

Mar 20, 2026

RE: EGUSPHERE-2025-4576: Response and Revision

Dr. Hans Verbeeck
Department of Environment
Ghent University

Dear Verbeeck,

Our manuscript, EGUSPHERE-2025-4576, had been in open public discussion and under review for GMD since Jan 14, 2026. The open discussion was closed on Mar 19, 2026. Around the world, 570 copies of the manuscript preprint have been downloaded. Six peers have given community comments, and two peers have provided referees' comments. All comments are addressable and two referees have recommended publication in GMD after their comments are addressed. We carefully reviewed, digested, and discussed all comments from both referees and community peers. During open public discussion, given that only community comment CC11 needs technical responses, all comments from Referees #1 and #2 along with this community comment CC11 were technically responded. Our responses along with revision details are documented into three enclosed documents:

1. Response to <https://doi.org/10.5194/egusphere-2025-4576-RC1> from Referee #1 and Revision
2. Response to <https://doi.org/10.5194/egusphere-2025-4576-RC2> from Referee #2 and Revision
3. Response to <https://doi.org/10.5194/egusphere-2025-4576-CC11>: Update and Revision

In these three documents, we technically addressed all comments. Accordingly, the manuscript is revised for final consideration of publication in GMD. Attached please find our revised manuscript in two versions:

1. Version of manuscript with revision trackers.
Word file: MS_egushhere_2015_4576_R2_trackers
2. Version of manuscript without revision trackers (i.e., after tracker removal).
Word file: MS_egushhere_2015_4576_R2

Because all revisions are minor (see attached manuscript with revision trackers), the revisions should be satisfactory. We are looking forward to hearing your decision.

We really appreciate your favorable consideration.

Sincerely,

Zhi Chen, Ph.D.
Professor, Institute of Geographic Sciences and Natural Resources Research
Chinese Academy of Sciences, China

Response to
<https://doi.org/10.5194/egusphere-2025-4576-RC1>
from Referee #1 and Revision
(See citations for following responses in the preprint)

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:

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

$$u_* \geq 0.2$$

$$z_m - d \geq 1$$

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).

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 II 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 $z \gg z_0+d$. 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.

Line 307

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

Response to
<https://doi.org/10.5194/egusphere-2025-4576-RC2>

from Referee #2 and Revision

(See citations for following responses in the posted manuscript)

Review of “Application of flux footprint equations from Kljun et al. (2015) to field eddy-covariance systems for footprint characteristics into flux network datasets” in Geoscientific Model Development (GMD) by Zhou et al.

General

The submission “Application of flux footprint equations from Kljun et al. (2015) to field eddy-covariance systems for footprint characteristics into flux network datasets” is in my opinion a suitable entry for the journal Geoscientific Model Development (GMD). The article in questions goes to great lengths explaining the need and way to make all variables dimensionless for an online flux footprint calculation on a datalogger, based primarily on the well-known footprint from Kljun et al. (2015) that allows for rather direct calculation of footprint percentages (like 70/80/90%) and the percentage for a fetch of interest. Additionally, they provide the code for a specific logger, describe the derivation of the (critical) boundary layer height that is quite necessary for the footprint calculation. The explanations are succinct and target, adding also the potential analysis of measurement height for a specific region of interest/annulus around the station.

I recommend publication after fixing the minor comments and discussion of the major comments, the latter with a focus on making the code more easily accessible and complete via a GitHub repo and the discussion of especially an addition for the realistic usage in a flux network with direct data submission.

Response

Thank you so much for your general comment and recommendation. Our responses to your comments are found below, along with proposed changes to the manuscript.

Major Comment(s)

C1 (usability and uptake of code): As this article focuses on the use of the footprint for dataloggers in the field and has an author from CSI, I would recommend that CSI (or ChinaFlux etc.) open a github/gitlab repository that does not only contain the CR6 code but also a CR1000X version. This would allow for easier use (rather than copy paste the appendix code) and allow for future adjustments (such as new loggers).

Response

The footprint algorithms have been incorporated into the latest beta version of the EasyFlux datalogger program, which will be released to the public following completion of testing and publication of this manuscript. Once released, it will be available for download at <http://Campbellsci.com/EasyFlux-DL>. Versions will be available for CR6 and CR1000Xe dataloggers. The algorithms are also being included in the soon-to-be-released TraceFlux datalogger program for CH₄/N₂O, CO₂ and H₂O fluxes, which will be compatible with the Granite 9 datalogger.

Upon the release of the new versions, we will work with CSI product managers to look into a github/gitlab repository for CR6, CR1000Xe, and Granite 9 flux programs. In the meantime, the section of code pertinent to the flux footprint will be in Appendix C, but we propose revising the manuscript with the note below.

Revision

After Line 725: Note: For current availability of a full flux code (e.g., EasyFlux-DL-CR1000X), including the code section in this appendix, please check <http://Campbellsci.com>.

C2 (completeness of code): Similarity, a ceilometer might not be available (as noted in the article itself too, e.g. section 4.4) and thus the boundary layer height h has to be estimated. To facilitate uptake, these functions (not “just” the equations) should be included in the logger program (with a proper comment noting that h may be replaced by the actual measurement if available in the measurement setting).

Response

We agree. The next release of the EasyFlux and TraceFlux series of programs will contain the algorithms for boundary layer height estimation, but they will also support measurement of h from a ceilometer. Using measured or estimated h will be among the user configuration options.

