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Brief communication: Contrasting Estimates of Global Glacier Mass Balance in 2025

Qiuyu Wang[1*2], Zihao Li[1], Ritu Anilkumar[2], Huake Zhang[1], Xiaojun Ma[1], Wenke Sun[1], Jonathan Bamber[2,3]

[1]State Key Laboratory of Earth System Numerical Modeling and Application, College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing, 100049, China
[2]Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol, BS8 1SS, UK
[3]Chair of Data Science in Earth Observation, Department of Aerospace and Geodesy, Technical University of Munich, Munich 80333, Germany

Correspondence to: Qiuyu Wang (wangqiuyu@ucas.ac.cn)

Abstract. Global glaciers were recently reported to have lost 408 ± 132 Gt in 2025, ranking it as the sixth-most negative year since 1975. Here, we provide an independent assessment using observations from NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) and ESA's Cryosphere Satellite-2 (CryoSat-2) radar altimeter. The two altimeters indicate global losses of 260 ± 56 Gt and 235 ± 121 Gt, respectively, substantially smaller than the reported value and below the respective mean rates of the past two decades. The reduced global loss estimate is primarily due to low mass losses or net mass gains in several regions that normally dominate global variability, particularly Alaska, Subantarctic & Antarctic Islands, and Arctic Canada, while High Mountain Asia experiences greater mass loss than its historical average. These results do not indicate that 2025 was a near-record year for global glacier mass loss. The contrast among recent estimates highlights the added value of combining in situ, altimetric, and gravimetric observations in annual global assessments as well as the large inter-annual variability in global glacier mass balance measurements.

1 Introduction

Glaciers worldwide have undergone sustained and accelerating mass loss in recent decades, contributing to sea-level rise and affecting regional water resources, ecosystems and glacier-related hazards (Hugonnet et al. 2021; Zemp et al. 2025; Zemp et al. 2019; Bamber et al. 2018). Multi-decadal trends have commonly been used to characterize long-term glacier decline. However, annual estimates and recent changes are increasingly important for tracking the pace of ongoing change (Zekollari et al. 2025; Rounce et al. 2023). Global glaciers were recently reported to have lost 408 ± 132 Gt in 2025, making it the sixth-largest annual loss since records began in 1975. The assessment placed 2025 within a recent cluster of strongly negative years and attributed the largest regional losses to High Mountain Asia, Alaska and the Russian Arctic (Zemp et al. 2026). Satellite altimetry, however, indicates a smaller loss in 2025. Our ICESat-2 and CryoSat-2 estimates are −260 ± 56 and −235 ± 121 Gt, respectively, both smaller in magnitude than the mean annual losses reported for 2000 – 2019 (−267 ± 16 Gt yr^{-1} ; Hugonnet et al., 2021) and 2000 – 2023 from the GlaMBIE dataset (−273 ± 16 Gt yr^{-1} ; Zemp et al., 2025).

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The reported 2025 estimate was derived from spatially interpolated glaciological mass-balance anomalies superimposed on long-term geodetic trends constrained mainly by observations ending in 2019 (Zemp et al. 2026). Although this framework provides a valuable long-term record, it must be noted that the geodetic observations from 2000-2019 were used to identify long-term trends which were then used to calibrate the anomalies derived from in-situ measurements. This means that the magnitude of the recent annual anomaly is not directly constrained by contemporaneous geodetic observations. Satellite altimetry offers a complementary approach by repeatedly measuring glacier surface-elevation change at sufficient temporal resolution to resolve year-to-year variability (Wang et al. 2017; Jakob et al. 2021). ICESat-2 laser altimetry and CryoSat-2 radar altimetry provide distinct observational constraints, with different measurement principles and sampling characteristics (Berthier et al. 2023).

Here, we use ICESat-2 and CryoSat-2 datasets to estimate global and regional glacier mass changes in 2025 and place them in the context of recent multidecadal averages. We compare the magnitude and regional distribution of these estimates with the glaciological assessment, examine the contrasting regional contributions to the global total, and explore how differences in observational coverage and estimation methods may contribute to the discrepancies.

2. Data and Methods

We derived glacier mass changes from ICESat-2 laser altimetry for 2018–2025 and CryoSat-2 radar altimetry for 2010–2025. The overlapping period was used to compare the two altimetry records, whereas the longer CryoSat-2 record provided an additional temporal context. GRACE-FO mascon solutions provided independent estimates for comparison. Glacier outlines and areas were obtained from the Randolph Glacier Inventory (RGI version 7.0), a globally complete inventory of glacier extents compiled from multiple satellite and regional datasets (RGI Consortium 2023). Different reference digital elevation models (DEMs) were adopted for different RGI glacier regions.

ArcticDEM was used for RGI regions 01 and 03–10 (Porter et al. 2023), while Copernicus DEM GLO and TanDEM-X were used for the mid- and low-latitude regions (RGI regions 02 and 11–18) (Guth et al. 2021; Rizzoli et al. 2017). For RGI region 19, the Reference Elevation Model of Antarctica (REMA) was used (Howat et al. 2022). These DEMs served as reference surfaces for calculating elevation differences and defining elevation bins used in the analysis of glacier elevation change.

