Pressure-gradient-induced (PGI) turbulent separation bubbles (TSBs) are a common occurrence in various fluidic devices and systems. When a separation bubble forms due to an adverse pressure gradient as opposed to a geometric discontinuity, its flow characteristics are notably different. Without a locally fixed separation point, pressure-gradient-induced TSBs have freedom of motion not only of the separation location but also the reattachment location, leading to large excursions in the separation bubble size and shape. The time-scales of oscillations of the detachment and reattachment zones are on the order of 10 – 100 times larger than the characteristic time scale (L_b/U, where L_b is the length of the separation bubble and U is the reference velocity) of the flow. The physical mechanism responsible for generating such a low-frequency unsteadiness remains unknown and a challenge to simulate/measure.

To further the understanding of the complex dynamics observed in these flows, this dissertation presents the results of an investigation of a pressure-gradient-induced TSBs in a canonical framework. A low-speed wind tunnel equipped with a suction duct atop its test section is used to generate a substantial adverse pressure gradient on the top surface of an elliptic leading edge flat plate model to separate the incoming turbulent boundary layer. A novel sensor decontamination method based on conditional spectral analysis is developed and used to analyze the unsteady surface pressure signals from a linear array of sensors. A thorough characterization of the static and dynamic content observed in the pressure-gradient-induced TSB is presented, discussed, and compared to what is observed in other studies.

Spectral proper orthogonal decomposition of two-dimensional time-resolved PIV measurements in a plane reveals the spatio-temporal behavior of the characteristic ‘breathing’ and `shedding’ modes of the PGI-TSB that are reported in the literature. To investigate the three-dimensional behavior, surface oil flow visualization is performed. Furthermore, synchronous surface pressure and multiple stereo particle image velocimetry (PIV) planes are measured and analyzed. In particular, non-time resolved (NTR) stereo-PIV at seven streamwise planes and one spanwise plane is captured with synchronous time-resolved (TR) pressure measurements and analyzed via the Spectral Analysis Modal Method (SAMM), with the goal of constructing a low-order reconstruction of the three-dimensional flow. New insights and interpretation of the characteristic unsteadiness in PGI-TSBs are presented, providing a unique perspective into the understanding of the complex dynamics.