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Sensing the Stable Boundary Layer in a Towing Tank

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Understanding and forecasting the stable atmospheric boundary layer (SBL) over land is a challenge for already several decades. Generally, the SBL covers two different regimes. The first regime is the weakly SBL, characterised by well defined wind driven turbulence. The second regime covers the very SBL with weak turbulence, and then additional processes become relevant, such as meandering motions, gravity waves, drainage flows, intermittent turbulence and radiation divergence. Especially in this regime this complexity limits the understanding of the SBL and its representation in numerical weather prediction, climate models and air pollution models. For calm conditions, these models typically overestimate near surface temperature and wind speed, with adverse effects for understanding polar climate and end users in agriculture, transportation, and air quality assessment. To improve our understanding of the SBL, we study SBL turbulence in the CNRM–GAME stratified water flume in Toulouse. This unique facility, particularly well suited for stratified flow and BL studies, provides novel laboratory observations that extend earlier efforts of field observations and wind tunnel studies. Among other things, laboratory observations have the advantage of statistical robustness due to repeatability of the experiment and provide access to an extensive set of data. Hence, a 3x3 m2 plate covered with LEGO of Lx=1.57 cm and Ly=3.57 cm, (roughness length = 0.0014 m, and roughness density =0.250, index of frontal area = 0.125) was towed at different velocities through the tank of 22 x 3 x 1.6 m. In this way we were able to achieve an SBL of $\sim$10 cm with bulk Richardson numbers in the range between 0.05 and 0.25, and turbulence with a well-behaved inertial subrange. We focus on the estimation of the non-dimensional velocity and density profiles, on higher order turbulent statistics (important for plume dispersion), as well as on the turbulence spectral behaviour. Finally, we aim to quantify the transition from weakly to very stable boundary layer, and the transition from a turbulent to laminar boundary layer in terms of non-dimensional quantities.