Response to
https://doi.org/10.5194/egusphere-2025-4576-RC1
from Referee #1 and Revision

I must reveal first that I have posted a community comment before being invited by the reviewer to review this paper. This is a very detailed study where the calculation methods of multiple footprint-related parameters are presented. It would be very useful to users of the Campbell Eddy Covariance Systems. I have multiple major comments, which should be addressed before the paper being accepted. Some comments from my community comment are also listed below.

Major comments

1. This study mainly focus on the fast calculation of footprint-related parameters. When doing the calculation, the authors used 1000 bins for each inflection zone. I am curious why so many bins are necessary because the footprint function is smooth within each inflection zone. I suggest perform a sensitivity test using progressively fewer bins to do the calculation and see whether an acceptable precision can be obtained with much fewer bins.

Response:
We agree that numerical integration with 1,000 bins over an inflection zone is more than sufficient. Because our study focuses on the development of algorithms and the derivation of nondimensional flux footprint characteristics (see Table 3) which can be directly used for field applications to minimize computations, we intended to use a more than sufficient number of bins to ensure accuracy of these characteristics.

Numerical integration is used to derive nondimensional flux footprint characteristics from Kljun et al. (2015) (Tables 1 to 3). The change in the number of bins (i.e., resolution) can surely change the values of these non-dimensional characteristics in the three tables. The transformation of these non-dimensional flux footprint characteristics to a field scale needs variables of wind speed, friction velocity, aerodynamic height, and boundary-layer height (see Eq. 29). Under different values of these variables, given a non-dimensional flux footprint characteristic, it would be difficult to evaluate how the number of bins changes the values of flux footprint characteristics in field scale from the nondimensional domain.

Also, for clarification, the resolution at 1,000 bins was used only in a lab to derive the non-dimensional flux footprint characteristics. These known characteristics are then used by the dataloggers ahead of the inflection zone (see Table 2) containing the nondimensional upwind fetch of interest is reached. Thus, for all but one inflection zone, this resolution is used just once in a lab to ensure the non-dimensional flux footprint characteristics to be accurate. In the field, only a portion of one inflection zone needs numerical integration just for the percentage of flux from a user-defined upwind fetch of interest and only up to the limit of integration. For the integration of this zone, a resolution of 1,000 bins is conservatively recommended. A user can adjust the number of bins, although modern dataloggers can handle this level of real-time computation, so it was left as the default.

Revision
Line 307: After … (Table 2), inserted "A user can use a lower or higher resolution as defined by less or more bins for confident accuracy."

2. This point is related to the last one. The authors keep 8 digits after the decimal point. They also mentioned that 8 digits are the maximum number of digits that can be achieved by a single-precision machine. However, I am curious about whether it is necessary to keep so many digits. Kljun et al. (2015) fitted the LPDM-B results to obtain the equations. As can be seen from their figures, the points are rather scattered, indicating that the fitted model should have substantial uncertainty, even when we assume the LPDM-B results are perfect. In addition, when the footprint-related parameters are used, an error of ~1 m or larger should be sufficient. Therefore, it might be unnecessary to spend resources to calculate so many digits.

Response

The LPDM-B results would have been obtained from computers having double precision processors, with the parameters in Kljun et al (2015) having been found from double precision calculations, although they are reported with lower precision (3 or 4 significant digits in their Table A1). As such, we consider their equations as exact and then use the maximum capacity of precision offered by the datalogger. The use of lower precision might be questioned by other readers or reviewers, although we agree with your point that the final result does not need this level of precision for practical use.

Revision

n/a

3. 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

Our response to this comment is found in section 4 below since they are closely related.

4. As mentioned in my community comment, I suggest clearly discuss the limitations of the footprint model.

Response:

The major objective of this study is to optimize field computations, balancing time and accuracy, in order to find flux 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:

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

$$u_* \ge 0.2$$

$$z_m - d \ge 1$$

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).

This manuscript was thoroughly reviewed by Dr. Kljun. We were advised to reduce the recurrence of content from Kljun et al. (2015). For the limitation of Kljun et al. (2015), a reader should refer to the original publication. It would be appropriate to add this advice to readers as revised below:

Revision

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

Minor comments

Lines 31-34. Theoretically, it is possible to use the footprint model to optimize the sensor height of an EC system. In practice, this is probably infeasible because the data used to run the footprint model are not available before the establishment of a site. Therefore, it may not be appropriate to state this in the abstract.

