Global High-resolution A Priori River Discharge for SWOT

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June 19th, 2019
SWOT Science Team Meeting

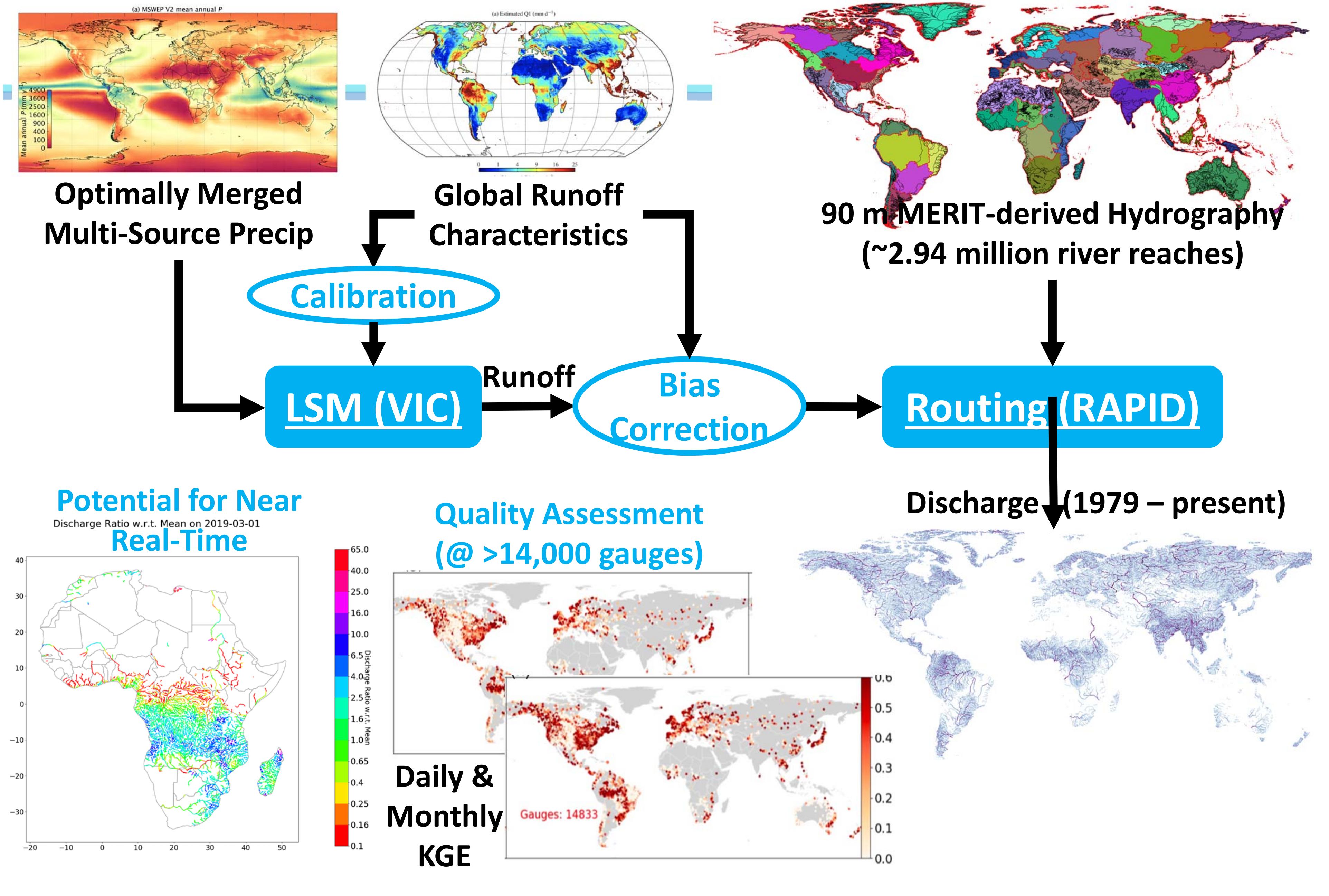
PRINCETON UNIVERSITY

Motivations and Goals

- Discharge retrieval is an **under-constrained problem** (e.g. unknown channel geometry, roughness)

- Retrieval quality (e.g. bias, variability range) strongly depends on **prior information (talks by Garambois, Larnier, Frasson, ...)**

- Goal: **global best-quality a priori discharge** database through a carefully designed **modeling effort** (VIC/RAPID) at **high resolution**



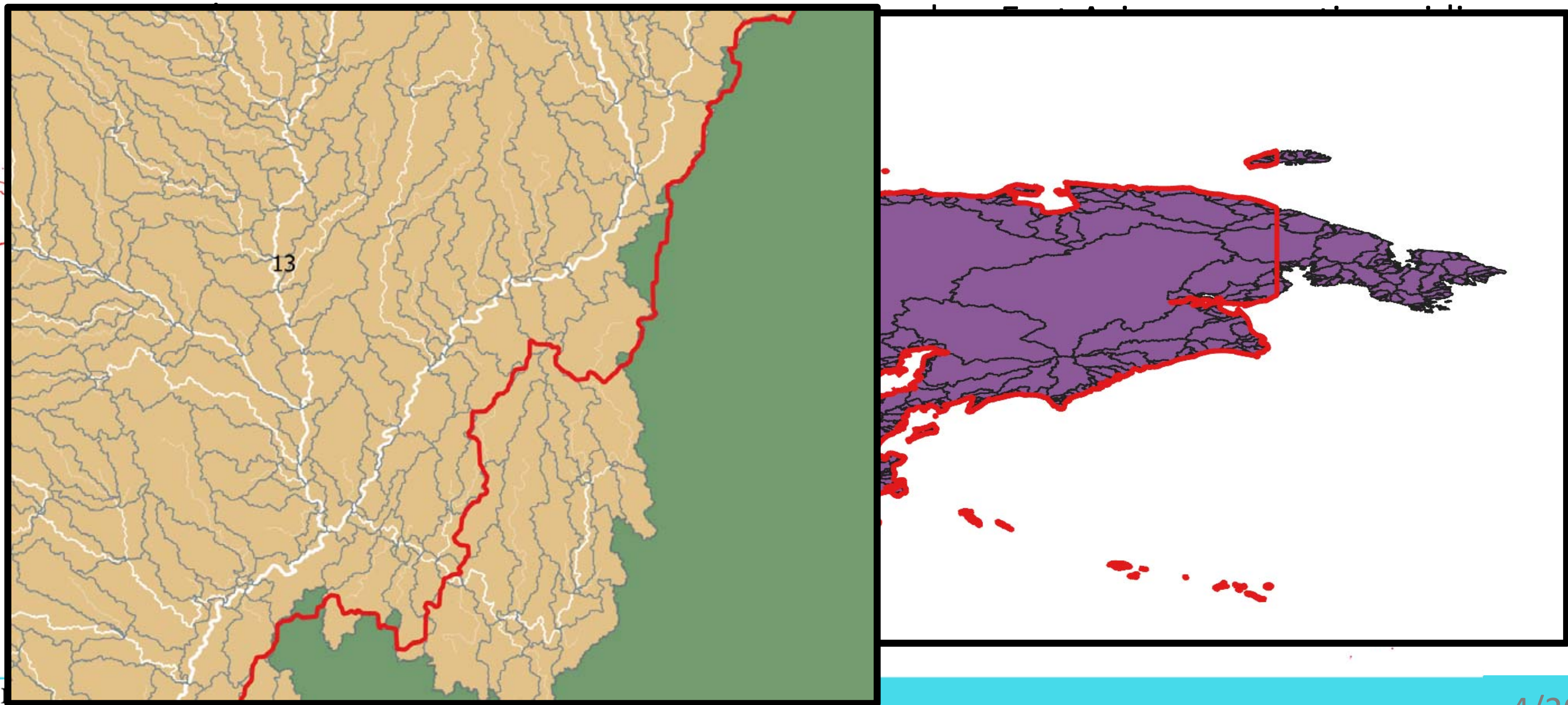
(a) MSWEP V2 mean annual P
Optimally Merged Multi-Source Precip
Global Runoff Characteristics
90 m MERIT-derived Hydrography (~2.94 million river reaches)
Calibration
LSM (VIC)
Runoff
Bias Correction
Routing (RAPID)
Discharge (1979 – present)
Potential for Near Real-Time
Discharge Ratio w.r.t. Mean on 2019-03-01
Quality Assessment (@ >14,000 gauges)
Daily & Monthly KGE
Gauges: 14833

Extract rivers/basins: MERIT-Hydro → MERIT-Basins

- **MERIT (Multi-Error-Removed Improved-Terrain) DEM** (**Yamazaki et al. *2017***)
  - Full global coverage (with >= 60°N);
  - 3s flow accum/dir (MERIT-Hydro, Yamazaki et al., 2019, WRR)

