MULTI-SCALE ENERGY TRANSFERS IN THE NEAR WAKE OF A MODEL WIND TURBINE

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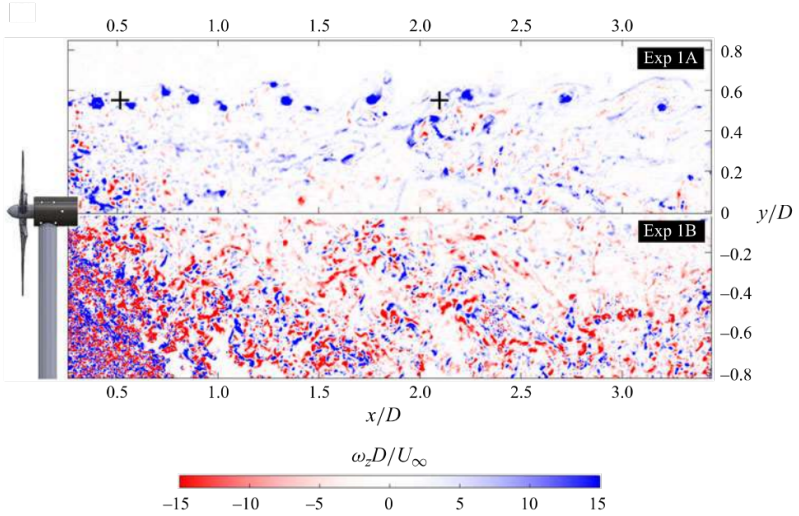

A composite image of the instantaneous vorticity (ω_z) field in the near wake of a model wind turbine operating at a tip speed ratio $\lambda = 6$ from two, non-concurrent, fields of view.

Many turbulent flows are forced at multiple length scales, imprinting coherent motions with multiple characteristic frequencies/length scales simultaneously. Examples include flows through a cityscape or a forest but also past a wind turbine where coherent motions are concurrently imparted into the wake by the tower, nacelle, blade-tip vortices etc. In our previous work we developed the multi-scale triple-decomposition of the velocity field into the mean, a sum of various periodic (coherent) motions, and a stochastic fluctuation [1]

$$\boldsymbol{u}(\boldsymbol{x},t) = \overline{\boldsymbol{u}}(\boldsymbol{x}) + \sum_{i=1}^{N} \tilde{\boldsymbol{u}}_i(\boldsymbol{x},t) + \boldsymbol{u}''(\boldsymbol{x},t)$$

which we subsequently used to develop the multi-scale triple-decomposed kinetic energy budgets for the mean flow, coherent motions, and stochastic turbulent kinetic energy [2]. The energy budget for the coherent motions contains a "new" term, called the triadic production term, that transfers energy from one coherent mode to another under the catalytic action of a third coherent motion in the triad. This triadic production term was observed to lead to the formation of secondary modes in simple, planar multi-scale flows [2]. In this talk we will observe the various coherent motions that exist in a wind-turbine wake (reported in [3]), and how these depend on the turbine operating condition via the tip speed ratio $\lambda = \Omega R/U_\infty$. We will also explore the ways in which the various coherent modes in the wake are energised through the framework of the multi-scale triple decomposed coherent kinetic energy budget (reported in [4]). Finally, we will examine the influence of free-stream turbulence on both the coherent modes that are produced within the wake and the energy transfers that yield them.

References

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[3] N. Biswas and O. R. H. Buxton. Effect of tip speed ratio on coherent dynamics in the near wake of a model wind turbine. Journal of Fluid Mechanics, 979:A34, 2024.

[4] N. Biswas and O. R. H. Buxton. Energy exchanges between coherent modes in the near wake of a wind turbine model at different tip speed ratios. Journal of Fluid Mechanics, 996:A8, 2024.