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The turbulence structure of katabatic flows below and above wind-speed maximum

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Measurements of atmospheric small-scale turbulence made over the complex-terrain at the US Army Dugway Proving Grounds in Utah during the Mountain Terrain Atmospheric Modeling and Observations (MATERHORN) Program are used to describe the turbulence structure of katabatic flows. Turbulent and mean meteorological data were continuously measured at multiple levels (up to seven) on four towers deployed along East lower slope (2-4 degrees) of Granite Mountain. The multi-level, multi-tower observations obtained during a 30-day long MATERHORN–Fall field campaign in September-October 2102 allow studying temporal and spatial structure of nocturnal slope flows in detail. In this study, we focus on the various statistics (fluxes, variances, spectra, cospectra, etc.) of the small-scale turbulence of katabatic winds. Observed vertical profiles of velocity, turbulent fluxes, and other quantities show steep gradients near the surface but in the layer above the slope jet these variables vary with height more slowly than near the surface. It is found that vertical momentum flux and horizontal heat (buoyancy) flux in a slope-following coordinate system change their sign below and above the wind maximum of a katabatic flow. The vertical momentum flux is directed downward (upward) whereas the horizontal heat flux is downslope (upslope) below (above) the wind maximum. Our study, therefore, suggests that a position of the jet speed maximum can be derived from linear interpolation between positive and negative values of the momentum flux (or the horizontal heat flux) and determination of a height where a flux becomes zero. It is shown that the standard deviations of all wind speed components (and therefore the turbulent kinetic energy) and the dissipation rate of turbulent kinetic energy have a local minimum, whereas the standard deviation of air temperature has an absolute maximum at the height of wind speed maximum. We report several cases when the destructive effect of vertical heat (buoyancy) flux is completely cancelled by the generation of turbulence due to the horizontal heat (buoyancy) flux. Turbulence in the layer above the wind-speed maximum is decoupled from the surface and it is consistent with the classical local z-less predictions for stably stratified boundary layer.