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Toward coupled glacio-hydrological modeling: Remote sensing approaches to construct calibration and validation datasets for a data-sparse basin of debris-covered glaciers, Langtang Khola, Nepal

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As glaciers retreat in response to climate warming, their pattern and timing of meltwater production and their hydrological routing and storage shifts, resulting in substantial changes to the hydrographs of glaciated basins. Glacio-hydrological modeling has been successfully applied to assess these changes, particularly for study sites with a good record of high-quality input data including climate, hydrologic, and glacier extent records. However, the communities most vulnerable to changes in glacier discharge are often situated downstream of glaciers with unreliable or broken environmental records. This is evident in High Mountain Asia, which supplies water to over one quarter of the globe's population, but combines several glaciological challenges: high climate variability, lack of historic data, uncertainties in climate change and glacier response, and numerous debris-covered glaciers. This research applies remote sensing analyses of readily available datasets to generate additional calibration and validation datasets for glacio-hydrological modeling in the ∼100km2 Langtang Khola basin of Nepal. Particular data needs addressed presently are twofold: snowcover records for melt model calibration and glacial lake delineation for hydrologic model validation.

All Landsat scenes (all sensors) covering the basin are accessed, and a subset of these are selected for further analysis based on cloud cover. These images are then ortho-rectified using the CGIAR-CSI SRTM4.1 digital elevation model and converted to surface reflectance using the LandCor MATLAB implementation of the 6S atmospheric correction model, creating long-term record of imagery with similar radiometric parameters. ETM+ data are pan-sharpened using a principal component approach to improve feature resolution. This record is then used to calculate NDSI, NDWI, and band ratios. The combination of these indices and the surface reflectance data is classified using an unsupervised migrating-means algorithm for each sensor type (across the many records for each sensor) to distinguish between vegetation, rock/debris, snow/ice, water over debris, and water over ice/frozen water. A maximum likelihood supervised classification is also run for a subset of images for each sensor to assess the misclassification of the images seasonally. The resulting historical snow and glacial lake datasets are limited to the temporal resolution of Landsat sensors (16 and 18 days) at the very best. Still, these data products allow a glacio-hydrological model to be run with fewer simplifying assumptions and to improved accuracy, and will enable a more rigorous analysis of the glacio-hydrological system for debris-covered glaciers.