2.1 ICESat-2 laser altimetry

We used the ICESat-2 ATL06 land-ice height product, which provides surface elevations over nominal 40-m segments at 20-m along-track spacing (Smith et al. 2020; Neumann et al. 2019). Elevation-change time series were derived following Wang and Sun (2022). Within each second-order RGI region, observations were grouped into elevation bands, and elevation-change

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estimates were weighted by the glacier area within each band. We then constructed first-order regional time series by area-weighted aggregation of the corresponding second-order regions (Wang et al. 2021).

2. 2 CryoSat-2 radar altimetry

We used the CryoTEMPO-EOLIS point product derived from swath-processed SIRAL observations (Jakob and Gourmelen 2023). Following Jakob and Gourmelen (2023), the elevation observations were aggregated onto regular grids before regional averaging. Grid sizes of 2-5 km were used for glacier in polar regions, whereas 100 km grids were used for High Mountain Asia and Alaska, consistent with the original CryoTEMPO-EOLIS processing framework. Regional elevation-change time series were then calculated by weighting each grid-cell estimate by the glacier area contained within that cell.

CryoSat-2 data were unavailable for North Asia, the Caucasus and Middle East, and New Zealand, and these regions were therefore excluded from the analysis. Fortunately, these regions contain just 4,936 km² of glacier area, equivalent to 0.70% of the global area considered (706, 744 km2). ICESat-2 estimates a combined 2025 mass change of -0.6 ± 1.0 Gt for these three regions, suggesting that their omission has little effect on the global comparison. We did not fill these gaps with ICESat-2 estimates, thereby keeping the observational inputs the two results independent.

2. 3 GRACE Mascon

We used Release-06 monthly GRACE-FO mascon solutions from three processing centers: the Center for Space Research (CSR) (Save et al. 2016), Goddard Space Flight Center (GSFC)(Loomis et al. 2019), and Jet Propulsion Laboratory (JPL)(Wiese et al. 2016; Watkins et al. 2015). These solutions are referred to as CSR-M, GSFC-M, and JPL-M. They provide gridded terrestrial water storage anomalies expressed as equivalent water height. We analyzed the 2018–2025 portion, corresponding to the GRACE-FO observation period.

The Global Land Data Assimilation System (GLDAS) integrates satellite- and ground-based observations with land-surface models to provide global estimates of terrestrial water and energy states and fluxes at a spatial resolution of 0.25°(Rodell et al., 2004). We used GLDAS-derived soil-moisture estimates to remove soil-moisture variations from GRACE-FO estimates to reduce non-glacier hydrological contributions. Further details on the data processing and the selection of glacier-region grids can be found in Ma et al. (2025).

2. 4 Annual and global mass-change estimates

Regional elevation changes were converted to mass changes using a density conversion factor of 850 kg m^{-3} (Huss 2013) and glacier areas from RGI 7.0. Global mass-change time series were obtained by summing the first-order regional estimates. The same glacier inventory, density conversion and aggregation procedure were applied to both altimetry data to ensure direct comparability.

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Annual mass changes were calculated as differences between mean mass states in successive hydrological years. For Northern Hemisphere regions, each hydrological-year mean was calculated from October of the preceding calendar year to September of the labelled year. For Southern Hemisphere regions, the corresponding period extended from April of the preceding calendar year to March of the labelled year. The annual mass change for year (t) was then calculated as the difference between the mean mass state during hydrological year (t) and that during hydrological year (t-1).

$$\Delta M_t = \widetilde{M}_t - \widetilde{M}_{t-1} \quad (1)$$

Where $\widetilde{M}_t$ and $\widetilde{M}_{t-1}$ are the mean glacier mass states during hydrological years t and t-1, respectively, ΔM_t is the glacier mass change in hydrological year t.

2. 5 Uncertainty estimation

Trend uncertainty was estimated by combining the statistical uncertainty of the linear regression with systematic uncertainties associated with glacier area and volume-to-mass conversion. The regression uncertainty was defined as 1.96 times the standard error of the fitted slope, corresponding to the 95% confidence level. Although the uncertainty in glacier area is estimated to be approximately 5% at the global scale for the RGI (Pfeffer et al. 2014), we conservatively assumed a 10% uncertainty in glacier area at the 95% confidence level, consistent with the magnitude of area uncertainties commonly adopted in previous glacier mass-balance studies (Shean et al. 2020; Gardner et al. 2013). The uncertainty associated with the volume-to-mass conversion was represented by a density of 850 ± 60 kg m^{-3} (Huss 2013). These three uncertainty components were treated as independent and combined to obtain the total uncertainty in the mass change trend.

