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The effects of void handling on geodetic mass balances

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Glacier mass balance is a direct expression of climate change, and has implications for changes in sea level, ocean chemistry, and oceanic and terrestrial ecosystems. Glacier mass balance has traditionally been measured through in-situ measurements of surface elevation change on a glacier surface. To estimate changes on a larger spatial scale, however, in-situ measurement is not feasible, and aerial or satellite measurements of digital elevation models (DEMs) over glaciers have been used recently in order to supplement and extend ground-based measurements. Though the resolution and accuracy of these products generally increases with time, there are still often gaps ("voids") in the data, as well as errors and biases that must be addressed. The occurrence and distribution of these voids is at least partially dependent on the sensor or acquisition method used to generate the source DEMs. For example, for optical stereo DEMs, voids can be especially frequent in the accumulation area of glaciers, impacting elevation measurements and the resulting estimates of glacier volume change to an unknown degree. Several methods for handling voids in elevation datasets have been proposed and implemented in the literature, though direct investigation of the uncertainty associated with these methods is generally not reported. In order to estimate the uncertainties associated with various methods for filling voids in elevation data, we simulate typical voids in high-resolution spatially-complete DEMs of glaciers in south-central Alaska (covering the Alaska Range, Chugach, Kenai, and Wrangel Mountains), USA. This region is home to over 7000 individual glaciers covering over 23000 km^2, ranging in elevation from sea level to over 6000 m, and representing many different glacier types including surging glaciers, advancing and retreating tidewater glaciers, and large and small valley glaciers. As such, it presents an ideal test region to investigate the impact of various methods for void-filling on regional estimates of glacier volume change. We implement four common methods used to fill voids in elevation data: (i) interpolation of raw elevations; (ii) interpolation of elevation changes; (iii) fitting a function to elevation change data with respect to elevation; and (iv) multiplying the mean elevation change by the glacier area. We then compare estimates of volume change from the resulting products to the unaltered volume change estimate in order to estimate the uncertainty associated with each method. Finally, we present an updated volume change estimate for glaciers in the region.