

3rd Review: Response to Editor - Data assimilation of generic boundary-layer flows for wind-turbine applications - An LES study

Linus Wrba¹, Antonia Englberger¹, Andreas Dörnbrack¹, Gerard Kilroy¹, and Norman Wildmann¹

¹Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

Correspondence: Linus Wrba (linus.wrba@dlr.de)

1 General Response

The authors thank the editor for her time and the renewed examination of our revised manuscript. We are glad that the topic and the presentation of our results has raised so much interest and thank again all referees for their thorough review.

We tried to modify our manuscript according to the four concerns of the associate editor's review. In principal this has changed the conclusions of our study in order to present a clear image of the advantages and drawbacks of our method. In the following the changes in the manuscript are cited, respectively.

1. Reviewer 1 asks for an explicit acknowledgment of the limitations of not considering potential temperature and moisture; please include a stronger statement about this in the introduction and/or conclusions

Manuscript: Another important aspect is potential temperature, especially when it comes to stably-stratified atmospheric regimes. In this first investigation of the proposed method for wind-energy applications we limit the relaxation to the velocity field while keeping the stratification from the precursor simulation in the relaxation simulation. Although the influence of the vibration method in combination with a nudging zone on the potential temperature (not shown) does not impact the horizontal velocity components in the presented SBL, an implementation of a potential temperature nudging would be favorable when it comes to the stratification of potential temperature in the considered atmospheric situation (cf. Allaerts et al. (2020)). Moisture is not included in this study, and therefore also not for relaxation, as we are focusing in this work on the dynamic processes of the atmosphere.

Additional response to the editor: Moisture effects and nudging thereof are not included in this study, as the simulations are explicitly designed to represent idealized, dry atmospheric boundary layers under stable and neutral conditions. The primary focus is on the evolution of the mean flow and turbulence characteristics in response to nudging, rather than thermodynamic processes such as condensation or latent heat release. In both stable and neutral boundary layers, moisture can play a role primarily through cloud formation, radiative feedbacks, or latent heat exchange. However, in the

absence of cloud microphysics or surface condensation, and under dry initial and boundary conditions, the dynamical influence of water vapor is negligible.

- 25 2. As acknowledged in the conclusion, an important constraint of the presented method is that “the main characteristics of the precursor simulation (vertical gradient of horizontal velocity, TKE) and the atmospheric measurements are similar.” This qualitative statement begs for more quantitative justification. How similar is similar enough? Please provide clearer guidance to the reader or possible user of this method.

30 **Manuscript:** In this work, two different highly resolved precursor simulations are applied. We found that the vibration method is only applicable when the basic atmospheric conditions and the target profile are relatively close to each other in structure, e.g. either veering inflow or pure zonal flow. It was not possible to assimilate a precursor simulation with no meridional wind component to a veering target profile. Under these preconditions, the presented setup with a nudging zone in the numerical domain has proven its utility to assimilate the mean inflow velocities towards a desired target velocity profile which propagates further downstream. Hence, computational time can be saved for the generation of atmospheric inflow fields for a wind turbine, if e.g. the atmospheric stratification of the precursor simulation and the atmospheric measurements are the same. This first single study applying the vibration approach provides valuable initial insights but is not sufficient for more quantitative statements about the general applicability of the method. Further sensitivity studies covering a larger variety of atmospheric situations are necessary to specify use cases for a generalized and more reliable application of the presented setup.

- 40 3. The statement that “By omitting the Coriolis force, our numerical simulations are limited to small domains . . . and short simulation periods” does not acknowledge the important role of the Coriolis force in defining the wind veer observed in stably stratified conditions which is important even in small domains. Please modify accordingly.

45 **Manuscript:** By omitting the Coriolis force in the simulations with data assimilation, the presented setup is limited to small domains on the order of kilometers and short simulation periods (<1 h in this study). Regarding the significance of wind veer and wind shear for stably-stratified regimes, it is important to know that the presented stably-stratified precursor simulation P3 results from a very computationally expensive diurnal cycle simulation (cf. Englberger and Dörnbrack (2018)) where a fully developed SBL is generated under application of the Coriolis force and a negative heat flux. Under the precondition that the domain size is small and the simulation time is rather short it can be assumed that the atmospheric flow coming from this precursor SBL P3 moving further downstream in the simulations SO and SOW, incorporates the Coriolis effect on the wind field, although SO and SOW do not actively include the Coriolis effect in the set of equations.

- 50 4. Reviewer 2 asks for WRF namelists - it should be simple to provide a namelist.wps and a namelist.input file in a zenodo or github repository (I realize the WRF simulations are just the boundary conditions here, but it was requested) and cite it in the Appendix.

55 **Manuscript:** The respective WRF namelists for this simulation can be found in: <https://doi.org/10.5281/zenodo.16321159>