3 Result

3. 1 Altimetry indicates moderate global glacier mass loss in 2025

During their overlapping observation period, ICESat-2 and CryoSat-2 both identify 2025 as a year of relatively low global glacier mass loss, comparable to the reduced mass loss in 2022 (Fig. 1a). For 2025, the hydrological-year mean-difference estimate from ICESat-2 gives a global glacier mass change of −260 ± 56 Gt, while CryoSat-2 gives −235 ± 121 Gt. Both altimetry estimates are substantially smaller than the recently reported 2025 loss of −408 ± 132 Gt (Zemp et al., 2026), with loss magnitudes 36% and 42% lower, respectively. The mean estimates from both altimetry records lie outside the WGMS 95% confidence interval, and the WGMS central estimate lies outside the 95% confidence intervals of both altimetry estimates.

The 2025 losses inferred from altimetry are also smaller than recent multi-year averages. WGMS reports an average loss of approximately −390 Gt yr^{-1} for 2016–2025, while published early twenty-first-century estimates indicate global glacier losses

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of roughly −273 ± 16 Gt yr⁻¹ over 2000–2023 (Zemp et al., 2025). Thus, 2025 was a year of continued mass loss, but neither altimetry result indicated exceptionally high mass loss. The cumulative records further show that the altimetry and WGMS estimates begin to diverge after around 2020 (Fig. 1b), with WGMS indicating progressively greater cumulative mass loss. This divergence culminates in 2025, reaching over 1,000 Gt.

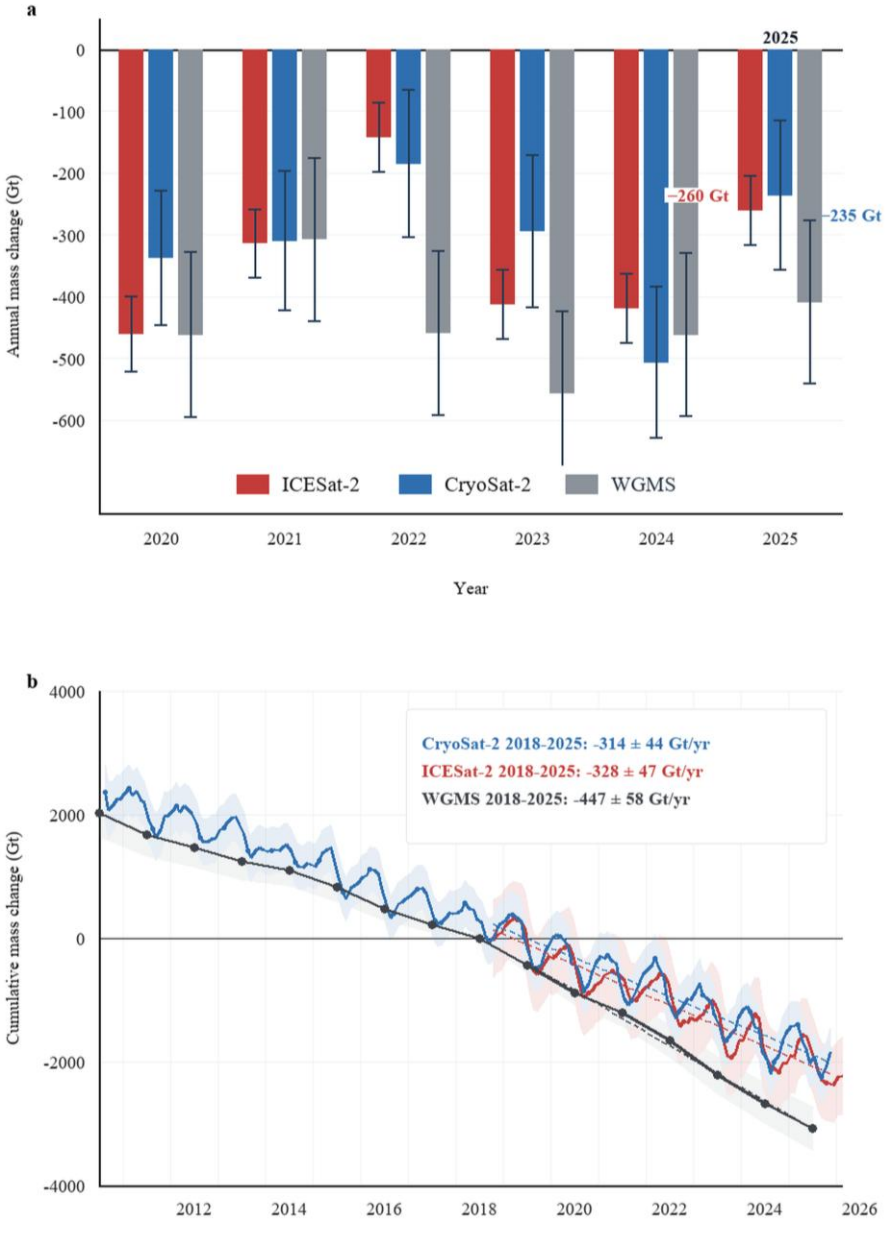


Figure 1. Global glacier mass changes from ICESat-2 and CryoSat-2. a, Annual global glacier mass change from ICESat-2, CryoSat-2 and WGMS (Zemp et al., 2026) during 2020–2025. Red and blue annotations indicate the 2025 mass-change estimates from ICESat-2 (−260 Gt) and CryoSat-2 (−235 Gt), respectively. Grey bars represent WGMS estimates. Negative values indicate glacier mass loss.

