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Jiayi Zhang

Tianjin Normal University

Jiaqi Yao

yaojiaqi@tjnu.edu.cn

Tianjin Normal University

Haohao Zhou

Yellow River Institute of Hydraulic Research

Teng Li

Sun Yat-sen University

Meng Ding

Kansas State University

Shuangxiao Luo

Sichuan Normal University

Xue Li

National Institute of Natural Hazards

Haoxiang Xue

Tianjin Normal University

Jimin Chen

Yellow River Institute of Hydraulic Research

Changwei Chen

Yellow River Institute of Hydraulic Research

Hui Lu

Tsinghua University

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SWOT-Based 3D Mapping of an Ice-Dammed Lake Outburst

Flood: A Case Study of Merzbacher Lake

Jiayi Zhang¹, Jiaqi Yao^{1,*}, Haohao Zhou², Teng Li³, Meng Ding⁴, Shuangxiao Luo⁵
Xue Li⁶, Haoxiang Xue¹, Jimin Chen², Changwei Chen² and Hui Lu^{7,*}

¹*Academy of Ecological Civilization Development for JING-JIN-JI Megalopolis, Tianjin Normal University, Tianjin, 300387, China;*

²*Information Center, Yellow River Conservancy Commission, Ministry of Water Resources, Zhengzhou 450000, China;*

³*School of Geospatial Engineering and Science, Sun Yat-Sen University, Zhuhai, China;*

⁴*Department of Geography and Geospatial Sciences, Kansas State University, Manhattan, KS, USA;*

⁵*College of Geography and Resources, Sichuan Normal University, Chengdu, China;*

⁶*National Institute of Natural Hazards, Ministry of Emergency Management of China, Beijing, China;*

⁷*Department of Earth System Science, Institute for Global Change Studies, Tsinghua University, Beijing, 100084, China.*

*Corresponding authors: yaojiaqi@tjnu.edu.cn (J. Y.) and luhui@tsinghua.edu.cn (H.L.).

Keywords : Glacial lake outburst flood; ice-dammed lake; Surface Water and Ocean Topography; Sentinel-2; water-surface elevation

Abstract

Glacial lake outburst floods (GLOFs) are among the most destructive hazards in high-mountain regions and are expected to become increasingly important under ongoing glacier retreat and climate warming. However, quantifying the magnitude of individual GLOFs remains challenging because satellite observations typically capture changes in lake area but lack direct measurements of water-level drawdown, leading to large uncertainties in released-water estimates. Here, we develop a satellite-based framework that integrates Sentinel-2 imagery and Surface Water and Ocean Topography (SWOT) observations to reconstruct the three-dimensional evolution of an ice-dammed lake outburst flood. Using the July 2025 drainage of Merzbacher Lake in the central Tian Shan as a case study, we combine optical observations of lake-area collapse with SWOT-derived water-surface elevation changes to quantify event-scale water loss. Sentinel-2 observations show that the lake area decreased from 1.560 to 0.008 km², while SWOT measurements reveal a concurrent water-level decline from 3270.38 to 3257.83 m, corresponding to a drawdown of 12.55 m. Integrating these horizontal and vertical constraints yields an estimated drained-water volume of $(9.84 \pm 2.4) \times 10^6$ m³. Residual water bodies concentrated near the glacier-contact outlet indicate an inferred outlet-control sector governing drainage. Our results demonstrate that SWOT enables GLOF assessment to move beyond two-dimensional lake-change detection toward quantitative stage–area–volume reconstruction. This approach provides a practical framework for estimating flood magnitude in remote glacierized regions where field observations are unavailable and offers new opportunities for satellite-based assessment of cryosphere-related hazards under a warming climate.

1. Introduction

Glacial lake outburst floods (GLOFs) are rapid releases of water stored behind ice, moraine, or debris dams. Although individual events may last only hours to days, they can generate flood waves that propagate far downstream and threaten infrastructure, settlements, hydropower facilities, and irrigation systems in confined mountain valleys (Carrivick & Tweed, 2016; Lützow et al., 2023; Richardson & Reynolds, 2000; Taylor et al., 2023; Veh et al., 2022). As glaciers thin and retreat, glacial lakes are expanding in many high mountain regions, increasing water storage in steep headwater basins (Hugonnet et al., 2021; Shugar et al., 2020; G. Zhang et al., 2024; Zheng et al., 2021). However, the hazard posed by a specific lake is not determined by lake area alone. It also depends on lake stage, outlet-control elevation, dam stability, drainage-pathway evolution, and the volume of water released during an event (Cook & Quincey, 2015; Huggel et al., 2002; Worni et al., 2014).

