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Parameterizing scalar transfer over a rough ice surface.

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Scalar transfer over ice surfaces in meso-scale and large-scale atmospheric models, and from Automatic Weather Station (AWS) data is typically calculated using the single level bulk-aerodynamic method. For this method the momentum (z_0) and scalar roughness (z_s) lengths are the key parameters. Usually z_0 is taken to be constant while z_s is calculated with a wellknown surface renewal model (Andreas, 1987). We present Eddy-Correlation (EC) and AWS data obtained at several locations in the ablation area of the Greenland ice sheet and the Vatnajökull ice cap in Iceland. In contrast to the above assumption of constant z_0, these data demonstrate the importance of large temporal and spatial variations of z_0 throughout a large part of the ablation area during the melt season. Next, we validated the z_s predictions of Andreas's model over a wide range of z_0 values by comparing the EC- and bulk-fluxes (the latter with included temporal z_0 variation). In agreement with results from others, the fluxes agree well when the ice surface is flat and smooth ($z_0 < 0.1$-1 mm). However, when during the melt season the surface becomes increasingly hummocky and rough, the ratio of EC- and bulk-flux increases well above 1 (between 1.5 and 2 for $z_0 > 10$ mm). Apparently, a hummocky ice surface, for which form drag dominating z_0, promotes higher heat transfer efficiency then predicted by the model. The model predicted z_s values are thus much too small. We hypothesize that the substrate ice crystal cover, that controls the heat transfer close to the surface, is better 'ventilated' for the hummocky ice surface than for its flat counterpart. In case of hummocky ice we therefore suggest to use, instead of the Andreas model, the alternative model curve that we derived from fitting our rough ice data.