Modeling and large-eddy simulation (LES) of a turbulent boundary layer over linearly-varying surface roughness\(^1\) A. SRIDHAR, D. I. PULLIN, California Institute of Technology, W. CHENG, King Abdullah University of Science and Technology — An empirical model is presented, after Rotta (1962), that describes the development of a fully-developed turbulent boundary layer in the presence of surface roughness with nominal roughness length-scale \(k_s\) that varies with stream-wise distance \(x\). For \(Re_x = U_e(x) x / \nu\) large, use is made of the log-wake model of the local turbulent mean-velocity profile that contains the Hama roughness correction \(\Delta U^+ (k_s^+)\) for the asymptotic, fully rough regime. It is shown that the skin friction coefficient \(C_f\) is constant in \(x\) only for \(k_s = \alpha x\), where \(\alpha\) is a dimensionless number. For \(U_e(x) = A x^m\), this then gives a two-parameter \((\alpha, m)\) family of solutions for boundary-layer flows that are self similar in the variable \(z / (\alpha x)\) where \(z\) is the wall-normal co-ordinate. Trends observed in this model are supported by wall-modeled LES of the zero-pressure-gradient turbulent boundary layer \((m = 0)\) at very large \(Re_x\). It is argued that the present results suggest that, in the sense that \(C_f\) is spatially constant and independent of \(Re_x\), this class of flows can be interpreted as providing the asymptotically-rough equivalent of Moody-like diagrams for boundary layers in the presence of small-scale roughness.

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