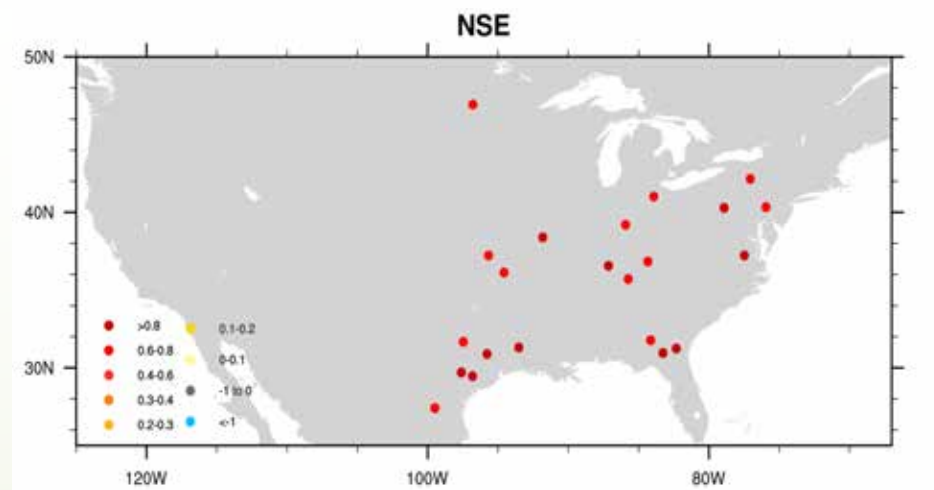


Not satisfactory without any adjustment to HAND



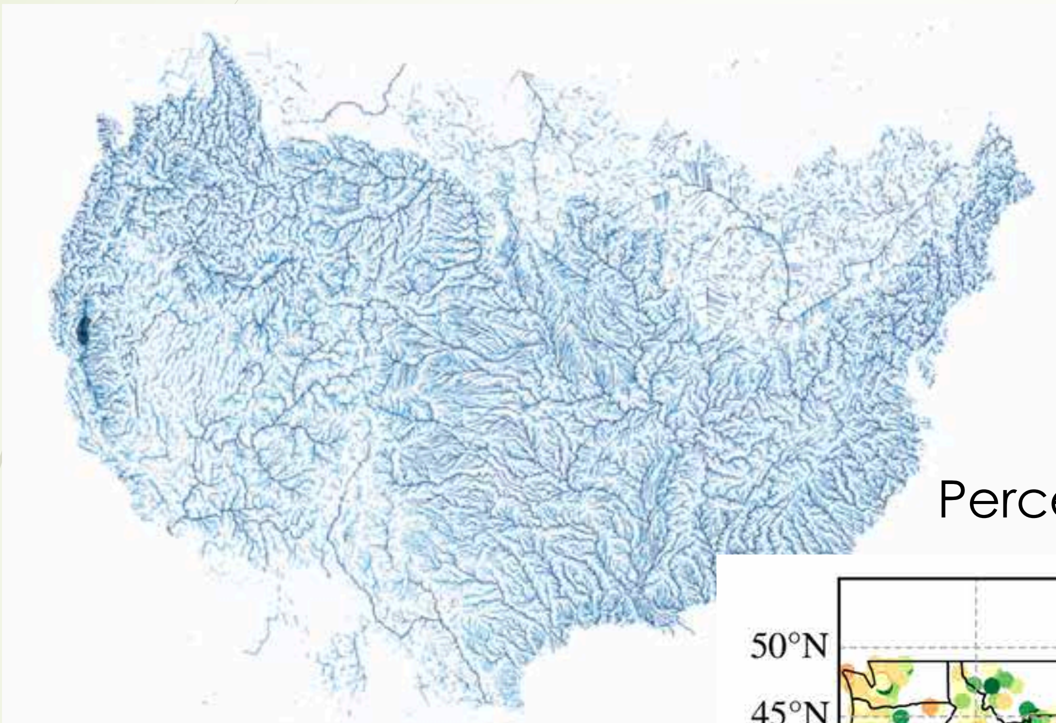


