Supplementary information

Supplementary note S1. Water surface elevation profiles

Geolocation quality flags

An investigation of the geolocation quality flag [1] revealed that flag 4 (bit 2) significantly affects data quality. Sometimes these points are assigned unrealistic elevations, while at other times they follow the trend of the remaining data (See Figure 1). In some data files, the water surface elevation profile consists of a large fraction of points with flag 4, for example, as shown in the top panel of Figure 1 on June 1st. Therefore, the points are retained in the dataset but assigned a lower weight of 0.2 to favour reliable geolocation quality flags.

Spline fitting for outlier filtering and slope estimation

A crude spline-based outlier filter is applied to remove extreme outliers from the pixel cloud using `scipy UnivariateSpline` [2]. Data that appear within the nadir gap between tiles are rejected as error-prone. Additionally, points with elevations greater than 14m are rejected, since the WSE ranges from 0m to 12m for the Dnipro River, and a threshold of 9 m is used for the Inhulets River.

As the distance to nadir increases, the noise level in the SWOT Pixel Cloud rises. This increase is particularly noticeable for the Dnipro River, prompting the application of a distance-dependent tolerance for outlier filtering. We define the tolerance as

$$\text{tolerance}(x) = c + \alpha \, |x - x_{\text{centre}}| \tag{1}$$

Where $x_{\text{centre}} = 70000$ is the chainage of the nadir gap, $c = 0.5$ is the tolerance at the nadir gap, and $\alpha = 1.8 \times 10^{-5}$ controls the increase of the tolerance away from the nadir gap. This approach ensures that points are filtered more strictly near the centre, where noise is low, while allowing a larger tolerance away from the nadir gap, where noise is higher, as shown by the red dotted lines in Figure 1. For the Inhulets River, the tolerance is kept constant at 0.9 m from the spline as the Inhulets River is approximately parallel to the SWOT nadir gap.

The water surface elevation profiles are estimated as the weighted median at each SWORD centrenode. Points within 1400 m of the node along the chainage are considered, with a maximum of 3000 points for Dnipro and 700 for Inhulets River, to stabilise estimates while reducing correlation in densely sampled areas. Based on the water surface elevation profiles, we fit a spline, and the maximum slope (i.e., the maximum first-order derivative) is estimated. For the Dnipro River, points within 2km of the nadir gap are assigned a weight of 3 to ensure that data near the nadir gap are represented in the spline fit. A smoothing factor of 15 is used for Dnipro and 3 for Inhulets, chosen to reflect the full wave slope while ignoring minor local variations.

	Dnipro River			Inhulets River		
Date	**Smooth**	**N obs.**	**% flag 4**	**Smooth**	**N obs.**	**% flag 4**
2023-06-01	95000	239105	26.4	2150	27469	5.3
2023-06-02	150000	235899	35.3	2410	27085	7.7
2023-06-03	60000	249540	0.6	2000	35356	5.4
2023-06-04	60000	250508	0.4	1700	35184	10.2
2023-06-05	60000	249720	0.6	2100	34924	3.0
2023-06-06	60000	244354	10.4	2000	29849	10.4
2023-06-07	21700	225142	23.3	1250	34855	65.4
2023-06-08	40500	211473	31.5	1250	39736	31.6
2023-06-09	24600	258038	5.7	2100	42756	5.2
2023-06-10	41000	218300	5.5	1500	42826	1.4
2023-06-11	38000	229731	3.8	4900	41522	2.2
2023-06-12	22500	257300	0.5	2200	41301	2.1
2023-06-13	19000	254579	0.5	2200	39261	13.0
2023-06-14	27400	253564	0.8	1800	35347	8.7
2023-06-16	95000	230834	31.1	2100	31493	14.0
2023-06-17	60000	235887	5.4	2300	36438	4.2
2023-06-18	40000	248522	0.8	2850	36085	8.6
2023-06-19	40000	236190	20.0	2200	35072	74.3
2023-06-20	40000	240182	1.6	3200	34930	10.7
2023-06-21	40000	228306	27.3	3900	32954	5.6
2023-06-22	40000	228651	17.1	4570	32496	10.1
2023-06-23	40000	238973	2.1	4000	35823	4.5
2023-06-24	40000	245852	1.0	3150	35909	6.8
2023-06-25	40000	244908	1.1	3100	31177	8.9
2023-06-26	40000	243102	1.6	3550	33678	6.9
2023-06-27	40000	249233	1.0	3950	35441	7.6
2023-06-29	40000	245902	1.2	4800	33714	7.6

