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Full-scale turbulence structure of wind and applications

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As today's wind farm clusters can be as large as thousands of kilometers squared and individual turbines hundreds of meters tall, we are challenged when applying classical wind and turbulence models for corresponding wind energy-related calculations. Typical boundary-layer turbulence models are applicable to time scales smaller than ~1 h, or as denoted by Högström et al. (2002) the Kolmogoroff inertial subrange, the shear production range, and for ranges within the spectral gap region.

This study revisits some key characteristics of the atmospheric boundary-layer turbulence, covering frequencies from 1/year, over the energy-containing range, to synoptic- and mesoscales, to the gap region and to the 3D turbulence range. This study aims at investigating the following fundamental questions: How to characterize the full-scale spectral behaviors and what are the mechanisms behind them? To which extent is the condition of stationarity fulfilled? What are the 2D-isotropy characteristics? How are numerical modeling abilities in capturing these characteristics? We also show how these findings have been used in wind energy applications, e.g. for generating time series of wind speed including meso-scale variability, for investigating meandering, for extreme wind calculation and for improving turbulence intensity calculation in the presence of organized atmospheric phenomena.

The study includes literatures as well as a series of our studies in recent years (e.g. Larsén et al. 2013, 2016, 2019, 2021). We combined measurements and modeling in the analysis. The primary datasets are from several met stations over Denmark and the North Sea region, including both 10-min and sonic measurements from about 10 m up to 240 m. The investigations include both statistical and numerical modeling.

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