Characterizing Alpine Glacier and Lake Changes in the Cordillera Blanca, Peru from 1987 through 2020 using Multi-Sensor Remote Observations and Random Forest Classification

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ABSTRACT

70% of Earth's tropical glaciers are found in the Peruvian Andes. As ice loss and lake expansion accelerate, there is a pressing need for accurate, on-demand data to inform risk management strategies due to growing geohazard risks and the depletion of water resources. However, the extent of these changes remains unquantified due to the observational limitations presented by steep terrain and dense cloud-cover. To address these challenges, we leverage four decades of NASA Earth observation data alongside recent advances in cloud computing and machine learning to characterize inter-annual changes. We introduce 1,400 total images collected by NASA's Landsat 5 and 8 satellites over the Cordillera Blanca since 1987 into Google Earth Engine where they are subjected to temporal, spatial, and cloud-filtering algorithms. 431 total images survive. Afterwards, we derive annual composite images using the median value of the high-confidence pixels preserved for each year. We calculate spectral indices for each of these annual composites that further distinguish water phases and land cover types across these glacierized alpine environments. We then use the derived indices alongside existing terrain models and Sentinel-1 synthetic aperture radar observations as feature inputs for a Random Forest (RF) classifier trained to map annual glacier and lake extent. Finally, we validate our model using a combination of high-resolution commercial satellite imagery, lidar data, and ground measures. Between 1987-2020, we observed a 27% reduction of total glacier surface area and 691% expansion of total lake surface area. Average annual ice loss measured 5.2 km^2 (down from 639.1 km^2 in 1987). This research represents two separate achievements with broad basic and applied science applicability: 1) an efficient workflow for generating accurate, cloud-free satellite imagery time-series data products on demand; and 2) the first regional assessment to quantify spatial-temporal patterns of lake evolution from 1987 to present, describe hotspots of accelerating change, and identify the emergence of potentially hazardous glacial lakes.

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