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Turbulent structures and heat fluxes over glacier ice and supraglacial debris

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As glacier shrinkage due to climate warming leads to progressively more glaciers supporting supraglacial debris cover, there is ever-increasing need to fully understand the effect of these expanding supraglacial debris covers on glacier behaviour and their interaction with the overlying atmosphere. Here we present results of eddy covariance measurements at a 1.6 m height, at two stations located at a clean-ice and a debris-covered part of the Suldenferner glacier in the Italian Alps. We focus on the contrasting structure of turbulence over the two surfaces under different flow regimes.

As expected, the debris cover shows a pronounced daily cycle of turbulence with strongly stable stratification during nighttime and strongly unstable stratification during daytime, in contrast to the persistent stable stratification over the exposed ice. Other aspects of the surface - atmosphere interaction are shown to be strongly dependent on the larger scale flow characteristics. During the synoptically undisturbed nighttime, persistent katabatic winds originating from the clean-ice part of the glacier extend over the debris-cover where both surfaces show remarkably similar fluxes although the depth of the katabatic flow and the associated turbulence is larger over the debris cover. During synoptically undisturbed daytime conditions katabatic flow breaks down over the debris and the heat fluxes change sign. Turbulence over the debris is always found to be more intense, more anisotropic and the turbulent eddy size is shown to be larger. As supraglacial debris becomes more pervasive on the remaining mountain glaciers it can be expected that these effects will have some impact on the properties of the valley atmosphere and its circulation characteristics.