

Estimating river cross-sections for hydrodynamic models from spaceborne and airborne lidar altimetry

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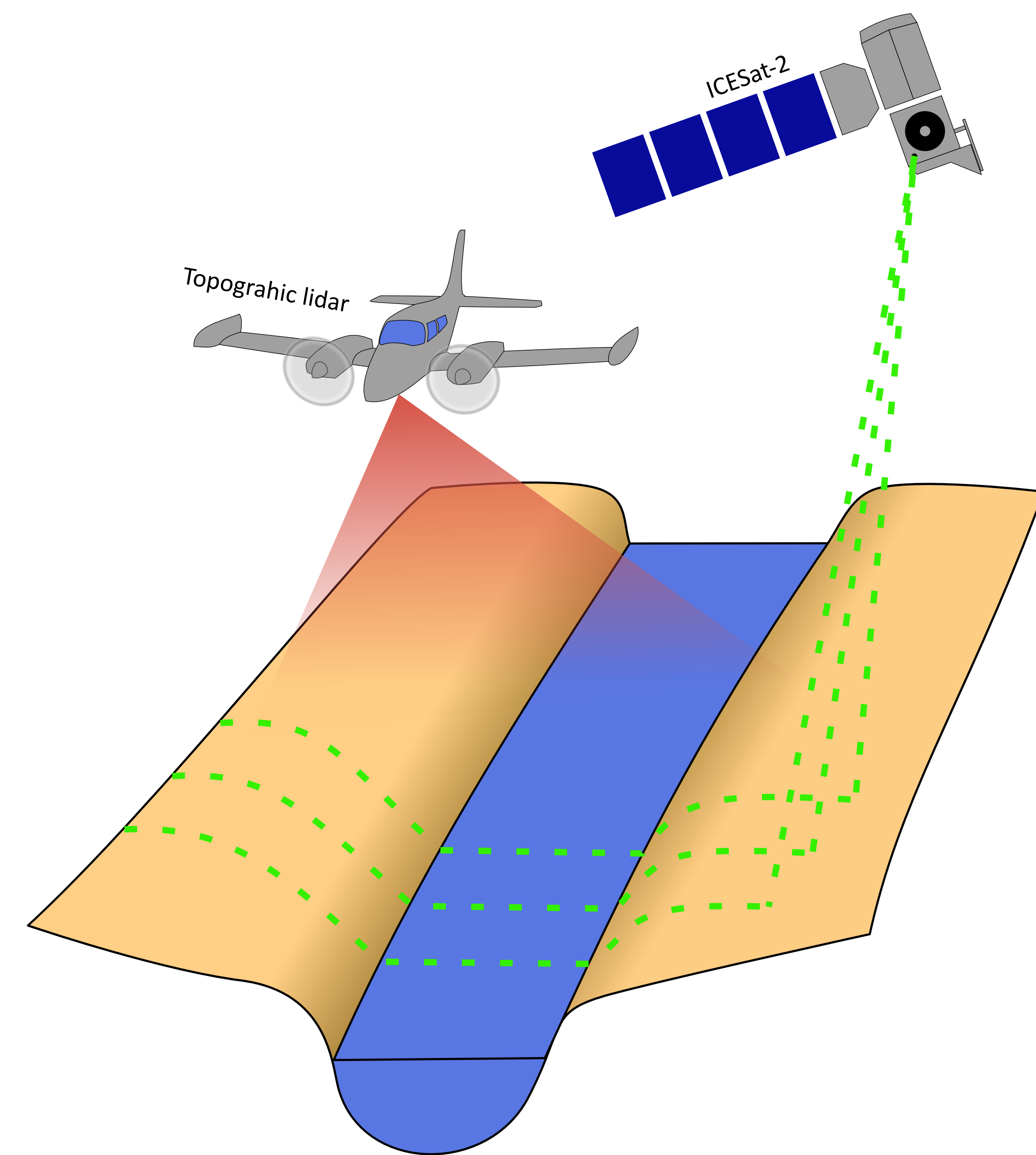
1. Introduction

Hydrodynamic river models are essential for flood forecasting and flood risk assessment, but require accurate **cross-section geometry**. Such surveys are rarely available at regional or global scales due to cost or access constraints.