This makes GLOF assessment a three-dimensional measurement problem. Optical satellite imagery can map lake extent before and after drainage and has supported most glacial-lake inventories and post-event reconstructions. Yet optical imagery cannot directly measure water-surface elevation (Drusch et al., 2012; Pekel et al., 2016; Shugar et al., 2020). Similar plan-view area losses may correspond to very different released volumes if lake-level drawdown differs. Conversely, steep basins may undergo substantial lowering with limited shoreline retreat. Without a direct elevation constraint, event-scale volume estimates commonly rely on empirical area–volume scaling, assumed basin geometry, or hydrodynamic back-calculation. These approaches remain sensitive to uncertain bathymetry, shoreline interpretation, and poorly constrained post-event water levels (Cook & Quincey, 2015; Crétaux et al., 2016; Huggel et al., 2002). This gap is especially important for ice-dammed lakes. Unlike moraine-dammed lakes with relatively persistent outlet geometry, ice-dammed lakes can drain through transient englacial or subglacial conduits. Drainage may be triggered or enhanced by ice-dam flotation, hydraulic connection to the glacier bed, conduit enlargement, roof collapse,

and subsequent conduit closure (Björnsson, 2003; Flowers et al., 2004; Roberts, 2005; Tweed & Russell, 1999; Walder & Costa, 1996). In such systems, the effective outlet-control threshold can change rapidly during drainage. Residual pools may remain in low-lying sectors after the main basin drains, providing a surface expression of the drainage state and likely outlet control. Key diagnostics therefore include not only lake-area collapse, but also lake-level drawdown, residual-water distribution, and source-lake storage loss.

Merzbacher Lake provides a compelling test case for this framework. Located in the central Tian Shan, it is a recurrent ice-dammed lake that repeatedly fills and drains in contact with the surrounding glacier system. Its drainage affects the Kumalak–Aksu–Tarim river system, making it both a benchmark cryospheric process site and a downstream water-hazard source (Bolch, 2007; Narama et al., 2010; Zheng et al., 2021). Historical monitoring and recent official reports have documented repeated filling, sudden drainage, and downstream flood response. However, most existing assessments remain largely two-dimensional. They identify when the lake fills or empties, but they do not directly quantify vertical drawdown or event-scale storage loss (Cook & Quincey, 2015; Crétaux et al., 2016; Huggel et al., 2002).

The Surface Water and Ocean Topography (SWOT) mission provides a new opportunity to close this observational gap. SWOT measures spatially distributed water-surface elevation over inland waters, adding the vertical dimension missing from optical-only mapping (Biancamaria et al., n.d.; Fu et al., 2024; Yao et al., 2024). Its wide-swath interferometric observations can capture lake-level patterns where valid returns are available, distinguishing SWOT from both image-based lake delineation and point-based stage measurements. When combined with Sentinel-2 lake outlines, SWOT enables event-scale stage–area–volume mapping: Sentinel-2 constrains horizontal lake-surface collapse, while SWOT constrains vertical drawdown during drainage (Crétaux et al., 2016; Drusch et al., 2012; Frasson et al., 2019; Fu et al., 2024).

Here we apply Sentinel-2 and SWOT observations to the July 2025 drainage of Merzbacher Lake. We map lake-surface collapse from pre- and post-event Sentinel-2 imagery, retrieve SWOT-derived water-surface elevation change, and quantify lake-level drawdown. We then combine these horizontal and vertical constraints to estimate bulk drained-water volume and examine the residual-pool footprint near the inferred outlet-control sector. This reconstruction does not resolve detailed bathymetry or a measured ice-dam profile. Instead, it provides an observation-constrained estimate of source-lake storage loss and demonstrates how SWOT-based 3D mapping can quantify rapid drainage from remote ice-dammed basins.

2. Study area and Data

2.1 Study Area

Merzbacher Lake is a recurrent ice-dammed lake in the central Tian Shan and a benchmark site for observing rapid glacier-controlled drainage (Bolch, 2007; Narama et al., 2010). The lake occupies a glacier-contact basin where steep topography, ice impoundment, and repeated filling–drainage cycles create favorable conditions for glacier lake outburst floods (Figure 1a). Its drainage is regulated by an ice-controlled outlet sector rather than a stable bedrock or moraine spillway, making lake release sensitive to ice-dam stability, outlet-control elevation, and englacial or subglacial hydraulic connectivity. Once a drainage pathway develops through or beneath the ice dam, stored water can be rapidly transferred to the downstream Kumalak–Aksu–Tarim river system (Roberts, 2005; Walder & Costa, 1996).

The July 2025 event represents a sharp transition from an impounded lake to a largely drained basin (Figure 1b). Post-event imagery indicates widespread exposure of the former lake bed, with residual pools confined near the outlet-side sector. This residual-water footprint suggests drainage focused near the glacier-contact control zone, although satellite observations cannot resolve the dam geometry or subglacial conduit structure.

