

Response to
<https://doi.org/10.5194/egusphere-2025-4576-CC11>
Update and Revision

(See citations for responses in the posted manuscript)

Again, thank you so much for your professionally detailed comments. We provided a brief response immediately after your comments were posted, and now that we have received additional feedback, including feedback from two referees recommending publication, we offer a more detailed response and revision plan as detailed below.

This is a very detailed study on the application of the footprint model. It would be very useful to users of the Campbell Eddy Covariance Systems. One particular point that is important in my opinion is that the limitations of the Kljun et al. (2015) model should be explicitly discussed. Further clarifications at some places may also be important. The specific comments are provided below.

Response

The major objective of this study is to optimize field computations, balancing time and accuracy, in order to find footprint characteristics from the analytical footprint equations commonly adopted by the flux community over last 20 years. Visualizations like Fig. 1 were used to help non-expert readers easily understand the footprint concept and how to relate the non-dimensional footprint equations from Kljun et al. (2015) to eddy-covariance systems (e.g., measurement height determination).

Kljun et al (2004) had some limitations as mentioned on page 512. Their application is limited to the following ranges of atmospheric stability, friction velocity, and measurement height:

$$-200 \leq (z_m - d) / L \leq 1$$

$$u_* \geq 0.2$$

$$z_m - d \geq 1$$

where z_m is measurement height (m), d is zero displacement height (m), L is Obukhov length (m), and u_* is friction velocity (m s^{-1}). These are no longer limitations in Kljun et al. (2015) (personal communication, Dr. Kljun). It would be appropriate to add this clarification to readers as revised below.

Revision

Line 238: For more applications including limits of applicability, refer to Kljun et al. (2004, 2015).

Line 17 and some lines later. A footprint is a transfer function relating the source area to the measured flux. The footprint itself is not an area. However, the footprint can be used to calculate the footprint. See Steinfeld et al. (2008) and Fu et al. (2025). In addition, even over a horizontally homogeneous terrain, it is likely that the footprint can extend to the downwind side of the EC system. Over complex terrain, as found by Fu et al. (2025), the extension in the downwind direction may be substantial.

References:

Steinfeld, G., Raasch, S., & Markkanen, T. (2008). Footprints in homogeneously and heterogeneously driven boundary layers derived from a Lagrangian Stochastic Particle Model embedded into large-eddy simulation. *Boundary-Layer Meteorology*, 129(2), 225–248. <https://doi.org/10.1007/s10546-008-9317-7>

Fu, S., Chen, J. M., Zhang, J., Cheng, Z., Miao, G., Wang, R., et al. (2025). Flux footprints over a forested hill derived from a Lagrangian particle model coupled into a large-eddy simulation model. *Journal of Geophysical Research: Atmospheres*, 130, e2025JD043591. <https://doi.org/10.1029/2025JD043591>

Response

“Footprint” here can be interpreted as the probability density or as the area over which a sensor “senses”, depending on the context. The unit of conventional crosswind-integrated footprint is m^{-1} , having been derived from m^{-2} over a 2D field, implicitly indicating the footprint is related to an area.

We acknowledge that the flux footprint can be extended to the downwind area in extreme cases under boundary-layer advection conditions (i.e., very low wind speed). The figures in this manuscript exclusively used equations of Kormann and Meixner (2001) and Kljun et al. (2015). The advancement beyond the analytical equations described in Fu et al. (2025) was published in Sept 2025 before the submission of this manuscript. For our revision, the two citations you provided were briefly reviewed and cited in relevant points of discussion.

Revision

Lines 48, 875 ~876, and 932~933: Insert “Steinfeld et al., (2008) and Fu et al., (2025)”

Lines 25-29. It is unclear why the model can be efficiently calculated in the field. From the summary section, it becomes clear that some parts are precalculated so it is not necessary to calculate them in the field. I suggest adding this explicitly into the abstract.

Response

Footprint characteristics are required with the submission of datasets to flux networks such as ChinaFlux, AmeriFlux (2018), and FluxNet. It represents a significant time saving if the datasets are submitted to a network directly from the field. We believe our writing is clear; see general comments from referee #2.

Revision

n/a

Lines 30-31. Since the footprint model by Kljun et al. (2015) was developed for flat ground, it may not be appropriate to state that the model developed based on Kljun et al. (2015) can be used over complex terrain.

Response

The applicability of Kljun et al. (2015) to complex terrains was not specifically mentioned. Our statement was on the applicability of this computational approach for a variety of conditions and footprint models, specifically: “*This computational approach*

may also be applied to footprint analyses over complex terrain, nonuniform sources/sinks, or in cases where other footprint equations are used.”

Revision

n/a

Lines 63-75. The discussion of the symmetry seems to suggest that the source area for a negative flux is in the downwind side of the EC system. This is in contrast to my expectation.

Response

Negative flux through the measurement volume would be transferred to downwind sinks, instead of sources. This flux footprint would be symmetric with its upwind-source counterpart.

Revision

n/a

Section 4.4. Since the boundary layer height appears at multiple places in the footprint model. It might be important to the users how sensitive the footprint model is to the boundary layer height. In addition, it might be informative to the users if some examples of the boundary layer height are calculated and provided using methods in Appendix B, and these example heights can be compared to the typical values from the literatures.

Response

Sensitivity tests are within the scope of the original footprint equations (refer to section 2 in Kljun et al. 2004 and section 3 in Kljun et al. 2015). This reference should be mentioned in our revision.

Revision

Line 455: Insert “, by Kljun et al. (2004; 2015),