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Logarithmic scaling in the longitudinal velocity variance explained by a spectral budget in a neutral and unstable atmosphere

TIRTHA BANERJEE, GABRIEL KATUL, Nicholas School of the Environment, Box 90328, Duke University, Durham, NC 27708, USA, SCOTT SALESKY, MARCELO CHAMECKI, Department of Meteorology, The Pennsylvania State University, University Park, PA 16802-501, USA — A logarithmic scaling for the streamwise turbulent intensity $\sigma_u^2/{u_*}^2 = B_1 - A_1 \ln(z/\delta)$ was reported across several high Reynolds number laboratory experiments as predicted from Townsend's attached eddy hypothesis, where u_* is the friction velocity and z is the height normalized by the boundary layer thickness δ. A phenomenological explanation for the origin of this log-law in the intermediate region is provided here based on a solution to a spectral budget where the production and energy transfer terms are modeled. The solution to this spectral budget predicts $A_1 = C_o/\kappa^{2/3}$ and $B_1 = (3/2)A_1$, where C_o and κ are the Kolmogorov and von Kármán constants. The spectral budget approach is then extended to explore the scaling behavior of σ_u/u_* in the unstably stratified atmosphere. It is demonstrated with support from recent datasets that σ_u/u_* does not only depend on δ/L but also depends on the atmospheric stability parameter $\zeta = z/L$. Thus, the proposed spectral budget shows how Townsend's attached eddy hypothesis, the k^{-1} spectral law in low wavenumbers and the similarity arguments for a stratified atmosphere are all interconnected.

Tirtha Banerjee
Nicholas School of the Environment, Box 90328,
Duke University, Durham, NC 27708, USA

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