Comments on the following paper: "The Lattice Boltzmann Method for Wind Farm Simulations: A Review" October 29, 2025

# 1 General comments

This paper provides a comprehensive overview of the current state of the Lattice Boltzmann Method (LBM) within the wind energy community. It is overall well-written and clearly structured, and will likely serve as a valuable resource for interested researchers and practitioners. In my opinion, the work is suitable for publication after minor revisions.

# 2 Discussion by themes

- Performance: The discussion on performance could be expanded slightly. For instance, the following two references, although focused on CPU implementations, could provide useful context:
  - `https://doi.org/10.1177/10943420211006169`
  - `https://doi.org/10.1016/j.compfluid.2021.104946`

  If available, including performance estimates of a code such as FastEddy (`https://doi.org/10.1029/2020MS002100`) in Figure 4, or at least discussing them in the text, would be valuable. Finally, the issue of memory boundedness and the need for advanced streaming patterns to reduce memory requirements could also be discussed in this section.

  We have added the proposed references and additional discussion on memory boundedness in section 3.8.

- LBM for ABLs: The review effectively highlights the potential of LBM for simulating kilometre- scale domains. However, I would suggest adding brief discussions on the following aspects:
  - Meso-scale simulations: LBM is likely constrained to micro-scale simulations due to its reliance on isotropic meshes, making meso-scale applications inefficient. This point seems to be missing from Section 3.5.

    We have added an remark in section 3.5
  - Coupling with meso-scale models: Related to the previous item, it would be useful to discuss the potential need for coupling LBM with meso-scale models and possible approaches for achieving this.

    We have added some discussion on this approach.
  - The study https://doi.org/10.1063/5.0039516 introduces an anelastic approximation within an LBM framework. This work, and the potential advantages of such an approach, merit at least a brief mention and discussion.

We added some discussion on the proposed paper.

- A genuine question: are there intrinsic limitations within the LBM framework that hinder simulations of non-neutral atmospheres, or the inclusion of humidity and other relevant processes? These might relate to the constant sound-speed assumption, the weakly compressible formulation, or the idealized thermodynamics typically adopted.

  The standard LBM is limited to small changes in temperature and density, i.e. the Boussinesq approximation. However, there are many ways to extend the valid range of conditions, for example the approach to use the anelastic approximation by Feng or the free energy model for multiphase flows. Several extensions for fully compressible flows have also been proposed.

- LBM theory:

  - Another question: higher-order stencils (beyond order 27) are not discussed. Could they offer any advantages for atmospheric flow simulations?

    We briefly mention higher order stencils in section 2.3. Due to their instability and very large memory footprint we dont believe that high order stencils offer any advantages over hybrid or DDF approaches.

  - Many Navier–Stokes-based ABL solvers include transport equations for humidity (or other scalars) and for kSGS . Implementing these in LBM, especially alongside a double-distribution- function (DDF) approach, might be prohibitive due to memory constraints. This trade-off could be worth mentioning.

    We added some remarks on the issue in section 2.3.

- Turbulence models in LBM:

  - The focus on LES is well justified for atmospheric flows, but a short discussion on the potential use of RANS-type eddy-viscosity closures in LBM, and their possible efficiency benefits, would strengthen the review.

    We have added a very short mention of the possibility to use RANS-type closures.

  - In Section 2.1.6, it would be helpful to comment on how the choice of subgrid-scale model affects performance. Not all SGS models are fully local, and some rely on additional trans- port equations for $k_{\mathrm{SGS}}$ . In a DDF framework, this would require solving yet another set of populations, significantly increasing memory usage — this limitation deserves mention (see also the related note in the LBM theory subsection).

    We have added some discussion in section in 2.1.6

– In Section 3.2, a dedicated discussion on the use of fourth-order limiters in the cumulant space could be beneficial. It is often argued that these limiters behave as implicit SGS models and therefore should not be used in combination with explicit SGS closures.

We have added some discussion on the topic at the end of section 3.2. However, to the best of our knowledge, this topic has not yet been examined in detail.

# 3 Small comments

- L.82: Avoid using superlatives such as "excellent description."
- L.94: It would be interesting to discuss the feasibility of incorporating more complex equations of state within LBM.
- L.175: Replace "an" with "a."
- L.260: The statement that LES is required for ABL flows may be too strong; RANS models could also be employed.
- L.282: Referring to "turbulence models" here creates some ambiguity. Since the discussion focuses on LES, "subgrid-scale models" would be more appropriate.

  We have clarified the above mentioned statements.
- Section 2.1.6: Is there a recommended approach overall?

  While we cannot give a general recommendation, we give a bit more detail in the discussion, particularly in terms of computational cost.
- Section 2.2: I may be misunderstanding this part, but in my view, the much smaller time steps in LBM are primarily due to the sound-speed-related restriction, rather than to the choice of explicit versus implicit schemes. This point could be clarified.

  We have removed the statement and only point to the more detailed discussion in the theory section.
- L.659: Could you elaborate on the assumption that urban flows reduce the need for wall models? Boundary layers developing along buildings are likely to be severely under-resolved.

  We have added some clarifying remarks and a source. Urban flows often feature complex flow separation and other features, making wall models ill-suitable.
- L.739: Typo — "different" should replace "difference."
- L.742: Typo — "date" should be "data."

  We have fixed the typos.

- A recent paper addressing wind farms in non-neutral ABLs could be included in the discussion: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4441495.

  We have included the study in the discussion.