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Comparison of Synthetic Turbulent Wind Fields with Large-Eddy Simulations of the Atmospheric Boundary Layer

T. Auerswald (1), J. Bange (1), R. Radespiel (2), C. Weinreis (3), and S. Raasch (3)

(1) TU Braunschweig, Institute of Aerospace Systems, Braunschweig, Germany (t.auerswald@tu-bs.de), (2) TU Braunschweig, Institute of Fluid Mechanics, Braunschweig, Germany, (3) Leibnitz University Hannover, Institute of Meteorology and Climatology, Hannover, Germany

Large-Eddy Simulation (LES) models are useful tools for studying turbulent processes in the atmospheric boundary layer (ABL). For turbulent flows to establish in the model domain, the model is often initialised e.g. with homogeneous fields overlayed by a random fluctuation in temperature. In these cases it will take some time in the simulation until the developing turbulent flow can be considered to be realistic.
Since there are many applications where a realistic turbulent field is needed right from the beginning of a simulation it is often necessary to initialise the model with an already realisticly turbulent wind field. For these cases a modified version of the random flow generator by Smirnov et.al. (2001) was used. The generator provides realistic turbulent wind fields with a given energy spectrum, covariances and variances for both isotropic and anisotropic turbulence.
The energy spectrum, covariances and variances are calculated from data measured with the Helipod system of the Institute of Aerospace Systems, Techn. U. Braunschweig. The Helipod is a unique measurement system that is attached to a 15 m rope under a helicopter. It is equipped with several sensors to measure the atmospheric wind vector, humidity, C02, air and surface temperature over a wide spectral range and thereby resolves small scale turbulence (sub-metre scale) and turbulent transport of momentum, heat and moisture very precisely.
The task of the random flow generator is to reproduce the statistical properties of the timeseries, measured with the Helipod along straight and level flight legs, in a three-dimenional domain. This three-dimensional wind field is then used to initialise the computational fluid dynamics solver developed by the DLR (Deutsches Zentrum für Luft- und Raumfahrt) called TAU.
With the TAU model it will be possible to study the effect of turbulence on e.g. an airfoil by initialising the model with the synthetic turbulent wind field and subsequently simulate the turbulent flow around the airfoil.
The talk will address the methods behind the random-flow generator and the application of the generator with TAU. The presented results do not contain any model runs with an airfoil, yet. Rather, the presentation explains the development of the generated field in the model with focus on the conservation of the statistical properties of the turbulence. Furthermore, results of a comparison study with the parallelised Large-Eddy Simulation Model (PALM) of the Institute of Meteorology and Climatology at the Leibnitz University Hannover are shown. In this comparison study PALM was used to simulate an ABL for different meteorological setups. During this simulation virtual measurements for the three components of the wind vector were taken at different altitudes in the model domain. The timeseries of wind speed are then treated like measurements from the helipod to generate turbulent 3D wind fields with the energy spectrum, covariances and variances obtained from the virtual measurements from PALM. Subsequently, the generated wind fields are compared with the PALM simulations regarding their meteorological properties.