This setting requires an observation framework that links plan-view lake collapse to vertical water-level change. Sentinel-2 lake outlines constrain the horizontal drainage signal, while SWOT water-surface elevation provides the vertical drawdown needed for volume estimation (Figure 1c). Although the Sentinel-2 and SWOT acquisitions are not simultaneous, they bracket the same pre- and post-drainage states around the inferred 5–7 July 2025 GLOF window (Figure 1d), providing the basis for the event-scale drained-volume reconstruction.

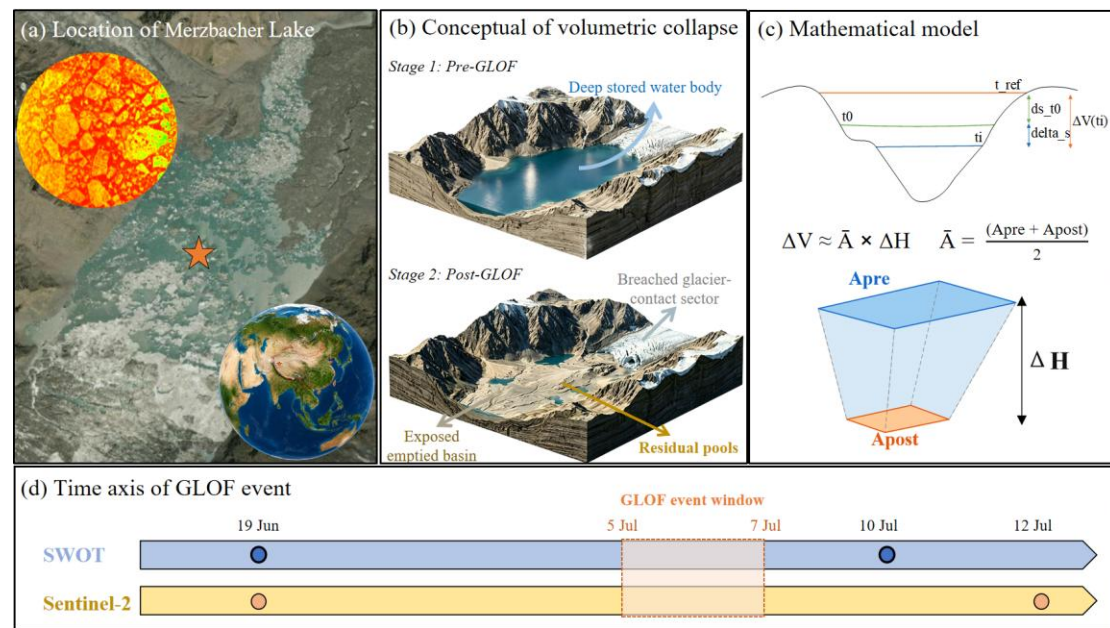


Figure 1. Observation framework and event constraints for the July 2025

Merzbacher Lake glacier lake outburst flood (GLOF).

a. Geographic setting of Merzbacher Lake in the central Tian Shan, showing the glacier-contact lake basin and the location of the July 2025 drainage event.

b. Conceptual model of the lake-drainage process, illustrating the transition from a pre-event impounded lake to a post-event drained basin with residual outlet-side pools.

c. Satellite-constrained framework for estimating drained-water volume, combining mapped lake-area change and SWOT-derived water-surface elevation lowering to reconstruct bulk water loss.

d. Timeline of Sentinel-2 and SWOT observations relative to the inferred GLOF window. The two data sets are not strictly simultaneous but bracket the same pre- and post-drainage states:

pre-event acquisitions captured the filled-lake condition, whereas post-event

observations documented the drained basin.

2.2 Satellite Data and Event Constraints

We used Sentinel-2 MSI imagery and SWOT observations to characterize the July 2025 drainage of Merzbacher Lake (Table 1). The acquisitions were not strictly simultaneous, but they bracketed the same event: pre-event observations sampled the filled or near-filled lake state, whereas post-event observations captured the drained basin after the inferred 5–7 July 2025 GLOF window.

Sentinel-2 imagery provided 10 m optical coverage for mapping lake extent before drainage and residual pools after the event (Drusch et al., 2012). Water boundaries were delineated using spectral contrast, NDWI-assisted interpretation, and visual refinement in glacier-contact, shadowed, snow-covered, and debris-covered areas. The final polygons were projected to a metric coordinate system before area calculation. This mapping quantified the lake-area collapse from 1.560 km² to 0.008 km², corresponding to a 1.552 km² loss.

SWOT L2_HR_Raster observations provided the water-surface elevation constraint (Biancamaria et al., n.d.; Fu et al., 2024; Hamoudzadeh et al., 2024). The 250 m raster product was used as the primary source for lake-level retrieval, with acquisitions on 2, 10, and 12 July 2025 used to define pre- and post-drainage WSE. Quality-screened pixels were extracted within the mapped lake domain or, for the drained state, within a local lake-centered window around residual water. The representative lake level decreased from 3270.38 to 3257.83 m, giving a 12.55 m drawdown. The 100 m raster product was used only to check spatial consistency and was not used in the final volume estimate.

