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Revisiting two-dimensional turbulence and mesoscale spectra

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Two-dimensional (2D) turbulence is not only a basic research topic that needs further investigations, it is also relevant for wind energy applications as today's wind farm clusters can be as large as thousands of kilometers squared and individual turbines hundreds of meters tall. This challenges the use of classical turbulence models applicable for scales smaller than ~1 h, or as denoted in Högström et al. (2002) the Kolmogoroff inertial subrange, the shear production range, and for ranges the spectral gap region.

This study revisits some key characteristics of 2D turbulence and interpretation of the physics behind it, including general literatures as well as a series of our studies in recent years (Larsén et al. 2013, 2016, 2021). This includes

- The respective frequency/wave number range and the spectral behaviours for the wind speed: the synoptic scales where the spectral slope is -3, the mesoscale where the spectral slope is typically -5/3, and the gap region. We analyze at what scales the spectra meet and merge, and how the spectra are affected by weather types, seasons and stability.
- The 2D-isotropy characteristics. We analyze how the longitudinal and lateral velocities correlate across the scales.
- The application of stationarity. The validity of an assumption of stationary time series decides to how large scales we can perform the analysis of the longitudinal and lateral velocity components, the Taylor frozen hypothesis and 2D-isotropy.

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.

References:

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