Long-Term Analysis of PBL Height and Climate-Driven Atmospheric Variables

The main objective of this study is to determine whether the height of the planetary boundary layer (PBL) has undergone statistically significant long-term change across climatically distinct regions of the continental United States over the past two decades, and to diagnose the physical mechanisms responsible for any observed trend, or the absence of one. Preliminary analysis of radiosonde data at three sites spanning distinct climate regimes (Albany, NY; Tallahassee, FL; Lincoln, NE) revealed no statistically significant long-term trend in PBL height at any location despite well-documented increases in surface temperature over the same period. This result suggests that compensating dynamical processes, such as changes in soil moisture, cloud cover, or wind shear, may be offsetting the thermodynamic forcing that would otherwise drive a detectable trend. This proposal will rigorously test that hypothesis using a multi-method framework that integrates radiosonde observations, reanalysis products, computational PBL parameterizations, statistical trend analysis, and machine learning. The proposed objective will be achieved through the following specific tasks:

Task 1: Acquire and quality-control 20 years (2004–2024) of radiosonde soundings and reanalysis data (NCEP/NCAR, NARR) at the three study sites, and compute PBL heights using two complementary computational parameterizations (the Bulk Richardson number and parcel methods), benchmarked against manually diagnosed PBL heights for 100 representative soundings.

Task 2: Characterize long-term trends and seasonal/diurnal variability in PBL height at each site using the Mann-Kendall trend test, and quantify agreement between radiosonde-derived and reanalysis-derived PBL heights to establish uncertainty bounds for the trend analysis.

Task 3: Apply Generalized Additive Models to identify which climate and surface variables (e.g., sensible heat flux, soil moisture, cloud cover, wind shear, aerosol optical depth) most strongly govern PBL height variability, then synthesize the trend and machine-learning results into a physical interpretation of the observed, or absent, long-term trend, culminating in a manuscript for peer-reviewed publication and a presentation at the North Carolina Space Grant Symposium.