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Error bars and shaded ranges denote 95% confidence intervals. The black-outlined bars highlight the 2025 estimates. b, Cumulative global glacier mass change derived from CryoSat-2 and WGMS over 2010–2025 and from ICESat-2 over 2018–2025. Blue, red and black annotations indicate the 2018–2025 linear mass-change rates (± uncertainty) from CryoSat-2, ICESat-2 and WGMS, respectively. Shaded ranges denote 95% confidence intervals. The CryoSat-2 estimates exclude North Asia, the Caucasus and Middle East, and New Zealand.

3. 2 Regional contributions to the reduced 2025 loss

Regional contributions to global glacier mass loss are broadly consistent between the two altimetry records over their common period, 2018–2025 (Fig. 2 and Fig.3a). To facilitate comparison with Zemp et al. (2026), regional aggregation follows the same first-order glacier-region framework used in the WGMS assessment. Over 2018-2025, Alaska is the largest individual contributor in both datasets, followed by High Mountain Asia, Arctic Canada and the Russian Arctic (Fig. 3a). WGMS in-situ data are consistent with these results for the total between 2018 and 2025 (Fig. 3a). More generally, ICESat-2 and CryoSat-2 identify the same top three and top eight contributing regions, with only minor differences in their internal ranking (Fig. 3a). This agreement indicates that the dominant regional sources of recent glacier mass loss are robust across the two observing systems. Although High Mountain Asia makes a major contribution, much of the mean global loss originates from glacierized regions in and around the Arctic, particularly Alaska, Arctic Canada, the Russian Arctic, Svalbard and the periphery of Greenland.

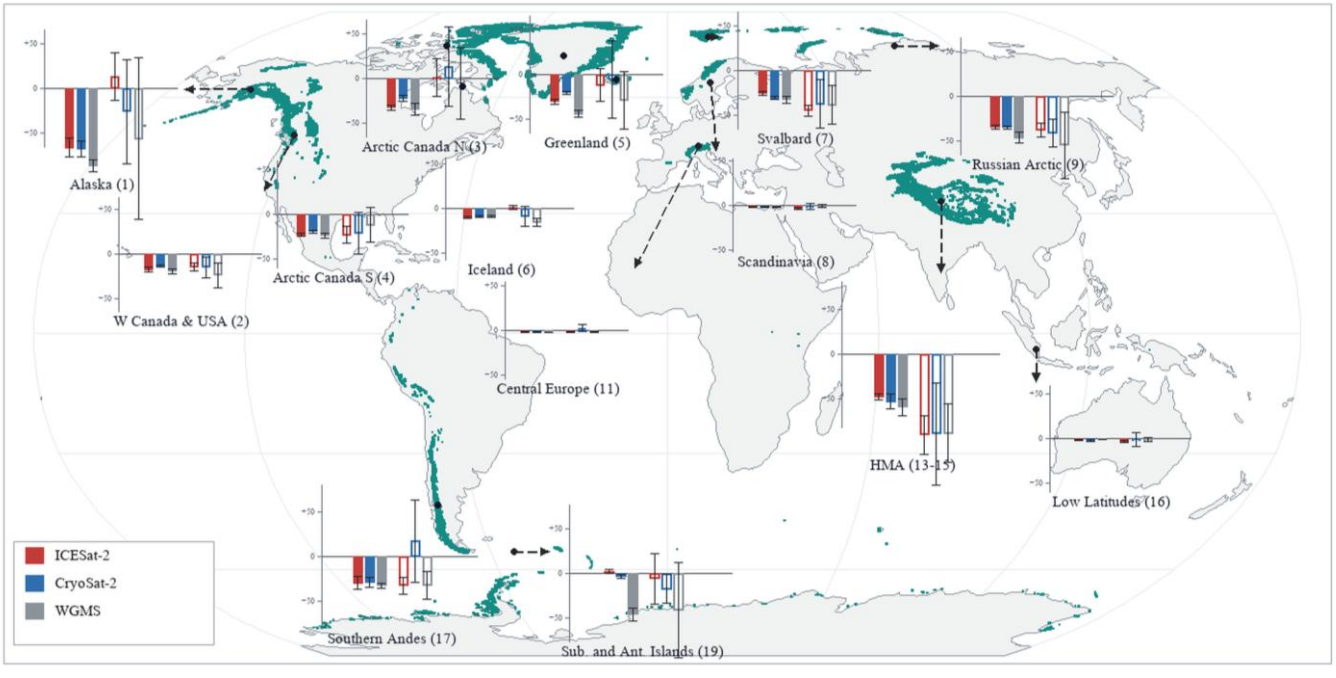


Figure 2. Spatial distribution of regional glacier mass balance contributions from ICESat-2 and CryoSat-2. For each region, the left pair of filled bars shows the mean annual contribution over 2018–2025, and the right pair of open bars shows the 2025 contribution. Red, blue and gray denote ICESat-2, CryoSat-2, and WGMS respectively; error bars indicate 95% confidence intervals.