Airborne and satellite lidar missions provide high-resolution observations of terrain and **water surface elevation (WSE)**. However, lidar cannot directly observe submerged channel geometry in turbid or whitewater rapid conditions.

We present a method to delineate full river cross-sections by combining lidar-derived WSE and **water surface slope (WSS)** with discharge to estimate the submerged section of the channel.

The method is collected in a python package, processing **ICESat-2** or **topographic lidar** data into cross-sections, enabling hydrodynamic modeling in data-scarce regions.



2. Methods

Water surface elevation and terrain profiles are delineated through lidar **point cloud processing**.

While ICESat-2 cross-sections must follow the satellite path, topographic cross-sections can be drawn freely on the 2D point cloud surface.

Water surface slope is estimated from multiple simultaneous WSE observations.

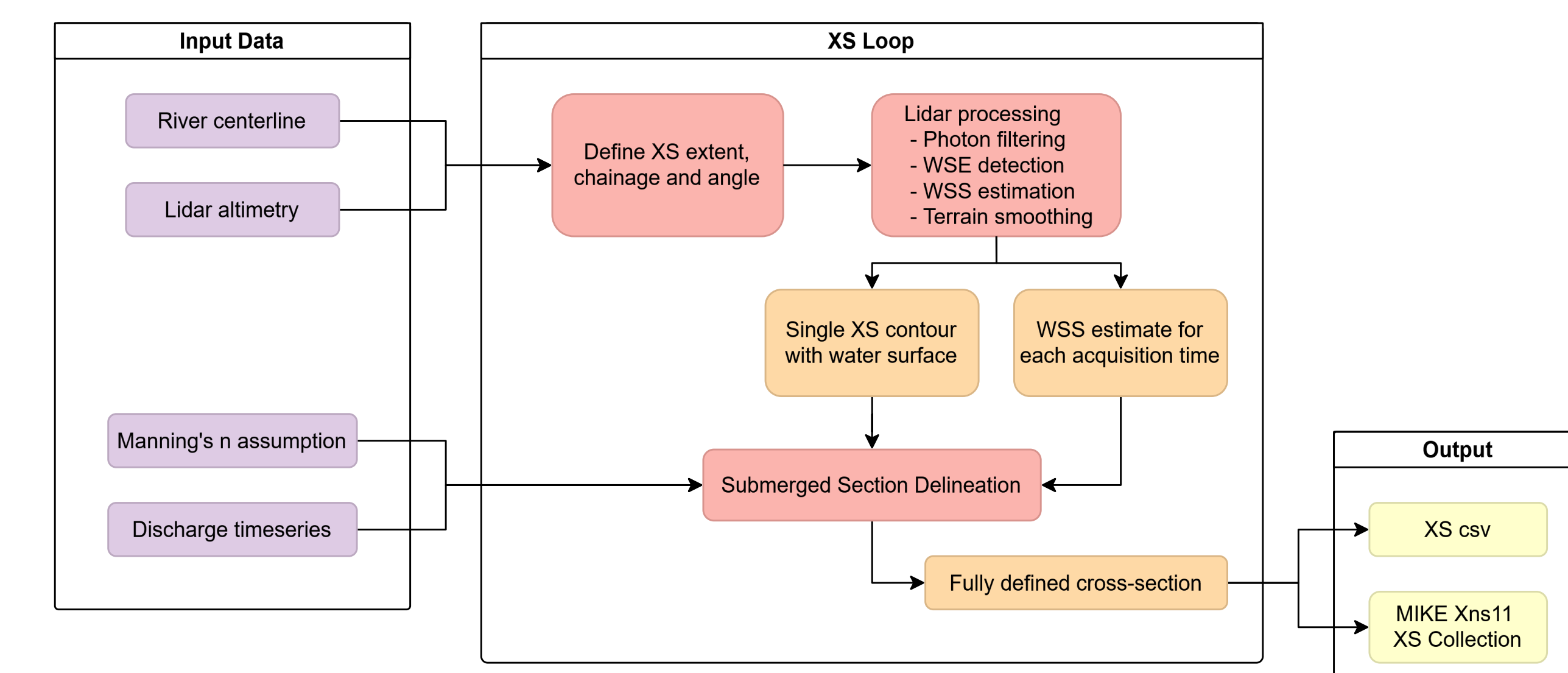
Assuming friction slope equal to WSS, valid for diffusive and kinematic wave assumptions, we interpolate **conveyance (K)** over the full cross-section from a known WSS and discharge, balancing Manning's equation.