Table 1 Supplementary table 1: Date, Spline smoothing factor, number of data points and the percentage of points flagged as geolocation flag 4 for each day for the Dnipro River and the Inhulets River.

Bootstrapping for uncertainty quantification

The outlier-filtered data are bootstrapped 1000 times to quantify the uncertainty of the water surface elevation profile and the maximum slope. We perform bootstrapping on data grouped by SWORD nodes, i.e., 200-meter river segments. Bootstrapping resamples the original data with replacement to generate an empirical distribution of the statistic, enabling confidence intervals to be estimated solely from the observed data rather than from a predefined model. However, bootstrapping assumes independent observations, which is not strictly true for SWOT data. Selecting points within 1400 m of each node introduces additional spatial correlation. Despite these limitations, bootstrapping provides a practical approximation of the uncertainty in the elevation estimates.

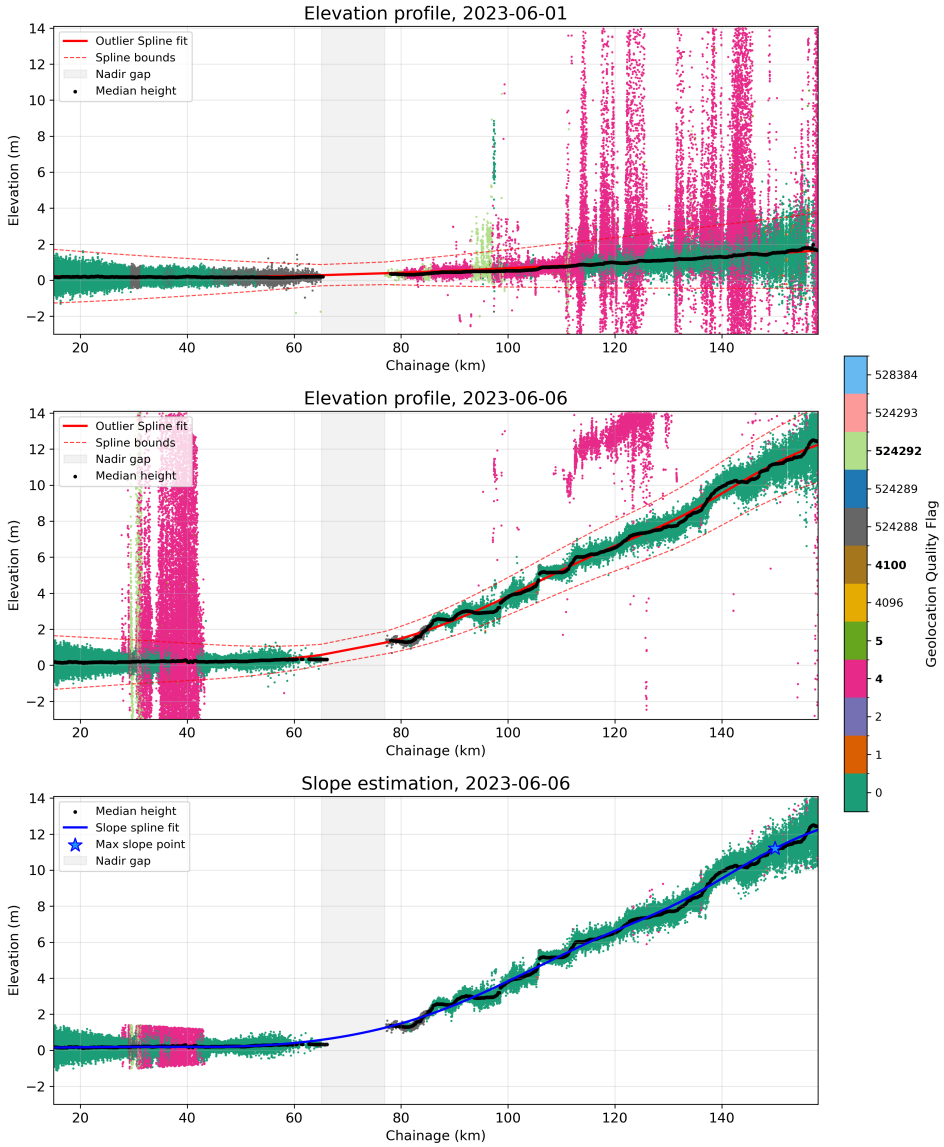

Fig. 1 Supplementary Figure 1: Two upper panels show examples of SWOT Pixel Cloud data within 1km of the Dnipro River centre line. Point data colours represent the geolocation quality flag [1], where flags written in bold indicate a quality flag of 4, which is assigned a lower weight. Bottom panel show the spline fit based on the outlier filtered data which is used to estimate the maximum WSS.

Supplementary note S2. Cross-section profiles

The cross-section profiles of the flood wave are derived from ICESat-2 ATL03 data and the SWOT pixel cloud. The cross-section profiles are outlier-filtered using the same procedure as the WSE profiles, with parameters summarised in Table 2.

Section	**Data**	**Range** [m]	**Smooth factor**	**Filter thres.** [m]	**Max elev.** [m]
a	SWOT 6 June	(-4100; 1450)	2500	0.4m	10
a	SWOT 7 June	(-4200; 2000)	2500	0.4m	10
a	ICESat-2	(-2000; 600)	1750	0.35m	4
b	SWOT 6 June	(-4000; 2000)	2500	0.4m	7
b	SWOT 7 June	(-4000; 600)	2500	0.4m	10