183 out of 928: some skill



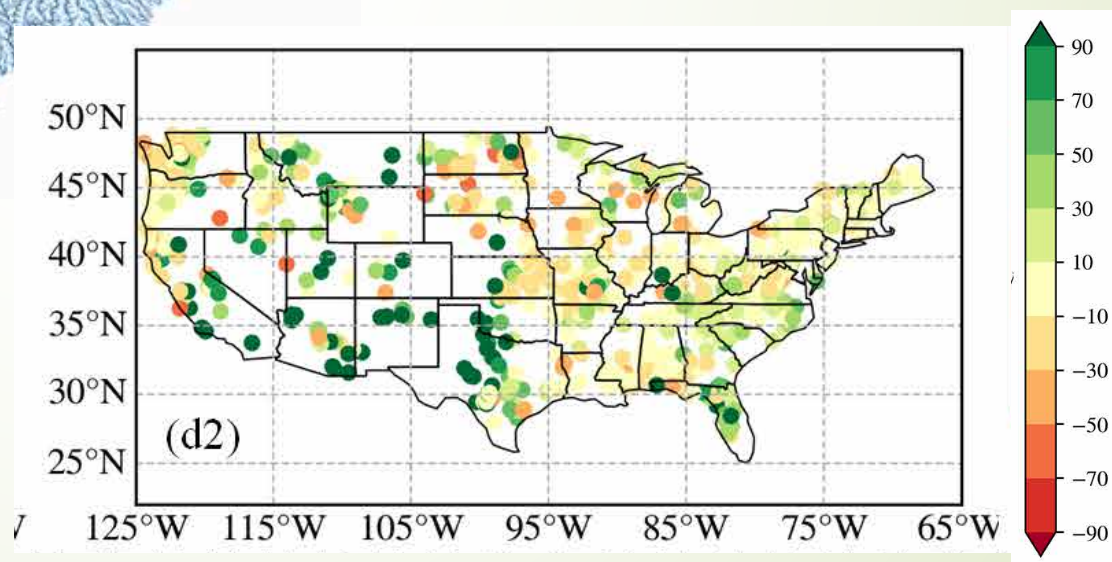
22 out of 928: very good skill

Model simulated streamflow climatology (VIC+HRR: 1915–2011)

