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Derivation of turbulent structure parameters from large-eddy simulations and comparison with large-aperture scintillometer data and aircraft observations.

B. Maronga (1), D. van Dinther (2), A. Moene (2), and S. Raasch (1)

(1) Institut für Meteorologie und Klimatologie, Leibniz Universität Hannover, Hannover, Germany (maronga@muk.uni-hannover.de), (2) Meteorology and Air Quality Section, Wageningen University, Wageningen, The Netherlands

Turbulent fluctuations in the atmospheric boundary layer are related to local fluctuations in the air density, which can be expressed by the refractive-index structure parameter (C_n^2). Since these fluctuations depend mainly on temperature and humidity, it is possible to relate C_n^2 to the structure parameters for temperature (C_T^2) and humidity (C_q^2). Recently, large-aperature scintillometers (LAS) have been increasingly used to measure C_T^2 over path lengths of several kilometers in the surface layer. By means of Monin-Obukhov similarity theory, the surface flux of sensible heat can be estimated from the C_T^2 measurements. However, a validation of these measurements is challenging.

We derive C_T^2 and C_q^2 from high-resolution large-eddy simulations (LES) of a homogeneously-heated convective boundary layer, driven by measurements at Cabauw (The Netherlands). Three different methods to obtain the structure parameters from LES are investigated. It is found that the shape of the vertical profiles of C_T^2 and C_q^2 from all three methods compare well with former experimental and modelling results. Depending on the method, deviations in the magnitude up to a factor of two are found and traced back to effects of subgrid-scale modeling in LES.

For the first time we show a direct comparison of C_T^2 between high-resolution LES data, an LAS ranging over a distance of [9.8]km as well as simultaneous aircraft measurements along the LAS path in different heights. Our results show that the LES data is in good agreement with the LAS in the surface layer. In the mixed layer we find that C_q^2 compares well between LES and aircraft data, whereas C_T^2 from the aircraft data lacks the proposed decrease with height.

By means of localized structure parameter data from the LES, we investigate the four-dimensional (space and time) variability of C_T^2 due to turbulent fluctuations in the surface layer. Our results clearly suggest that sufficient temporal averaging and an appropriate path-length is required in order to obtain representative values of C_T^2 by an LAS system.