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TAKING THE PULSE OF OUR PLANET FROM SPACE

Discharge estimates with simulated stage-fall-discharge rating curves and ICESat-2 altimetry at backwater-affected virtual stations

Jun Liu[1], Liguang Jiang[2], Monica Coppo Frias[1], Peter Bauer-Gottwein[1]

[1]Department of Environmental and Resource Engineering, Technical University of Denmark, Kgs. Lyngby, 2800, Denmark
[2]School of Environmental Science and Engineering, Southern University of Science and Technology, Shenzhen, China

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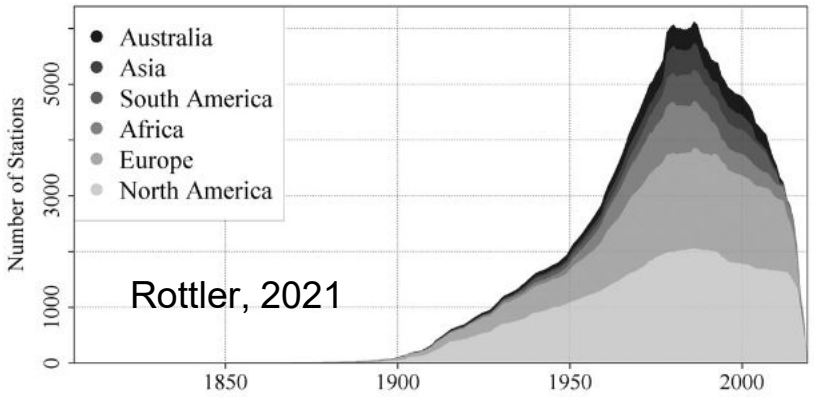
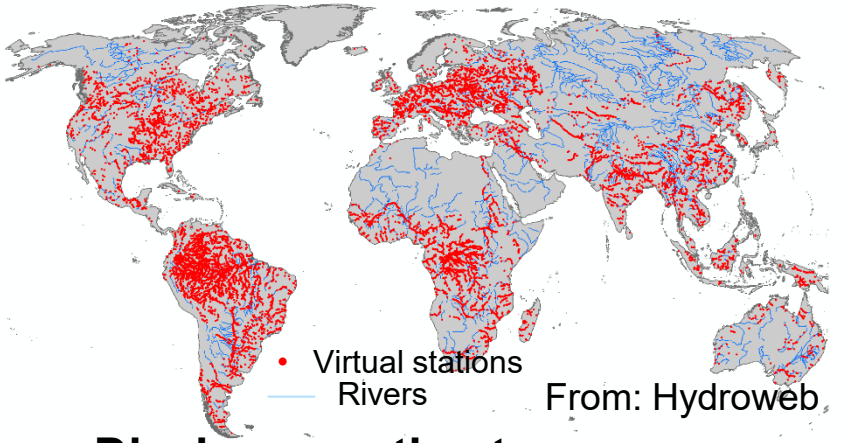
Introduction

- **River discharge is a fundamental quantity**
  - hydrological cycle, to inform flood, drought, and water resources management



- **The amount of global river gauging stations are decreasing.**
  - Challenges of installation, maintenance, data accessibility, etc.

- **Virtual stations**
  - The intersections between water bodies and satellite altimetry ground tracks, delivering water level measurements.



- **Discharge estimates**
  - Rating curves, hydrology-hydrodynamic modeling, hydraulic inversion.

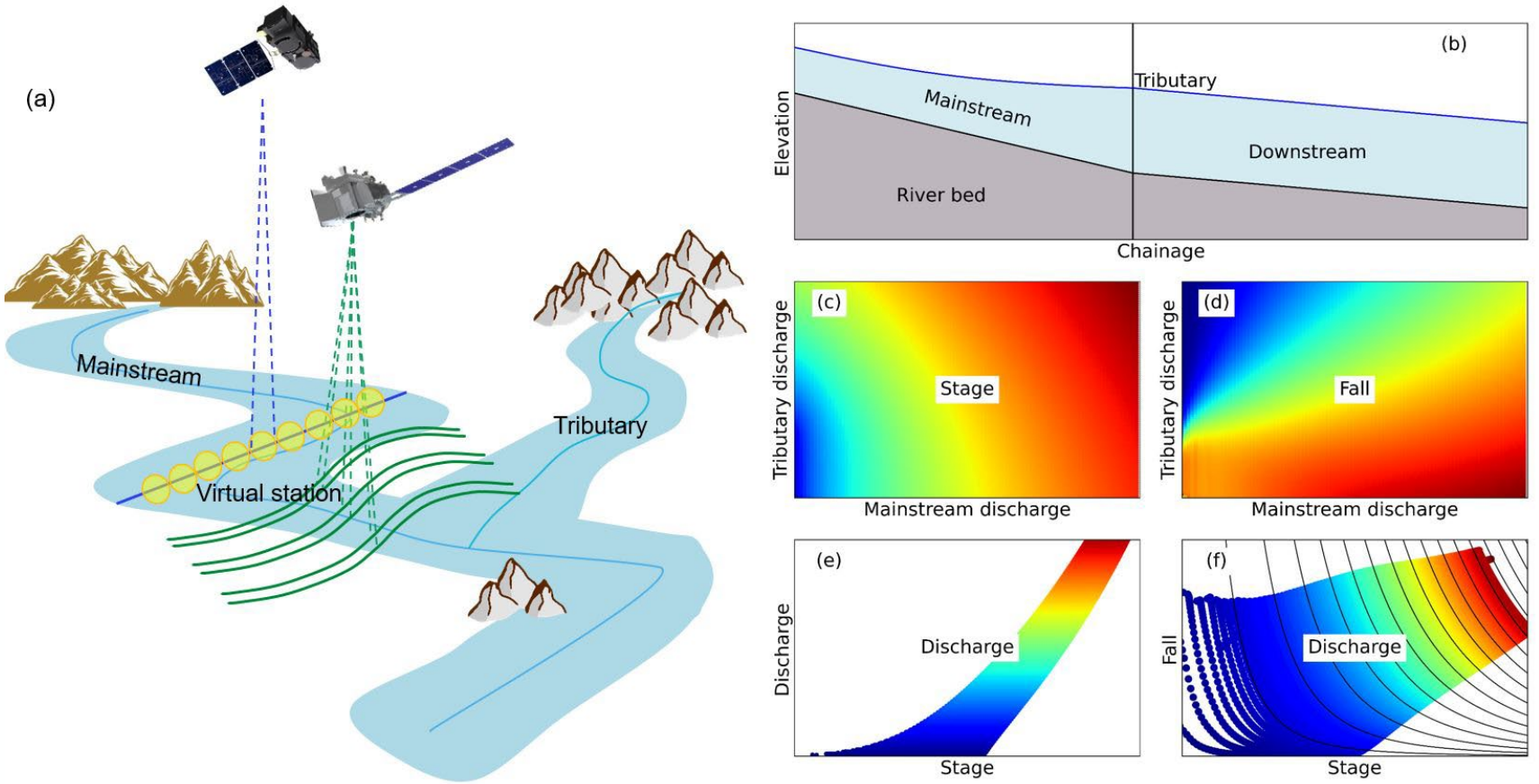
- **Problems of discharge estimation based on rating curves**
  - Changes of river geometry
  - Flood Plains
  - Vegetation Growth
  - Backwater effects
  - ……

