A Spectral Model for Stratified Atmospheric Flows

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The knowledge of the instantaneous velocity field characteristics in the atmospheric boundary layer has crucial importance in both fundamental and applied fluid dynamics. Wind turbines are examples of machines that must be designed to operate in such an environment, where the high Reynolds number prohibits to simulate the natural transition process, so that the only feasible approach is to force a realistic turbulent field at the inlet in terms of two-point velocity spectra. However, the existing models provide results in absence of density stratification and empirical observations must be used alternatively.
A solution of the inviscid rapid distortion equations of a stratified flow with homogeneous shear is proposed, extending the work of Hanazaki and Hunt (JFM, 507, 2004) to the two horizontal velocity components. The analytical solution allowed for the determination of the spectral tensor evolution at any given time starting from a known initial condition. Following the same approach adopted by Mann, a model for the velocity spectral tensor in the atmospheric boundary layer is obtained where the spectral tensor, assumed to be isotropic at the initial time, evolves until the break-up time where the spectral tensor is supposed to achieve its final state observed in the boundary layer. The model predictions are compared with atmospheric measurements obtained over a forested area, giving the opportunity to validate the model as shown in the figure (where symbols are measurements, lines are models outputs for F_{uu}, F_{vv}, F_{ww} and F_{uw} in the left part of the figure, and F_{uT} and F_{wT} in the right part). The model is currently validated for stable stratification and will be extended to unstable stratification as well.