b	ICESat-2	(-2000; 600)	2200	0.4m	4
c	SWOT 6 June	(-6400; 2000)	110	0.4m	7
c	SWOT 7 June	(-8300; 2000)	2500	0.4m	10
c	ICESat-2	(-2000; 600)	1350	0.4m	3.5

Table 2 Supplementary table 2: Parameters for transverse WSE profiles.

The reference profiles are produced using a combination of ICESat-2 elevations, SWOT elevations from 3 June 2023, and the Copernicus 30m DEM [3], as these contribute to different parts of the profile. ICESat-2 elevation is used where the flood wave does not cover the ground, thus mainly the terrain elevations. The Copernicus 30m DEM is used to derive floodplain elevations; however, this product does not contain elevations for the WSE of the river channels. Therefore, SWOT elevations from 3 June 2023 are used to estimate the WSE under normal-flow conditions and the water-covered areas of the floodplains. To create a robust reference profile, the three datasets are combined and sampled every 2 meters using a 5-meter moving window.

References

[1] JPL: Swot product description document: Level 2 karin high rate water mask pixel cloud (l2_hr_pixc) data product. Technical report, Jet Propulsion Laboratory (2025)

[2] Virtanen, P., Gommers, R., Oliphant, T.E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E., Peterson, P., Weckesser, W., Bright, J., van der Walt, S.J., Brett, M., Wilson, J., Millman, K.J., Mayorov, N., Nelson, A.R.J., Jones, E., Kern, R., Larson, E., Carey, C.J., Polat, İ., Feng, Y., Moore, E.W., VanderPlas, J., Laxalde, D., Perktold, J., Cimrman, R., Henriksen, I., Quintero, E.A., Harris, C.R., Archibald, A.M., Ribeiro, A.H., Pedregosa, F., van Mulbregt, P., SciPy 1.0 Contributors: SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. Nature Methods **17**, 261–272 (2020) https://doi.org/10.1038/s41592-019-0686-2

[3] European Space Agency: Copernicus Global Digital Elevation Model. Distributed by OpenTopography (2024). https://doi.org/10.5270/ESA-c5d3d65 . https://dataspace.copernicus.eu/explore-data/data-collections/copernicus-contributing-missions/collections-description/COP-DEM