Objectives

1. **Investigation of the relationship between stage, fall and discharge at backwater-affected VS using hydrodynamic modeling.**
    - Discharge, river bathymetry, light calibration methods for unknown model parameters
2. **Quantify the uncertainties of using stage-discharge rating curves for discharge estimates at variable backwater-affected virtual stations.**
    - The backwater effects of inflow from the tributary significantly deteriorate the rating curves in some river reaches, thus reducing the accuracy of the estimated discharge.
3. **Estimate discharge using the simulated stage-fall-discharge rating curves with ICESat-2 measurements**

Methods and data

- Rating curves at backwater affected virtual stations



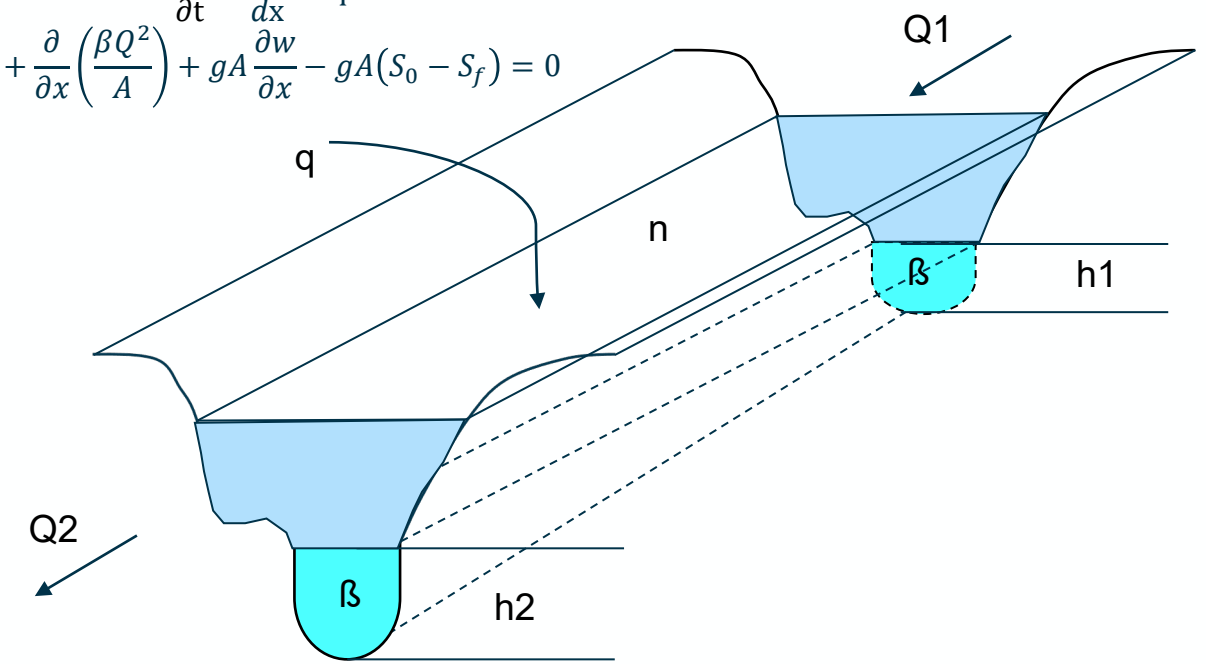
Methods and data

- Hydrodynamic model

1. Cross sections geometry
2. boundary conditions (discharge)
3. Manning number, low-flow depth, ß

$$\frac{\partial A}{\partial t} + \frac{dQ}{dx} = q$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{\beta Q^2}{A}\right) + gA\frac{\partial w}{\partial x} - gA(S_0 - S_f) = 0$$



Hydrodynamic model

In-situ data
Satellite altimetry

Simulated WSE

Observed WSE

$$\varphi = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(WSE_{sim,i} - WSE_{obs,i}\right)^2}$$

Shuffled Complex Evolution (global optimization)

