Investigations of Correlation and Coherence in Turbulence from a Large-Eddy Simulation

Reviewer's comments

General comment

The manuscript "Investigations of Correlation and Coherence in Turbulence from a Large-Eddy Simulation" by Thedin et al deals with the study of 2-point characteristics of turbulence in the marine atmospheric boundary layer (MABL) by the mean of Large Eddy Simulation (LES). These characteristics are the auto-correlation function, integral time and length scales and coherence. The paper is of broad international interest and reads well. The topic is within the scope of Wind Energy Science. The manuscript discusses many relevant scientific questions but addresses them superficially only. Despite the potential of the numerical tools displayed by the authors, I am afraid that the analysis is currently too shallow to be considered for publication in Wind Energy Science. Maybe focusing on one or two specific questions would lead to more significant conclusions.

The fundamental importance of the literature review

The manuscript needs to include a more attentive literature review on the coherence of turbulence to identify which aspects of the coherence of natural wind are needed in wind energy. The coherence of turbulence has been studied during the 1970s and 1980s by e.g. Pielke and Panofsky (1970); Ropelewski et al. (1973); Kristensen and Jensen (1979); Kristensen et al. (1981); Bowen et al. (1983). I am aware that these studies are fairly old. Yet, they are still highly relevant to the present work and actually answer some of the questions raised by the authors. Similarly, the work by Davenport (1962) and other wind engineers in the 1960s and 1970s (e.g. Scanlan, 1978) is central to connecting the concept of coherence and wind loading on the structure. I understand well that reviewing the past literature is tedious. Nevertheless, it is a crucial task to better anchor the present study into contemporary challenges of wind loading on wind turbines.

Identifying a more specific research question

Besides the literature review, the choice of research question should prioritize the important challenges for wind turbine design. This was partly advertised in the abstract, which I found well written and successfully caught my attention. Yet, it seems that these challenges were not clearly identified in the present manuscript. In the following, I attempt to name a few of them. I hope these can be useful to the authors:

- The study of the lateral coherence of turbulence. Focusing on the coherence at lateral separation and discussing how it relates to the coherence at vertical separations is highly

valuable. Indeed, there are only a few studies focusing on the lateral coherence in the MABL and those relying on lidar instruments (e.g. Cheynet et al., 2016, 2021) still face considerable challenges. As correctly pointed out by the authors, meteorological masts are rarely deployed in arrays. Therefore, large Eddies Simulation (LES) offers an excellent occasion to study the lateral coherence. In particular, it would be valuable to know whether the lateral coherence can be inferred from the vertical coherence. This can be discussed with respect to the uniform shear model (Mann, 1994) and/or in terms of decay coefficient from the Davenport model (see Solari and Piccardo (2001) for a review of these coefficients).

- The authors point out that the asymmetry effect, related to the blocking by the ground and the non-linear variation of the Davenport decay coefficient with the separation distance (e.g. Bowen et al., 1983; Sacré and Delaunay, 1992). The role of the blocking by the ground on the structure of turbulence is mentioned in Mann (1994). Accounting for the asymmetry effect may be significant for wind turbine design (Cheynet, 2019). The dependency of the asymmetry effect on atmospheric stability is not well known. Studying this dependency and quantifying it through LES simulation is a fascinating topic that could be a stand-alone paper.

- There exist only a few studies of the coherence of turbulence above the atmospheric surface layer (ASL) (e.g. Lothon et al., 2006). A large portion of the rotor plane of modern offshore wind turbines is located above the ASL. How to scale the coherence of turbulence above the ASL? Can the depth of the atmospheric boundary layer influence the coherence above the ASL? LES could give some insight into these questions. This topic is maybe more related to atmospheric science, but it could still be relevant to wind energy science.

Specific comments

Additional specific comments were summarized as “Community Comment” in Cheynet (2022).

References

Pielke, R., Panofsky, H.. Turbulence characteristics along several towers. Boundary-Layer Meteorology 1970;1(2):115–130.

Ropelewski, C.F., Tennekes, H., Panofsky, H.A.. Horizontal coherence of wind fluctuations. Boundary-Layer Meteorology 1973;5(3):353–363.

Kristensen, L., Jensen, N.. Lateral coherence in isotropic turbulence and in the natural wind. Boundary-Layer Meteorology 1979;17(3):353–373.

Kristensen, L., Panofsky, H.A., Smith, S.D.. Lateral coherence of longitudinal wind components in strong winds. Boundary-Layer Meteorology 1981;21(2):199–205.

Bowen, A.J., Flay, R.G.J., Panofsky, H.A.. Vertical coherence and phase delay between wind components in strong winds below 20 m. Boundary-Layer Meteorology 1983;26(4):313–324.

Davenport, A.G.. The response of slender, line-like structures to a gusty wind. Proceedings of the Institution of Civil Engineers 1962;23(3):389–408.

Scanlan, R.. The action of flexible bridges under wind, II: Buffeting theory. Journal of Sound and vibration 1978;60(2):201–211.

Cheynet, E., Jakobsen, J.B., Svardal, B., Reuder, J., Kumer, V.. Wind coherence measurement by a single pulsed Doppler wind lidar. Energy Procedia 2016;94:462–477.

Cheynet, E., Flügge, M., Reuder, J., Jakobsen, J.B., Heggelund, Y., Svardal, B., et al. The cotur project: Remote sensing of offshore turbulence for wind energy application. Atmospheric Measurement Techniques Discussions 2021;2021:1–32. doi:10.5194/amt-2020-511.

Mann, J.. The spatial structure of neutral atmospheric surface-layer turbulence. Journal of fluid mechanics 1994;273:141–168.

Solari, G., Piccardo, G.. Probabilistic 3-D turbulence modeling for gust buffeting of structures. Probabilistic Engineering Mechanics 2001;16(1):73–86.

Sacré, C., Delaunay, D.. Structure spatiale de la turbulence au cours de vents forts sur differents sites. Journal of Wind Engineering and Industrial Aerodynamics 1992;41(1-3):295–303.

Cheynet, E.. Influence of the measurement height on the vertical coherence of natural wind. In: Conference of the Italian Association for Wind Engineering. 2019, p. 207–221.

Lothon, M., Lenschow, D.H., Mayor, S.D.. Coherence and scale of vertical velocity in the convective boundary layer from a Doppler lidar. Boundary-layer meteorology 2006;121(3):521–536.

Cheynet, E.. Comment on wes-2022-71. 2022. doi:10.5194/wes-2022-71-CC1.