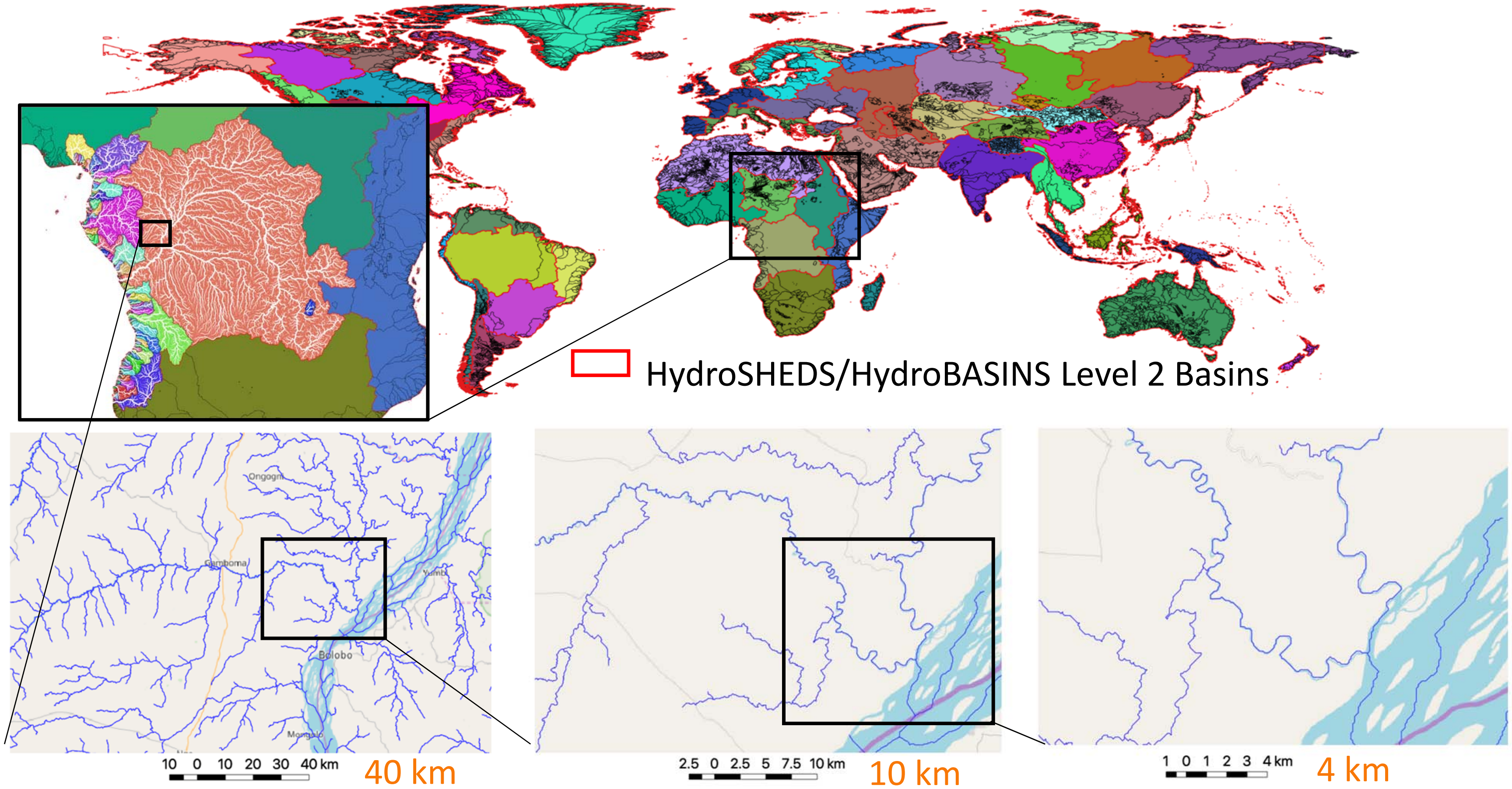
✓ **Deriving global hydrography: vectorized 2.94 million river reaches & catchments**

- o Channelization threshold: **25 km²** drainage area
- ▪ **Basin/region definition: HydroBASINS level 1 and 2**



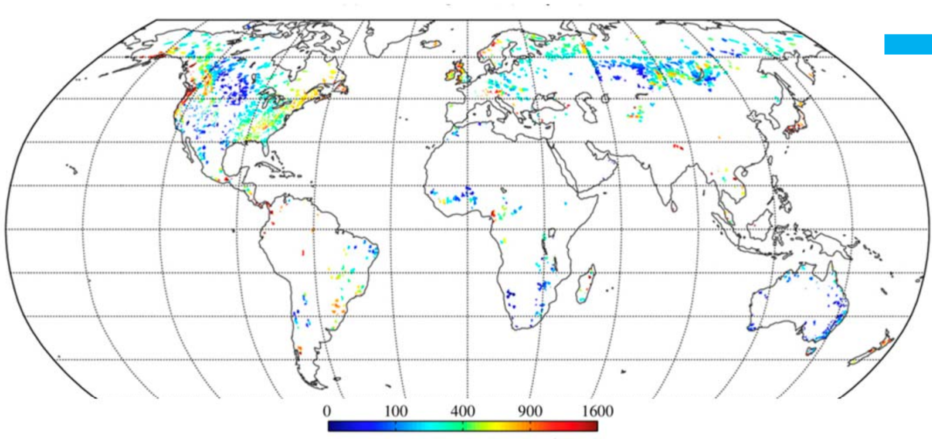
Channel/network properties for modeling

- **2.94 M reaches & catchments + properties (e.g. COMID, *slope, connectivity) organized at Level 1 (9 regions) and Level 2 (61 basins)***
- ***MEDIAN = 6.8 km; MEAN = 9.2 km; TOTAL LENGTH = 2.6x10⁷ km***

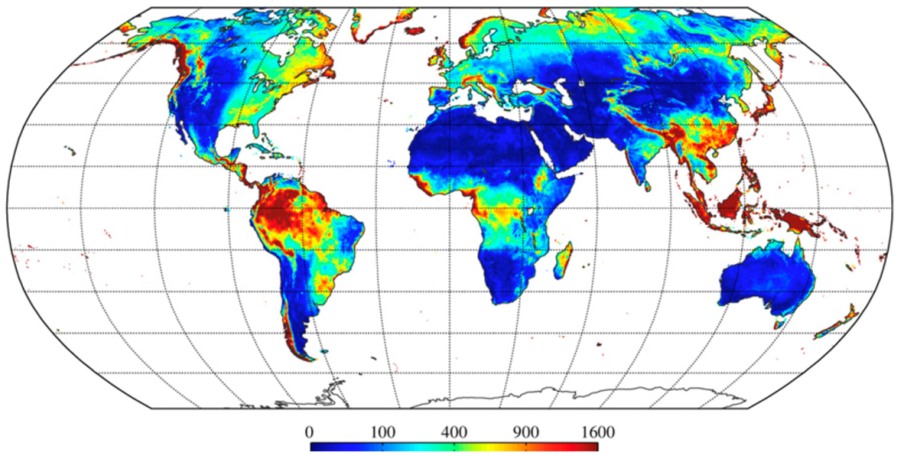


Runoff characteristics derived from machine learning

Q_{MEAN} from >3,000 naturalized catchments



Regionalization via ML: trained against 20 climate, topography, geology, land cover, soil factors

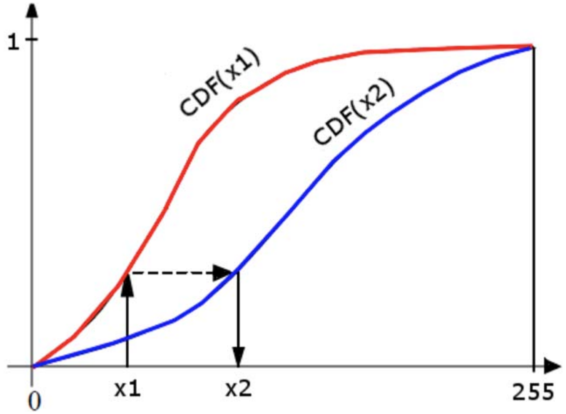


Similarly, Q_1, Q_5, Q_{10}, Q_{20}, Q_{50}, Q_{80}, Q_{90}, Q_{95}, Q_{99}, and BFI are derived globally (Testing R^2: 0.55 – 0.93)

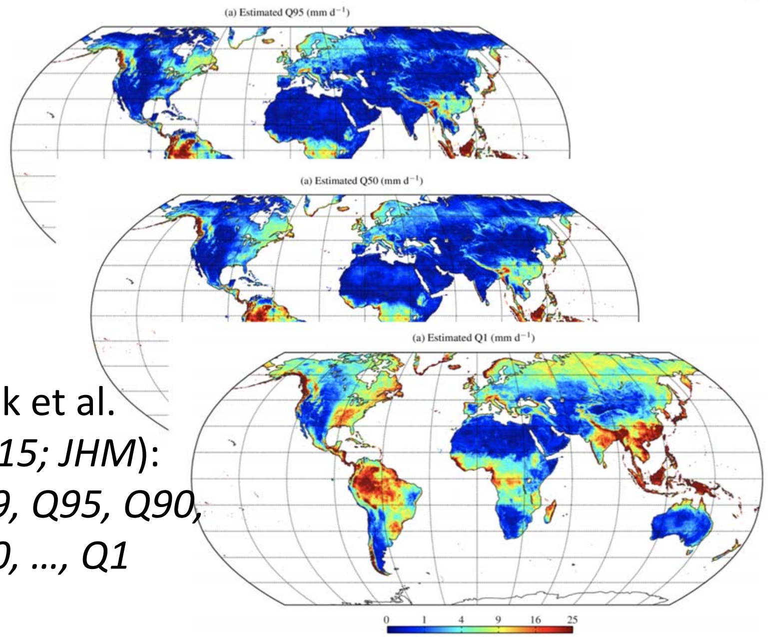
Beck et al. (2015; *JHM*)

New bias correction method: “Sparse CDF Matching”

- Traditional bias-correction: CDF matching

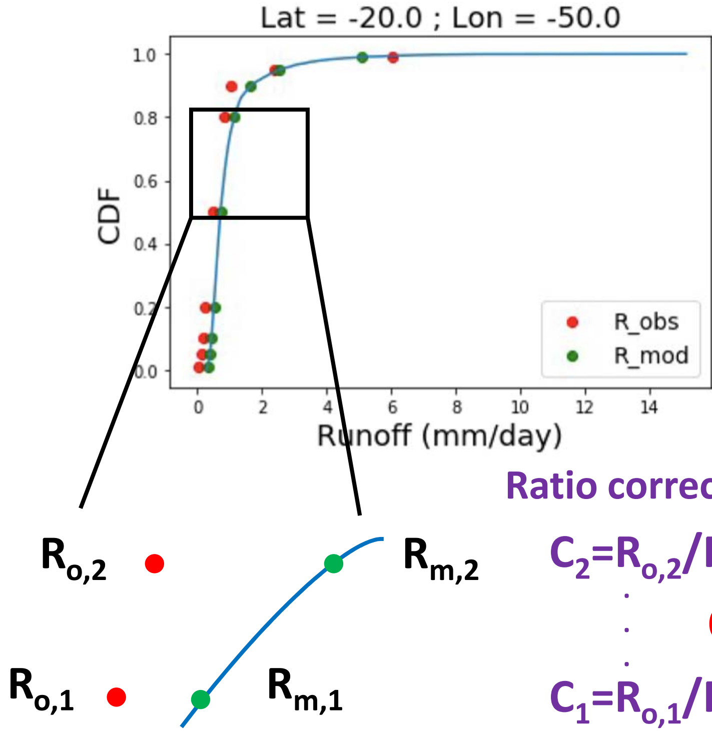


- Q characteristics from machine learning



Beck et al. (*2015; JHM*): *Q99, Q95, Q90, Q50, …, Q1*

- What if no full CDF of the reference data?