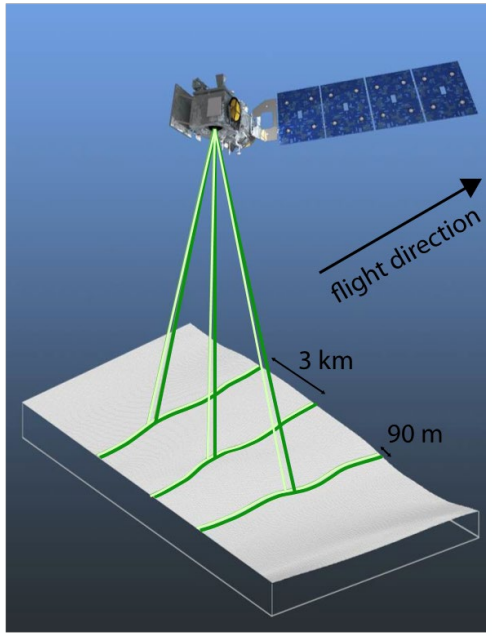
Optimum parameter set

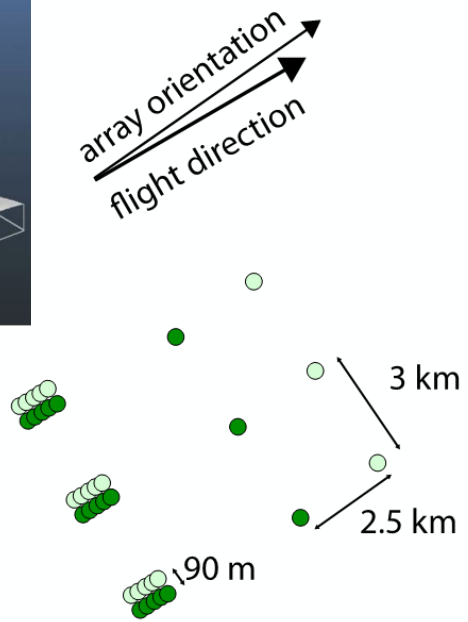
Hydrodynamic model

Rating curves

Methods and data

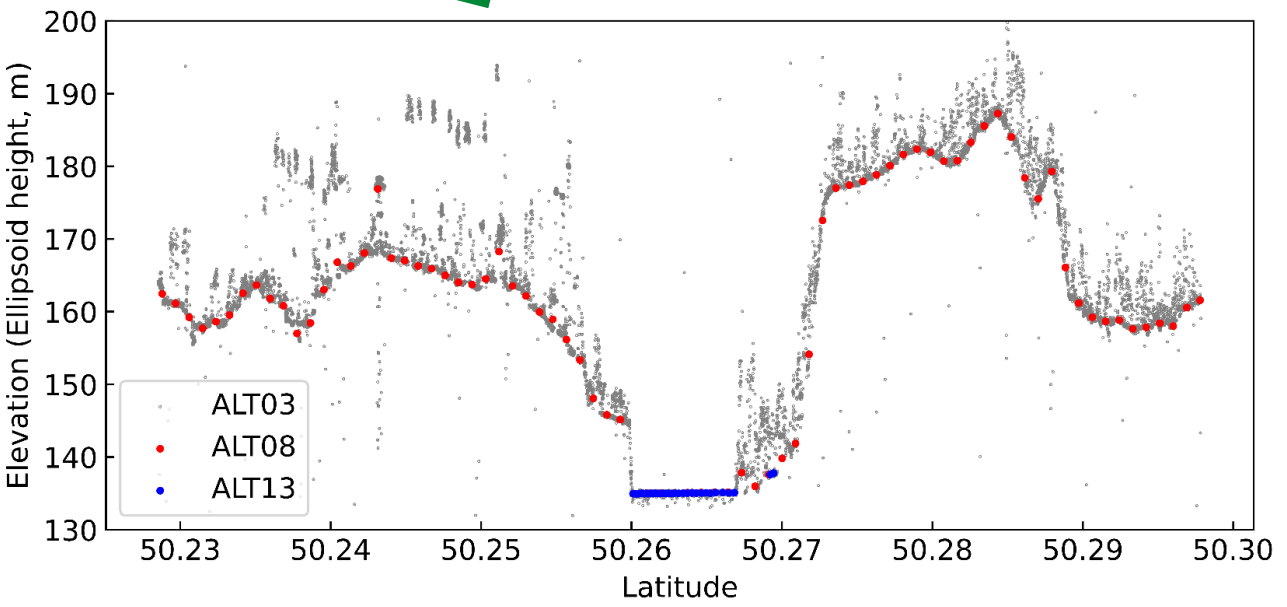
- ICESat-2 laser altimetry





(Figure from: NSIDC)

https://openaltimetry.org/data/icesat2/



Methods and data

- River geometry (Cross section)

