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Towards Flow-Field Characterization for AWES

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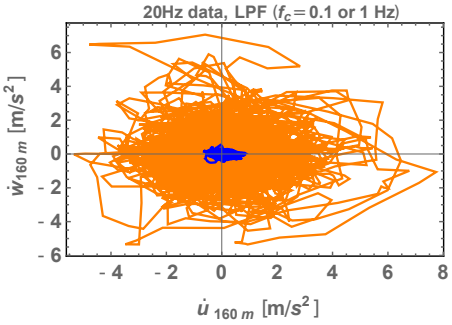
Characterizing the flow field encountered by airborne wind energy systems (AWES) is crucial for both their design and operation. In addition to affecting potential wind resources, the highly variable and complex turbulent flow at heights above the atmospheric surface layer (z>100m) also impacts the control system and flight paths which are optimal for a given AWES design. The interplay between flow field, flight paths, control system, and design ultimately affects the loads and reliability of AWES.

10-minute statistics commonly used in wind energy lack information about the events and flow at temporal and physical scales relevant for AWES. Re-analysis, mesoscale, and lidar data also fail to capture primary flow features which affect AWES operation and design. Finer resolution data is needed to cover the response times and physical dimensions of AWES; these can reach 1s and 1–10m, respectively (or shorter). Stationary horizontal axis wind turbines (HAWTs) have scales of 100m and longer response times, acting to average the inflow and its inhomogeneities. E.g., accelerations encountered in a 10-minute period are shown in the Figure, filtered separately for typical AWES and HAWT scales. Significant accelerations in multiple directions occur for AWES, whereas for HAWTs these are much smaller and mostly streamwise.

After recent parallel analysis for HAWTs [1], we investigate flow statistics at AWES scales and operational heights, showing where they cannot (or can) be expressed using conventional 10-minute statistics. Following analogous statistical characterization [2], we also give flow metrics for AWES design, operation, and resource assessment; this includes conditional vector velocity and acceleration statistics missing from typical 10-minute data.



10-minute streamwise/vertical acceleration space: Høvsøre offshore sector, 160m height, sampled at 20Hz. Filtered (O2 Butterworth) for characteristic response times of 10s (blue) and 1s (orange).

References:

[1] Kelly, M. Environmental joint probability distributions and uncertainties in HiperWind, DTU report E-02XX (in prep/2022)

[2] Kelly, M. et al. Probabilistic meteorological characterization for turbine loads. Journal of Physics: Conference Series, 524, 012076 (2014)