Ratio correction factor:

$C_2 = R_{o,2}/R_{m,2}$

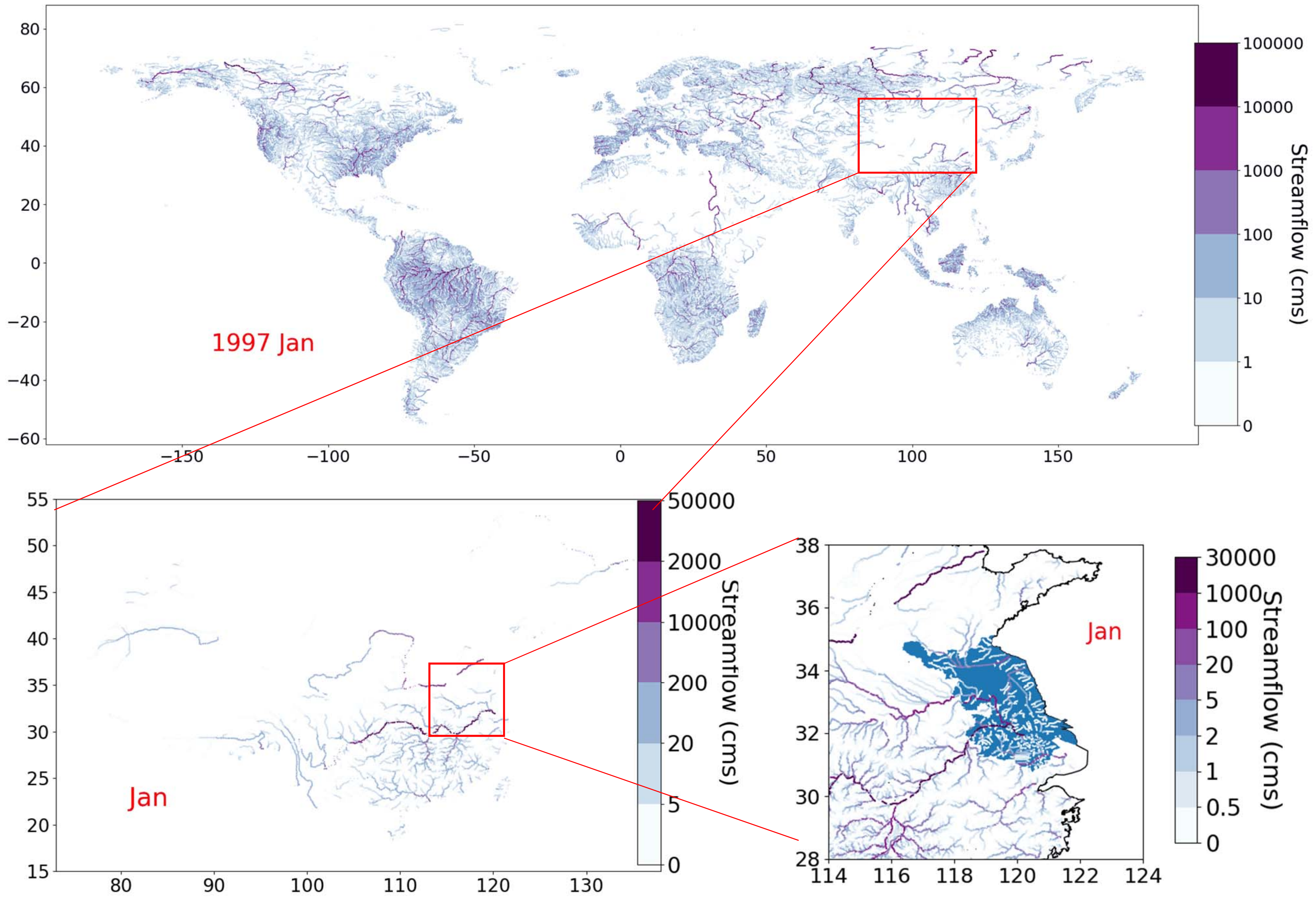
C_j?

$C_1 = R_{o,1}/R_{m,1}$

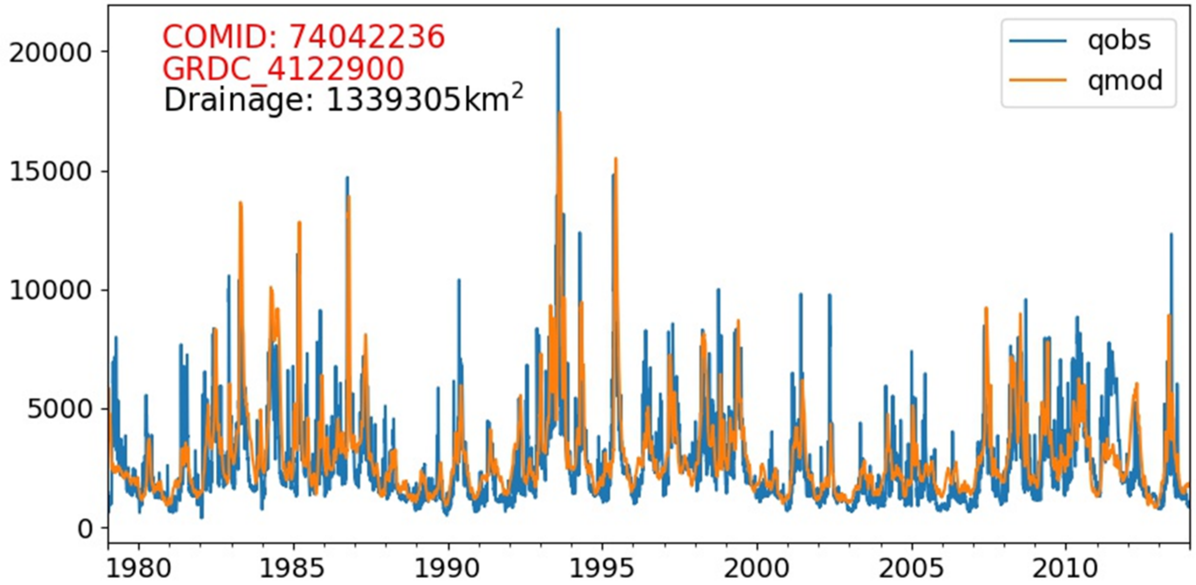
Assume error is log-linear:

- $C_j = C_1^{\,1-j/N} \cdot C_2^{\,j/N}$
- j and N are the j-th element and total number of element in between C_1 and C_2

40-year daily discharge @ 2.94 x 10^6 reaches



Performance Metrics



CC: 0.63

BR: 1.14 (PBIAS: 11.4%)

