Responses to Referee #3

By using scaling approach and suitable fitting functions, the authors present an easy to use, full (in terms of along wind and cross-wind representations) footprint function for variety of stabilities and Atmospheric Boundary Layer (ABL) flow regimes. It is the first such footprint model enabling to make fast footprint estimation for the measurements outside the Atmospheric Surface Layer (ASL) scaling domain. The model therefore serves as a useful tool not only for tall tower sites but also for the measurement conditions violating the ASL assumptions, which are typically constrained to the measurement heights less than or equal to the magnitude of the Obukhov length scale. I fully support publication and hope that addressing the comments below helps to improve the manuscript.

Many thanks!

The scaling is performed via four dimensionless groups. The dimensionless groups do not include directly any parameters related to ABL flow characteristics such as the convective velocity scale. Have the authors considered including this velocity scale to improve (potentially) the footprint parameterization under convective conditions and would it help to explain different parameterization coefficients obtained for the convective regime (Table 6)?

Indeed, we have tried to include the convective velocity scale, but this did not prove to be successful. What we presented in this manuscript is the statistically best scaling approach we found and the result of research over an extended period of time.

The second comment is related to the third dimensionless group which is formulated based on the common phenomenon that the surface fluxes decrease approximately linearly with height in the ABL (page 6765, line 6-9). On the other hand, the footprint function is formulated such that it obeys the basic property of integration to unity (page 6769, line 13-15), which according to eq. (1) implies that the flux measured at zm equals to the surface flux. According to the given references (e.g. Kljun et al., 2004), the model LPDM-B is formulated such that the upper boundary condition of the simulation domain was not set to reflection. In forward Lagrangian approach this would imply that the surface release of particles eventually means absorption (or exit of the particles from the domain) at the upper boundary, and consequently constant particle flux with height up to the boundary layer top. The forward and backward Lagragian approaches are known to be equivalent and the same must apply to the backward approach. Please discuss the effect of the upper boundary condition used in LPDM-B on the results and help the reader to clarify the apparent inconsistency of the dimensionless scaling group 3 (or the reasoning behind it) with the footprint formulation eq. (1).

This must be a misunderstanding. Particles tracked by the model LPDM-B (Kljun et al. 2002) are reflected at either boundary, i.e. at the surface AND at the top of the planetary boundary layer. The particles are fully elastically reflected; i.e. no absorption or transformation at the boundaries is taken into account. A description of the reflection scheme can be found in Rotach et al. (1996) and in Wilson and Flesch (1993). We have added a sentenced highlighting the reflection at the surface and the top of the planetary boundary layer in Section 2.

The parameterization is based on the set of simulations for a range of values describing the flow as well as the surface conditions (the roughness length). The momentum flux (or the friction velocity used in the MS) is driven by the flow forcing as well as the surface characteristics (roughness) and therefore it the aerodynamically smooth surfaces induce lower momentum fluxes especially under stable conditions. For example for the roughness length value 0.01 m I would assume that the friction velocity 0.1 m/s is rather common under normal meteorological conditions (meaning that not under extreme stability conditions). The range of friction velocities used in the MS for stable conditions is quite narrow (Tables 1 and 2). Could the authors assure that scaling performs well also for low u*, in particular for the surfaces with low roughness?

To address the above, we have run three additional simulations with LPDM-B for a friction velocity of u = 0.1 m/s, a roughness length of z0 = 0.01 m, and a measurement height of zm = 10 m. For the stable case, we set L = 500 m and h = 280 m; for the neutral case, L = inf, h = 300 m, and w* = 0 m/s, and finally, for the convective case we set L = -50 m, h = 2500 m, and w* = 0.5 m/s.*
Figure 1R shows the same density plot of all original LPDM-B simulations as Fig. 2 of the manuscript. We added the scaled footprints of the above additional simulations (stable case: dash-dotted line, neutral case: dashed line, convective case: solid line). As can be seen in Fig. 1R, the scaled footprints of the low-u scenarios nicely fit the ensemble of other scenarios.*

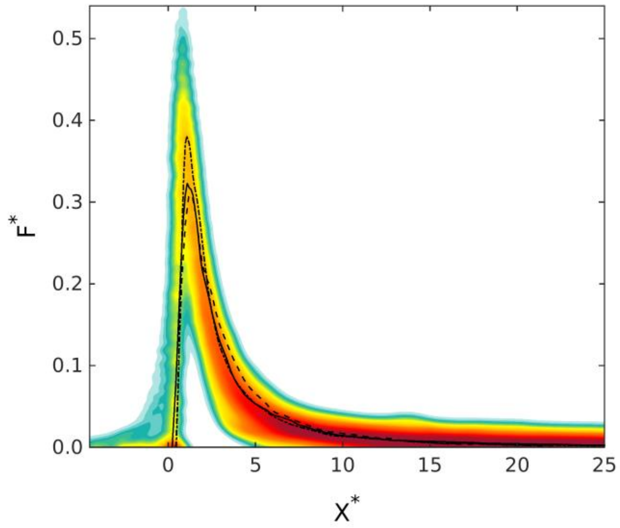

Figure 1R: Density plot of scaled crosswind-integrated footprints of LPDM-B simulations (cf. Fig. 2 of manuscript). Black lines depict additional low-u scenarios (stable: dash-dotted line, neutral: dashed line, convective: solid line).*

References

Rotach, M. W., Gryning, S.-E., and Tassone, C.: A Two-Dimensional Lagrangian Stochastic Dispersion Model for Daytime Conditions, Quart. J. Roy. Meteorol. Soc., 122, 367–389, 1996.
Wilson, J. D. and Flesch, T. K.: flow Boundaries in Random-Flight Dispersion Models: Enforcint the Well-mixed Condition, J. Appl. Meteorol., 32, 1695-1707, 1993.