Virtual station rating curves derived from hydraulic models informed with UAS hydrometry and SWOT WSE

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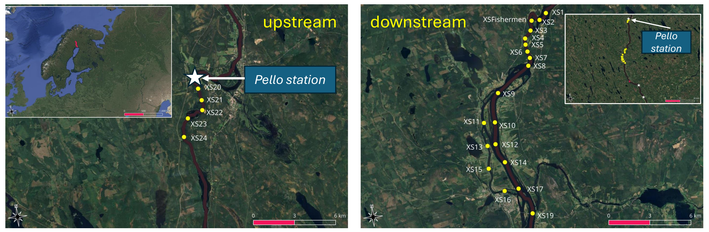
Research purpose

We investigated the potential of using Unoccupied Aerial Systems (UAS) hydrometry surveys to develop a hydraulic model for extracting rating curves, which can then be used to derive discharge from satellite altimetry-based Water Surface Elevation (WSE) measurements.

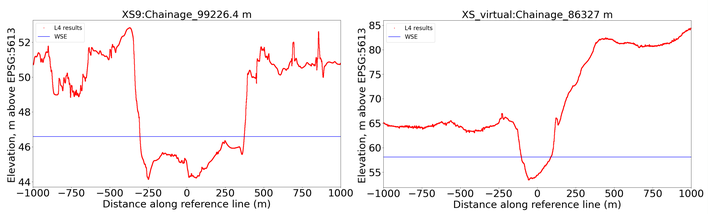
Study site

The study site was surveyed from September 3rd to 9th, 2024, and is located along the Torne River in northern Scandinavia and forms part of the national border between Sweden and Finland.



Estimation of riverbed elevation combining UAS-WPR and DEM models

The submerged portions of the river cross-sections (XSs) were measured using a UAS-mounted water-penetrating radar (WPR), while the non-submerged portions were derived from Digital Elevation Models (DEMs). Specifically, we used a 1-meter resolution DEM from Lantmäteriet for the Swedish side and a 2-meter resolution DEM from the Finnish national elevation model. We selected 2 XSs shown in the figures below.



SWOT data

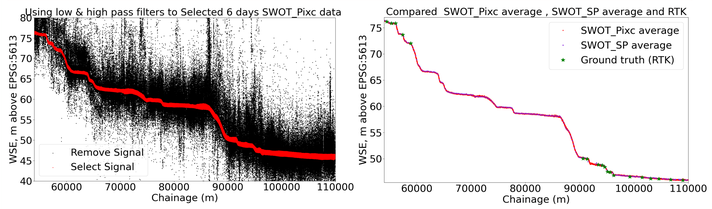
We utilized the full-period SWOT RiverSP_Node and SWOT pixel cloud datasets corresponding to the in-situ measurement dates at the study site. The dates of satellite tracks covering the study area are summarized in the below.

SWOT_L2_HR_RiverSP_Node_021_178_EU_20240916T202611_20240916T202612_PIC0_01.shp

307_EU_20240831 (-0.13); 456_EU_20240905 (-0.01); 001_EU_20240910 (0.08); 029_EU_20240911 (0.10); 178_EU_20240916 (0.14); 484_EU_20240906(0.00)

SWOT_L2_HR_PIXC_020_307_274L_20240831T145840_20240831T145851_PIC0_01.nc

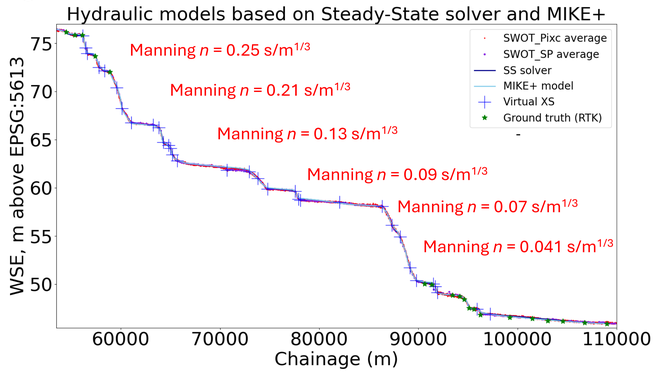
307_274L_20240831 (-0.13); 456_034R_20240905 (-0.01); 456_035R_20240905 (-0.01); 484_036L_20240906 (0.00); 001_273L_20240910 (0.08); 029_274R_20240911 (0.10); 029_275R_20240911 (0.10); 178_035l_20240916 (0.14)



Modeling results compared between Steady-State solver and MIKE+

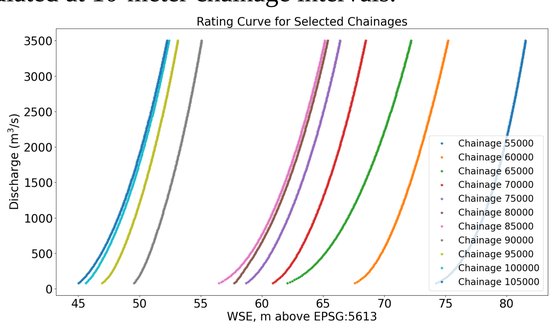
The in-situ measured XSs are shown as green stars in the figure below. In addition, several virtual XSs (blue crosses) were inserted at locations where the WSE changes abruptly, in order to improve the fitting between SWOT-derived WSE and the hydraulic model results.