  Exposed part: ICESat-2 photon ALT03

  Submerged part: power-law cross section geometry

$$A = a \times d^{b}$$

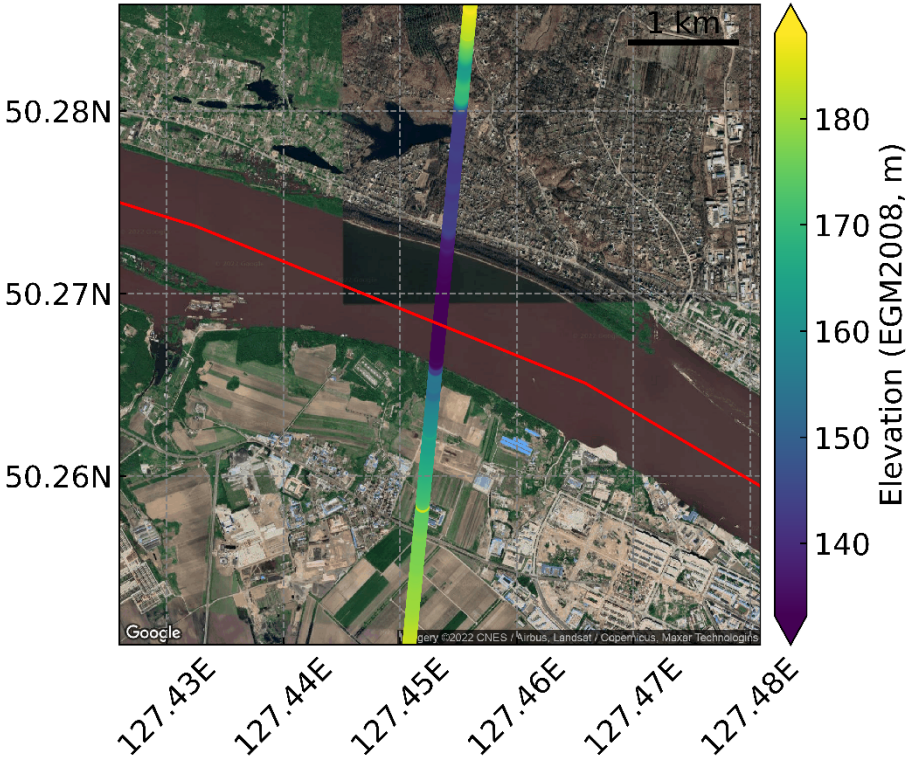
$$w = \frac{\partial A}{\partial d} = a \times b \times d^{b-1}$$