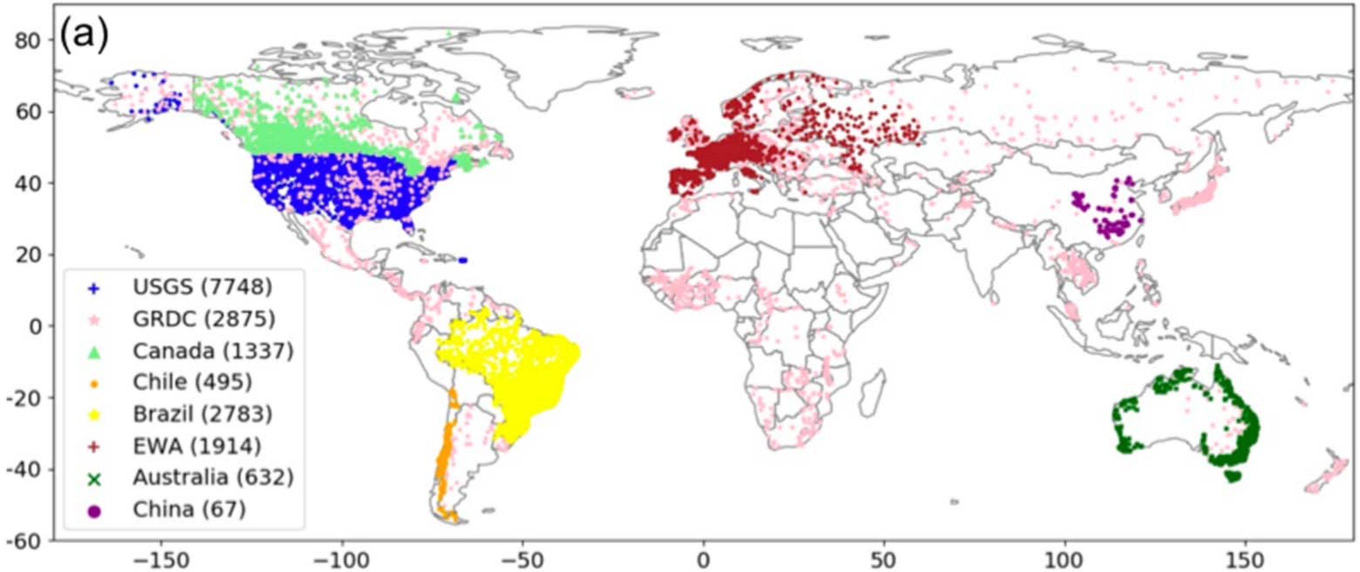
RV: 0.95

KGE: 0.6

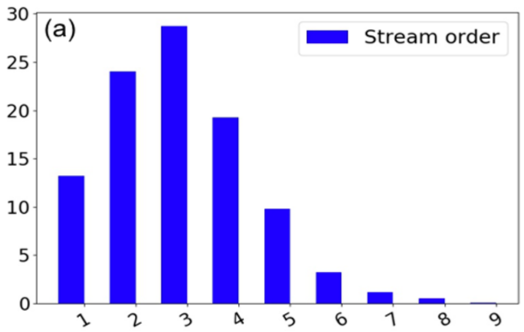
- **Correlation:** $CC = \frac{cov(Q_m, Q_o)}{\sigma_{Q_m} \cdot \sigma_{Q_o}}$
- **Bias Ratio:** $BR = \overline{Q_m} / \overline{Q_o}$; **Percentage Bias**: PBIAS= $\frac{\overline{Q_m} - \overline{Q_o}}{\overline{Q_o}} \times 100\%$
- **Relative variability:** $RV = (\sigma_{Q_m} / \overline{Q_m}) / (\sigma_{Q_o} / \overline{Q_o})$
- $\boldsymbol{KGE = 1 - \sqrt{(CC-1)^2 + (BR-1)^2 + (RV-1)^2}}$

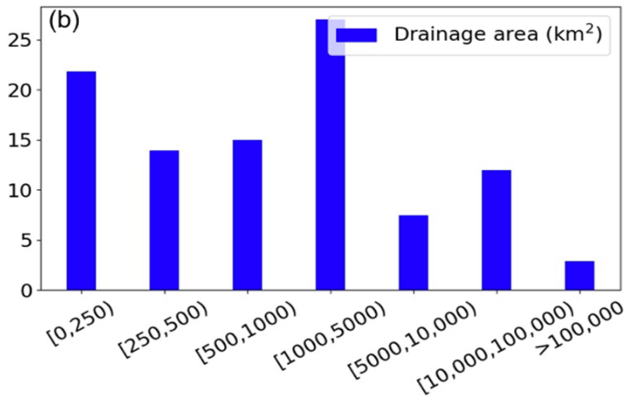
Evaluation at >14,000 gauges globally

A global database of daily streamflow obs @ >21,000 gauges



(Data source: Hylke Beck @ Princeton University)

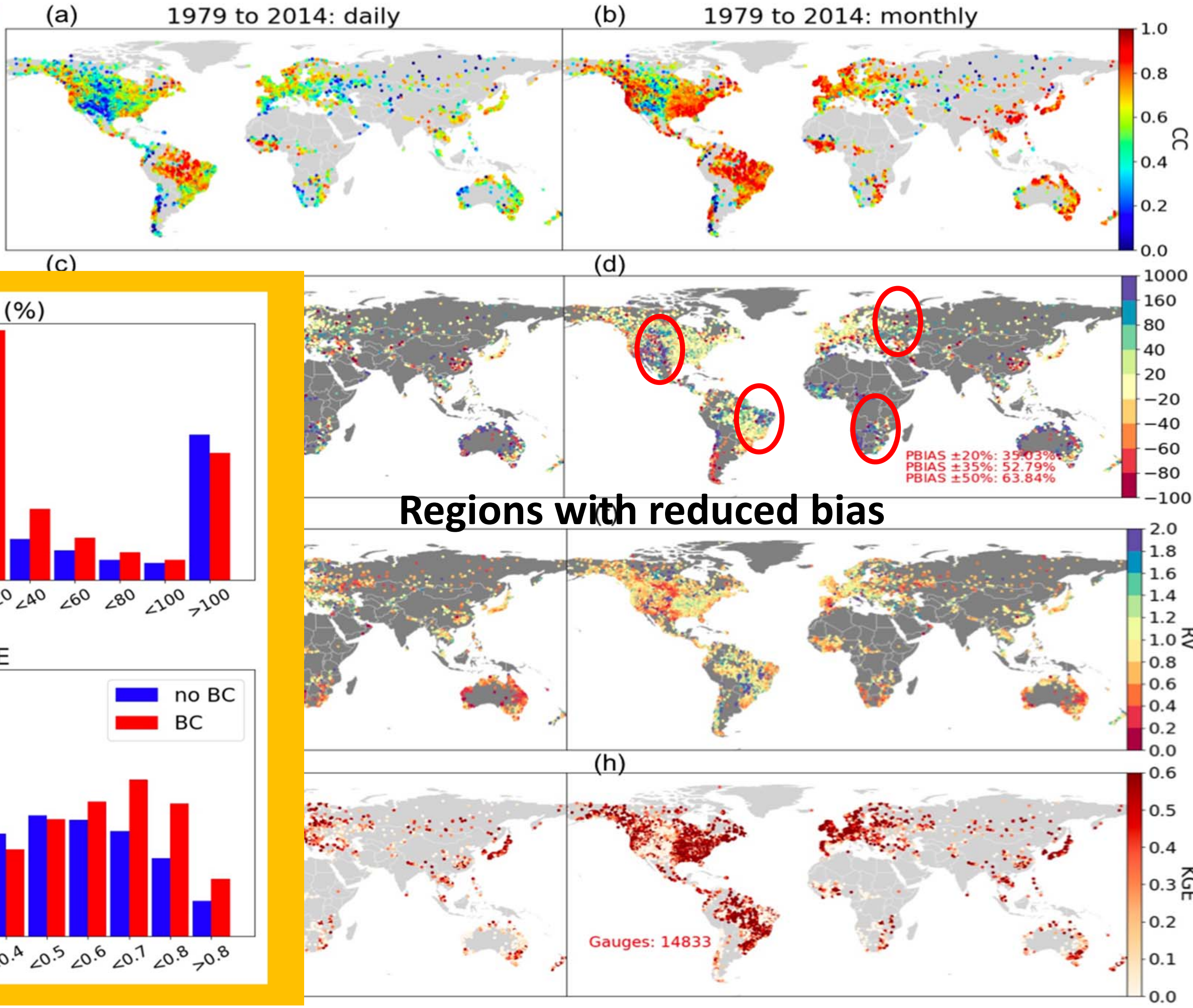


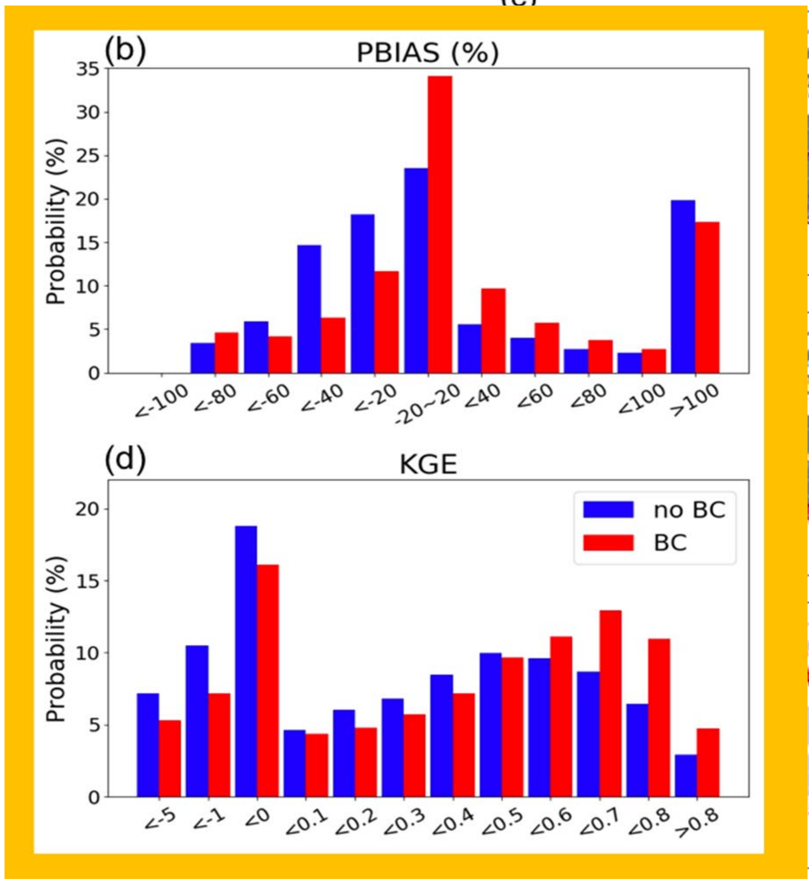


- Uneven distribution
- Covering spectrum of stream orders (from small creeks to large streams)

Performance (after Bias Correction)

