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Relationship between near-surface similarity and turbulence anisotropy

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Numerically unresolved boundary layer processes such as the surface momentum and energy exchange remain one of the great challenges of numerical weather prediction. The parametrizations employed to represent these processes still rely heavily on the similarity theory, which shows large scatter even over flat and horizontally homogeneous terrain when applied to real datasets. Thus, horizontal velocity variances are consistently found to elude scaling. Similarly, under very stable stratification lack of scaling is generally attributed to non-Kolmogorov turbulence and influence of non-turbulent submeso motions.

Within this work we present a novel approach where anisotropy of the Reynolds stress tensor is used as a means of testing the validity of similarity relationships and examine the causes of their failure. The dataset employed is the well-known CASES-99 dataset obtained over semi-flat and horizontally homogeneous terrain. Results illustrate that different states of anisotropy (isotropic, two component axisymmetric and one component turbulence) correspond to different similarity relations. This in turn explains the large scatter found in the scaling of horizontal velocity variances and also under stable conditions. The best scaling is found for experimental data with isotropic turbulence. On the other hand, strongly anisotropic turbulence significantly deviates from the traditional scaling relations. These limiting states of anisotropy are finally put into relation with governing parameters based on the TKE budget that identify conditions in which each anisotropy state occurs.