Response

The first author of this manuscript has worked on installations of various eddy-covariance flux systems for over 25 years at US institutions. Using prevailing climate data, he has heretofore used the analytical flux footprint equation for neutral boundary-layer conditions in Hsieh et al. (1994) for determination of sensor height at typical sites. Similarly, prevailing climate data along with the known site layout may be used with nondimensional footprint equations from Kljun et al. (2015) for a preliminary estimate of optimum sensor height. Once a station is operational and additional data are available, our developed method continues to be a tool for the sensor height to be adjusted and further optimized. We have developed this method and reported it in this manuscript since the topic of this manuscript is the application of flux footprint equations from Kljun et al. (2015).

The corresponding author on this manuscript is the Director of ChinaFlux. In reference to local prevailing wind data and surface conditions, ChinaFlux always pays attention to flux footprint analyses for sensor height determination, even since the beginning of survey for a flux tower establishment. It has been an indispensable topic in Annual ChinaFlux Training Courses over the last 20 years. Please also see the comments from referee #2 about this practical issue.

Revision

n/a

Figure 1c. The stability and the friction velocity were simultaneously, making the figure difficult to understand. I suggest showing the impacts of stability and friction velocity separately.

Response

Figure 1c is meant to demonstrate the influence of boundary-layer stability on the flux footprint. We will note the range of friction velocities but make it clearer that the point is to show stability versus footprint.

Revision

Figure 1c: Remove u_*-related information.

line 73: insert "— 0.45" between "0.3" and "m s^{-1}".

Line 83. I am confused by "…a mean of…"

Response
The word of "mean" here means "average".

Revision
n/a

Line 129. Please consider changing the section title to "A brief introduction of the flux footprint equations by Kljun et al. (2015)"

Revision
Line 129: "Brief the development" is replaced with "A brief introduction"

Eq. (3). Need "=".

Revision
Line 147: "=" is inserted into Eq. (3).

Line 143. Please consider revising the section title. Section 2.1 in the present form is not directly related to the dimensional analysis but discusses some definitions. The later sections are directly related to the dimensional analysis.

Revision
The title of section 2.1 was revised to be "Preliminary analysis of Buckingham Π dimension for flux footprint"

Line 149. Need "." at the end of the sentence.

Revision
Added.

Line 173. Remove "," before the citation. I also suggest removing "positively".

Response
a. "," before citation after "e.g." is the format required by EGU journals.
b. "positively" matches the wording of "inversely" in line 167.

Revision
n/a

Eq. (10). The second approximation is $z >> z0+d$. The limitation of this assumption should be clearly pointed out. Over forest canopy, this assumption is not valid.

Response
Yes, this assumption is not sound in the case of a tall canopy where sensor installation is not much higher than the canopy top. We will make readers aware of insufficiency in this assumption.

Revision
Line 179: insert "for common cases of eddy-covariance sensor installation significantly higher than canopy".

Line 178. 'u' to '$\bar{u}$'?

Response
For expression of gradient, $\bar{u}$ is commonly used.

Revision
n/a

Lines 186-187. Eq. (11) shows that the $k\bar{u}/u*$ is related to Ψm, which is further related to stability. Since it is $k\bar{u}/u*$ instead of Ψm that is used in the calculation, it might be necessary to clearly state that $k\bar{u}/u*$ reflects the stability effects.

Response
We agree. This clarification can help readers better understand the influence of atmospheric boundary-layer stability on vertical profile of wind.

Revision
Line 187: After "… length)", Insert "Apparently, ϕ_m approximated by the right side of Eq. (10) (i.e., left side of Eq. 11) includes the effects of atmospheric boundary-layer stability.

Line 192. "eddy0covariance"?

Revision
Corrected.

Line 306. I suggest change this to "Dividing an inflection zone to 1000 bins is considered adequate".

Revision.
Change
"One thousand increments of X^* within an inflection zone are considered adequate, with increments smaller than 5.14×10^{-4} (Table 2)."
To
"Dividing an inflection zone to 1000 bins is considered more than adequate in resolution, with increments smaller than 5.14×10^{-4} (Table 2)."

Line 309. "in-situ" to "in-field" for consistency with the earlier texts. Please consider change "in a lab" to "in advance".

Revision
Change "in-situ" to "in-field"

Section 4.6. As mentioned earlier, the optimization of sensor height may not be feasible because the data used to run the footprint model are not available before the establishment of a site.

Response
See our response to minor comments for Lines 31-34.

Revision
n/a