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Quantifying surface roughness over debris covered ice

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Aerodynamic roughness length (z0) remains a major uncertainty when determining turbulent heat fluxes over glacier surfaces, and can vary by an order of magnitude even within a small area and through the melt season. Defining z0 over debris-covered ice is particularly complex, because the surface may comprise clasts of greatly varying size, and the broader-scale surface relief can be similarly heterogeneous. Several recent studies have used Structure from Motion to data model debris-covered surfaces at the centimetric scale and calculate z0 based on measurements of surface microtopography. However, few have validated these measurements with independent vertical wind profile measurements, or considered how the measurements vary over a range of different surface types or scales of analysis.

Here, we present the results of a field investigation conducted on the debris covered Khumbu Glacier during the post-monsoon season of 2015. We focus on two sites. The first is characterised by gravels and cobbles supported by a fine sandy matrix. The second comprises cobbles and boulders separated by voids. Vertical profiles of wind speed measured over both sites enable us to derive measurements of aerodynamic roughness that are similar in magnitude, with z0 at the second site exceeding that at the first by < 1 cm. During our observation period, snow covered the second site for three days, but the impact on z0 is small, implying that roughness is predominantly determined by major rock size obstacles rather than the general form of the surface. To complement these aerodynamic measurements we also conducted a Structure from Motion survey across each patch and calculated z0 using microtopographic methods published in a range of recent studies. We compare the outputs of each of these algorithms with each other and with the aerodynamic measurements, assess how they perform over a range of scales, and evaluate the validity of using microtopographic methods where aerodynamic measurements do not exist.