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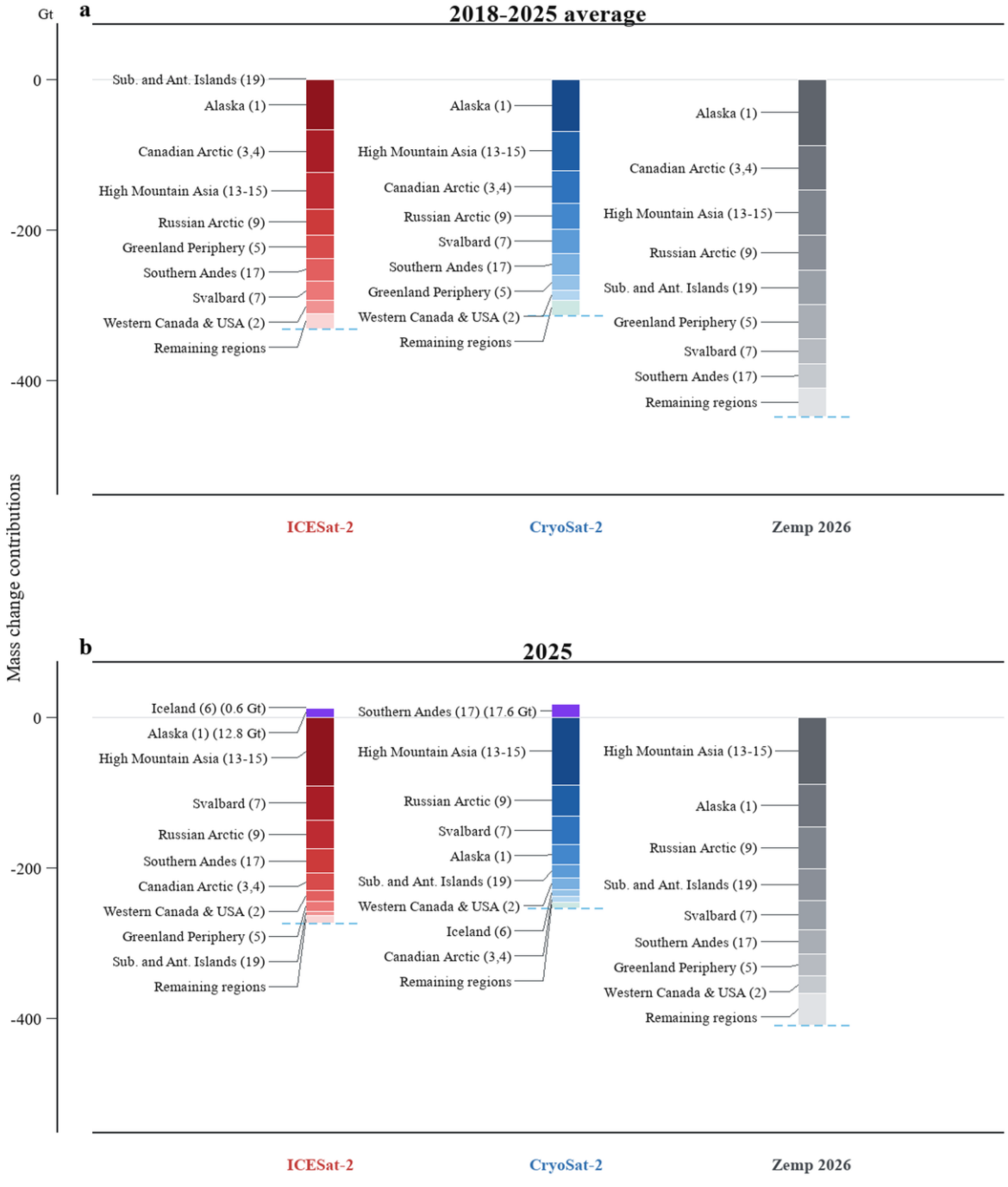


Figure 3. Regional contributions to global glacier mass change. a, Ranked regional contributions to the mean global mass-change rate over 2018–2025. b, Ranked regional contributions to global mass change in 2025. Regions are ordered according to their contribution. Regions not shown individually are grouped as "Remaining regions", provided they are covered by the corresponding dataset. Negative values indicate mass loss and positive values indicate mass gain. Dashed horizontal lines mark the corresponding

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global totals. CryoSat-2 estimates include the 16 regions with available observations; North Asia, the Caucasus and Middle East, and New Zealand are excluded.

