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Wind-tunnel experiments of thermally-stratified turbulent boundary layer flow over a wall-mounted 2-D block

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Turbulent boundary-layer flows over complex topography have been extensively studied in the atmospheric sciences and wind engineering communities. The upwind turbulence level, the atmospheric thermal stability and the shape of the topography as well as surface characteristics play important roles in turbulent transport of momentum and scalar fluxes. However, to the best of our knowledge, atmospheric thermal stability has rarely been taken into account in laboratory simulations, particularly in wind-tunnel experiments. Extension of such studies in thermally-stratified wind tunnels will substantially advance our understanding of thermal stability effects on the physics of flow over complex topography. Additionally, high-resolution experimental data can be used for development of new parameterization of surface fluxes and validation of numerical models such as Large-Eddy Simulation (LES).

A series of experiments of neutral and thermally-stratified boundary-layer flows over a wall-mounted 2-D block were conducted at the Saint Anthony Falls Laboratory boundary-layer wind tunnel. The 2-D block, with a width to height ratio of 2:1, occupied the lowest 25% of the turbulent boundary layer. Stable and convective boundary layers were simulated by independently controlling the temperature of air flow, the test section floor, and the wall-mounted block surfaces. Measurements using high-resolution Particle Image Velocimetry (PIV), x-wire/cold-wire anemometry, thermal-couples and surface heat flux sensors were made to quantify the turbulent properties and surface fluxes in distinct macroscopic flow regions, including the separation/recirculation zones, evolving shear layer and the asymptotic far wake. Emphasis will be put on addressing thermal stability effects on the spatial distribution of turbulent kinetic energy (TKE) and turbulent fluxes of momentum and scalar from the near to far wake region. Terms of the TKE budget equation are also inferred from measurements and correlated to distinct flow regions.