Correlation Coefficient





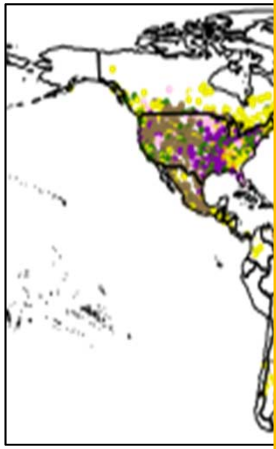
Regions with reduced bias

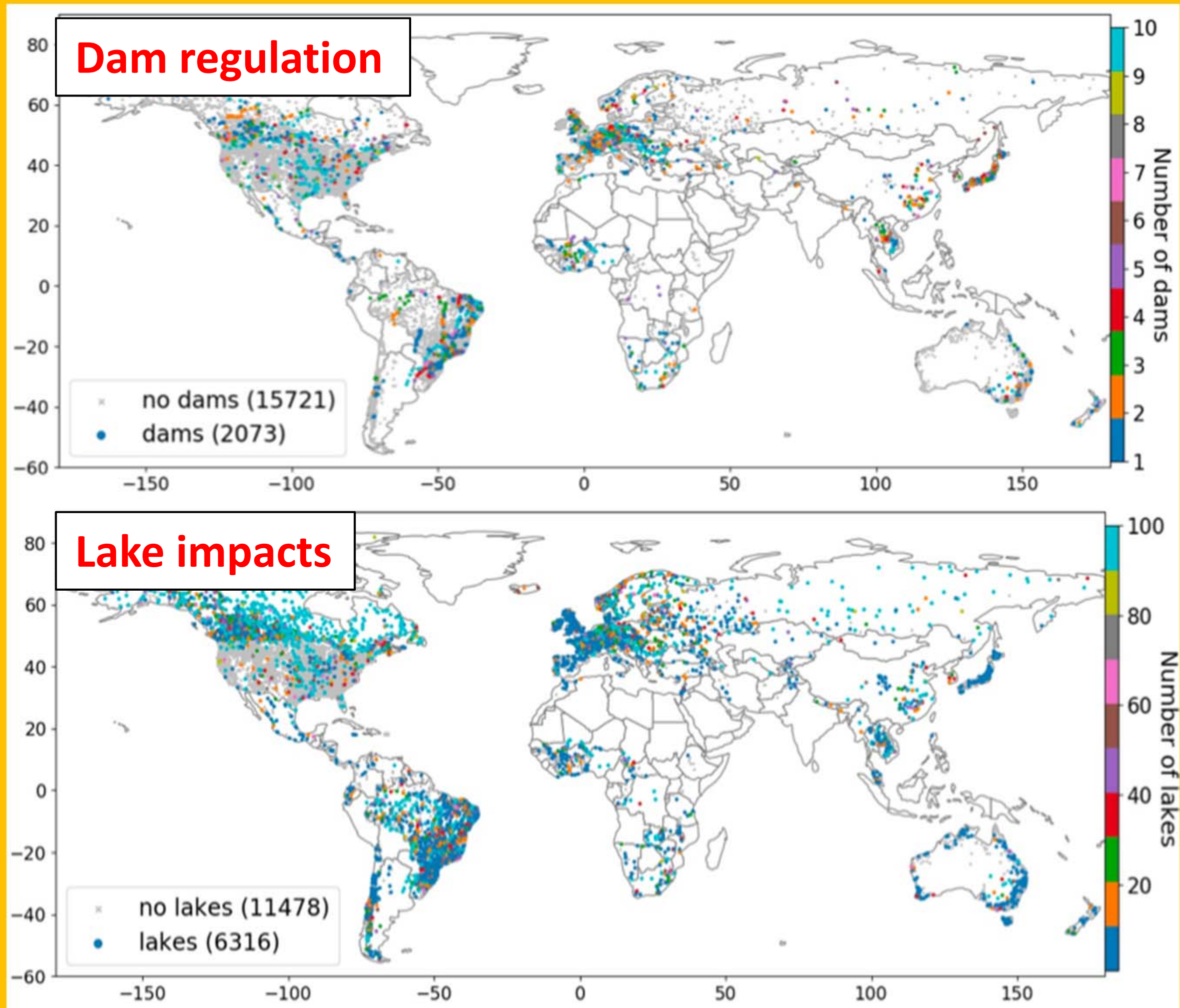
Dam regulation and lake impacts

• GRanD

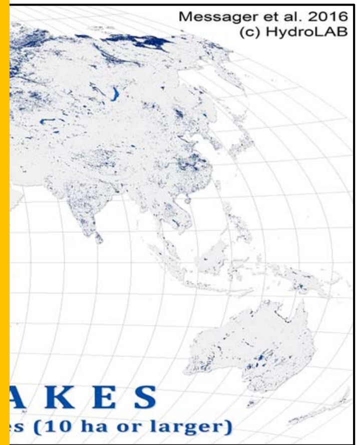
Lehner et al.

Communications)





Lin et al. (*2019; WRR, in review*)

