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Historical Structure From Motion (HSfM): Automated production of high-resolution DEMs from historical aerial photography for long-term geodetic change analysis

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Mountain glaciers have lost significant mass over the past century in response to a globally warming climate. However, on interannual to decadal time scales, many glaciers in Western North America show periods of both advance and retreat. To better understand these systems and their sensitivity to climate forcing, we are generating regional records of glacier surface elevation change from scanned historical film photographs acquired between the 1950s to 1990s. Our results will help constrain projections of future glacier change under different climate scenarios, as well as impacts on downstream water resources and geohazard risk.

Historical image pre-processing and manual ground control point (GCP) selection are time-intensive bottlenecks during traditional SfM processing workflows. We developed an automated photogrammetry processing pipeline (HSfM) to systematically process large archives of vertical aerial film photographs and generate sub-meter resolution digital elevation models (DEMs), without manual GCP selection. We present several case studies for glaciers in the Western North America using photos from the USGS North American Glacier Aerial Photography (NAGAP) and Earth Explorer Aerial Photography Single Frame archives, which differ in terms of available image overlap, survey area extent, and terrain characteristics. Absolute vertical accuracy of <0.5-1.0 m is achieved through iterative closest point (ICP) co-registration over stable bare-ground surfaces between the historical DEMs and modern high-resolution satellite or lidar reference DEMs. We demonstrate the potential for these new DEM records to quantify geodetic glacier mass balance and geomorphological change including moraine deposition, moraine degradation, and sediment redistribution in proglacial areas.