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Fluctuating snow line altitudes in the Hunza basin (Karakoram) using Landsat OLI imagery

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Snowline altitudes (SLAs) on glacier surfaces are needed for separating snow and ice as input for melt models. When measured at the end of the ablation season, SLAs are used for inferring stable-state glacier equilibrium line altitudes (ELAs). Direct measurements of snowlines are rarely possible particularly in remote, high altitude glacierized terrain, but remote sensing data can be used to separate these snow and ice surfaces. Snow lines are commonly visible on optical satellite images acquired at the end of the ablation season if the images are contrasted enough, and are manually digitized on screen using various satellite band combinations for visual interpretation, which is a time-consuming, subjective process.

Here we use Landsat OLI imagery at 30 m resolution to estimate glacier SLAs for a subset of the Hunza basin in the Upper Indus in the Karakoram. Clean glacier ice surfaces are delineated using a standardized semi-automated band ratio algorithm with image segmentation. Within the glacier surface, snow and ice are separated using supervised classification schemes based on regions of interest, and glacier SLAs are extracted on the basis of these areas. SLAs are compared with estimates from a new automated method that relies on fractional snow covered area rather than on band ratio algorithms for delineating clean glacier ice surfaces, and on grain size (instead of supervised classification) for separating snow from glacier ice on the glacier surface.

The two methods produce comparable snow/ice outputs. The fSCA-derived glacierized areas are slightly larger than the band ratio estimates. Some of the additional area is the result of better detection in shadows from spectral mixture analysis (true positive) while the rest is shallow water, which is spectrally similar to snow/ice (false positive). On the glacier surface, a thresholding the snow grain size image (grain size > 500μm) results in similar glacier ice areas derived from the supervised classification, but there is noise (snow) on edges of dirty ice/ moraines at the glacier termini and around rock outcrops on the glacier surface. Neither of the two methods distinguishes the debris-covered ice, so these were mapped separately using a combination of topographic indices (slope, terrain curvature), along with remote sensing surface temperature and texture data.

Using average elevation of snow and ice areas, we calculate an ELA of 5260 m for 2013. We construct yearly time series of the ELAs around the centerlines of selected glaciers in the Hunza for the period 2000 – 2014 using Landsat imagery. We explore spatial trends in glacier ELAs within the region, as well as relationships between ELA and topographic characteristics extracted on a glacier-by-glacier basis from a digital elevation model.