SWOT L2_HR_PIXC provided an independent radar-based view of drainage-related spatial change. The raw 10–70 m pixel-cloud observations were quality screened and

gridded to the 30 m SRTM DEM grid using the median σ^0 value of valid points within each cell. This step created a common raster format for comparison with Sentinel-2 lake masks and reduced effects from irregular sampling density. After drainage, valid PIXC cells over the former open-water surface became fragmented and concentrated near residual pools and low-lying sectors, supporting the interpretation of rapid drainage rather than gradual shoreline fluctuation.

Table 1. Satellite data products and ancillary information used in this study.

Data product	Spatial resolution	Source	Time	Purpose
Sentinel-2 imagery	10 m	Copernicus/ESA	Pre- and post-event scenes bracketing 5–7 July 2025	Mapping pre- and post-event lake extent and residual pools
SWOT L2_HR_Raster	250 m	NASA/CNES SWOT mission	2, 10, and 12 July 2025	Quantifying pre- and post-event lake water-surface elevation change
SWOT L2_HR_Raster	100 m	NASA/CNES SWOT mission	Pre- and post-event acquisitions	Supporting analysis of spatial WSE patterns before and after drainage
SWOT L2_HR_PIXC	Raw 10–70 m pixel cloud; gridded to 30 m	NASA/CNES SWOT mission	Pre- and post-event acquisitions	Assessing PIXC spatial changes before and after drainage
Regional monitoring report	Document record	Xinjiang Water and Disaster Prevention Center	5–7 July 2025; 27 March 2026	Independent constraint on event timing and post-drainage state

3. Methods

3.1 Optical Lake-Extent Mapping

Pre- and post-event lake extents were mapped from Sentinel-2 imagery using a combination of spectral water detection and visual refinement. The normalized difference water index was used as an initial guide (McFEETERS, 1996; Xu, 2006):

$$NDWI = \frac{\rho_{green} - \rho_{NIR}}{\rho_{green} + \rho_{NIR}} \quad (1)$$

where ρ_{green} and ρ_{NIR} are the Sentinel-2 green and near-infrared reflectance values, respectively. The resulting water mask was visually checked and refined to reduce misclassification in shadowed terrain and glacier-contact areas (Drusch et al., 2012; Pekel et al., 2016).

The mapped water area for each stage was calculated from the corresponding water polygons:

$$A_t = \sum_{j=1}^{n_t} a_{j,t} \quad (2)$$

where $a_{j,t}$ is the area of the j-th mapped water polygon and n_t is the number of water polygons at time t. The pre-event lake polygon represents the filled lake surface, whereas the post-event polygons represent residual water bodies remaining after drainage.

3.2 SWOT Water-Surface Elevation Retrieval

SWOT L2_HR_Raster observations were used to retrieve lake water-surface elevation (WSE) before and after drainage (Bergeron et al., 2020; Biancamaria et al., n.d.; Fu et al., 2024; Hamoudzadeh et al., 2024). The 250 m raster product was used as the primary WSE source, while the 100 m raster product was used as a consistency check of spatial WSE patterns. Raster observations were filtered using the WSE quality band, retaining pixels with quality flags of 0 and 1, corresponding to good and suspect-quality observations. For each acquisition, valid pixels were extracted within the mapped lake domain or within a local lake-centered window.

The representative lake level for each acquisition was calculated as the median of valid WSE pixels:

$$H_t = \text{median}_{i \in \Omega_t}(WSE_{i,t}) \quad (3)$$

Where H_t is the representative lake water-surface elevation at time t , $WSE_{i,t}$ is the WSE of pixel i , and Ω_t is the set of quality-screened valid SWOT pixels. The median was used because it is less sensitive than the mean to isolated noisy pixels, mixed land-water returns, and local topographic effects in this small alpine basin (Bergeron et al., 2020; Hamoudzadeh et al., 2024). The water-level drop was calculated as $\Delta H = H_{pre} - H_{post}$, where H_{pre} and H_{post} are the representative pre- and post-event lake levels.

3.3 Bulk Drained-Volume Estimate

The drained volume was estimated by combining the mapped lake-area change with the SWOT-derived water-level drop. Because detailed lake bathymetry is not available, we used a first-order average-end-area approximation rather than a full basin-volume reconstruction (Cook & Quincey, 2015; Crétau et al., 2016; Huggel et al., 2002):

$$\Delta V \approx \frac{A_{pre} + A_{post}}{2} \times \Delta H \quad (4)$$

where A_{pre} is the mapped pre-event lake area, A_{post} is the mapped post-event residual water area, and ΔH is the SWOT-derived water-level drop. This formulation is consistent with the revised conceptual framework in Figure 1c. It should be interpreted as a satellite-constrained bulk estimate of water loss, not as a detailed bathymetric reconstruction of the lake basin.

