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A study of the surface roughness lengths of a high-altitude tropical glacier using profile and eddy covariance measurements

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The turbulent fluxes remain poorly understood on tropical glaciers. Studies based on the bulk method have shown that sublimation can be high during the dry season, reducing the energy available for melting. However, uncertainties on the bulk method are large, especially when katabatic flows cause a wind speed maximum at low height. Wind and temperature data from an 8-level 6-m mast positioned at 5060 m a.s.l. in the ablation area of the Zongo Glacier, Bolivia (16°S), were collected during a one-month period in the dry season of 2007. Concomitant measurements of radiation fluxes and eddy covariance turbulent fluxes were conducted. The surface roughness lengths for temperature (zT) and momentum (z0) were calculated using the profile and the eddy covariance methods at the hourly timescale. The measurement period was characterized by low synoptic forcing conditions and katabatic wind prevailed at night and most of the day. Katabatic flows were often associated with a wind speed maximum at a height of about 2-3 m and with a strong temperature inversion. Near-neutral profiles were selected to avoid the presence of the katabatic wind speed maximum. Results indicate z0 values of about 3 mm and zT values of about 0.2 mm, in rough agreement with terrain observations. However the scatter in the zT values is large indicating large random errors. The relation between the ratio zT/z0 and the roughness Reynolds number (Re*) is in rough agreement with the surface renewal model. However, this relation turns out to be mostly due to spurious self-correlation because of the shared variable z0 in zT/z0 and Re*. Finally, the random and systematic errors on the roughness lengths derived from the profile measurements were briefly investigated. The results emphasize the need of accurate measurements of the sensor heights to obtain unbiased roughness lengths.