$$S_f = WSS \quad Q_t = K(z_0) \cdot S_f^{\frac{1}{2}}$$

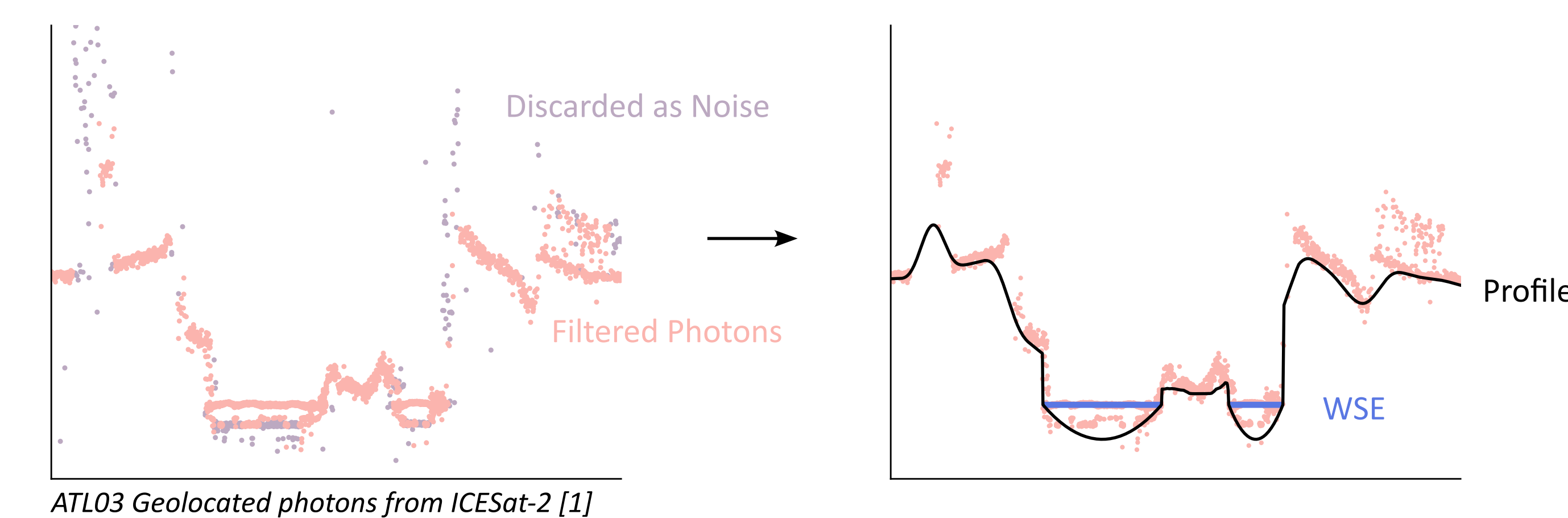
Conveyance is calculated as a function of hydraulic roughness, cross-sectional area and hydraulic radius. **Hydraulic roughness** is assumed and can be calibrated.

The open-source **Python package** automates the data processing, cross-section generation, and outputs a collection of cross-sections.

Workflow



Processing Steps



3. Results

The method was validated against **surveyed cross-sections** in four rivers spanning local to large-scale systems. WSE differences were evaluated at fixed values of flow area and conveyance.