The regional pattern in 2025 differed markedly from the recent-period mean and from the WGMS reconstruction (Fig. 3b). The largest differences occurred in Alaska and the Subantarctic and Antarctic Islands. In Alaska, ICESat-2 indicates a positive mass change of +13 ± 26 Gt, while CryoSat-2 gives only a small loss of −27 ± 58 Gt, compared with −57 ± 90 Gt in the WGMS assessment. Around the Subantarctic and Antarctic Islands, both altimetry records indicate near-zero mass changes, −7 ± 29 Gt for ICESat-2 and −18 ± 16 Gt for CryoSat-2, whereas WGMS reports a much more negative value of −42 ± 54 Gt. These two regions therefore account for much of the lower 2025 global loss in the altimetry estimates. High Mountain Asia became the largest negative contributor in both altimetry records in 2025, while the Russian Arctic and Svalbard also retained pronounced negative balances.

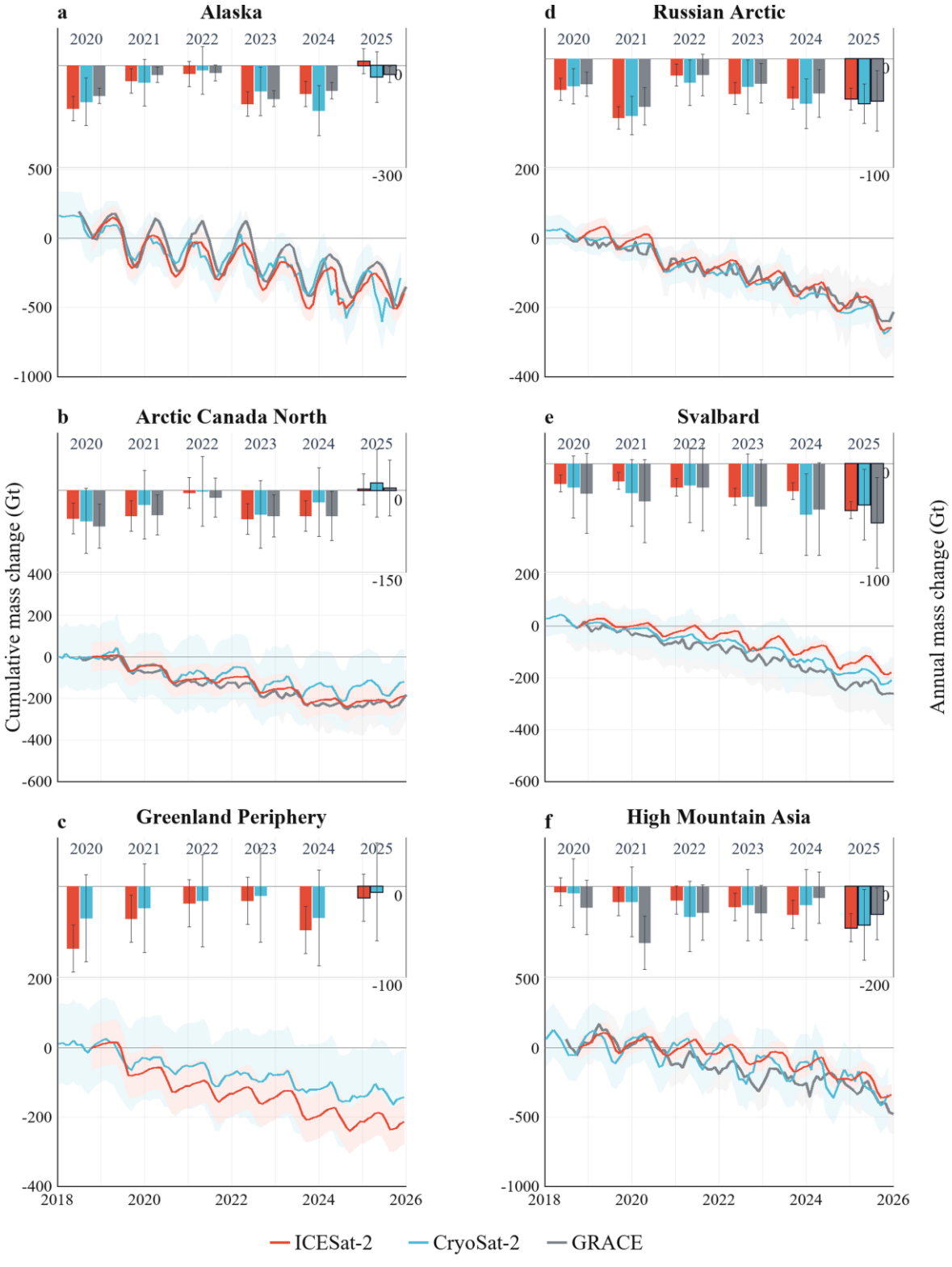
3. 3 GRACE validation across major contributors and weakened-loss regions

We used independent GRACE-FO mascon estimates to evaluate the altimetry-derived mass changes across regions that either dominate recent global glacier loss or experienced marked weakening in 2025 (Fig. 4). Unlike ICESat-2 and CryoSat-2, GRACE-FO directly observes mass redistribution and therefore provides an external check on the absolute magnitude of the mass changes obtained using the adopted density conversion.

