STRUCTURE OF TURBULENCE OVER CLEAN & DEBRIS-COVERED ICE

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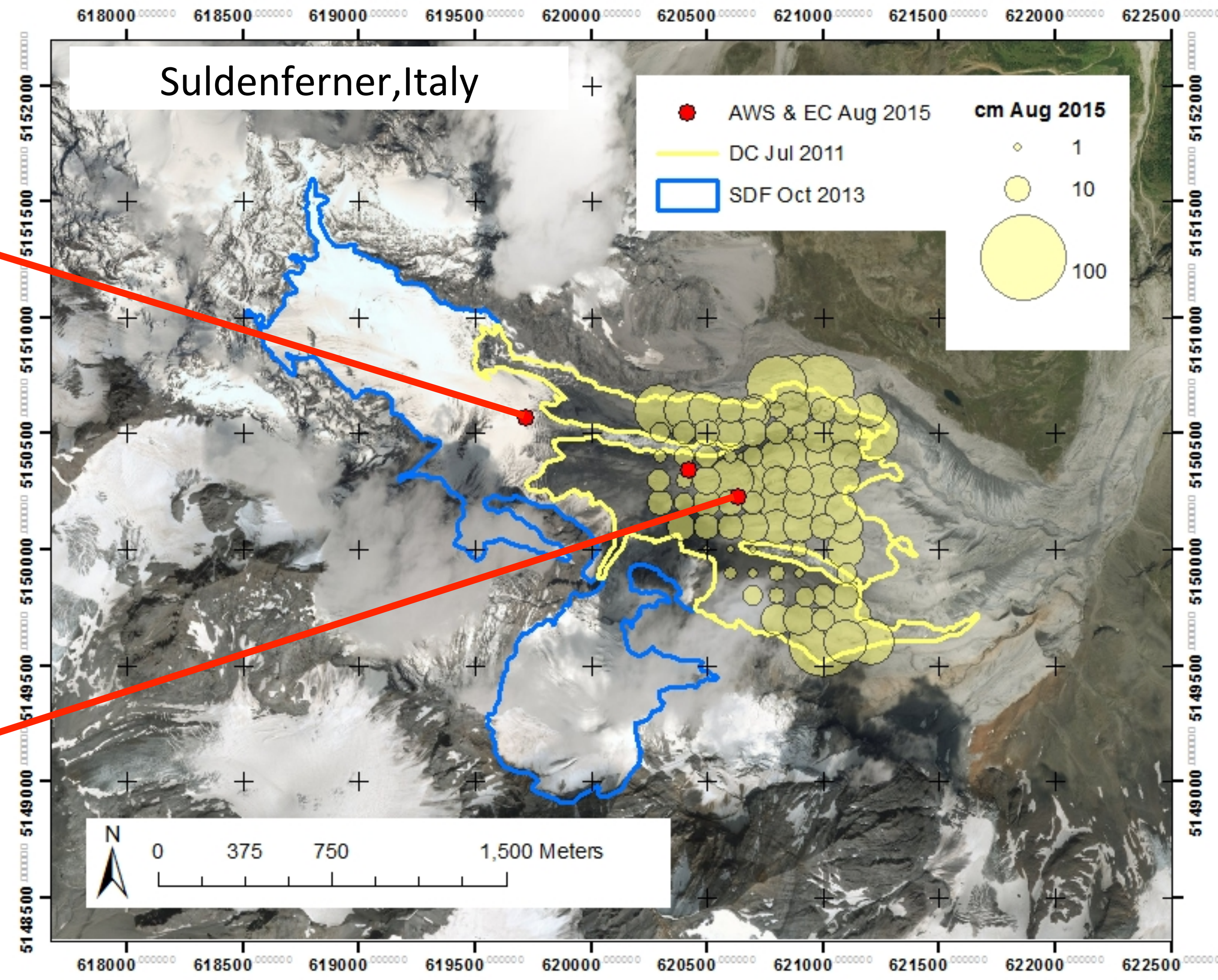
