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Generation of a three-dimensional turbulent initial wind field for large-eddy simulation

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Large-eddy simulation (LES) models are useful tools for studying turbulent processes in the atmospheric boundary layer. For turbulent flows to establish in the model domain, the model is often initialized 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 initialize 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 and covariances for both isotropic and anisotropic turbulence.

The energy spectrum and covariances are taken 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, CO^2, 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 turbulent wind field, that was 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 tubulence on e.g. an

airfoil by using the model in DES (detached eddy simulation) mode in combination with the Chimera-method. In DES the flow in the boundary layer of the airfoil is simulated by RANS. Outside the boundary layer the turbulent wind field is computed with LES. By using the Chimera-method, the turbulent wind field outside of the boundary layer is computed with LES on a secondary grid that is advected to the airfoil by the mean flow. This technique saves computation time, since the computational expensive LES-method is only used on the smaller secondary grid that contains the turbulence of interest. The wind field on the secondary grid is initiated by the turbulent wind field produced by the random flow generator.
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.