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Comment on wes-2021-156

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Community comment on "Scientific challenges to characterizing the wind resource in the marine atmospheric boundary layer" by William J. Shaw et al., Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2021-156-CC1, 2022

This paper does a nice job of summarizing many important unresolved issues related to offshore wind energy (WE), and how the ocean surface modifies the lower boundary of the atmosphere in the coastal zone to affect the wind resource there. Key aspects and attributes of the marine BL, ocean processes affecting sea surface state, roles of LES and mesoscale numerical models, need for improved parametrizations, and others are all nicely detailed.

Another aspect of the problem deserves greater attention: the challenges presented by meteorology itself are rather underrepresented in this overview. By this, I mean:

It is the upwind wind-speed profile across the turbine rotor layer of the atmosphere that is the quantity of greatest importance to WE, as it is the variable most highly correlated with wind power generated by a turbine or a wind farm.

The critical question becomes, then: what are the major controls on this inflow? Upstream profiles are produced from the movement and evolution of larger-scale (meso- to synoptic scale) flow systems that have major diurnal and annual cycles, are strongly driven by transient weather systems both synoptic and mesoscale, and are significantly modified by local topographic, sea-surface, and coastline effects. These larger-scale systems are responsible for the largest wind variations and the biggest obstacles to characterization, understanding, modeling, and predictability of rotor-layer inflow properties in the coastal zone (as elsewhere). Knowledge of the resulting flows and what drives them is important for forecasting, for assessing the reliability of models in predicting them, and for understanding the vertical structure, temporal behavior, and horizontal variability of the inflow profiles. According to my reading of this manuscript, these flow features are mentioned as being things one finds in the offshore environment, but mentioned only in passing.

Without a serious discussion of these phenomena, this skirts the next, deeper level of questions, which are relevant to planning of research efforts: what are the important forcing mechanisms behind these flow systems, what do we need to measure in order to document and understand the mechanisms, how well are these flows and mechanisms modeled in NWP forecast models, what do we need to do to improve the modeling of these phenomena, and so on ?

For example, sea/land breezes and many LLJs are forced by horizontal land-sea temperature gradients. These phenomena each bring particular characteristics to the rotor-layer inflow profiles, including evolution of the magnitude and vertical structure of the wind speed and direction. How these inflows develop depends on superimposed large-scale pressure gradients, the evolution of the daily heating-cooling cycles, and key time-dependent and spatially-varying processes. Comprehensive understanding of these flow features is needed and requires profile measurements offshore and inland, as well as other offshore-inland paired measurements including near-surface pressure, temperature, and representative surface-energy balances. In recent studies we have shown that a particular type of recurrent diurnal flow can influence the annual average of rotor-layer winds and can produce a distinctive diurnal HRRR-model error signature, which propagates through the averaging process to be discernable in the annually averaged error (Pichugina et al. 2019, *JAMC*; Banta et al. 2020, *MWR*). Such results can provide insight into the nature of model error sources (error diagnosis) and thus have potentially significant implications for NWP improvement, as well as basic understanding of the essential nature of the diurnal flows themselves. To understand these phenomena, to characterize their effects on rotor-layer inflow profiles, and to determine whether NWP models are getting them right (or, if not, *why* they are getting them wrong), these and other variables must be measured or calculated from measurements. Carefully designing field measurement campaigns to do so is a major challenge.

The set of processes and issues discussed in the present overview manuscript mostly constitute effects that modify the inflow profiles that have been presented to a wind farm by the larger-scale meteorology—which I would characterize as the primary forcing. Although this means that the overview issues would be classified as secondary or even tertiary effects on the profiles, they are not in any sense unimportant. But it is also important to establish quantitatively how each of these processes or effects modifies inflow profiles, i.e., what level of modification or uncertainty each of the processes introduces to basic wind-profile properties—is it at 2%, 10%, 50%? Clarity in this kind of prioritization and perspective is key for setting goals for future research.

Prioritization is even more complicated. We (Banta et al. 2013, *BAMS*) and many others have pointed out previously that the discipline of wind energy has many sub-disciplines or ‘sub-applications,’ such as resource assessment, forecasting, turbulence-wake effects and wind-farm layout, hardware design, refurbishment, etc.; and each of the issues in this overview manuscript can be critical to one or more of these subapplications. Challenges facing wind energy thus would include providing perspective on what level of uncertainty each of these issues imposes on each subapplication, and how important is that level of uncertainty to the subapplication? For example, hypothetically, updating the ocean-wave parameterization in a model may produce a 3% improvement in the wind speed through the rotor layer, which may be insignificant for operational forecasting but critical for resource assessment.

There is no doubt that each of the topics discussed in the current version of this overview has implications for one aspect or another of the wind-energy subdisciplines, and clearly any research that improves NWP model skill benefits wind energy. **The role of day-to-day meteorology in controlling the shape, evolution, and magnitude of the wind profile through the turbine rotor layer of the lower atmosphere also deserves a prominent place in this discussion**.

This paper seems aimed at a broad audience. To those readers having experience in meteorology, many of these points may be obvious. Other readers, who may not have a sophisticated appreciation of meteorology in all its complexity, should be made aware of the strong role of transient weather systems in determining the most fundamental aspects of the inflow wind profile, as well as the difficult but important paths to better understanding and modeling them.

Other comments:

Section 2, second para, line 137: I was going to recommend using h instead of Zi to represent ABL depth, since the subscript 'i' in Zi refers to the inversion at the top of the unstable convective boundary layer (CBL), and the ABL depth is important over the entire 24-h daily cycle for all the reasons mentioned. But—the techniques described in this paragraph really do only relate to finding the top of the unstable CBL. In the stable boundary layer (SBL), the top of the nocturnal inversion and the top of the SBL do not necessarily coincide, so 'Zi' is not appropriate to describe ABL depth under stable conditions. For times of the day when the ABL is stable, Doppler lidar techniques for finding h in the SBL using a specialized elevation-scanning strategy has been reported by Pichugina and Banta (2010, *JAMC*), and approaches to blending several different candidate lidar-determined BL-depth estimates to obtain 24-h determinations of h have been described by Tucker et al. (2009, *JTech*.), illustrated by overwater measurements (Galveston Bay). These and other approaches have been combined into a fuzzy logic calculations of h over the 24-h cycle using Doppler lidar data by Bonin et al. (2018, *JTech*.).

Line 566: "…refactoring of existing codebases in order to be ported to future exascale high-performance computing (HPC) systems." – could this be rephrased, or explained, in plain English? I'm guessing other readers would also appreciate this…

A final issue is the spatial variability of winds in the offshore zone. In our *BAMS* overview (Banta et al. 2018, cited in the manuscript) and our DOC/NOAA report to DOE (2014, cited), we broke this down into cross shore, which includes factors affecting the increase of wind speed with distance from shore, and along shore, which certainly affects resource assessment and also is a forecasting factor. The ability of NWP models to capture this variability is an important issue. I would suggest at least a brief discussion of this topic (spatial variability of offshore winds) as related to the various elements of offshore wind energy.