The effects of the atmospheric turbulence on wake vortices

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Wake vortices are strongly affected by ambient atmospheric parameters such as wind shear, stratification, and turbulence as well as by the proximity of the ground. The lifespan of wake vortices may be short in presence of strong turbulence but may also be of the order of several minutes in case of weak turbulence. The vortex lifespan is an essential aspect in the issue of wake vortex encounters. In this study we focus on the effect of three-dimensional ambient atmospheric turbulence on vortex decay using temporal large eddy simulations.

The effect of ambient atmospheric turbulence has been investigated by placing vortex systems in homogeneous isotropic turbulence, which is assumed to be either a good approximation of atmospheric turbulence as well as a suitable option for generic vortex/turbulence interaction studies. A large set of single vortex and vortex pair configurations has been considered in order to determine the quantitative and qualitative effects of ambient turbulence on the vortex dynamics. The different mechanisms that have been observed during the decay process are turbulent diffusion, the creation of azimuthal structures of vorticity, the concurrent exchange of vorticity between primary vortices and the surrounding turbulence, as well as occurrence of large deformation and the onset of instability processes. The circulation, which quantifies the strength of the vortex is significantly affected by the presence of turbulence, and an accompanying parameter study resulted in the identification of pertinent parameters governing the circulation decay.

Based on the numerical simulations, a simple turbulence decay model is proposed as a function of the parameters characterizing the ambient turbulence. The observations made during the analysis of the results showed the appearance of the different phenomena mentioned above that dominate the vortex decay. The relationship is assumed to model the circulation decay of vortices interacting with ambient turbulence, a neutrally stratified background with no wind shear and no ground effect.

A second three-dimensional large eddy simulation code is used to simulate the behavior of aircraft wake vortices in a more realistic atmosphere. In this case, both weak turbulence and stratification effects are studied. Stable stratification is here a consequence of the earth’s boundary layer activity. A system of vortices in post roll-up phase placed in a suitable meteorological background form the initial conditions of a temporal simulation. Mesh refinement techniques enable the use of a large computational domain to capture the different scales of motion present in the atmospheric boundary layer as well as a sufficient resolution in the region where the vortices reside. Eventually, the decay processes identified in the homogeneous isotropic turbulence simulations and in the more realistic test case will be compared.

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