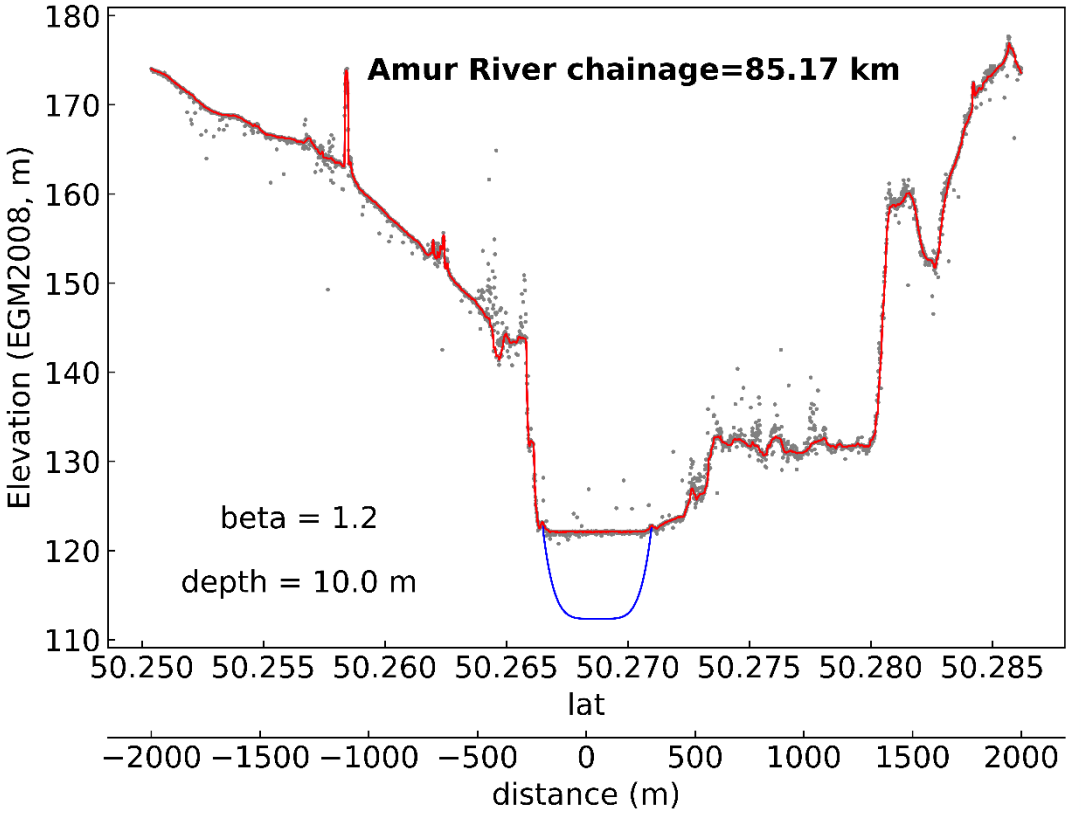
A: Flow cross sectional area

d: Flow depth

w: Flow width

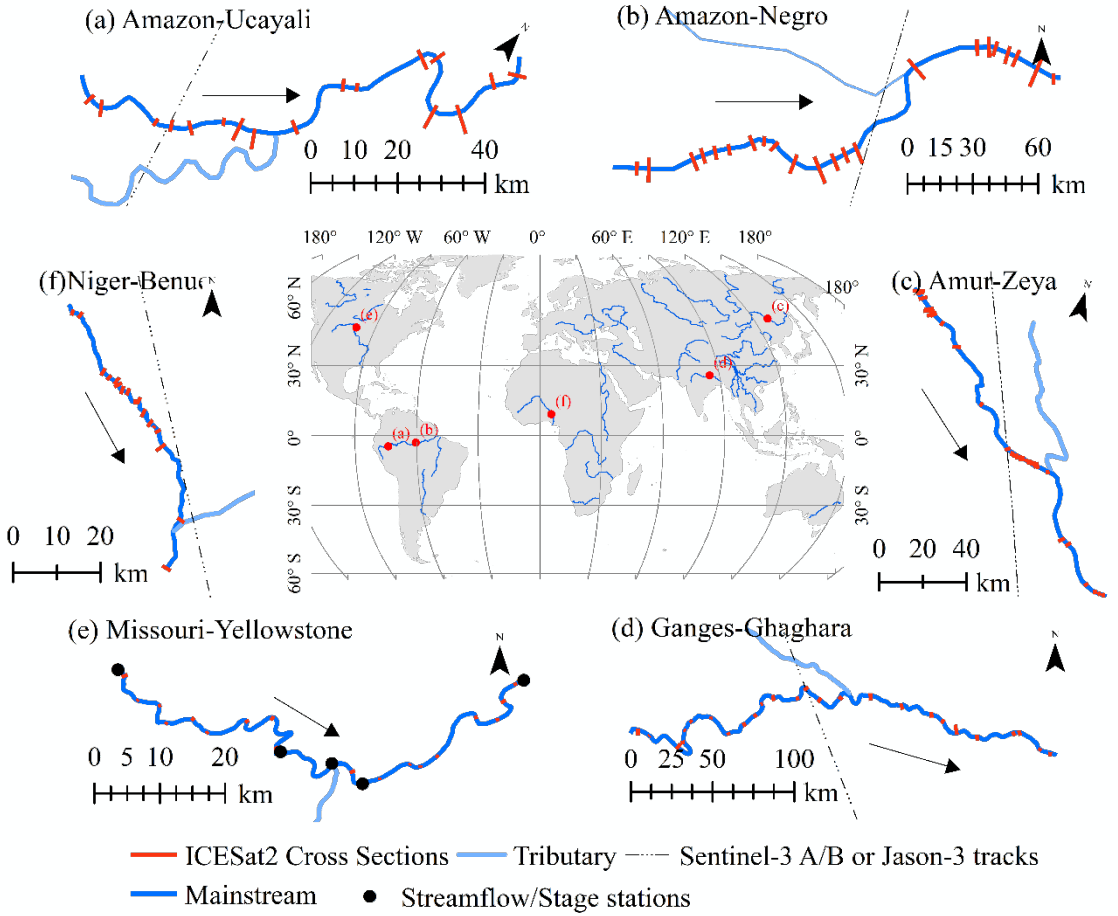
alpha, beta – shape parameters, alpha=0.2