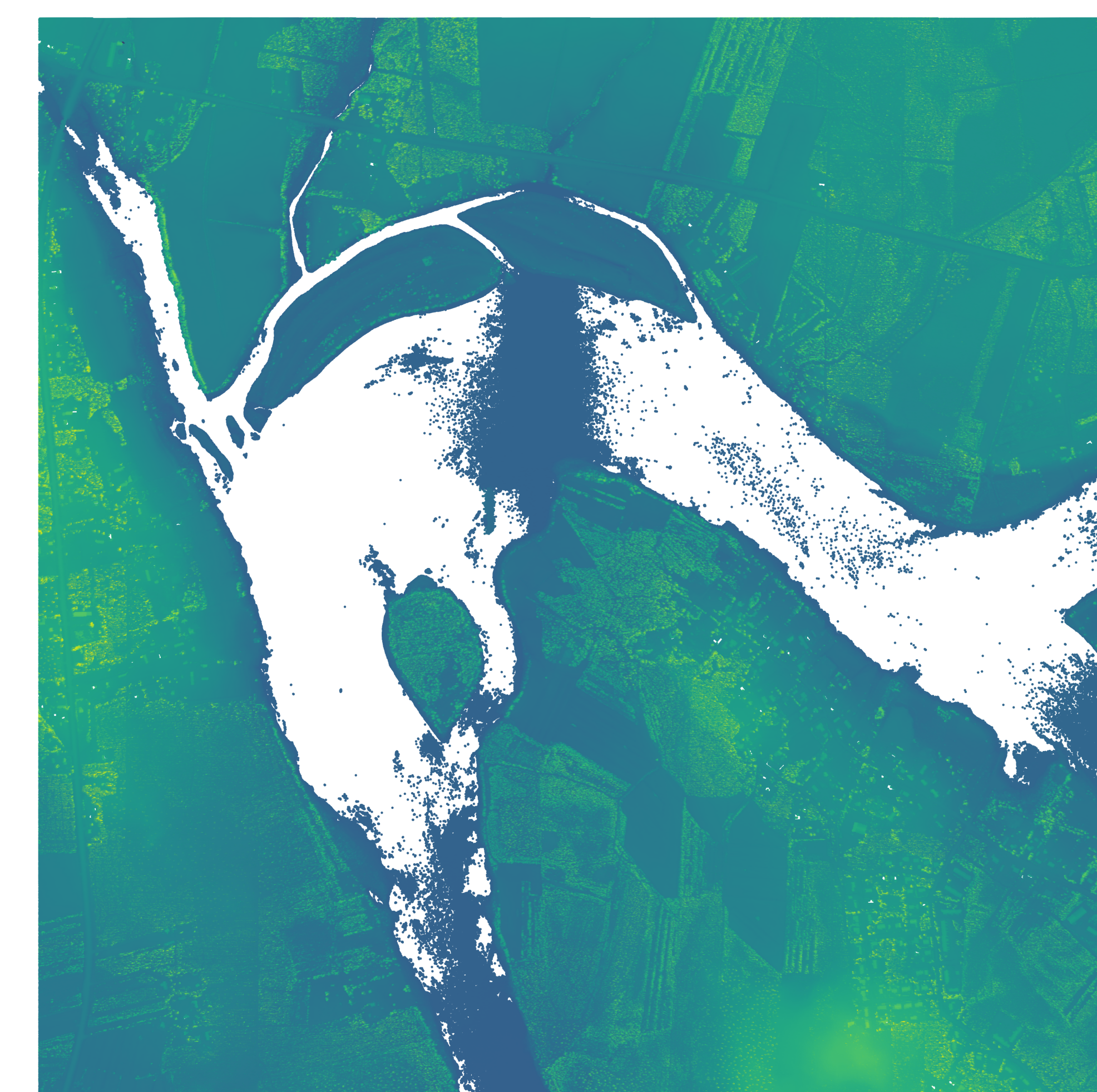
Topographic lidar provides highly detailed cross-section geometry at local and regional scales, matching surveyed geometry closely. ICESat-2 enables dense cross-section coverage along large rivers, if airborne surveys are not available.

Lidar-based cross-sections reproduce area- and conveyance-WSE relationships well, with **median WSE differences ≈ 0.5 m**. Larger negative ΔWSE at very low flows occur where the true channel bottom is not identified.

Discrepancies at low conveyance can persist at higher conveyance even when upper cross-section geometry is well matched. Inaccuracies are primarily linked to **uncertainty in discharge and slope estimates**.