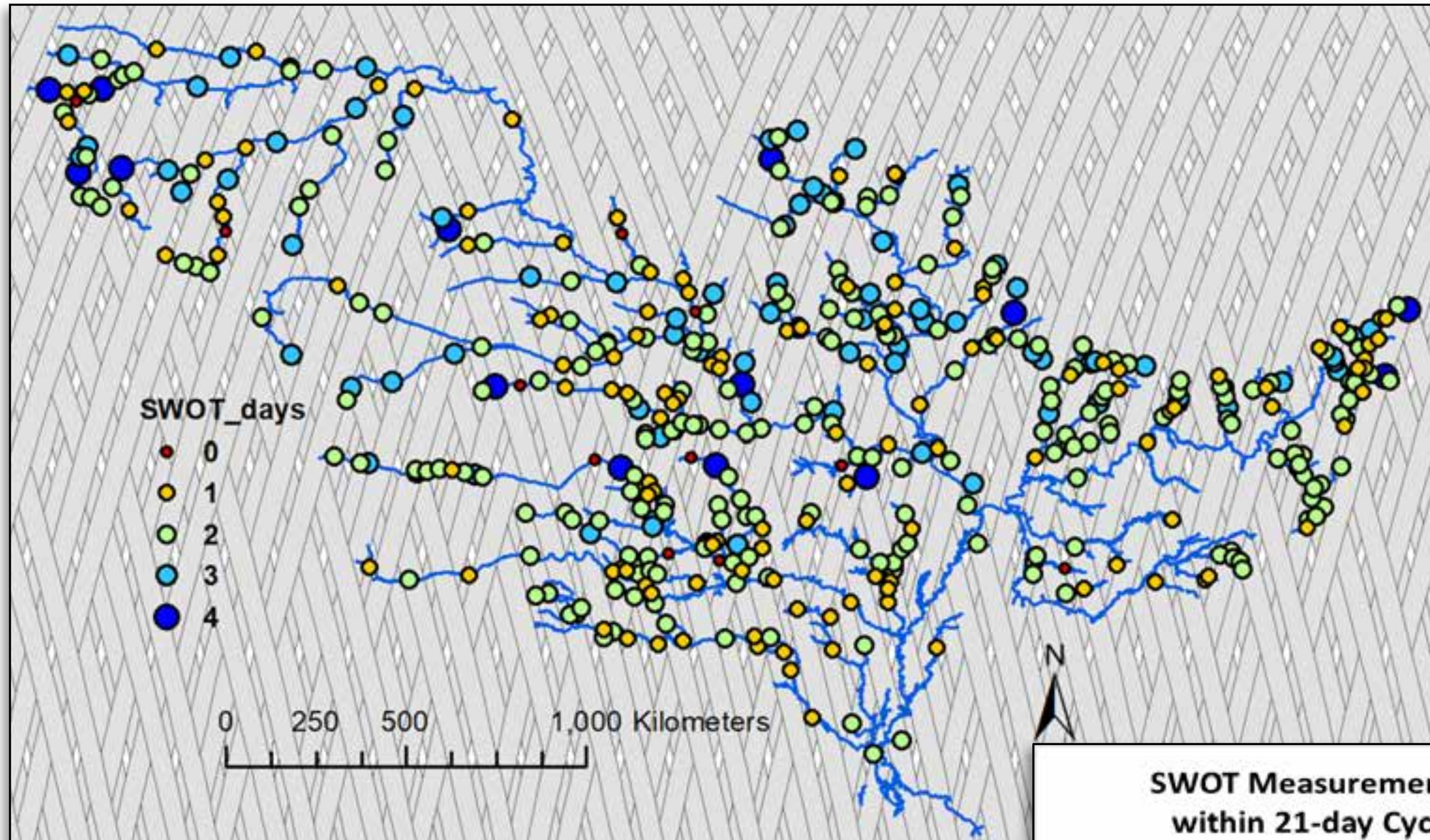


Use bias-corrected Q_o to adjust HAND bottom for every river reach

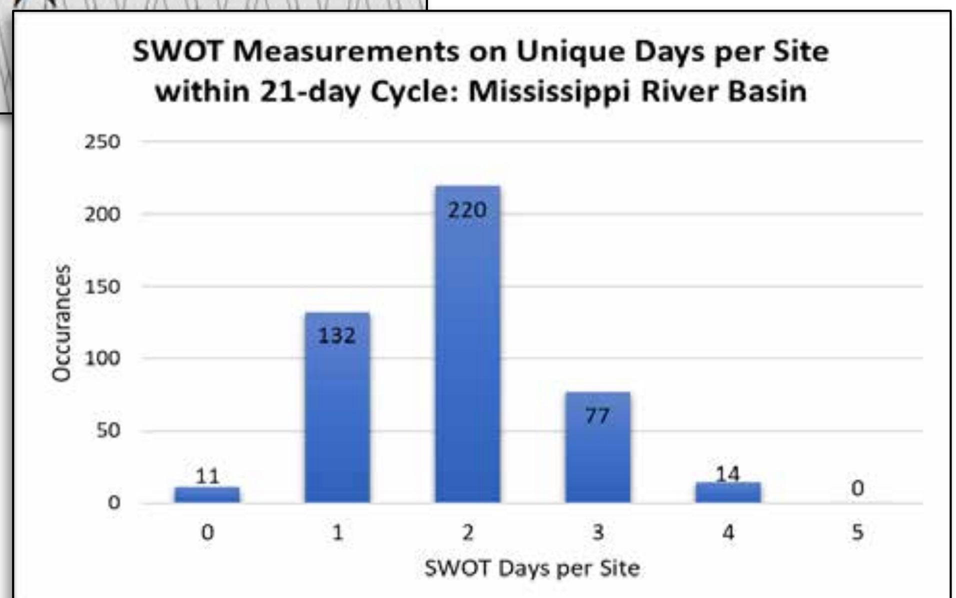
Percentage bias (2002–2011)