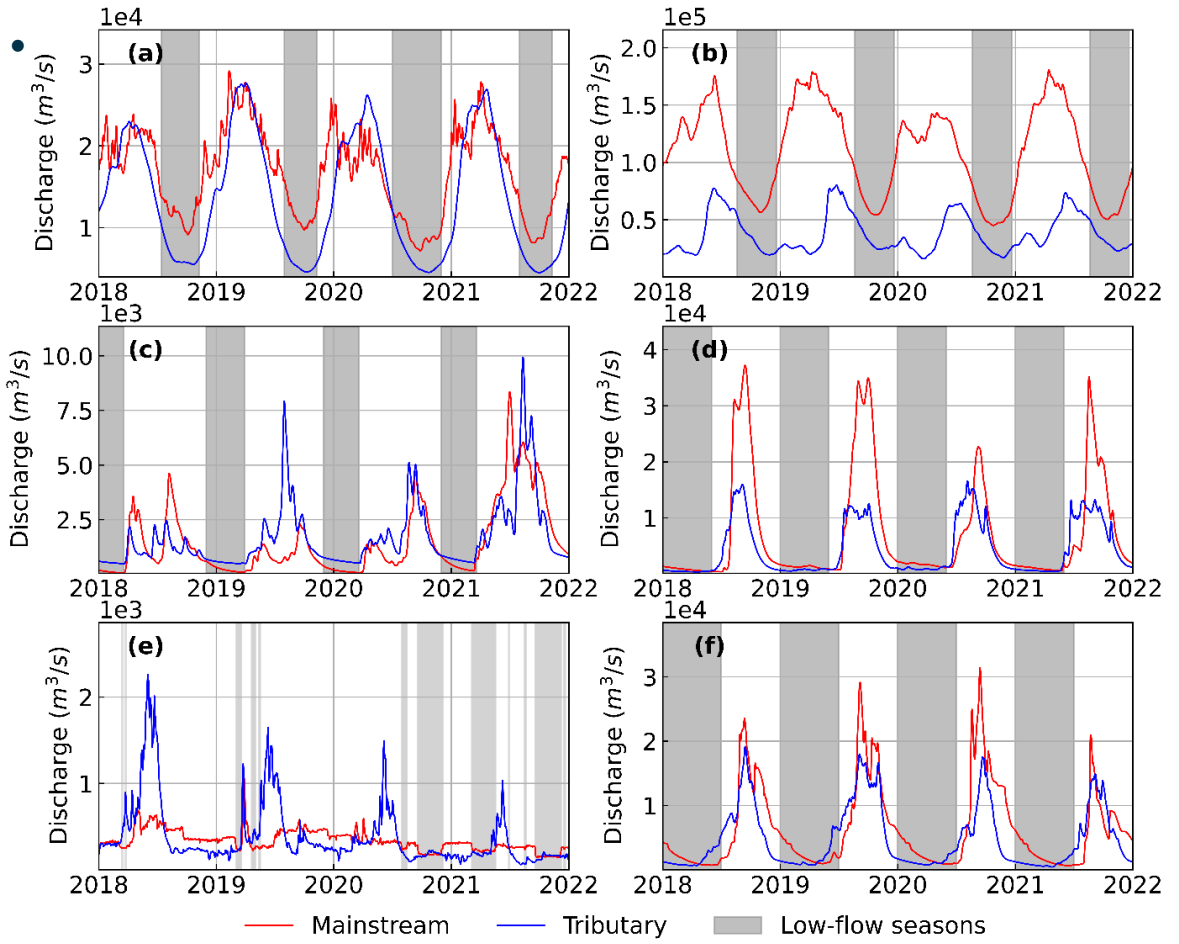


Methods and data

- Study cases



- Boundary conditions - GloFAS-ERA5 global river discharge reanalysis dataset

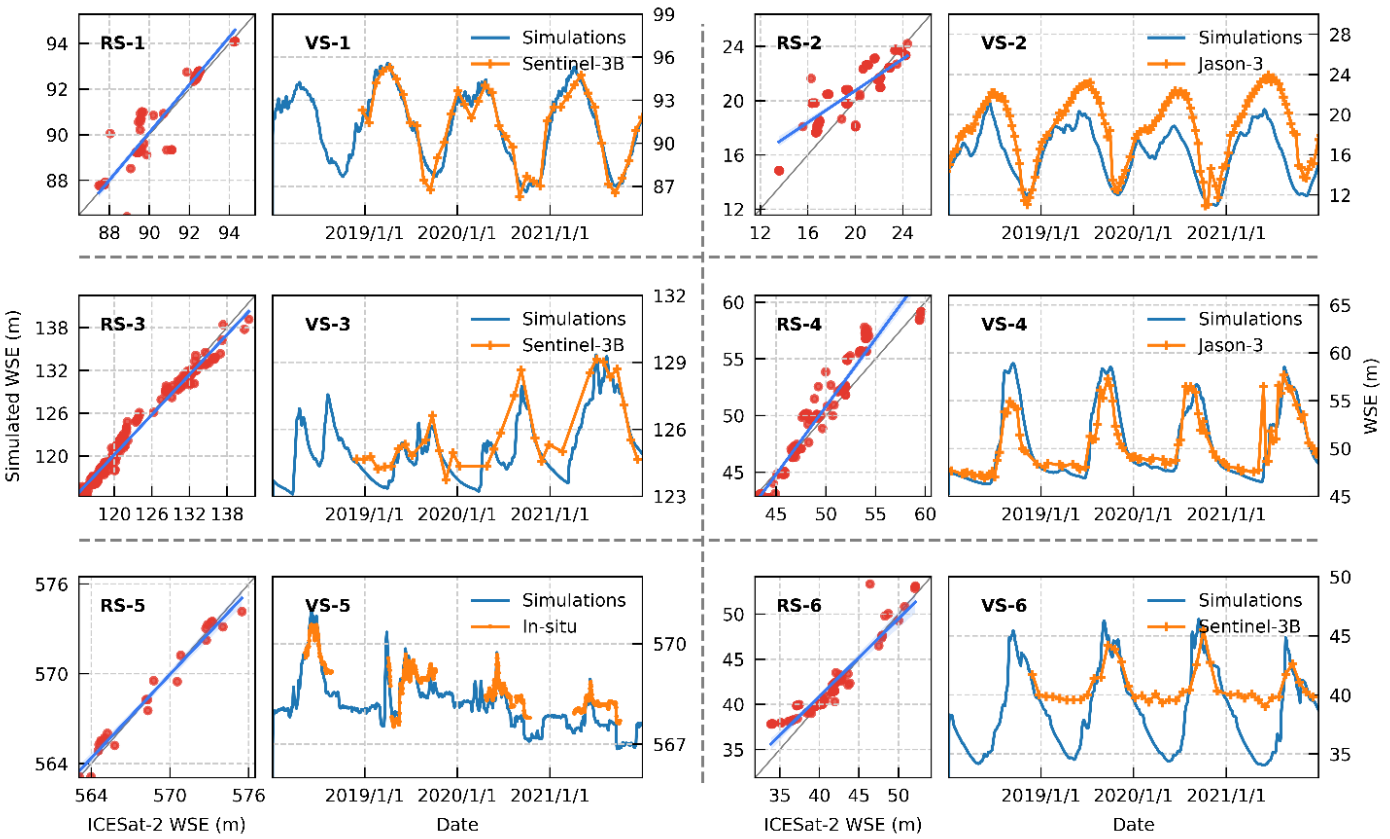


Results

- Performance of hydrodynamic model at the virtual stations

➢ Model Calibration:
  - ICESat-2 ALT13 and ALT08,
  - RMSE is in [0.62 m, 1.36 m].
  - ALT08 and ALT03 are 100m resolution; the data is insufficient in narrow river reaches with no data.