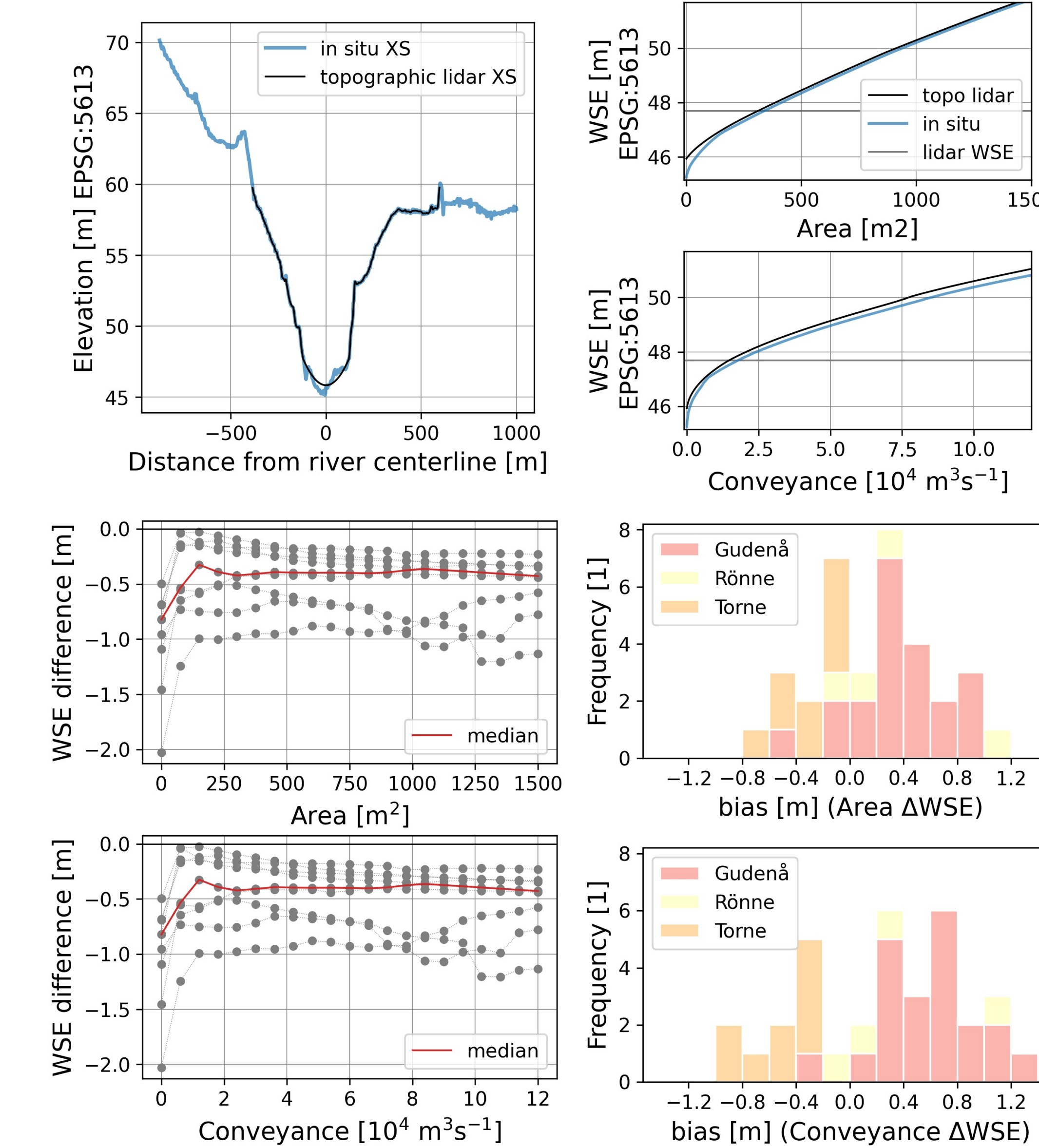
Data Source	Site	N (XS)	Median RMSE [cm]		Median bias [cm]	
			Area	Conveyance	Area	Conveyance
Topographic lidar	Torne	9	32.98	49.09	-29.63	-43.13
	Rönne	4	20.62	16.19	17.58	12.11
	Gudenå	21	50.68	67.11	38.17	61.62
ICESat-2	Loire	31	47.08	46.71	3.70	-6.58

