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Decadal altitudinal glacier mass balance for the Maipo and Santa basins of South America

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Andean glaciers are an important part of the water cycle of high elevation catchments and supply fresh water to large populations downstreams, especially during dry periods. They are experiencing dramatic mass loss due to a warming climate, and their catchments are among the most vulnerable. However, relatively few glaciers are monitored systematically due to accessibility and cost, limiting our understanding of mass accumulation and ablation rates. In this study, we estimated the decadal altitudinal mass balance of glaciers in the Maipo River Basin in central Chile and the Rio Santa Basin in the Cordillera Blanca in Peru for the periods of 2000-2009 and 2009-2018. We accomplished this by 1) correcting current ice thickness estimates for recent thinning, 2) deriving glacier velocities from Landsat data using the Glacier Image Velocimetry (GIV) toolbox, and 3) modelling ice flux divergence using the continuity approach to correct observed glacier thinning for flow. We validated the altitudinally-resolved mass balance with the few available observational datasets, then determined each domain's equilibrium line altitude, accumulation area ratio, and ablation balance ratio for each period, which identifies the portion of annual ablation that is compensated by accumulation.

Our results highlight the influence of the Chilean 'Mega-drought' (2010-present) on glacier health in the Maipo River Basin, causing a dramatic reduction in glacier mass balance (decrease of 0.5 m w.e. a-1) below 5000 m a.s.l., raising the regional equilibrium line altitude from 4210 m a.s.l. during 2000-2009 to 4470 m a.s.l. ± 15 m during 2009-2018, and lowering accumulation area ratios from 0.65 to 0.55. In contrast, the Santa Basin glaciers showed very similar altitudinal mass balance patterns for both decades, with equilibrium line altitudes at ~5100 m a.s.l. and accumulation area ratios of ~0.5, indicating a basin already out of balance prior to 2000.

Large populations rely on glaciers' water supply in both basins and the two basins' glaciers contrast in terms of water supply sustainability. In the Maipo Basin, glaciers experienced little mass change in the first period (ablation balance ratio of 1.01) and experienced only slightly unsustainable mass loss in the second period (ablation balance ratio of 0.9) despite the Megadrought. The ablation balance ratio for the Santa Basin was lower for both periods (0.75) indicating that these glaciers are moderately unhealthy despite their recent retreat, and water

managers should expect further reductions in glacier water supply. Our results will help to constrain glacier models to understand the timing of glacier change for this data-sparse region.