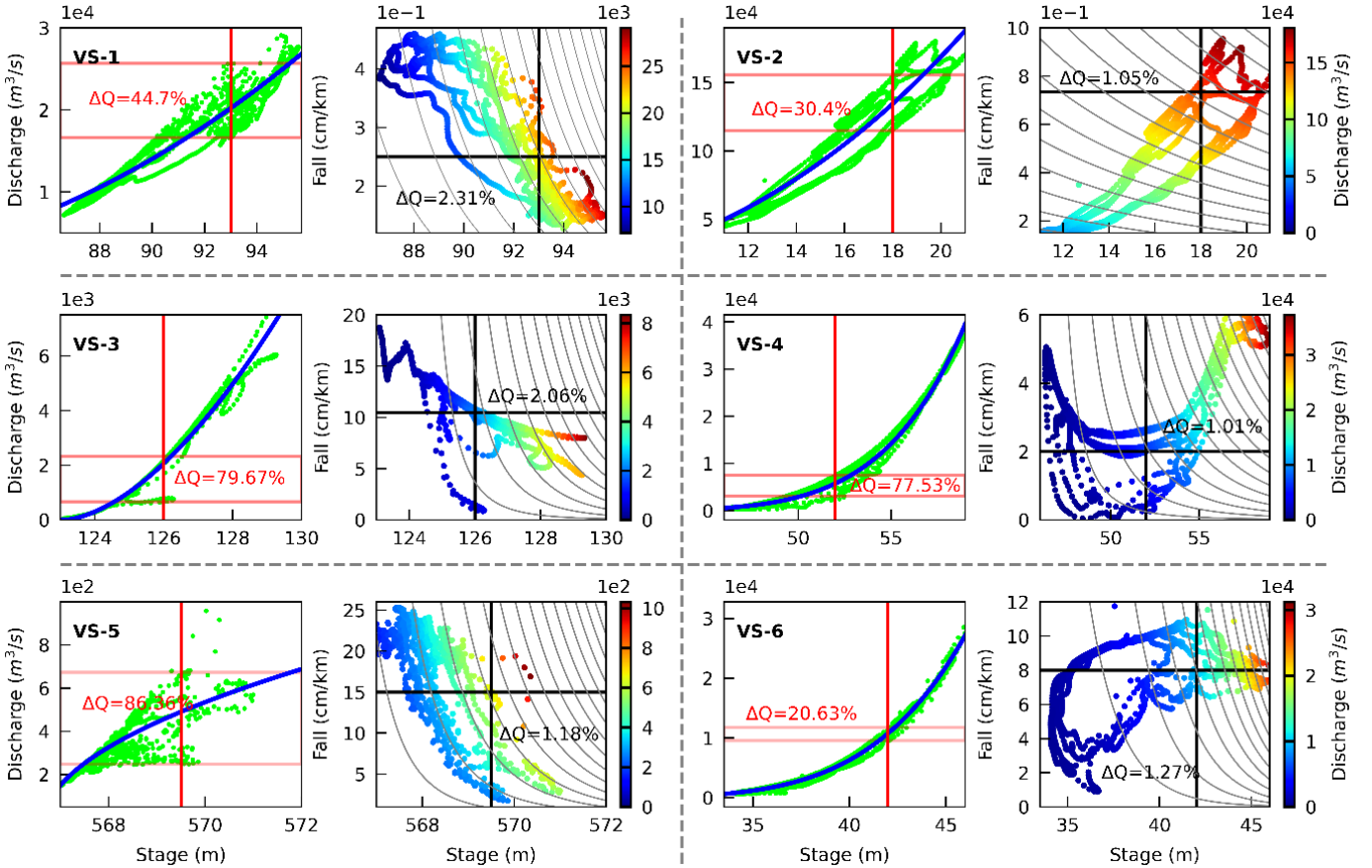
➢ Model validation:
  - Sentinel-3A/B, Jason-3, or in-situ observations,
  - RMSE is in [0.83 m, 3.14m],
  - GloFAS discharge predictions have low skill downstream of reservoirs that are not included in the GloFAS model



Results

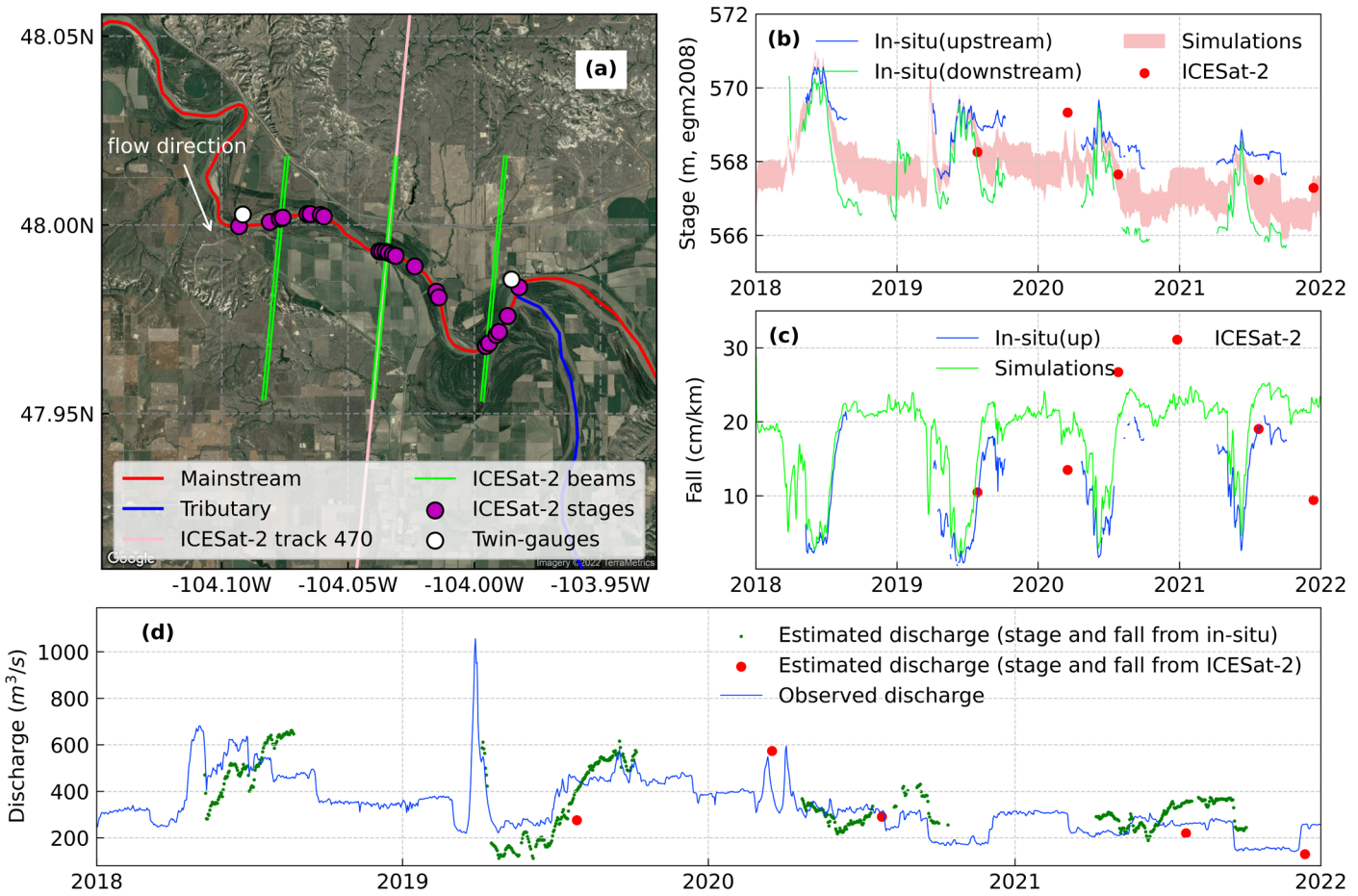
- Simulated rating curves at backwater affected virtual stations

