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A multi-season investigation of turbulent heat flux and its parameterisation on glacier surfaces, Purcell Mountains, Canada

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In situ measurements of the complete surface energy balance (SEB) are rare on glacier surfaces, necessitating the use of parameterisation methods for one or more of the energy fluxes. The turbulent fluxes of sensible and latent heat (QH and QL) can form a large component of glacier SEB, but are not directly observed in the vast majority of studies, due to the difficulties in obtaining these measurements in a glacial environment. The bulk aerodynamic method is commonly used to parameterise QH and QL, but substantial uncertainties remain in the application of this method to sloped glaciers, and the selection of appropriate roughness length (z0) values and atmospheric stability schemes. Customised weather stations were installed on two glaciers in the Purcell Mountains of British Columbia, Canada, over three melt seasons (2014 – 2016), to directly measure all relevant heat fluxes. This included the use of both open and closed path eddy covariance (EC) systems to observe QH and QL, and to calculate z0 values. A SEB model was applied to the obtained datasets, and showed excellent agreement with measured ablation rates on seasonal and sub-daily timescales. Through comparison with the EC-observed fluxes, a range of commonly used bulk turbulence parameterisation methods was evaluated, highlighting performance sensitivity to roughness length determination and atmospheric stability correction. A stability function based on Monin-Obukhov similarity theory was found to offer the best bulk performance, but with substantial overestimation of the parameterised fluxes during very stable, katabatic conditions. Roughness length values derived from the EC data were found to differ substantially in some cases from those commonly assumed in the literature, emphasising the importance of obtaining site-specific values. High resolution, LiDAR-derived surface height datasets were obtained for each study season and glacier, and utilised to develop remote estimation methods for z0. The resulting estimates were evaluated using in situ EC-observed and microtopographic values, and showed good agreement.