Geophysical Research Abstracts
Vol. 17, EGU2015-14490, 2015
EGU General Assembly 2015
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Turbulence vertical structure of the boundary layer during the afternoon transition

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The transition from a well-mixed convective boundary layer to a residual layer overlying a stabilized nocturnal layer raises several issues, which remain difficult to address from both modeling and observational perspectives. The well mixed convective boundary layer is mainly forced by buoyancy, with fully developed turbulence. The daily decrease of the surface buoyancy flux leads to the decay of the turbulence kinetic energy (TKE), and a possible change of the structure of the turbulence before it reaches the stable regime, with more anisotropy and intermittency. It is important to better understand these processes, as they can impact on the dispersion of tracers in the atmosphere, and on the development of the nocturnal and daytime boundary layers of the following days.

The presented work is based on both observations from the BLLAST (Boundary Layer Later Afternoon and Sunset Turbulence) experiment and Large-Eddy Simulation (NCAR LES code). The field campaign took place in summer 2011 in France, on the northern side of the Pyrenean foothills. A well-documented cloud-free weak wind day is considered here to analyze in details the evolution of the turbulence along the day, from midday to sunset.

The case study combines observations of the mean structure and of the turbulence. It is the base of a complementary idealized numerical study with a large eddy simulation. From both observations and numerical simulations, the turbulence is described, according to time and height, with the characteristics of the spectral energy density, especially the typical turbulence lengthscales and the sharpness of the transition from energy-containing eddies to the inertial subrange. An analytical model proposed by Kristensen and Lenschow (1988) for homogeneous nonisotropic turbulence is used to approximate the observed and LES-modeled spectra and estimate their characteristics.

The study points out the LES ability to reproduce the turbulence evolution throughout the afternoon. Two periods have been defined and caracterized: the "Early Afternoon", quasi-stationary, during which the TKE decays with a slow rate, with no significant change in the turbulence characteristics, and the "Late Afternoon", characterized by a larger TKE decay rate and a change of its spectral characteristics (increase of vertical velocity lengthscale, and change of the inertial spectral range slope). We also point out that the turbulent changes occur first in the upper part of the ABL. We have extended the analysis to several other days of aircraft observation, and to a LES sensitivity analysis with a TKE budget analysis, in order to confirm our findings and propose an explanation of these results with the role of the wind shear, entrainment, and by considering the effect of turbulent structures and anisotropy.