Across the major contributing regions, the cumulative ICESat-2 and CryoSat-2 mass-change time series generally agree with GRACE-FO. This agreement is especially evident for Alaska, Arctic Canada, the Russian Arctic, Svalbard and High Mountain Asia, which together dominate the recent global signal. The consistency among the three independent observing systems indicates that the adopted density scheme does not introduce a large systematic bias in the altimetry-derived mass changes.

The GRACE-FO estimates are broadly consistent with the shift in regional contributions identified by altimetry. In particular, Alaska and Arctic Canada North experienced much weaker losses than their recent-period averages, although the exact magnitudes differ among the observing systems. By contrast, High Mountain Asia, the Russian Arctic and Svalbard remained substantial negative contributors. The reduced 2025 global total therefore reflects weakened mass loss in several normally dominant regions, rather than uniformly weak glacier loss worldwide.

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Figure 4. Temporal evolution of glacier mass change in major contributing regions. Annual mass changes for hydrological years 2020–2025 are shown by the paired bars in the upper part of each panel and refer to the right-hand axes. Cumulative mass changes since 2018 are shown in the lower part of each panel and refer to the left-hand axes. Shading and error bars denote 95% confidence intervals.

4 Discussion

The lower altimetry estimate for 2025 is not an isolated difference. The WGMS estimate indicates persistently high glacier losses in recent years, with six of the seven largest annual losses in its 1975–2025 record occurring between 2019 and 2025. Over the last seven years, the reported annual losses average 441 ± 69 Gt yr^{-1}, and the mean loss over 2016–2025 is 390 ± 76 Gt yr^{-1}. In comparison, satellite altimetry gives mean losses of 328 ± 25 Gt yr^{-1} from ICESat-2 and 314 ± 22 Gt yr^{-1} from CryoSat-2 over these recent seven years, and 299 ± 15 Gt yr^{-1} from CryoSat-2 over 2016–2025. Both altimetry data therefore show an acceleration of global glacier mass loss, but its recent magnitude is smaller than implied by the WGMS. The difference extends across several years and is not limited to 2025.

The definition of annual change affects the magnitude of individual-year estimates (Table 1) depending on whether the balance period is defined using fixed month. It can affect how glacier loss is assigned between adjacent years, particularly when estimates are based on fixed-month endpoints (Table 1). For example, the ICESat-2 estimate for 2024 changes from −418 Gt using hydrological-year averaging to −64 Gt using September-to-September endpoints, while the corresponding estimate for 2023 becomes more negative, changing from −418 to −617 Gt. Endpoint selection can therefore shift part of the apparent loss from one year to the next without substantially changing the cumulative loss over several years.

The estimates become more stable when observations from all months within each annual window are included. Under this approach, using a hydrological or calendar year produces broadly comparable results. For 2025, the hydrological- and calendar-year estimates are −260 and −231 Gt, respectively, for ICESat-2, and −235 and −194 Gt for CryoSat-2. Annual definitions may therefore explain part of the spread among individual-year satellite estimates, but they cannot account for the persistent multi-year discrepancy with the WGMS. This discrepancy becomes particularly visible in 2025, and to some extent in 2022, but mainly reflects the more negative WGMS after 2019. One possible contributor is that the post-2019 WGMS annual anomalies are not directly constrained by contemporaneous large-scale geodetic observations.

Table 1 Sensitivity of glacier mass balance to the definition of annual change. M1 represents the difference between consecutive hydrological-year mean masses, defined over October–September in the Northern Hemisphere and April–March in the Southern Hemisphere. M2 is based on consecutive calendar-year means (January–December). M3 uses fixed-month endpoints, calculated from September-to-September differences in the Northern Hemisphere and March-to-March differences in the Southern Hemisphere. Uncertainties are given at the 95% confidence level.

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Year	Altimetry	M1	M2	M3
2020	ICESat-2	−460 ± 61	−430 ± 54	−415 ± 188
	CryoSat-2	−336 ± 109	−317 ± 106	−276 ± 367
2021	ICESat-2	−313 ± 55	−232 ± 54	−135 ± 188
	CryoSat-2	−309 ± 113	−282 ± 109	−237 ± 380
2022	ICESat-2	−141 ± 56	−228 ± 54	−350 ± 190
	CryoSat-2	−184 ± 119	−214 ± 115	−258 ± 399
2023	ICESat-2	−412 ± 56	−465 ± 54	−617 ± 190
	CryoSat-2	−294 ± 123	−391 ± 119	−405 ± 421
2024	ICESat-2	−418 ± 56	−334 ± 55	−64 ± 189
	CryoSat-2	−505 ± 122	−387 ± 120	−398 ± 423
2025	ICESat-2	−260 ± 56	−231 ± 55	−227 ± 189
	CryoSat-2	−235 ± 121	−194 ± 121	−189 ± 422

The global difference is concentrated in a small number of large glacierized regions rather than being spatially uniform. In 2025, WGMS reports mass loss in all 19 first-order regions, with gains confined to individual glaciers or subregions, such as northern Scandinavia and parts of the Andes. Altimetry, by contrast, indicates positive or near-zero regional changes in Alaska and Arctic Canada North. This difference matters because Alaska and the Canadian Arctic largely contribute to global glacier mass loss.

