

# **Response to Reviews for the Manuscript “The Boundary Layer Dispersion and Footprint Model: A fast numerical solver of the Eulerian steady-state advection-diffusion equation”**

## **Response to Reviewer #1**

We sincerely appreciate the referee’s thorough review of our manuscript and the valuable comments and suggestions provided. The feedback has been instrumental in enhancing the quality of our research. We have carefully considered each of the remarks and will accordingly make comprehensive revisions to the manuscript based on the content of the study. Here, we will provide a detailed point-by-point response to all comments, citing the reviewer statements in black font, while our answers are given in blue font.

The validity of the method is verified by selecting a case for which analytical solutions exist. Then an example of an unstable situation is shown where the wind and stability profiles obey Monin-Obukhov similarity. It is compared with a footprint model that uses exponential profiles (FKM). The results are obviously different given that wind profiles are different and that diffusion along the direction of the wind is neglected in FKM. The authors attribute the difference mainly to the missing downwind diffusion, about which I have doubts because diffusion in the direction of the wind is overwhelmed by advection.

We thank the referee for this comment. We agree with the referee that in most situations diffusion is overwhelmed by advection. Nevertheless, we will extend our numerical framework by anisotropic eddy diffusion. This modification allows us to switch off the eddy diffusion component that acts in the direction of the mean flow. With this modification, a direct comparison with the Korman & Meixner model will become possible, which will show that in certain conditions – very unstable atmospheric boundary layer – eddy diffusion can in fact become comparable in its effect to advection.

As a scientific paper, publication would be harder to justify. In that case it would be necessary to simulate a range of cases with more emphasis on the results of the

computational method. Before publication and to show what can be done with the code, I suggest presenting a few more cases, e.g., a stable case and a case with wind turning in the stable boundary layer.

We appreciate the reviewer’s comment. To justify a scientific publication, we will add more experiments: in addition to the experiments with the stable and unstable PBL, we will also include the neutrally stratified atmosphere. Two numerical studies will also be incorporated that will prove convergence, challenging the two key components of BLDFM: the Fourier and the Exponential Integrator Methods. Furthermore, we will improve BLDFM by a more precise treatment of the vertical boundary condition and introducing stretched vertical coordinates to further speed up the algorithm.

Wind turning is an important component of dispersion. Vertical diffusion spreads the pollution in the vertical and wind turning amplifies the horizontal spreading of the plume by advection in different directions.

We are thankful for this comment. Wind turning is implicitly accounted for in BLDFM by the turbulent horizontal mixing due to eddy diffusivity. We plan to accommodate this comment by extending the scalar eddy diffusivity acting on the three-dimensional Laplacian to fully three-dimensional vector-like eddy diffusion, which will improve the framework by allowing us to model anisotropic diffusion and simulate, in particular, horizontal diffusion caused by wind veering. A fully dynamic treatment of wind turning goes beyond the capabilities of BLDFM, as the time dependency of the wind is unavailable.

The mention of a “Well-mixed criterion” may be confusing here. In boundary layer meteorology “well mixed” is often used for the convective boundary layer where potential temperature and tracers are fairly constant in the vertical due to strong mixing. Steady state is appropriate near the surface because the mixing time scale is fast compared to evolution of the large scale forcing, often called “quasi-equilibrium”. It means that the shape of the profiles are nearly instantaneously in equilibrium with the large scale forcing. The well-mixed criterion is mentioned a few times in the paper. Perhaps it is better to call it the “quasi-equilibrium” assumption throughout.

We appreciate the referee for bringing this issue to our attention. Indeed, the term “well-mixed condition” is misleading and not well explained in the manuscript. The term was coined by Thomson (1987), referring to whether initially well-mixed tracers will remain well-mixed throughout the integration. In a revised version of the manuscript, this will be explained more thoroughly.

To substantiate the conclusion that the difference between BLDFM and FKM is due to differences in diffusion along the wind vector, it would help to run BLDFM without diffusion in the wind direction to see the effect of down wind diffusion.

We are thankful for this comment. As mentioned before, we plan to implement a version of BLDFM without streamwise diffusion for a direct comparison with FKM; the corresponding results will be integrated into this manuscript.