Submitted Abstract

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Abstract

High-mountain glaciers are the water towers of the tropical Andes and fundamentally important to downstream populations. The greatest concentration of extant tropical glaciers is found in the Cordillera Blanca, Peru, where ice loss has accelerated over recent decades. Past research has revealed that the Rio Santa watershed has passed “peak” discharge, while some sub-catchments with greater ice volume are still building up to peak discharge. Thus, accurate projections of future glacier storage loss provide the critical information to ensure successful water management, inform adaptation strategies, and strengthen community resilience.

Previous continental-to-regional glacier ice thickness and water storage estimates for the Cordillera Blanca range widely between 10-21 Gt. However, a systematic lack of observations above the snowline has hindered efforts to reliably calibrate or validate many of the modeled projections of future changes in glacier mass and meltwater availability. As a result, regional glacio-hydrological projections have relied upon discontinuous and spatially limited measures from more accessible, low-elevation sites to calibrate multiple model parameters, introducing systematic biases tied to over-parameterization and underestimated uncertainties. This complicates the reproducibility of computational studies and confounds decision-making.

Here, we describe an approach to “calibrating the water clock” that systematically addresses these high-altitude, accumulation zone knowledge gaps to improve the parameterization, validation, and output reliability of locally calibrated glacier mass balance, ice thickness, and meltwater runoff models. We examine the extent to which output generated using the flexible Open Global Glacier Model (OGGM) can be enhanced by supplementing and improving upon the minimal input data requirements of the model framework using a combination of direct and remote repeat measures — dGNSS-GPR surveys (ranging 4800-6787 m), airborne lidar, Worldview-derived DEMs, meteorological stations, ice cores, and UAS — compiled in a novel database detailing seasonal to multi-decadal changes in mass balance and morpho-geometric characteristics for individual glaciers across the mountain range. We discuss how a time series approach facilitates stricter chronological alignment of independent input, calibration, and validation datasets, resulting in greater temporal consistency across model boundary conditions. Ouruse of time-synchronous glacier model inputs (e.g. pairing a 2014 GPR survey with a 2014 Worldview stereo DEM instead of 2000 SRTM) is not common practice in mountain regions due to data gaps, but we show how it can improve model output reliability. Finally, we contextualize our locally calibrated model estimates of glacier water storage changes alongside a 33-year observational time series of alpine lake volume fluctuations across the Cordillera Blanca.