Part of the discrepancy may arise from the different spatial scales and sampling characteristics of the observing systems. WGMS is based on high-accuracy in situ measurements from individual glaciers, with annual anomalies interpolated across regions and constrained by longer-term geodetic estimates. These measurements provide detailed local information but are necessarily limited to a relatively small number of monitored glaciers. Satellite altimetry and satellite gravimetry operate at much broader spatial scales. They are less suited to resolving individual glaciers, but they provide regionally integrated estimates over large glacierized areas. The two approaches therefore sample glacier change differently and should be viewed as complementary rather than directly equivalent.

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Altimetry also has limitations in steep and complex terrain. Very steep glacier surfaces are often poorly sampled because of surface slope, roughness, radar geometry, or the spatial distribution of valid elevation measurements. Such areas can experience rapid thinning and may therefore be underrepresented in direct elevation-change estimates. Glaciers are dynamic systems, and mass changes in steep zone are partly transmitted through ice flow and expressed in geometry and regional volume change. This does not remove the sampling limitation, but it reduces the extent to which unsampled steep terrain is entirely disconnected from the observed glacier-wide signal

Regional differences also remain in the altimetry records. In the Southern Andes, for example, ICESat-2 and CryoSat-2 produce substantially different 2025 estimates, and the CryoSat-2 record shows large short-term fluctuations and a poorly defined seasonal cycle. These variations may reflect unresolved observational effects and should be treated cautiously. Nevertheless, the broad agreement between laser and radar altimetry across most major regions suggests that the lower recent global loss rates are unlikely to be a sensor-specific error.

The conversion from elevation to mass change may also contribute to differences between altimetry and GRACE-FO in individual years. We apply a density of 850 kg m^{-3} consistently to all elevation changes, which is appropriate for estimating glacier-wide mass change over longer periods but may be less representative of short-term anomalies dominated by snowfall. For example, the positive 2025 elevation anomaly in Alaska may partly reflect enhanced snow accumulation, for which a lower effective density would reduce the inferred mass gain and bring the altimetry estimate closer to GRACE-FO. The resulting adjustment would, however, be small relative to the global uncertainty and would not affect our main conclusions.

5 Conclusion

ICESat-2 and CryoSat-2 provide independent evidence that global glaciers continued to lose mass in 2025, but at a substantially lower rate than the 408 ± 132 Gt reported by WGMS. Over 2018–2025, the two altimetry indicate a mean mass-change rate of −321 ± 45 Gt yr^{-1}, substantially less negative than the −441 ± 69 Gt yr^{-1} from WGMS. These confirm an acceleration of global glacier mass loss in recent years, but suggest a smaller magnitude than that inferred from the reconstructed annual series. The relatively moderate global loss in 2025 was driven primarily by low mass losses or net mass gains in several regions that largely contribute to the global total, particularly Alaska and Arctic Canada, while High Mountain Asia remained a major source of mass loss. The agreement between laser and radar altimetry, together with regional consistency with GRACE-FO, supports the overall pattern. These results highlight the value of combining in situ, altimetric, and gravimetric observations in annual global glacier assessments.

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Data availability

The ICESat-2 ATL06 Land Ice Height, Version 7 product is publicly available from the NASA National Snow and Ice Data Center at https://nsidc.org/data/atl06/versions/7. The CryoSat-2 point product is available through the ESA CryoTEMPO-EOLIS data portal at https://cryotempo-eolis.org/point-product/. Glacier outlines, glacier areas and regional definitions were obtained from the Randolph Glacier Inventory version 7.0 at https://nsidc.org/data/nsidc-0770/versions/7. The regional and global glacier mass-change time series generated in this study, together with the data underlying the figures, will be made publicly available in a permanent repository upon publication.

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Author contributions

QW: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Writing – original draft. ZL: Data curation, Formal analysis, Validation (ICESat-2). HZ: Data curation, Formal analysis, Validation (CryoSat-2). XM: Data curation, Formal analysis, Validation (GRACE-FO). RA: Formal analysis, Validation, Writing – review and editing. SW and JB: Conceptualization, Supervision, Writing – review and editing. All authors contributed to the interpretation of the results and reviewed and approved the final manuscript.

Competing interests

The authors declare that they have no conflict of interest.

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