The hydraulic model computed with the Steady-State solver (SS-solver) was applied to calibrate the Manning numbers along the river reach. The resulting calibrated Manning values range from 0.041-0.25 s/m$^{1/3}$ across the study area.



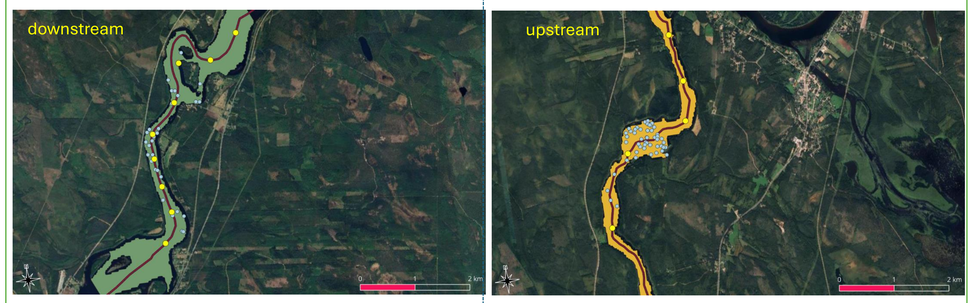
Rating curves based on Steady-State solver

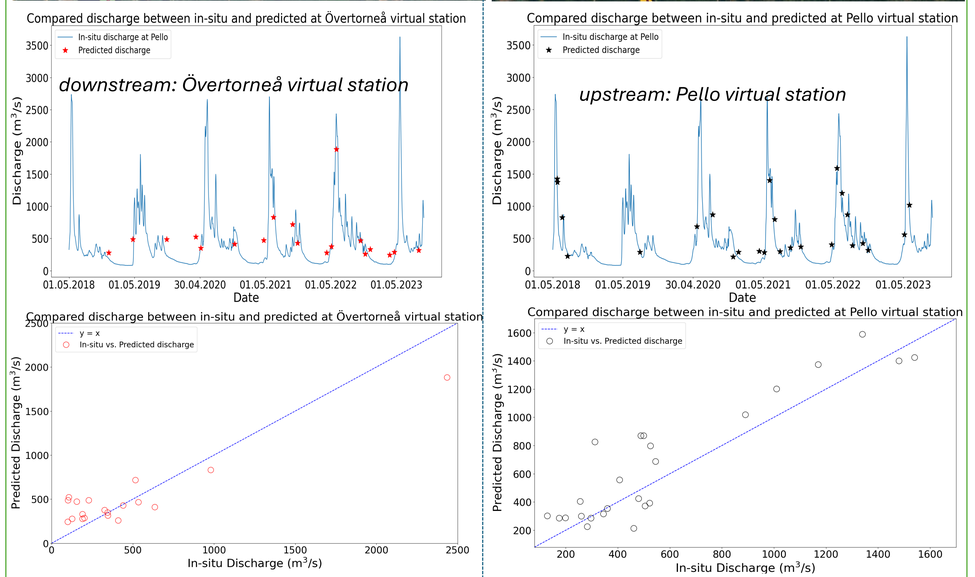
Based on the hydraulic model (SS-solver), rating curves were calculated at 10-meter chainage intervals.



Compared discharge between Pello station and predicted discharge at Sentinel-3 virtual station

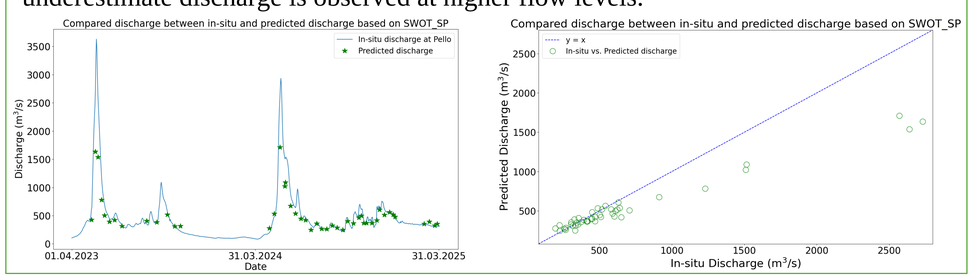
Based on the rating curves and Sentinel-3 observations, a discharge time series was constructed. Two virtual stations were positioned at the upstream and downstream sections of the river.





Compared discharge between Pello station and predicted based on SWOT data

Furthermore, by combining the rating curves with SWOT RiverSP_Node WSE observations, a discharge time series was also constructed. When comparing the in-situ and predicted discharge values, the hydraulic model shows better agreement under lower discharge conditions (i.e., < 650 m³/s), while a tendency to underestimate discharge is observed at higher flow levels.



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