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Statistical classification of different flow regimes in the nocturnal boundary layer

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This work is focusing on intermittent turbulence in a stably stratified environment. The goal is to improve the understanding of the physical mechanisms behind turbulence intermittency and the transition process between weakly stable and strongly stable regimes.

To accomplish this, data analysis on high resolution nocturnal eddy-correlation data (FLOSSII field program) is performed. The idea of the approach is to apply a machine learning methodology (FEM-VARX) to find characteristic flow regimes which differ by the signature of their scales of motion. The physical hypothesis is that some strongly stable flow regimes will be influenced by submeso scales of motion. Thereby they have a different scale signature than weakly stable regimes under the main influence of the mean shear. The FEM-VARX methodology separates flow regimes by fitting several locally stationary statistical models on a time series, and allows regime modulation by external variables. We investigate regime dependent modulation of vertical velocity fluctuations by the mean shear, the wind velocity on the submeso scales and by buoyancy fluctuations. The dataset is preprocessed and reduced to 68 nights to meet requirements of the algorithm. The following model structure is found based on seven most intermittent nights, which corresponds to a time series of 15k samples.

In this analysis the variance of the vertical velocity fluctuations (σ_w) from scales of motion faster than 1 min is considered. This study is showing that it can be modeled by a set of three locally stationary moving-average models with exogenous factors, each corresponding to a distinct flow regime. The different flow regimes are found to describe the weakly stable, strongly stable and the transition regime respectively. The model output σ_w is modulated by the following three inputs or external variables defined on different scales: the wind speed on submeso scales (V_{sm}) ranging from 1 min to 30 min, the mean shear (V_m) spanning the frequency band from 30 min and upwards and the buoyancy fluctuations (b_{sm}) on the scale from 1 min to 30 min. Using the three forcing variables, the statistical model explains 40% of the signal energy and 80% of the modeled cluster states are found to be statistically significant.

We quantify the relative influence of submesomotions, mean shear and buoyancy fluctuations on the vertical velocity fluctuations in all three identified models. This analysis brings new insights on the intermittent turbulence in the nocturnal boundary layer.