Topographic Tile

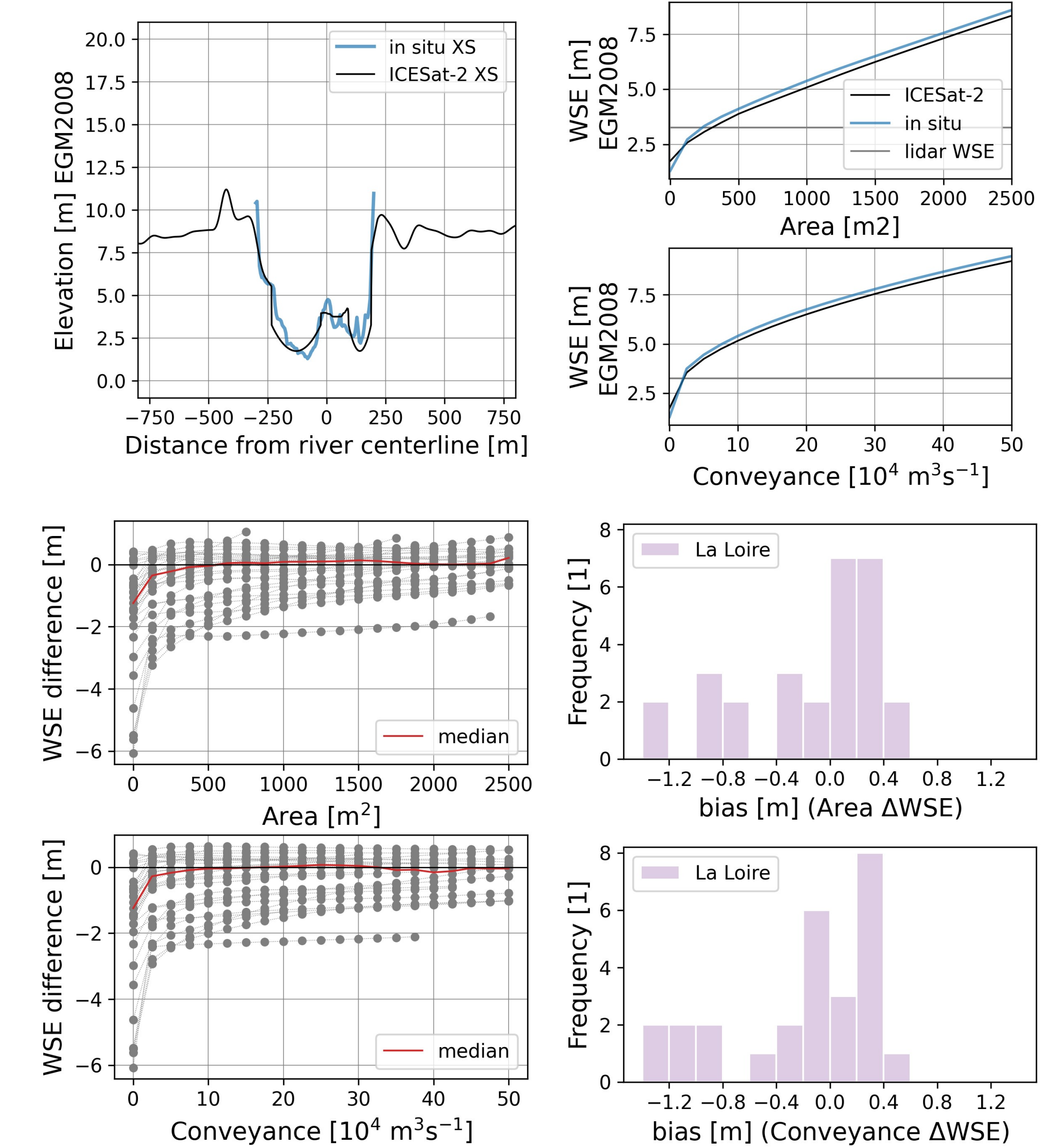


Cross-section can be drawn freely on the 2D point cloud. Elevation along the profile is estimated from points within a set range of the drawn line. ©Lantmäteriet [2]

