A spectral model of stratified surface-layer turbulence

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The knowledge of the instantaneous velocity field characteristics of the atmospheric boundary layer has crucial importance for efficient wind-energy utilization. Wind turbines must be designed to operate in such a turbulent environment, and to simulate such a high Reynolds number flow the only feasible approach is to force a realistic turbulent field at the inlet of the computational domain in terms of two-point velocity spectra [1]. However, the existing models provide results in absence of density stratification and empirical observations or corrections must be used alternatively to improve the results accuracy.

A solution of the inviscid rapid distortion equations of a stratified flow with homogeneous shear is proposed, extending the work of Hanazaki and Hunt [2] to the two horizontal velocity components. The analytical solution allowed for the determination of the spectral tensor (F_{ij}, where i and j correspond to the fluctuating stream-wise, span-wise and wall-normal velocity components u, v, w or temperature θ) evolution at any given time starting from a known initial condition. Following the same approach adopted by Mann [1], a model for the velocity spectral tensor in the atmospheric surface 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 surface layer. The model predictions are compared with atmospheric measurements obtained over a forested area, giving the opportunity to determine the model parameters and to validate it against real atmospheric data, as shown in fig. 1.

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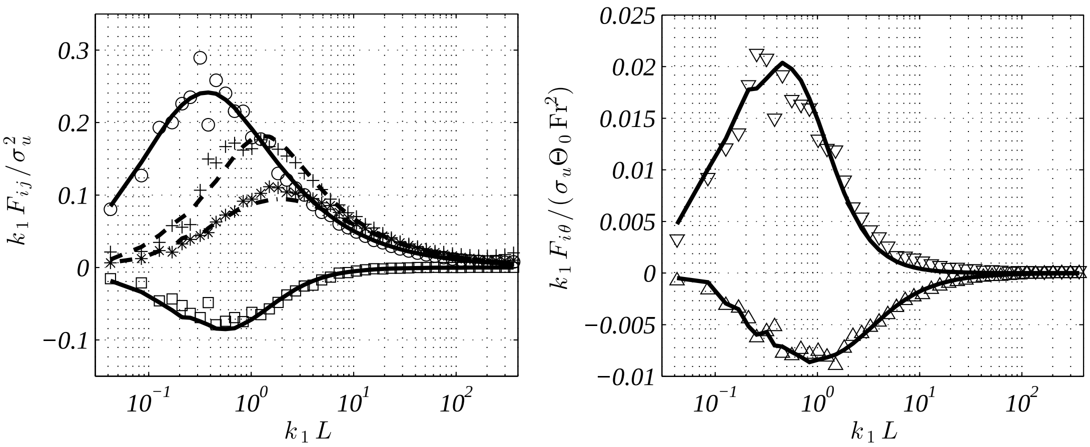

Fig. 1: Comparison between measurements and the model predictions for a stably stratified case. Experimental data: ($\circ$) F_{uu}, ($+$) F_{vv}, ($*$) F_{ww}, ($\square$) F_{uw}, ($\bigtriangledown$) $F_{u\theta}$, ($\bigtriangleup$) $F_{w\theta}$. Model prediction: (*solid line*) F_{uu}, F_{uw}, $F_{u\theta}$, $F_{w\theta}$. (*dashed line*) F_{vv}. (*dash-dotted line*) F_{ww}.

References

[1] Mann J *J Fluid Mech* **273**: 141–168, 1994.
[2] Hanazaki H & Hunt JCR *J Fluid Mech* **507**: 1–42, 2004.

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