Uncertainty in the bulk volume estimate was propagated from the mapped lake-area uncertainty and the SWOT-derived water-level uncertainty (Bergeron et al., 2020; Cook & Quincey, 2015; Hamoudzadeh et al., 2024):

$$\sigma_{\Delta V}^2 = \left(\frac{\Delta H}{2} \sigma_{A_{pre}} \right)^2 + \left(\frac{\Delta H}{2} \sigma_{A_{post}} \right)^2 + \left(\frac{A_{pre} + A_{post}}{2} \sigma_{\Delta H} \right)^2 \quad (5)$$

Here, $\sigma_{A_{pre}}$ and $\sigma_{A_{post}}$ denote uncertainties in the mapped water areas, and $\sigma_{\Delta H}$ denotes

uncertainty in the SWOT-derived water-level change. Area uncertainty was estimated by perturbing the Sentinel-2 shoreline by ± 10 m, yielding $\sigma_{Apre}=0.081$ km² and $\sigma_{Apost}=0.0086$ km². The pre-event WSE was well constrained within the former lake domain. The post-event residual pools were smaller than the 250 m SWOT raster posting; therefore, post-event WSE was estimated from a local window around the mapped residual pools after robust removal of terrain-contaminated pixels. We used a conservative $\sigma_{\Delta H} \approx 3.0$ m to account for sparse valid pixels and mixed land-water returns. The resulting volume estimate and uncertainty are reported in the Results.

4. Results

4.1 Multi-Source Evidence for Rapid Lake Drainage

The Sentinel-2 optical sequence constrains the horizontal drainage signal. Lake area decreased from 1.560 km² before the event to 0.008 km² after drainage, equivalent to a 1.552 km² loss and more than 99% reduction of the mapped water surface (Figures 2a1–a3). Post-event water was limited to small residual pools near the outlet-side sector, while most of the former lake bed was exposed. This near-complete area collapse indicates basin-scale drainage rather than ordinary shoreline fluctuation.

SWOT PIXC σ^0 observations capture the radar expression of drainage. The native 10–70 m PIXC observations were quality screened and gridded to 30 m before spatial comparison. Before the event, 859 valid 30 m gridded PIXC cells were distributed across the main lake basin (Figure 2b1).

After drainage, 772 valid cells remained within the analysis domain, but their spatial pattern changed markedly: cells over the former open-water surface became fragmented and concentrated near residual pools and low-lying sectors (Figure 2b2). The PIXC result is therefore interpreted as drainage-related spatial reorganization, not as a normalized estimate of water-covered area. The change panel, compiled from 2,343 PIXC cells, highlights the transition from a spatially continuous pre-event lake surface to a largely drained basin with isolated residual water bodies (Figure 2b3).

SWOT WSE observations constrain the vertical drainage signal. The representative lake level decreased from 3270.38 m before drainage to 3257.83 m after the event, giving a 12.55 m drawdown. These values were derived from 2,229 valid pre-event WSE pixels and 2,094 valid post-event pixels, respectively (Figures 2c1–c2). To avoid mixing unmatched observations, the Δ WSE map was calculated only from strict-overlap cells with valid WSE retrievals in both acquisitions, yielding 1,991 paired cells (Figure 2c3). Negative Δ WSE values dominate the common observation domain, confirming post-event lowering.

Together, the >99% area loss, PIXC spatial reorganization, and 12.55 m SWOT-derived drawdown document rapid drainage during 5–7 July 2025 (Roberts, 2005; Walder & Costa, 1996). Official reporting independently supports this timing, stating that the Merzbacher ice-dammed lake began draining on 5 July, was nearly emptied by 7 July, and produced a downstream flood response by 9 July (Tarim River Basin Administration, 2025). These observations provide the horizontal and vertical constraints for the stage–area–volume reconstruction in Figure 3.

