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Mass-budget anomalies and geometry signals of three Austrian glaciers

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Glacier mass-budget monitoring documents climate fluctuations, provides context for observed glacier-geometry changes, and can provide information on the glaciers' states. We examine the mass-budget series and available geometries of three well-documented glaciers located in the same catchment area less than 10 kilometers from one another in the Austrian Ötztal Alps. The altitudinal profiles of the 1981–2010 average specific mass budgets of each glacier serve as climatic reference. We apply these *reference mass-budget profiles* on all available glacier geometries, thereby retrieving for each glacier *reference-climate mass budgets* that reveal in a discrete way each glacier's geometric adjustment over time and its impact on mass loss; interpolation of the reference-climate mass budgets over the 1981–2010 period provides the glaciers' *geometry signals*. The *geometric mass-budget anomalies* derived with respect to these geometry signals indicate decreasing mass budgets over the 1981–2010 period by 0.020 m water equivalent (w.e.) a^{-2}, or 31% additional mass loss compared to the *centered anomalies* derived with respect to the 1981–2010 averages of the conventional mass-budget series.

Reference-climate mass budgets with respect to 1981–2010 of older geometries highlight Hintereisferner's adapting geometry by almost continuous retreat since 1850. Further retreat is inevitable as Hintereisferner is the furthest from a steady state amongst the three glaciers. The relatively small Kesselwandferner has been also mostly retreating, while briefly advancing in response to short-term climatic trends. In a stable 1981–2010 climate, Kesselwandferner would relatively quickly reach a steady state. Vernagtferner's geometry since 1979 favors mass loss by thinning, primarily due to extended surge-related mass losses since 1845; this inability to retreat has led to – and will further – Vernagtferner's disintegration.