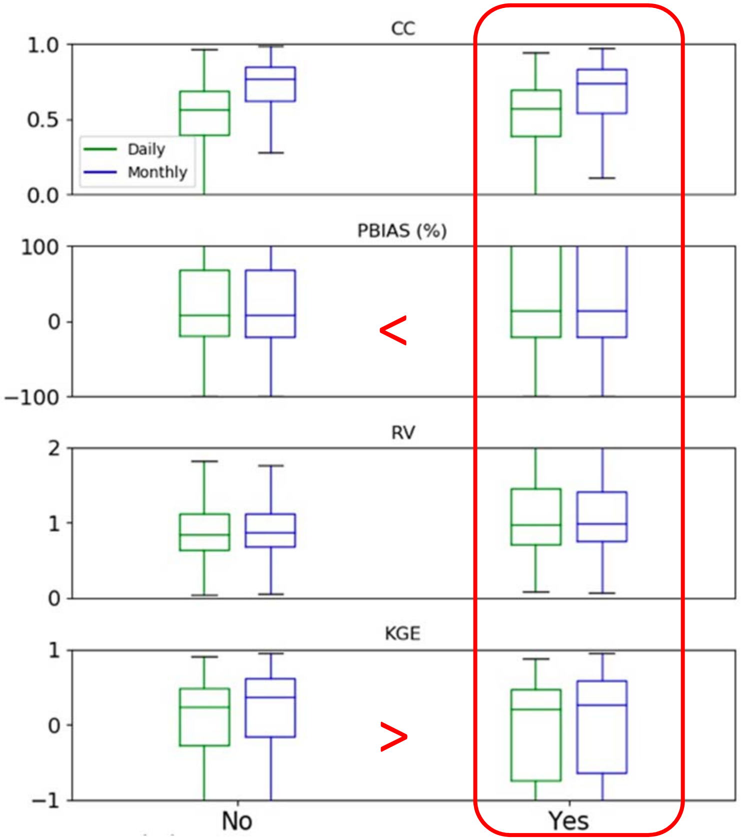


6,862 dams

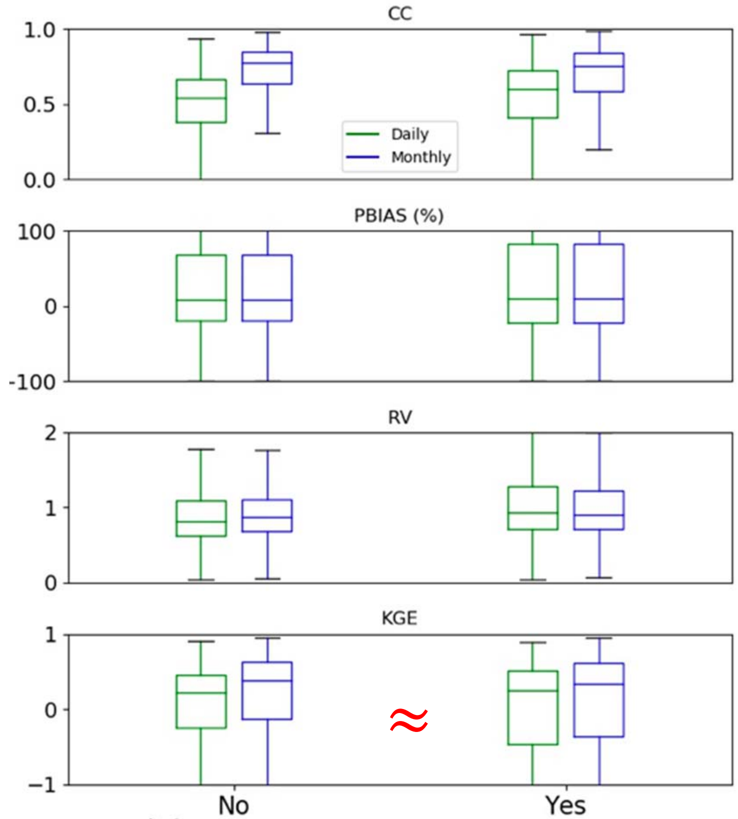
n 10 hectors

Dam/lake impacts

Dam regulations



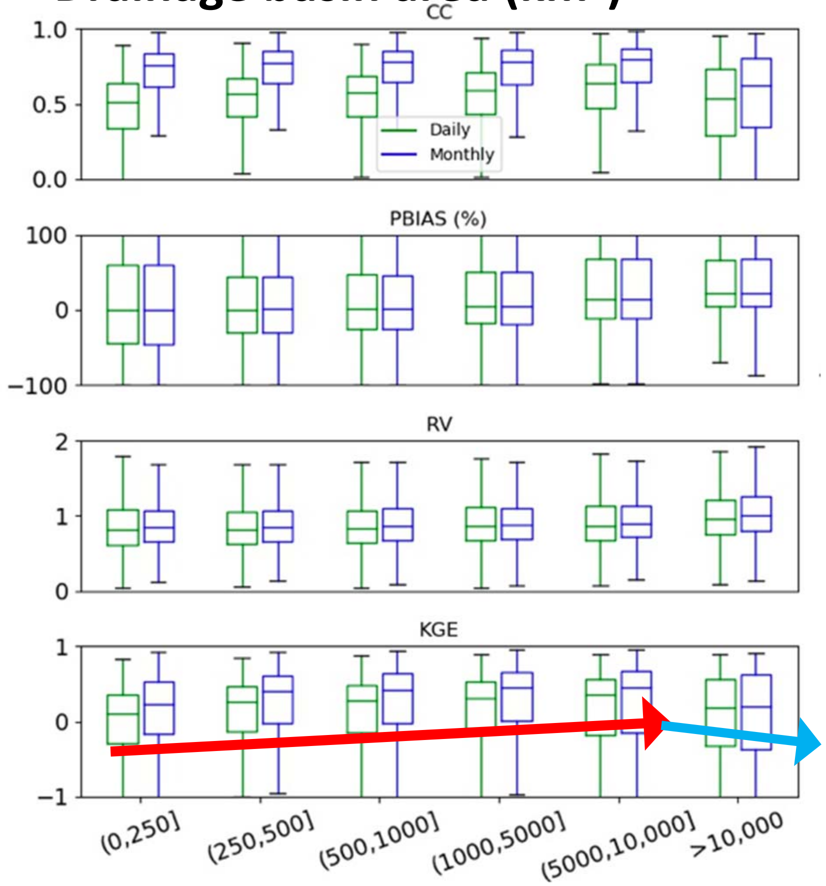
Lake impacts



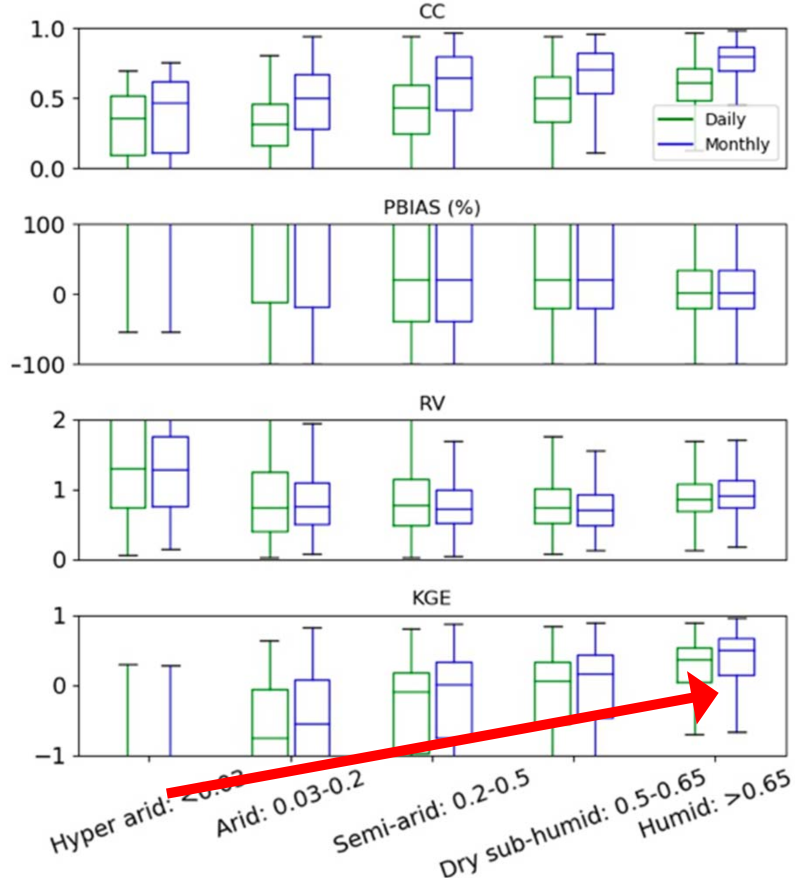
- Dams have stronger impacts than lakes
- Dams and lakes: smaller-than-expected influence

Drainage area & aridity

Drainage basin area (km^2)



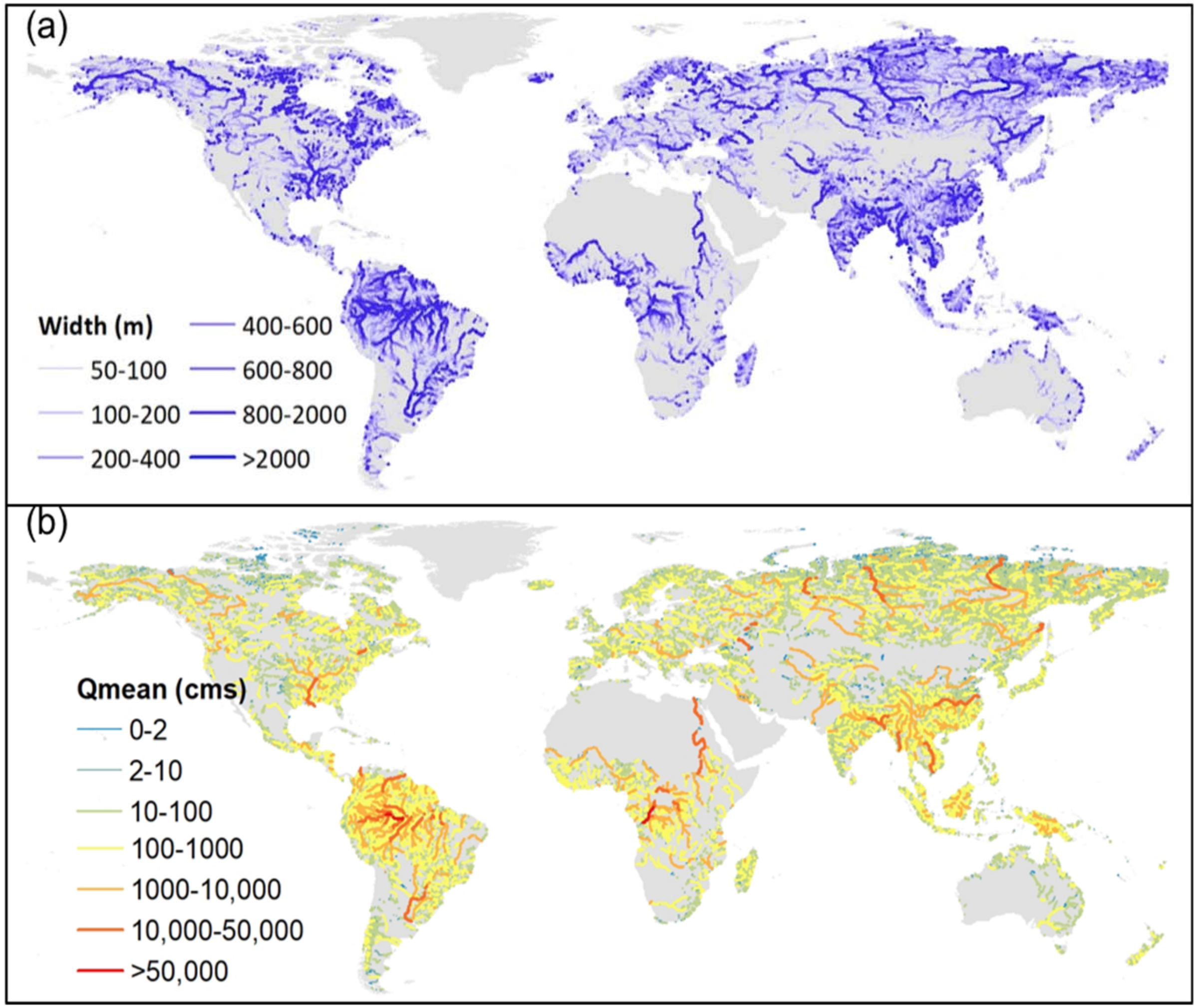
Climate aridity



- Flow regulation issue
- Difficulty in dry region

SWOT-Observable Reaches (8%, w>50m)

8.8% reaches potentially observable by SWOT per GRWL



- PBIAS:
  44% within $\pm 20\%$
  76% within $\pm 50\%$

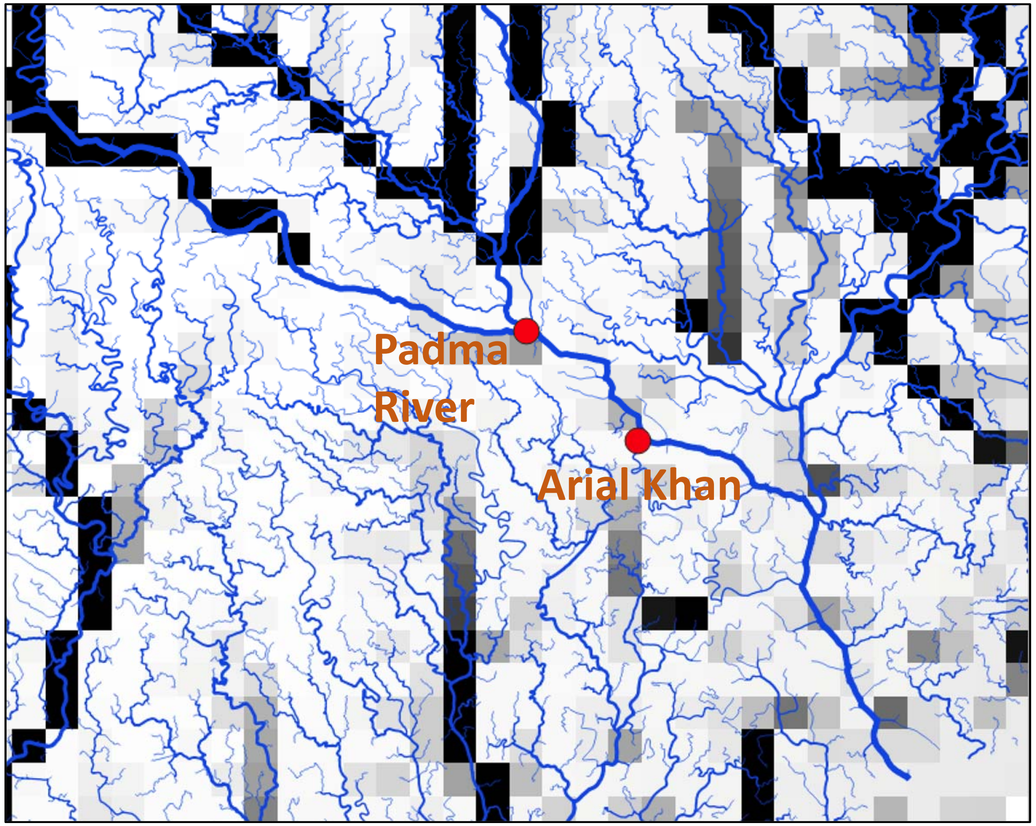
- KGE:
  $42\% \geq 0.6$
  $75\% \geq 0.2$

