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Scale interactions and anisotropy in stable boundary layers

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Stable boundary layers are strongly controlled by multi-scale interactions. Here we investigate the regimes of interaction using the FLOSSII and SNOHATS datasets for nocturnal near-surface stable boundary layer turbulence. The non-stationary response of turbulent vertical velocity variance to non-turbulent, sub-mesoscale wind velocity variability is analyzed using the bounded variation, finite element, vector autoregressive factor models clustering method. Several locally stationary flow regimes are identified with different influences of sub-mesoscale wind velocity on the turbulent vertical velocity variance.

In each flow regime, we analyze multi-scale interactions and quantify the amount of turbulent variability which can be statistically explained by the individual forcing variables. The state of anisotropy of the Reynolds stress tensor in the different regimes is shown to relate to these different signatures of scale interactions. Finally, we relate the different regimes and associated anisotropy to the vorticity fields and turbulence budgets. In flow regimes dominated by sub-mesoscale wind variability, the Reynolds stresses show a clear preference for strongly anisotropic, one-component stresses. These periods additionally show stronger persistence in their dynamics, compared to periods of more isotropic stresses. The analyses give insights into how the different topologies relate to non-stationary turbulence triggering by sub-mesoscale motions.