A globally complete, spatially and temporally resolved estimate of glacier mass change: 2000 to 2019

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The world’s glaciers distinct from the Greenland and Antarctic ice sheets are shrinking rapidly, altering regional hydrology and raising global sea level. Yet, due to the scarcity of globally consistent observations, their recent evolution is only known as a heterogeneous temporal and geographic patchwork and future projections are thus not optimally constrained.

Here, we present the first globally complete, consistent and resolved estimate of glacier mass change derived from more than half a million digital elevation models (DEMs) generated or extracted from multiple satellite archives including ASTER, ArcticDEM and REMA. Combining state-of-the-art numerical photogrammetry and novel statistical approaches, we reconstruct two decades of glacier surface elevation change at an unprecedented spatial and temporal resolution. We validate our results by comparing them to independent, high-precision elevation measurements from the ICESat and IceBridge campaigns, as well as to very high resolution DEM differences from LiDAR, Pléiades, and SPOT-6. The elevation time series are integrated to volume changes for every single glacier on Earth and, by assuming an average density, aggregated to regional and global mass changes. We compare our revised glacier mass changes to earlier estimates derived from altimetry, gravimetry, geodetic and field data. As an illustration, our integrated geodetic mass loss over all Icelandic glaciers yields -8.3 +/- 1.1 Gt yr⁻¹ over the period 2002-2016 in agreement with a recent gravimetry estimate of -8.3 +/- 1.8 Gt yr⁻¹ (Wouters et al., 2019), known to perform well in this region. Both estimates are more negative than -5.7 +/- 1.2 Gt yr⁻¹, compiled from glaciological observations and geodetic data (Zemp et al., 2019).
Our global estimate of glacier mass change constitutes a new benchmark dataset that will help to: (i) assess present-day and future climate change impacts on glaciers; (ii) close the sea-level rise budget; (iii) assess the threat on water resources and (iv) facilitate research on natural hazards related to glaciers. Our results specifically provide a strong observational basis that holds a great potential to further our understanding of the multi-scale morphologic and climatic drivers of glacier mass change, essential to improve physically-based glaciological modelling and calibrate future projections.