High-resolution VIC-RAPID vs. QWBM

Padma River (Pepsi 2):

QWBM underestimates Q_{mean}: incorrect hydrography along the coast (due to coarse resolution)

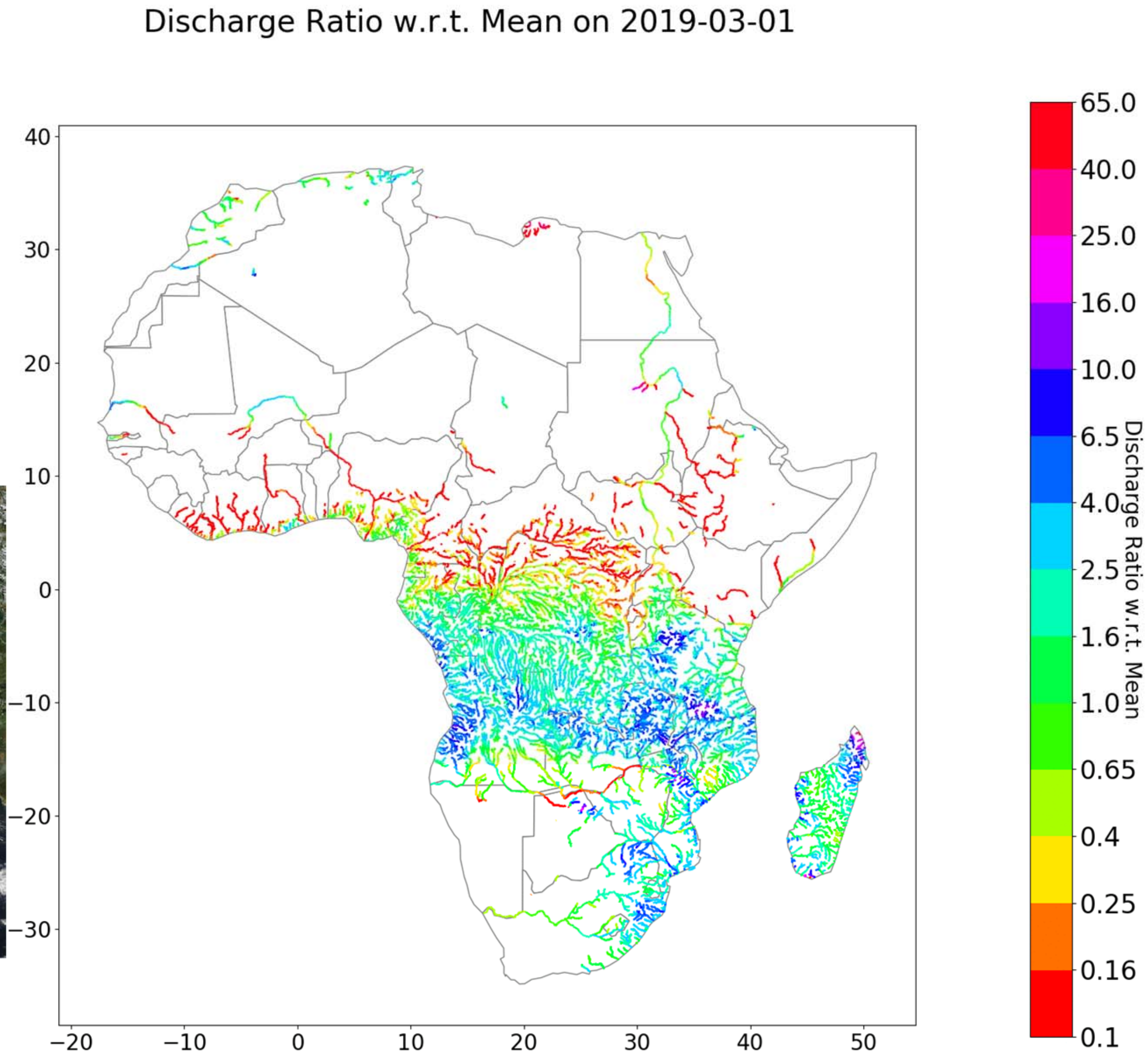
Q_{TRUE} (m^3/s):	30017
Q_{WBM}:	106
Q_{VIC_RAPID}:	30633



Black: QWBM
Blue: MERIT-Basins

Thanks for your attention!

- **Tropical cyclone Idai in Africa in March 2019**



Thank you for your attention!

- **Questions? Comments?**
- **mpan@princeton.edu**, **peirongl@princeton.edu**

- Major references:

➢ Beck et al. (*2015, JHM*): Global maps of streamflow characteristics based on observations from several thousand catchments

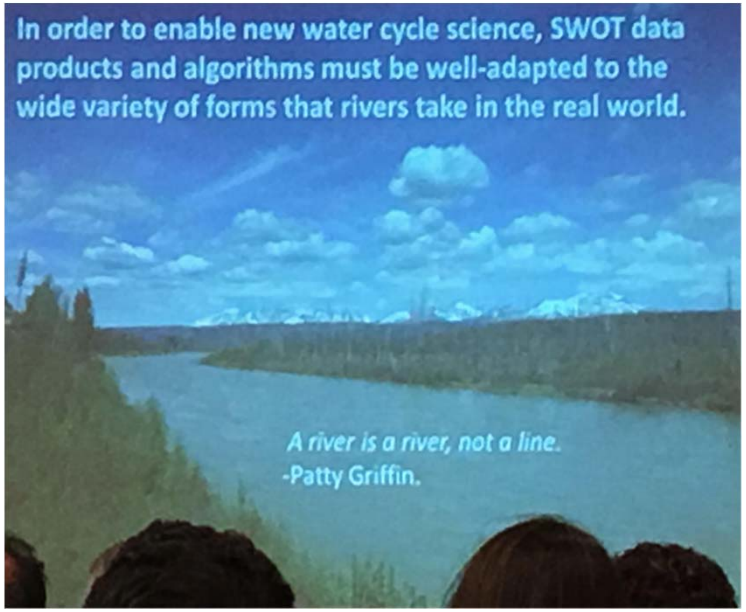
➢ Beck et al. (*2019, BAMS*): MSWEP V2 global 3-hourly 0.1° precipitation: methodology and quantitative assessment

➢ Yamazaki et al. (*2017, GRL*): *A high-accuracy map of global terrain elevations*

➢ Yamazaki et al. (*2019, WRR*): A high-resolution global hydrography map based on latest topography datasets

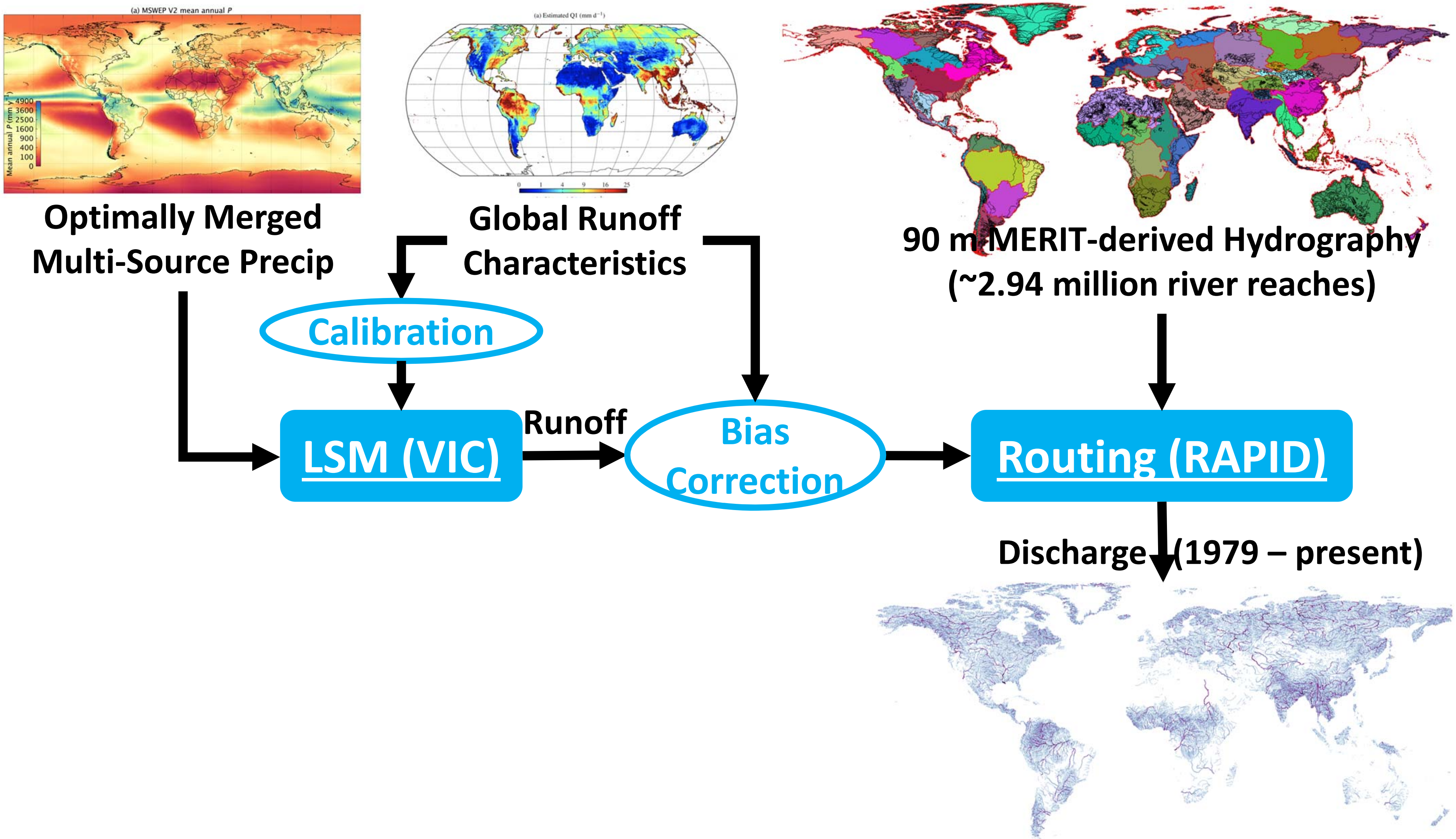
➢ Yang et al. (*2019, WRR, in review*): In quest of calibration density and consistency in hydrologic modeling: distributed parameter calibration against Q characteristics

