THE MULTI-SCALE NATURE OF TURBULENT BOUNDARY LAYERS SUBJECT TO PRESSURE GRADIENT AND STRATIFICATION

By

Gustavo A. Rivera-Rosario

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Major Subject: MECHANICAL ENGINEERING

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Approved:

Luciano Castillo, Thesis Adviser

Rensselaer Polytechnic Institute
Troy, New York

December 2011
(For Graduation December 2011)

For more than fifty years, boundary layer theory has become one of the fundamentals aspects of fluid dynamics. The early work in understanding how a flow behaves with respect to the nearby surface has yielded many improvements in modern designs from cars to airplanes and submarines and many other applications. Recently, atmospheric boundary layer study has been drawing interest due to the favourable opinion about renewable energy viability, particularly in wind turbines. Unlike many other cases, this boundary layer is subjected to stratification, or simply the build up of layers caused by changes in temperature throughout.

A multi-scale method will be proposed based on proof that the boundary layer equations for turbulent flow cannot accept a single scale approach. This method will incorporate scales for both the inner and the outer region. The equations of motion will be used to determine the dependence of the boundary layer growth for cases with and without pressure gradient and stratification as well as the thermal boundary layer growth characteristics. This dependency will be tested with numerical and experimental data using similarity scales derived from the classical theory as well as cases for boundary layers subjected to forced convection and stratification. The multi-scale nature will be studied by looking into the collapse of the temperature, Reynolds shear stress and Turbulent heat fluxes profiles for the various regions. The new approach relies on analyzing the boundary layer equations including the Boussinesq Approximation. Scales derived from this equation accounted for the effects of buoyancy and thermal changes. Results demonstrate that the profile collapse is achieved for different scales in the inner and the other region for the temperature and Reynolds shear stress profile. Particularly, it is suspected that scales for forced convection and classical theory suffice in the analysis.

Lastly, a numerical method proposed for direct numerical simulations in turbulent flow is described for a boundary layer subjected to stratification. The method relies on the theoretical scales provided from historical literature review as well as the new scales being proposed and studied. The method developed by Lund *et al.* [**?**] has been implemented for boundary layers subjected to thermal instabilities by integrating the classical theory into the experiment. It is expected that the new method that uses particular scales developed for the stable and unstable boundary layer will yield important results in boundary layer studies subject to stratification once exercised.