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The impact of non-stationary flows on the surface stress in the weak-wind stable boundary layer

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The behaviour of turbulent transport in the weak-wind stably stratified boundary layer is examined in terms of the non-stationarity of the wind field based upon field observations. Extensive sonic anemometer measurements from horizontal networks and vertical towers ranging from 12 to 20 m height and innovative fiber-optic distributed temperature sensing observations were collected from three field programs in moderately sloped terrain with a varying degree of surface heterogeneity, namely the Shallow Cold Pool (SCP) and the Flow Over Snow Surfaces (FLOSS) II experiments in Colorado (USA), and the Advanced Canopy Resolution Experiment (ARCFLO) in Oregon (USA). The relationship of the friction velocity to the stratification and small non-stationary submeso motions is studied from several points of view and nominally quantified. The relationship of the turbulence to the stratification is less systematic than expected due to the important submeso-scale motions. Consequently, the roles of the wind speed and stratification are not adequately accommodated by a single non-dimensional combination, such as the bulk Richardson number. However, cause and effect relationships are difficult to isolate because the non-stationary momentum flux significantly modifies the profile of the non-stationary mean flow. The link between the turbulence and accelerations at the surface is examined in terms of the changing vertical structure of the wind profile and sudden increases of downward transport of momentum. The latter may be significant in explaining the small-scale weak turbulence during stable stratification and deviations from conventional flux-profile relationships. Contrary to expectations, the vertical coherence was strongest for weakest winds and declined fast with increasing velocities, which suggests that submeso-scale motions are much deeper than previously thought.