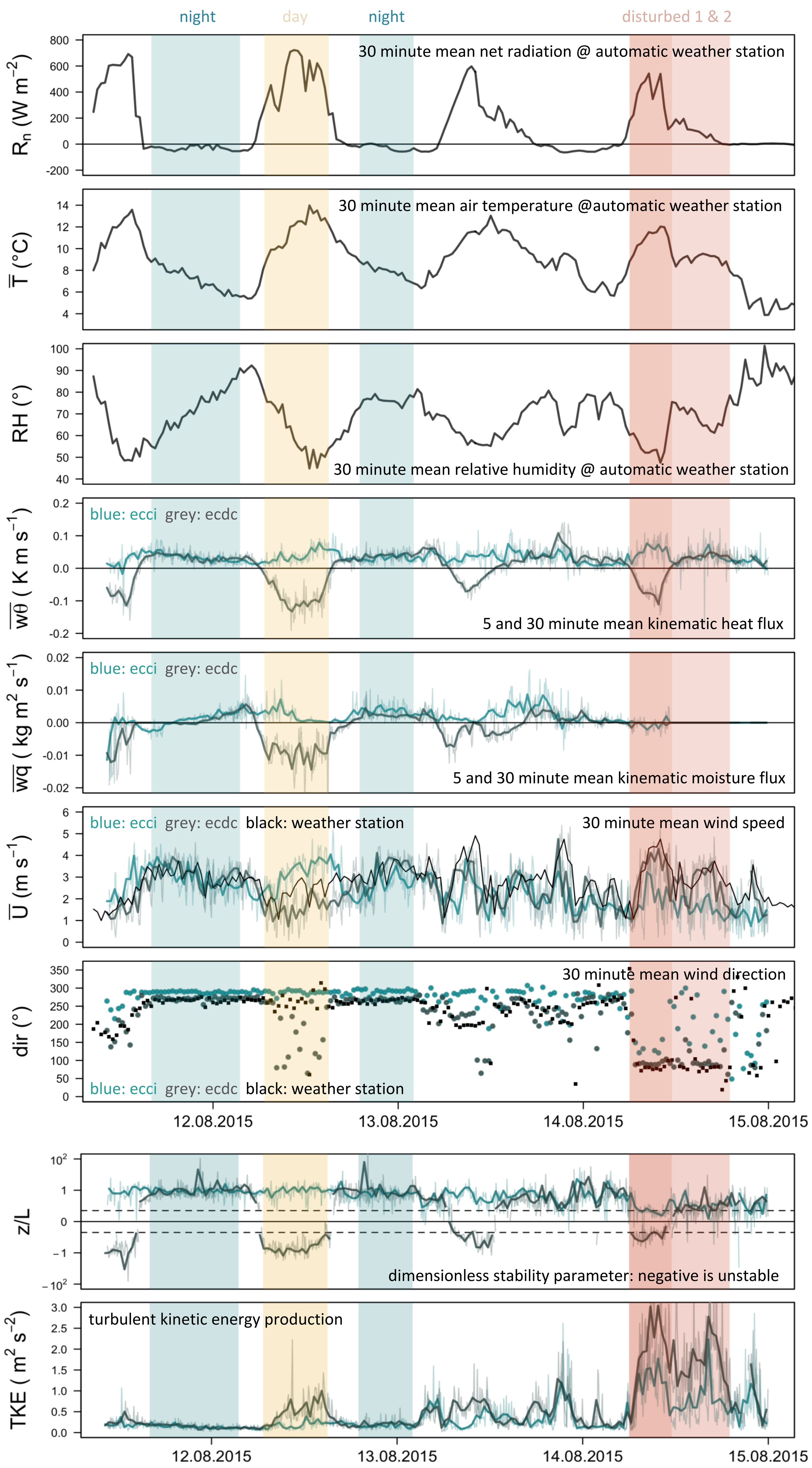
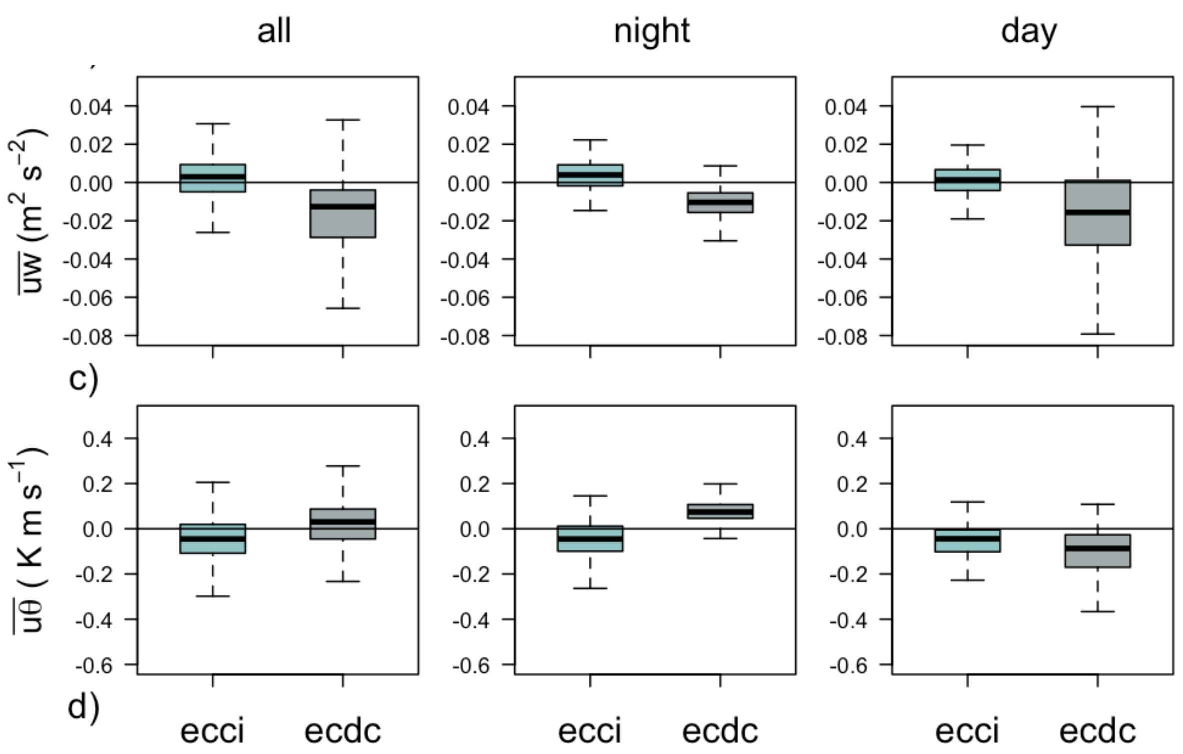
INTRODUCTION

