A Multi-Scale Approach for Modeling of the Atmospheric Turbulent Boundary Layer Subject to Stratification

by

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ABSTRACT

A multi-scale approach for modeling of the atmospheric turbulent boundary layer subject to stratification has been investigated via multi-scale similarity analysis of the equations of motion. Using the Navier-Stokes equations and boundary conditions, order of magnitude analysis has been performed to determine an alternative form of the boundary layer equations. The effects of stratification and stability have been considered in the boundary layer growth and scaling laws.

Additionally, a multi-scale similarity analysis has been developed for a 2-D, steady on the mean, incompressible mixed convection turbulent boundary layer that is subject to an external pressure gradient. The asymptotic invariance principle (AIP), developed by George and Castillo [1], has been successfully explored to obtain new scalings for the inner and the outer regions. In addition, the new outer temperature scale contains the Richardson number (based on mean quantities) providing insight into the stability of the flow. Furthermore, the thermal and momentum boundary layer growth has been found to be proportional to the product of the Stanton and Richardson numbers. Therefore, the stability and the wall heat flux are the primary mechanisms of boundary layer growth in the limit as the Reynolds number approaches infinity. These new parameters are compared with the Reynolds analogy and Monin-Obukhov length and temperature scales.

Furthermore, a new power law for the thermal boundary layer is defined as a function of a new buoyancy parameter. This is similar to the pressure parameter and power law derived by Castillo and George [2] for flows subject to an external pressure gradient including separated flows.

These new equations and scalings provide new models for the Near-Asymptotic method. Future plans also include using highly resolved DNS data to validate the new theory. More importantly, the multi-scale approach could be used to develop inflow conditions for DNS of spatially evolving flows.