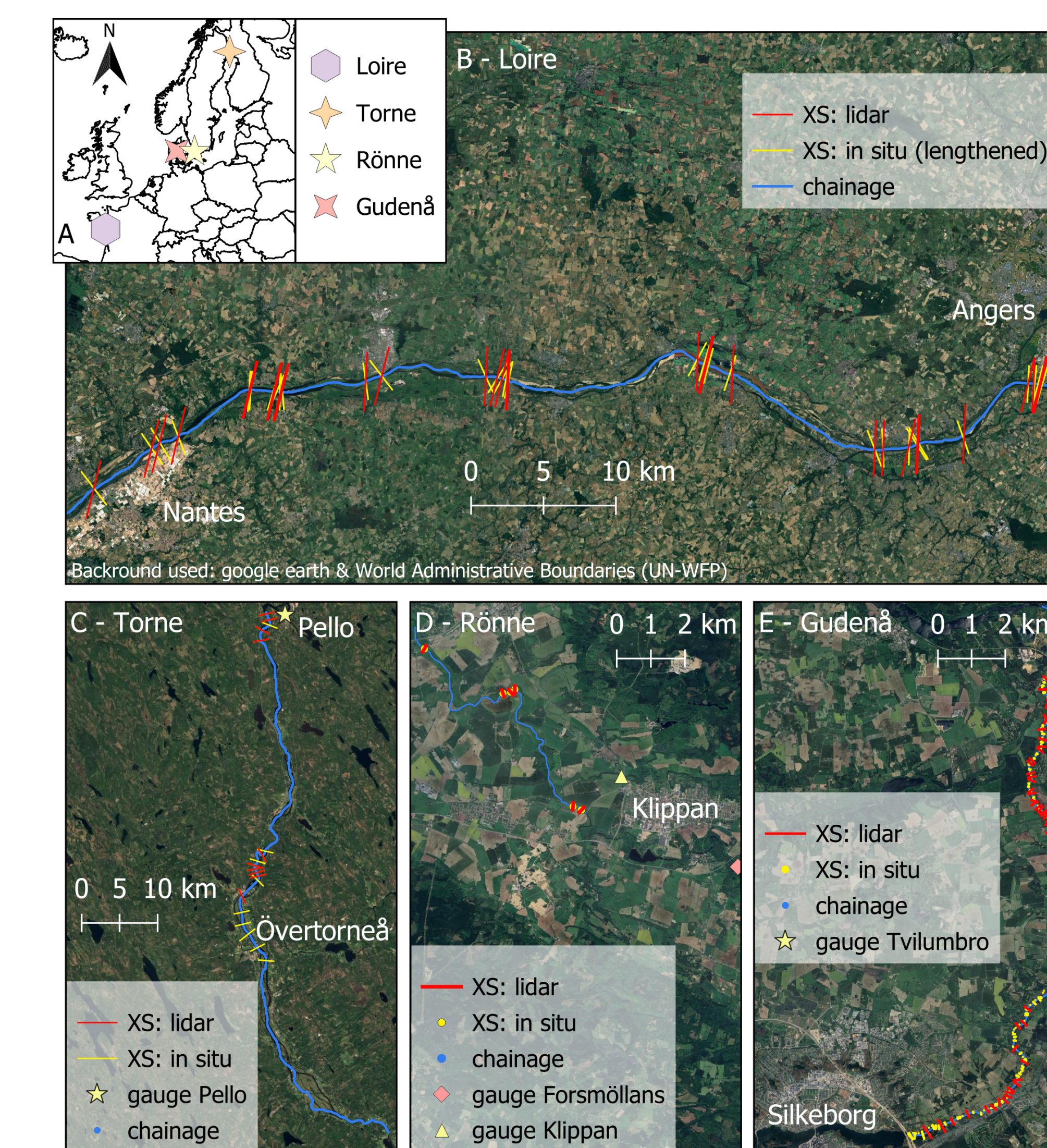
Topographic lidar



ICESat-2



Study Sites



4. Conclusion & Outlook

Combining topographic and ICESat-2 lidar with discharge estimates enables **hydraulically consistent river cross-section delineation** in data-scarce regions.

Automated processing allows **rapid application** across diverse river systems and scales, suitable for operational hydrodynamic modeling and scenario analysis.

Hydraulic roughness must be adjusted while validating later modeling results, considering the compensatory relationship between resistance, bathymetry and discharge.

When combined with **global hydrological models**, hydrodynamic models can be constructed and operated fully remotely, with validation and refinement supported by **SWOT WSE observations**.

5. References

[1] Neumann, T., Hancock, D., Robbins, J., Gibbons, A., Lee, J., Brenner, A., Felikson, D., Harbeck, K., Saba, J., Luthcke, S., Rebold, T., Reese, A., and Sutterly, T.: ATLAS/ICESat-2 L2A Global Geolocated Photon Data, Version 7, <https://doi.org/10.5067/ATLAS/ATL03.007>

[2] Lantmäteriet: Laser data Download, forest, product documentation, https://www.lantmateriet.se/globalassets/geodata/geodataprodukter/hojddata/e_pb_laserdata_nedladdning_skog.pdf