- Turbulence governs near surface atmosphere-surface exchanges of energy, momentum and mass, which can be important contributors to glacier ablation.
- With continued climate change (1) increasing importance of turbulent energy exchanges over most glacier environments; (2) increasing debris cover over remaining mountain glaciers.
- This is significant because turbulent theory, and bulk approaches, do not apply well to glacier surfaces (e.g. Radic et al., 2018) and apparently also not to the even less well studied case of debris covered ice (Steiner et al., 2018).
- We argue there is a need to better understand some fundamental properties of turbulence over glaciers so here we analyse the properties of eddy covariance data collected during a short mid-summer period of observations collected simultaneously over exposed and debris covered ice on a small alpine glacier under different wind regimes.



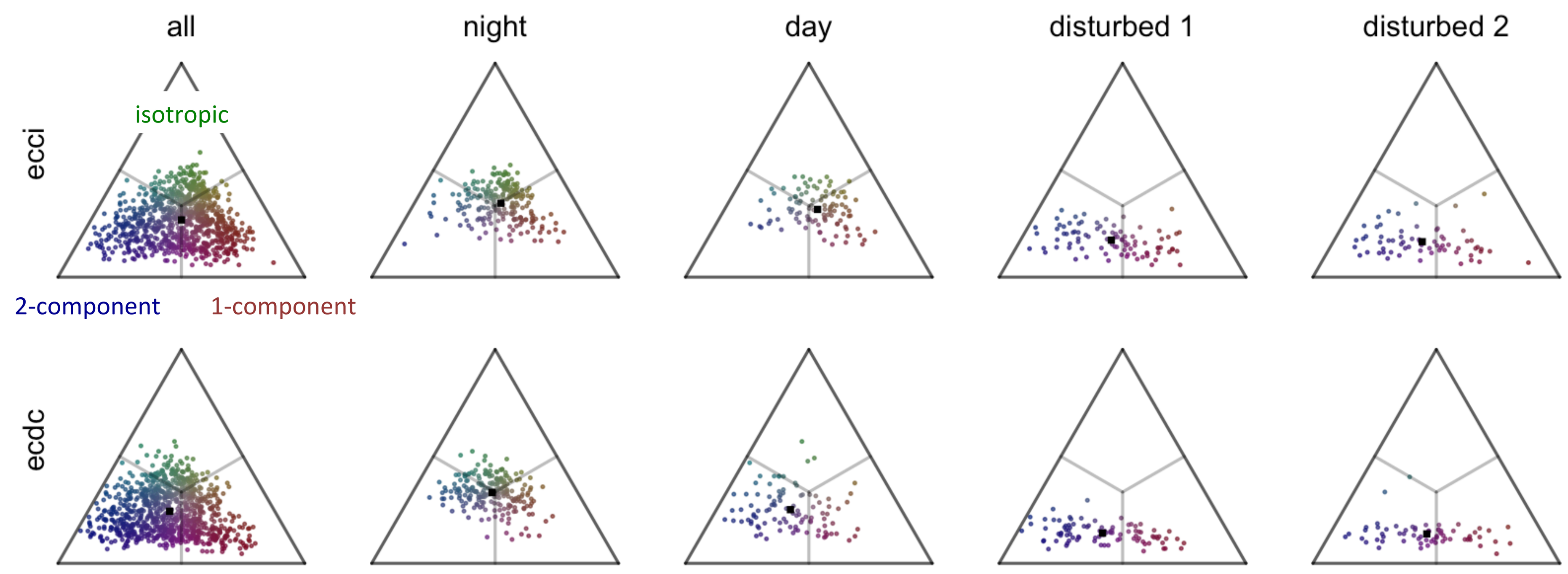
RESULTS



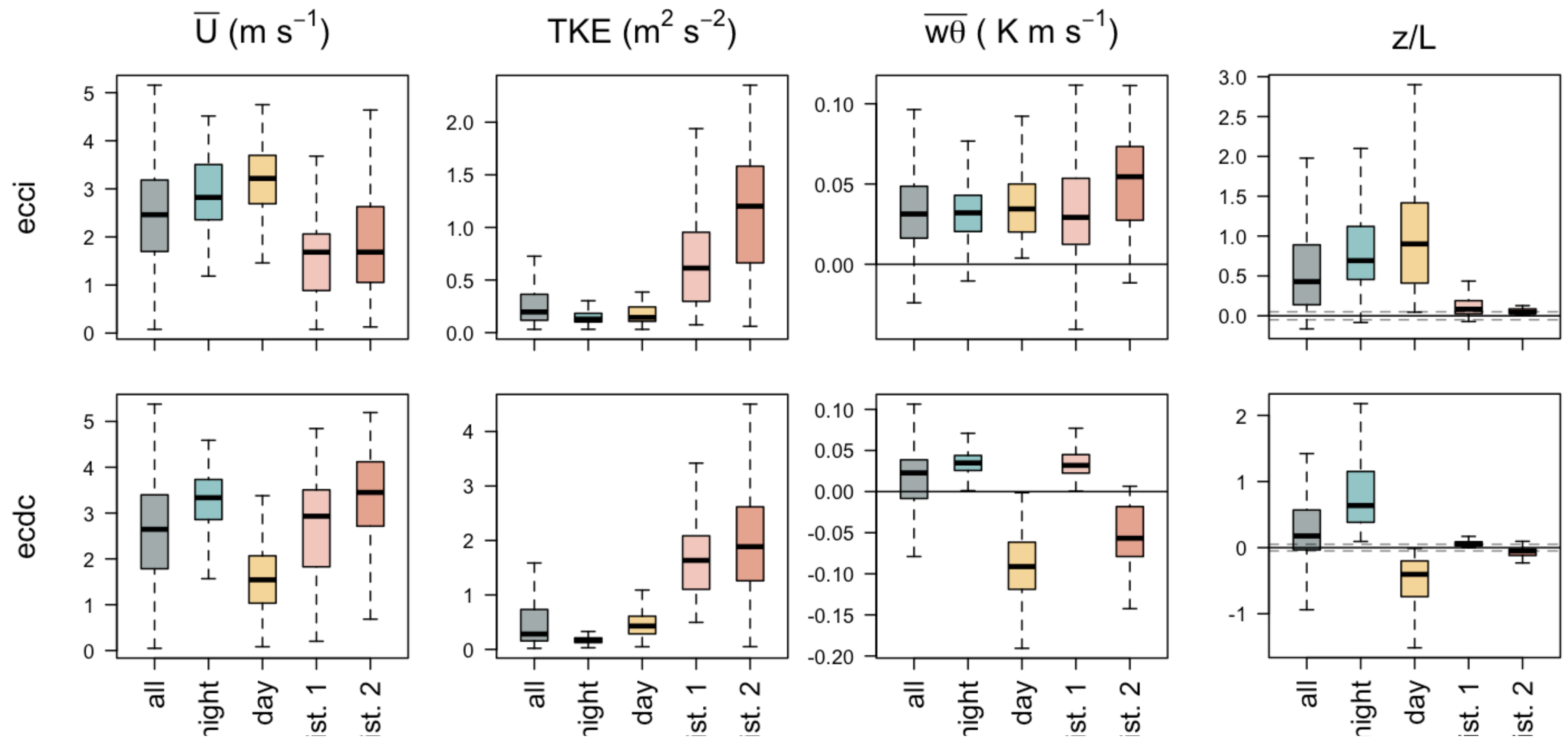


Streamwise fluxes indicate 1.6m measurement height is typically above the katabatic jet maximum at ecci and below it at ecdc (Grachev et al., 2016)

- deepening katabatic flow downglacier and over debris
- jet maxima coincides with minimum TKE
- measurements in turbulent boundary layer, but above jet less influenced by surface