  - stage and discharge relationships are scattered.
  - The interactions between mainstreams and tributaries are different, resulting in the different shapes of the stage-discharge rating curves.
  - Variations of discharge for the same stage can be predicted from variations in fall.



Results

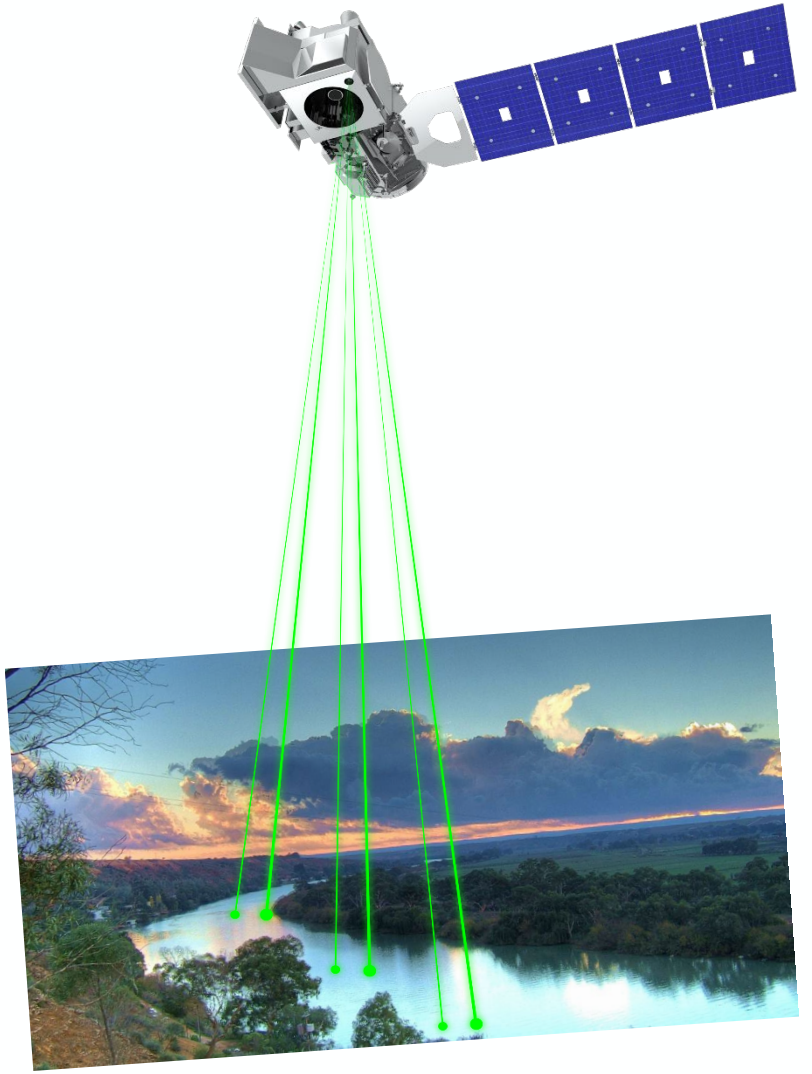
- Discharge estimates in real cases



- Missouri-Yellowstone river has in-situ observations of discharge and stage, which can be used for validation of the methods.
- The stage and fall measured by ICESat-2 have different locations, resulting in the misfit between ICESat-2 and the in-situ.
- Uncertainty of the estimated discharge with stage-fall-discharge rating curves and in-situ observations at the upstream gauge is 28.60%, and with ICESat-2 measurements is 36.32%.

Conclusions

- Some river reaches are affected by the backwater, the stage-discharge rating curves are non-unique, and the stage-fall-discharge rating curves should be used.
- ICESat-2 laser altimetry measures water surface elevation by 6 laser beams, and water surface fall can be estimated.
- Discharge estimates are possible using ICESat-2 altimetry and the simulated stage-fall-discharge rating curves.



Thank you for your attention

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[1]Department of Environmental and Resource Engineering, Technical University of Denmark, Kgs. Lyngby, 2800, Denmark; juli@env.dtu.dk, mcfr@env.dtu.dk, pbau@env.dtu.dk
[2]School of Environmental Science and Engineering, Southern University of Science and Technology, Shenzhen, China; jianglg@sustech.edu.cn