



## **Twentieth century contribution to sea-level rise from uncharted glaciers**

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Whether based on observations or results of climate models, the sum of estimates of individual contributions to sea-level rise (ice sheets, glaciers, hydrology, and thermal expansion) tends to fall short of the observed global mean sea-level rise (GMSLR) during the twentieth century. Current estimates of the glacier contribution to GMSLR rely on the analysis of glacier inventory data, which are known to undersample the smallest glacier size classes. Here we show that from 1901 to 2015, missing and disappeared glaciers contributed between 17 and 48 mm sea-level equivalent (SLE) to GMSLR.

Missing glaciers are those small glaciers that we expect to exist today, owing to regional analyses and theoretical scaling relationships, but that are not represented in the inventories. These glaciers contributed approximately 12 to 43 mm SLE to the 20th century GMSLR. Additionally, disappeared glaciers (those that existed in 1901 but had melted away by 2015, and that therefore cannot be included in modern global glacier inventories) made an estimated contribution of between 4 and 5 mm SLE. Failure to consider these uncharted glaciers may be an important cause of difficulties in closing the GMSLR budget during the twentieth century: their contribution is on average between 0.17 and 0.53 mm SLE per year, compared to a budget discrepancy of about 0.5 mm of GMSLR per year between 1901 and 1990. Although the uncharted glaciers will have a minimal role in GMSLR in the future, and are less important after 1990, these findings imply that undiscovered physical processes are not required to close the historical sea-level budget.