5 minute anisotropy of the Reynolds stress tensor (Stiperski and Calaf, 2018) shows that low measurement height prevents isotropic turbulence. Turbulence topology is similar over both surfaces except for in sunny days, and becomes more anisotropic under disturbed air flow.



Similar turbulent conditions during night-time, and in cloudy conditions. Instability (z/L) over debris cover under sunny conditions (day) causes immediate/gradual switch from prevailing positive heat/moisture fluxes to negative fluxes. Though an order of magnitude less than heat fluxes, moisture is both deposited and removed from debris.

Katabatic winds prevail but are broken down by buoyant convection over debris cover in sunny conditions. Mesoscale upglacier flow disturbs this katabatic wind regime, bringing more neutral stability profiles and a pronounced increase in TKE even though measured kinematic fluxes change little.

CONCLUSIONS

Multilevel measurements over a longer period would tell us more, but we can confirm that moisture fluxes are active over the whole glacier including the debris cover, and are generally deposition under these midsummer conditions. Turbulence structures, scales and topology are actually rather similar over exposed and debris covered ice except during sunny conditions when instability and buoyant convection over the debris significantly alters the exchange with the atmosphere, and also influences the extent of the glacier wind. These findings have relevance for representing glaciers in coupled atmospheric models and for extrapolating meteorological fields over glaciers.