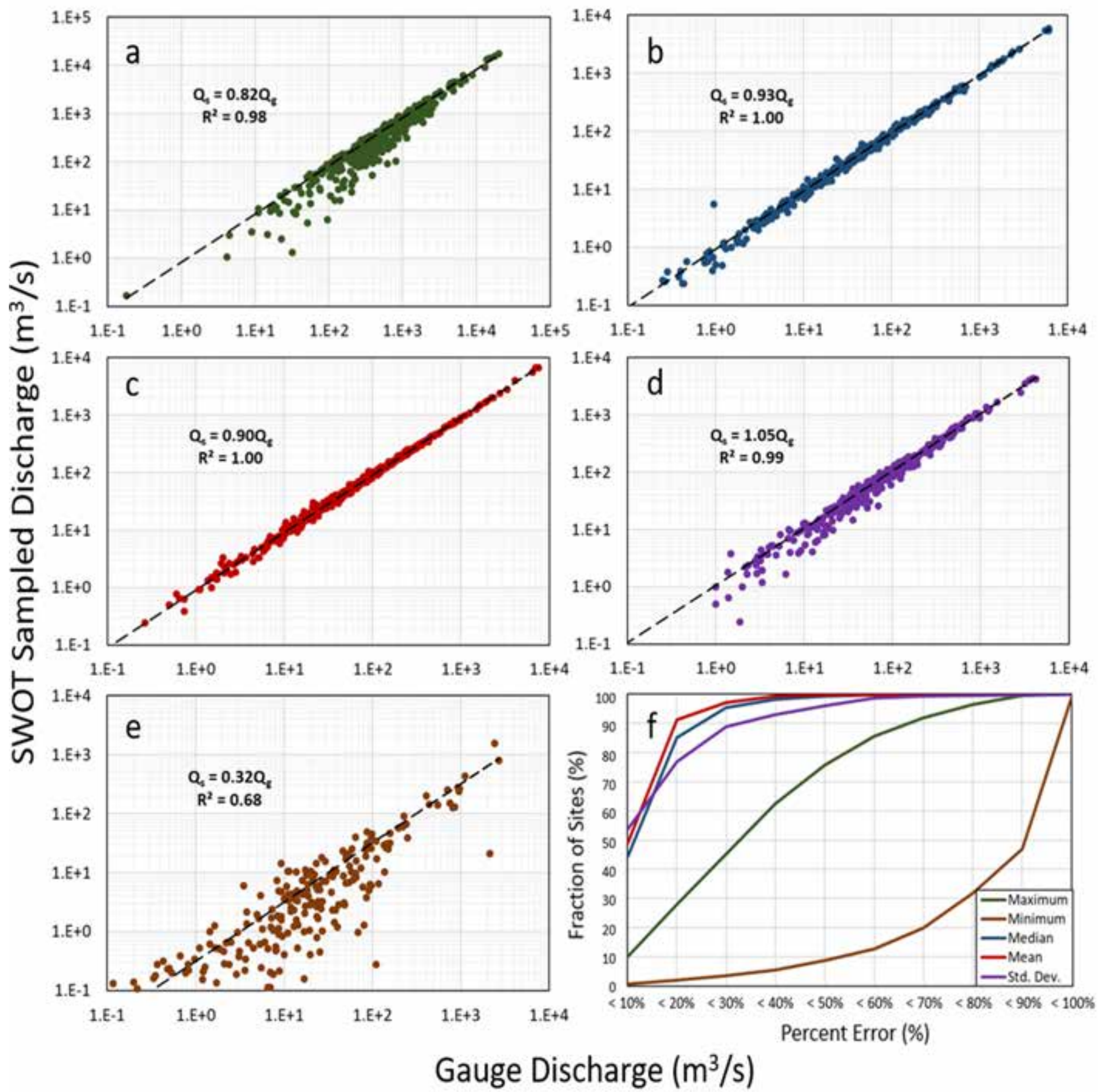
(Courtesy to Yuan Yang for model simulation and statistics mapping)



What will SWOT see at my site?



Comparing Annual Streamflow Statistics & Percent Errors



Willamette ‘in-situ’ results