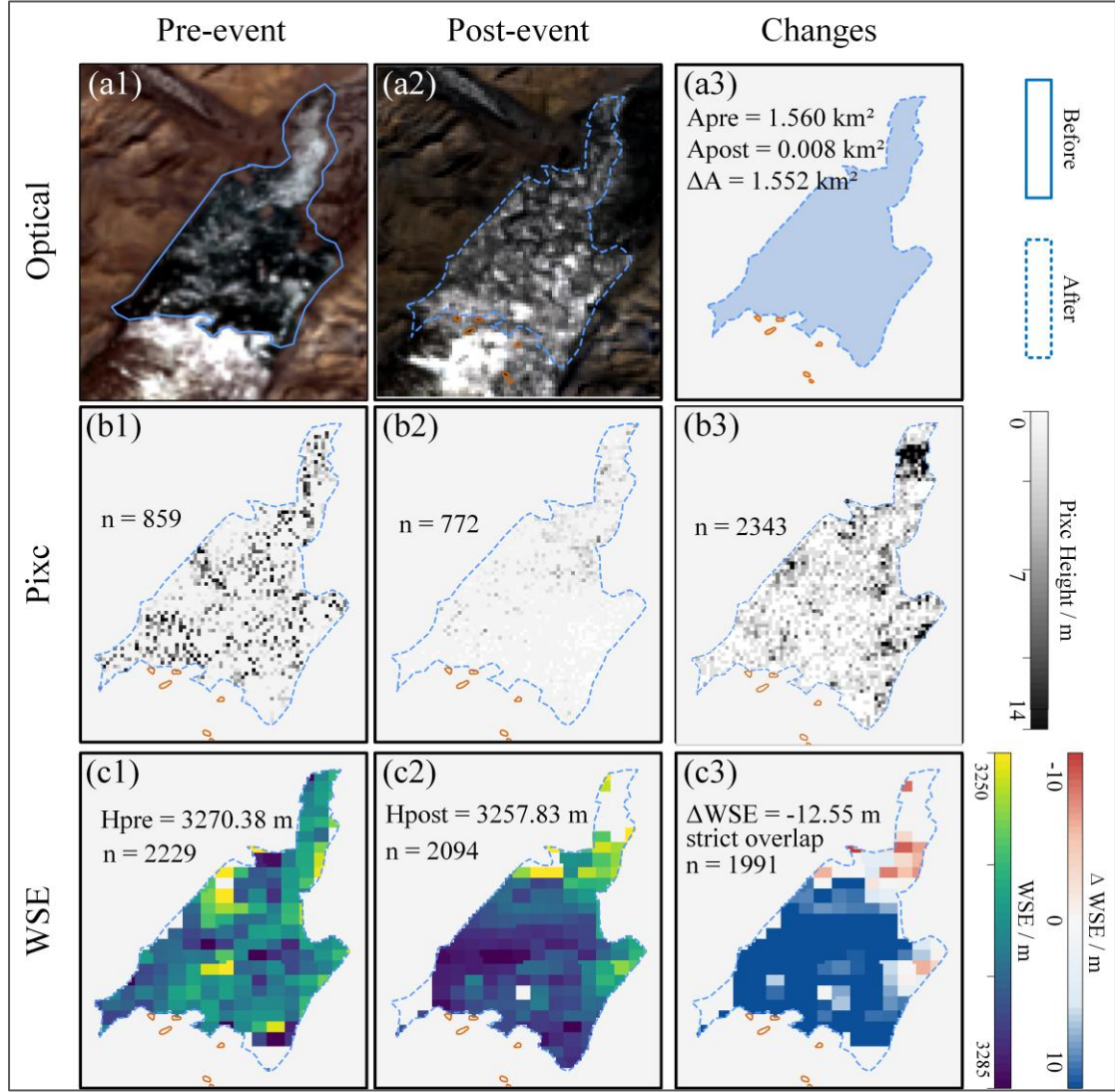


Figure 2. Multi-source satellite observations of the July 2025 Merzbacher Lake drainage event. **a.** Sentinel-2 optical mapping of lake-area collapse. **a1–a3.** The Sentinel-2 optical sequence constrains the horizontal drainage signal. Lake area decreased from 1.560 to 0.008 km², equivalent to a 1.552 km² loss and near-complete drainage of the mapped lake surface, **b.** SWOT PIXC observations before and after drainage. **b1–b3.** SWOT PIXC σ^0 observations capture the radar expression of drainage. Native 10–70 m PIXC observations were quality screened and gridded to 30 m; after drainage, valid cells over the former open-water surface became fragmented and concentrated near residual pools and low-lying sectors. Reported n values denote valid 30 m gridded PIXC cells, not normalized estimates of water-covered area **c.** SWOT water-surface elevation (WSE) observations of lake-level drawdown. **c1–c3.** SWOT

WSE constrains the vertical drainage signal: lake level fell from 3270.38 to 3257.83 m, giving a 12.55 m drawdown. The Δ WSE map uses strict-overlap valid cells only; negative values indicate post-event lowering. Together, the >99% area loss, PIXC spatial reorganization, and 12.55 m drawdown document rapid drainage during 5–7 July 2025.

4.2 Stage–Area–Volume Reconstruction of Drained Water

We next convert the observed area collapse and SWOT-derived drawdown into a stage–area–volume estimate of source-lake storage loss. The pre-event lake outline defines the initial water-surface footprint, the post-event residual pools define the remaining water footprint, and the SWOT-derived drawdown provides the vertical separation between the two states. This framework does not resolve lake-bed bathymetry, but it provides an observation-constrained basis for estimating bulk water loss during the outburst.

