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Turbulent flow over a surface-mounted 2-D block: thermal stability effects

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Momentum and scalar transport in turbulent boundary-layer flows over complex topography has been of great interest in the atmospheric sciences and wind engineering communities. The physical geometry of the topography, surface characteristics (e.g., roughness and temperature) and atmospheric thermal stability play important roles in momentum and scalar flux distribution. Numerous studies of flow over simplified topography, 2-D or 3-D blocks and sinusoidal hills have been conducted under neutral boundary-layer conditions. However, thermal stability effects are seldom taken into account due to the challenge of performing such laboratory simulations, for instance, wind-tunnel experiments. A limited number of experimental data sets are currently available, which severely hinders understanding of the underlying physics. Such data sets are also in high demand for development of new parameterization of surface fluxes and validation in numerical models such as Large-Eddy Simulation (LES).

We present an experimental investigation of neutral and thermally-stratified boundary-layer flows over a surface-mounted 2-D block at the Saint Anthony Falls Laboratory boundary-layer wind tunnel. The 2-D block, with a width to height ratio of 2:1, was fully immersed in the surface layer of the turbulent boundary layer. Thermal stratification conditions were achieved by independently controlling the temperature of both the air flow and the test section floor and block surfaces. Measurements were obtained, using high-resolution PIV, x-wire/cold-wire anemometry and surface heat flux sensors, to quantify the thermal stability effects on the turbulent flow properties, especially the separation/recirculation zone, coherent vortex structures, the subsequent boundary layer recovery and spatial distribution of surface fluxes. This work aims to enhance our understanding of the thermal stability effects on the turbulent boundary-layer flows over complex topography, and provide a reliable database for validating and improving LES modeling.