➢ Lin et al. (*2019, WRR, in review*): Step change in global reconstruction of naturalized river flows at 2.94 reaches



(Picture taken on 2018 SWOT ST Meeting)

Modeling Workflow



Performance before Bias Correction

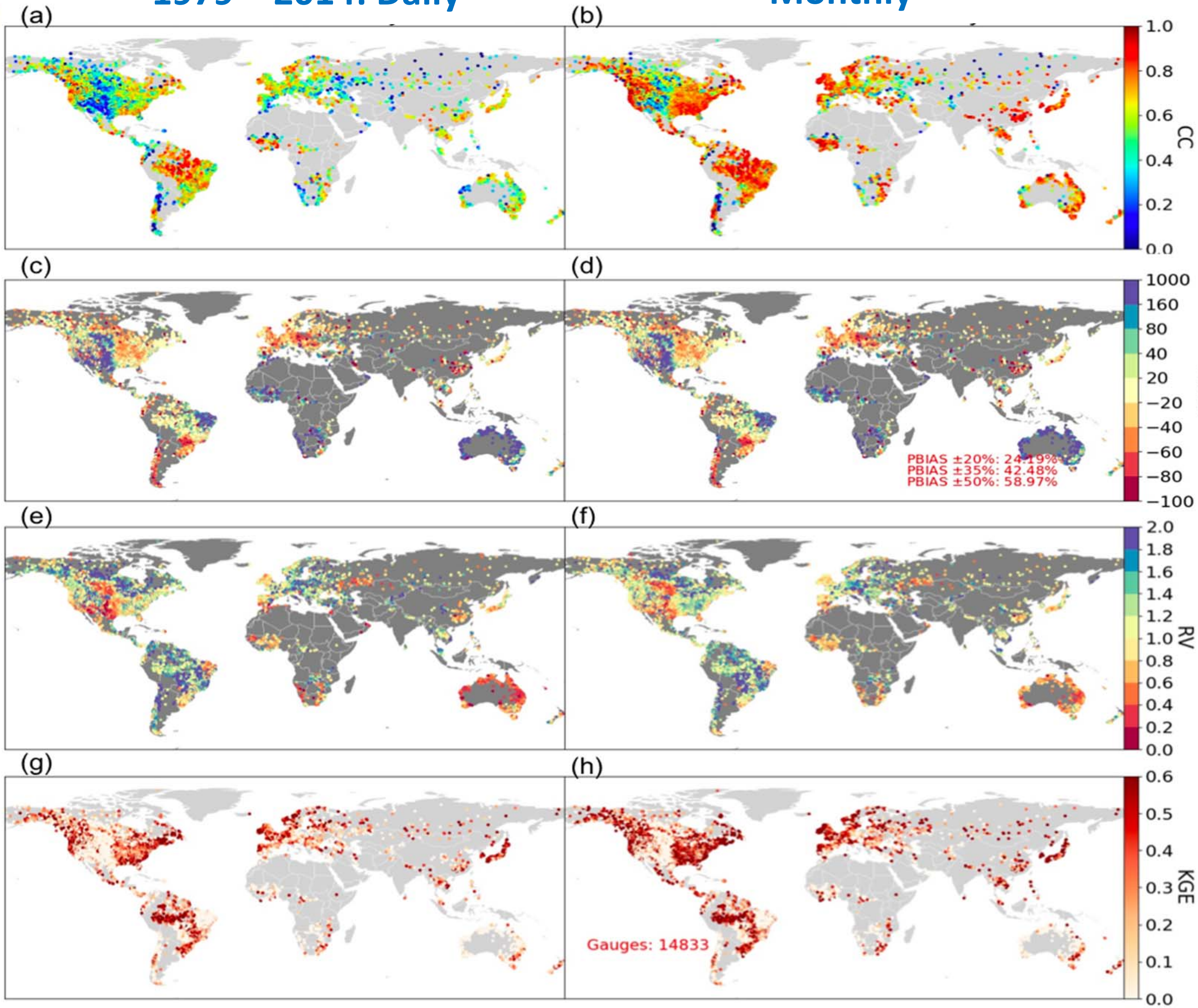
1979 – 2014: Daily | **Monthly**

Correlation Coefficient [-]

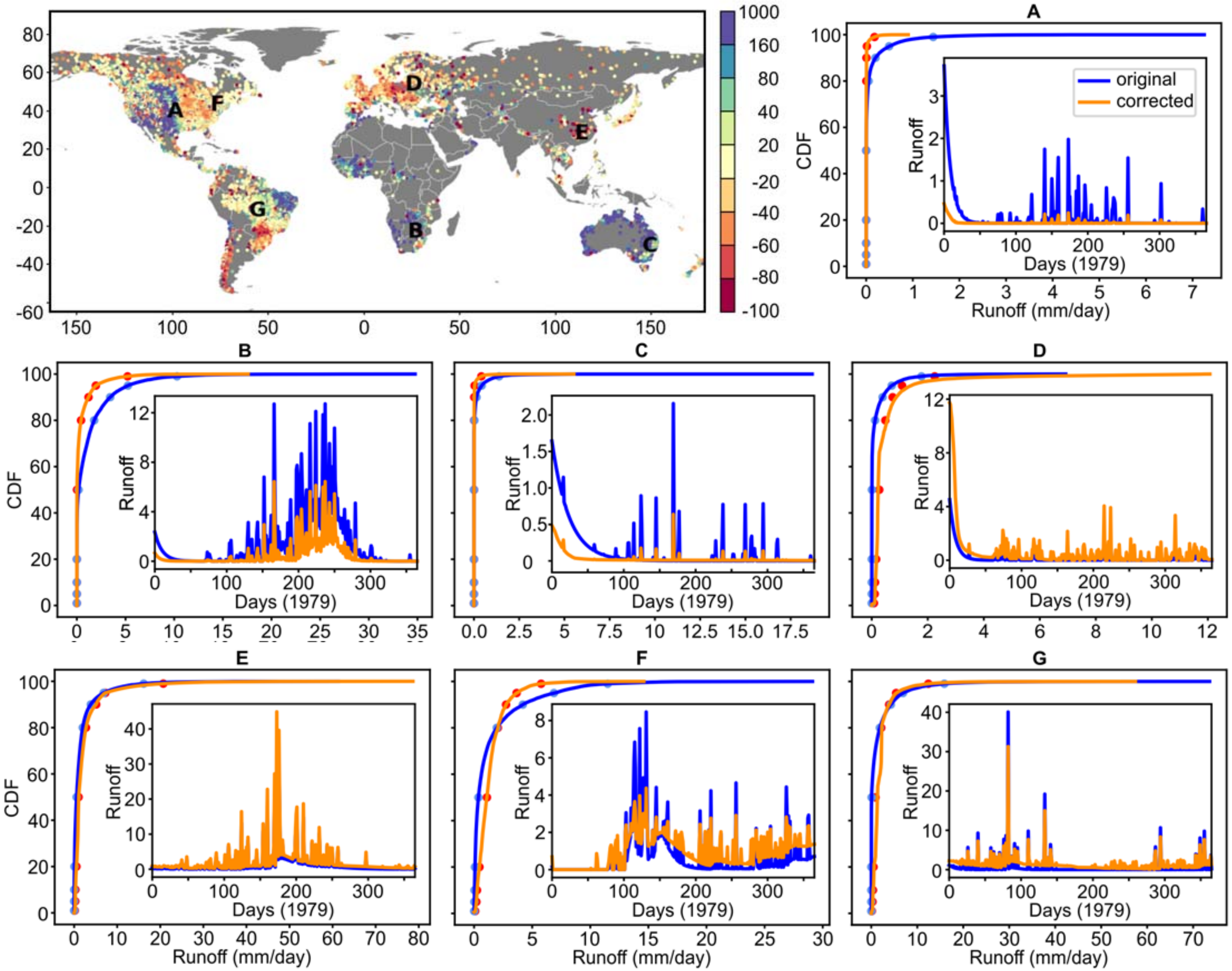
Percentage Bias [%]

Relative Variability [-]

KGE [-]



Grid-by-grid Bias Correction



Regions: wet bias
(A, B, C)
Runoff → lower

Regions: dry bias
(D, E)
Runoff → higher

Regions: bias ±20%
(F, G)
Mean runoff → little change