Before drainage, Merzbacher Lake covered 1.560 km², after the event, residual water covered only 0.008 km², corresponding to a 1.552 km² areal loss and a >99% reduction of the mapped water surface (Figure 3a). SWOT measured a representative water-surface elevation decrease from 3270.38 to 3257.83 m, equivalent to a 12.55 m drawdown. Using an average-end-area approximation, these horizontal and vertical constraints yield a bulk drained-water volume of $(9.84 \pm 2.4) \times 10^6$ m³ (Figures 3b–3c). This value represents a first-order, satellite-constrained estimate of lake-storage loss, not a complete downstream flood-volume reconstruction.

The main uncertainty arises from the post-event WSE retrieval. After drainage, residual pools were much smaller than the 250 m SWOT raster posting, so post-event elevation had to be extracted from a local residual-pool window and screened for mixed or terrain-contaminated pixels. This limitation affects the precision of the volume estimate, but not the interpretation that the event involved substantial lake-level lowering and

basin-scale water loss.

The residual-pool footprint provides an additional constraint on drainage geometry. Post-event pools were concentrated near the outlet-side sector, where the mapped lake margin retreated most strongly. We interpret this area as an inferred outlet-control sector associated with the glacier-contact or ice-dam control zone. This inference is based on residual-water distribution and lake-margin collapse, not on a measured dam-crest profile or resolved subglacial conduit geometry. Together, the 1.552 km² area loss, 12.55 m drawdown, and $(9.84 \pm 2.4) \times 10^6$ m³ storage loss show that the July 2025 event was a measurable three-dimensional drainage of an ice-dammed lake.

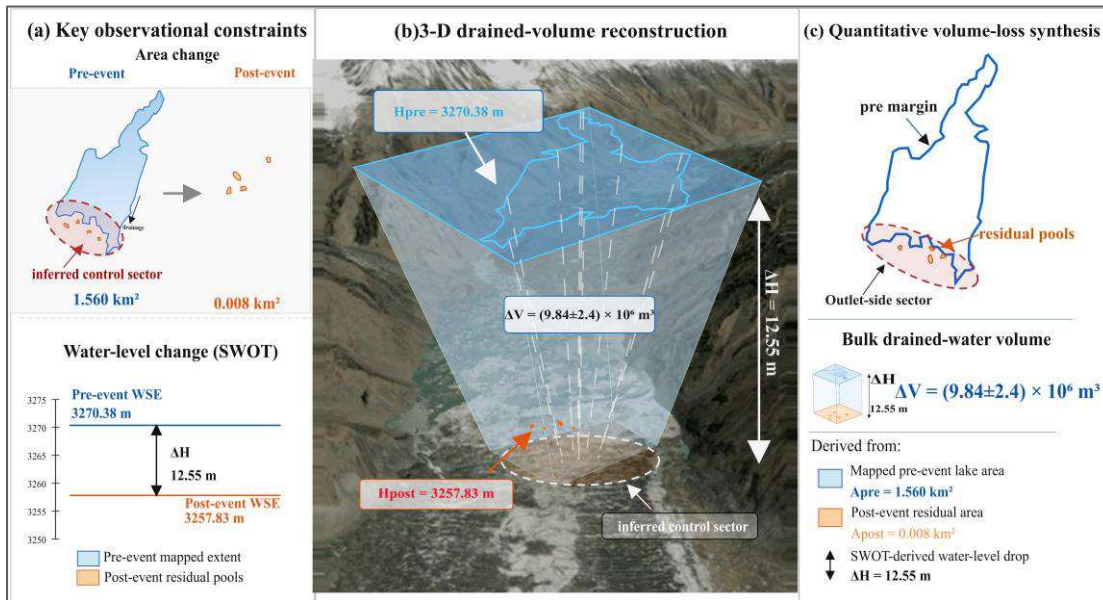


Figure 3. Observation-constrained reconstruction of the July 2025 Merzbacher Lake drainage. **a.** Observational constraints on lake-area collapse and water-level lowering, which show that Sentinel-2-derived lake area decreased from 1.560 to 0.008 km² while SWOT-measured water-surface elevation dropped from 3270.38 to 3257.83 m, with residual pools concentrated near the inferred outlet-control sector marked by the dashed red ellipse. **b.** Three-dimensional volume-loss visualization, in which the pre-event lake surface, post-event residual pools, and translucent water-loss prism define the first-order storage loss associated with the 12.55 m drawdown. **c.**

Quantitative synthesis of mapped water-area change, residual-pool distribution, and SWOT-derived elevation lowering. The average-end-area estimate gives a bulk drained-water volume of $(9.84 \pm 2.4) \times 10^6 \text{ m}^3$, with drainage inferred to have focused near the outlet-side-control sector.

