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Attribution of mass change of western North American Glaciers over the period 2000-2018

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Western North American (WNA) glaciers straddle the Alaska/Canada border and cover 14,384 km^2 of mountainous terrain. To better quantify the response of these glaciers to early 21st century climate variability we generated over 15,000 multi-sensor digital elevation models from spaceborne optical imagery. Over the period 2000-2018, WNA glaciers lost 117 $\pm$ 42 Gigatons (Gt) of mass, which accounts for up to 0.32 $\pm$ 0.11 mm of sea level rise over the full period of study. Using existing surface mass balance measurements for 14 glaciers in WNA we estimate that these glaciers experienced an average mass change of -874 $\pm$ 100 kg m^{-2} yr^{-1} over the period 2000-2017. When multiplied by the total glacierized area of WNA, this value yields an annual mass loss of 13.6 $\pm$ 4.3 Gt yr^{-1}, close to the value [14 $\pm$ 3 Gt yr^{-1}] calculated previously for WNA glaciers. Both of these values are twice as large as those based on our trend analysis. The discrepancy between surface mass balance measurements and those obtained from our geodetic surveys suggests that glaciers chosen for long-term monitoring programs are losing mass more rapidly than the region as a whole. We also note a four-fold increase in mass loss rates between 2000-2009 [-2.9 $\pm$ 3.1 Gt yr^{-1}] and 2009-2018 [-12.3 $\pm$ 4.6 Gt yr^{-1}] which we attribute to a shift in regional meteorological conditions driven by the location and strength of upper level zonal wind. Under moderate emission scenarios, glaciers in both the conterminous US and western Canada are expected to undergo continued mass loss throughout this century. These projected changes will affect thermal- and flow-buffering capacity provided by glacier runoff for many watersheds, with implications for downstream ecosystems and water resources. Although an increase in thermal energy caused by increased greenhouse gas concentration will drive widespread mass loss throughout the century decadal scale climate variability will likely modulate this long-term change in the years ahead.