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Aerodynamic Analysis of an Airborne Wind Energy System in Turbulent Wind Conditions

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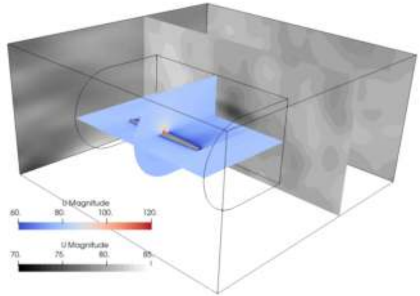
Airborne wind energy (AWE) systems operate in the turbulent atmospheric boundary layer (ABL) by flying complex manoeuvres. The systems are therefore subject to unsteady flight conditions which affect their flight dynamics and overall performance. In particular, this work focuses on the effects of the inherent wind turbulence on the unsteady aerodynamic performance of the system's lifting surfaces.

For this aerodynamic analysis, we consider the multi-megawatt reference AWE system, MegAWES [1]. Pynaert et al. investigated the aerodynamic performance of the MegAWES system in crosswind flight using unsteady Reynolds-Averaged Navier-Stokes (RANS) in [2]. While the effects of large motions on the system's aerodynamic characteristics can be evaluated, the turbulence modelling inherent to the URANS method falls short at capturing the unsteady effects of resolved wind turbulence. In the present contribution, an aerodynamic analysis of the MegAWES aircraft is performed in the presence of added freestream turbulence. Resolved synthetic turbulence is fed as transient inflow condition to the simulation domain to emulate the flow characteristics of the turbulent ABL. The flow is simulated using hybrid RANS/LES (Large-eddy simulation) techniques in order to capture the large structures of the turbulent and separated flows. The local aerodynamics around the AWES are computed on a boundary-layer resolving body-fitted mesh, which is subsequently coupled to the ABL domain using the overset mesh coupling technique, see the figure.

This contribution investigates the effects of wind turbulence on the system's performance during level flight, in particular on the spanwise distribution of aerodynamic loads. This study ultimately helps assessing the feasibility of using hybrid RANS/LES capabilities in combination with overset techniques for the future investigation of complex flight configurations, including large crosswind motions, and wing deformation.



Instantaneous turbulent wind flow past the MegAWES wing computed using overset and hybrid RANS/LES.

References:

[1] D. Eijkelhof and R. Schmehl. Six-Degrees-of-Freedom Simulation Model for Future Multi-Megawatt Airborne Wind Energy Systems. Renewable Energy, 196:137–150, 2022. doi:10.1016/j.renene.2022.06.094

[2] N. Pynaert, J. Wauters, G. Crevecoeur and J. Degroote. Unsteady aerodynamic simulations of a multi-megawatt AWE reference system using computational fluid dynamics. J. Phys.: Conf. Ser. 2265 042060, 2022. doi:10.1088/1742-6596/2265/4/042060