5. Discussion and Conclusions

Glacial lake outburst flood (GLOF) volume remains difficult to quantify from space because optical satellite observations usually resolve lake-area change but not the accompanying water-level drop. This gap is critical for ice-dammed lakes, where drainage can be controlled by transient outlet conditions, englacial or subglacial pathways, and rapid changes in the effective outlet-control level (Cook & Quincey, 2015; Roberts, 2005; Walder & Costa, 1996). Here we address this limitation with a SWOT-based three-dimensional mapping framework for the July 2025 drainage of Merzbacher Lake. By combining Sentinel-2 lake outlines with SWOT water-surface elevation (WSE), the framework links lake-area collapse, lake-level drawdown, residual-water distribution, and source-lake storage loss within a single event-scale reconstruction (Biancamaria et al., n.d.; Fu et al., 2024).

The Sentinel-2 record captures the horizontal expression of drainage. Merzbacher Lake decreased from 1.560 to 0.008 km², corresponding to a 1.552 km² loss and a reduction of more than 99% of the mapped water surface. This magnitude of area loss indicates basin-scale drainage rather than minor shoreline fluctuation. Post-event water was confined to small residual pools near the outlet-side sector, suggesting that drainage was focused near a glacier-contact or ice-dam control zone. This sector remains inferred from residual-water distribution and lake-margin retreat, because the satellite observations do not resolve the dam-crest geometry or subglacial conduit structure.

The SWOT record provides the vertical constraint that is missing from optical-only assessments. Representative lake level decreased from 3270.38 to 3257.83 m, giving a

12.55 m drawdown across the event. This observed WSE change allows the mapped lake-area collapse to be interpreted as a three-dimensional water-loss signal rather than only a plan-view contraction. The post-event reorganization of SWOT PIXC observations toward residual pools and low-lying sectors further supports rapid drainage from the former open-water basin.

The stage–area–volume reconstruction converts these observations into a quantitative storage-loss estimate. Combining the 1.552 km² area loss with the 12.55 m SWOT-derived drawdown yields a drained-water volume of $(9.84 \pm 2.4) \times 10^6$ m³. This value represents a first-order, satellite-constrained estimate of source-lake storage loss, not a complete downstream flood-volume reconstruction. The dominant uncertainty comes from the post-event WSE retrieval, because the residual pools were smaller than the 250 m SWOT raster posting and required local-window extraction and screening of mixed or terrain-contaminated pixels (Bergeron et al., 2020; Hamoudzadeh et al., 2024). The official downstream flood-volume estimate provides complementary evidence rather than a direct validation target (Tarim River Basin Administration, 2025). The report stated that Merzbacher Lake began draining on 5 July 2025, was nearly emptied by 7 July, and produced a downstream flood response by 9 July, with an estimated downstream flood volume of approximately 6.0×10^7 m³. This value represents an integrated river-flow response downstream of the source lake, whereas our estimate of $(9.84 \pm 2.4) \times 10^6$ m³ quantifies the directly observed storage loss within the mapped lake basin from Sentinel-2 area change and SWOT-derived water-level lowering. The two quantities are therefore not expected to be identical, because they differ in control volume, observation footprint, flood routing, background glacier meltwater input, and possible sediment or debris entrainment during downstream propagation. We therefore use the official report to support the timing and hydrological significance of the July 2025 drainage, while the satellite analysis isolates lake-level drawdown and source-lake storage loss.

Overall, the July 2025 Merzbacher Lake event shows that SWOT-based 3D mapping can move GLOF analysis beyond plan-view change detection toward event-scale stage–area–volume reconstruction. For remote ice-dammed lakes without gauges, bathymetric surveys, or field observations, this approach provides a practical observational basis for quantifying drainage magnitude and improving satellite-based assessment of high-mountain water hazards (Carrivick & Tweed, 2016; Fu et al., 2024; Taylor et al., 2023).

DECLARATION OF INTERESTS

The authors declare no competing interests.

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The derived datasets and analysis scripts supporting this study are publicly available on Figshare at <https://doi.org/10.6084/m9.figshare.32612586> (Zhang et al., 2026). The archived dataset includes derived lake-boundary shapefile, drained-volume estimates, uncertainty-propagation tables, figure-source statistics, and analysis scripts. SWOT L2_HR_PIXC and L2_HR_Raster products are available from NASA PO.DAAC (https://podaac.jpl.nasa.gov/dataset/SWOT_L2_HR_PIXC_D; https://podaac.jpl.nasa.gov/dataset/SWOT_L2_HR_RASTER_D). The SRTM 1 Arc-Second Global DEM is available from the U.S. Geological Survey at <https://doi.org/10.5066/F7PR7TFT>.

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