We propose the revision below to help with clarity.

Revision

1. Lines 257 – 258
Revise

“... h can be either directly measured using a Lidar Ceilometer (e.g., SkyVue Pro, Campbell Scientific Inc., 2025) or alternatively estimated from its measurements using the algorithms in Appendix B, ...”

to

“... h may be either measured using a Lidar Ceilometer (e.g., SkyVue Pro, Campbell Scientific Inc., 2025) as the first choice or estimated as an alternative using the algorithms in Appendix B based on field eddy-covariance flux data,”

2. Lines 721– 723
Revise

“The algorithm developed above was implemented into EasyFlux series (Campbell Scientific Inc. UT, USA) for computing h . The h value is used for the applications of flux footprint equations from Kljun et al. (2015).”

to

“The algorithm developed above was implemented into upcoming release of EasyFlux series (Campbell Scientific Inc. UT, USA) for computing h . Without a measured h values in an eddy-covariance system, the h values from this algorithm are used for the applications of flux footprint equations from Kljun et al. (2015).”

C3 (realistic usage): How to the authors rate the usefulness for automatic handling in flux networks as usually other device than data loggers are available, which are usually capable of handling more computational intensive task, i.e. won't the initial calculation (as there is the limit of integration) be used as first estimate only and then be replaced later during post-processing? At least to my knowledge that is the typical approach.

Response

According to our experience, many users now use automatic final flux outputs from individual eddy-covariance stations and only pursue manual data post-processing in the lab if they are experimenting with non-traditional corrections or have atypical data. LICOR Bioscience released SmartFlux in 2013, and Campbell Scientific, Inc. (CSI) later released EasyFlux, both of which are meant to automatically output final corrected fluxes. With the development of the footprint algorithms in this manuscript, EasyFlux can output footprint characteristics with saving computation resources. With this saving, more functionalities in computation can be added to automatic final flux outputs (e.g., net ecosystem exchange). We recognize that there are some users that still post-process data, in which case you are correct that they may replace footprint characteristics with their own estimates.

We should note that the term “datalogger” is not quite the right name for modern dataloggers. A modern datalogger, such as the CR6, CR1000Xe, or Granite 9, is a control, measurement, data processing, data storage, and communication module, which can operate in rugged environmental conditions (e.g., the top of Mount Everest). It can perform measurements at frequencies up to 1 MHz while synchronizing dozens of fast-response sensors. While a notebook or desk top computer has higher computation capacity, it has limited abilities in the following areas: operating in rugged environments, controlling measurement speed, and synchronizing multiple fast-response sensors.

Revision: n/a

C4 (understanding of integration requirements): Based on the example in section 3.2.3, it appears that the first term can be used as its pre-calculated to 32.52.. %. Would it not be easier to have a fixed lookup table in the logger program which holds 100 or 1000 values (or up to 70% in 1% steps, then 0.1% or better) giving a resolution of 0.1% instead of integrating? Based on typical land cover/land usage (1/m10m or coarser), would this not suffice (also with C3) in mind, also to retrieve *FP_FETCH_INTRST*? This is noted on L558-L564 by the authors as well.

Response

It would be possible to load a table of values for each increment of X^* within an inflection zone. However, since we don't necessarily know which integration zone X^*_{intrst} will be in, we would need to load 1000-value tables for each of the four zones and for each convective and neutral/stable condition (a total of eight tables with 1,000 values). Because numerical integration within a single inflection zone is limited and well within the abilities of a modern datalogger, it was simple and convenient to write in the code for the integration.

Revision: n/a

Minor Comment(s)

L113-114: “Each datalogger operates a program from the EasyFlux series, which handles instructions for system control, field measurements, and data transfers (e.g., to FTP site or Campbell Cloud)” While it is certainly true that many do, I find it hard to believe that all do (and→ I know of some that do not). Hence rephrase as “Many .. operate a ...”

Response

Yes, an inaccurate expression. In this sentence, each datalogger is referred to as a datalogger in an eddy-covariance flux system. This sentence needs revision.

Revision

Line 113:

Revise

“Each datalogger”

to

“Each datalogger in an eddy-covariance flux system”

L133: The 80%@270km is a rather extreme example, it would be useful to give then also the lower bound and the typical size and to what z_m this relates to.

Response

Yes, this number is an extreme case intentionally given in Kljun et al. (2015). This number resulted from LPDM-B simulation by Kljun et al. (2015). To us, other numbers are unavailable to exemplify “the vast range in flux footprint size”.

Revision

It is necessary to give a typical number, but we are not able to provide one because we do not have resources to do LPDM-B simulation.

L259 – 261: This is a bit unclear to me. Typically this is given as a constant (“entered into the field ED flux system”) rather than calculated inside the system as the canopies are usually not know by the logger system.

Response

In a field eddy-covariance flux system, zero-plane displacement height (d) and aerodynamic height (z) can be acquired through two avenues: 1) User input d as the first choice. If no user input d available, 2) d can be calculated from land type and canopy height. This d and sensor height are used to calculate z (see a program subroutine below). Land type, canopy height, and sensor height are station variables inputted through CR1000KD at any time while an eddy-covariance flux system is running.

```

5644 '***** ZERO-PLANE DISPLACEMENT, ROUGHNESS LENGTH, AND AERODYNAMIC HEIGHT
5645 '
5646 ' Variable Notation
5647 ' SUBROUTINE          MAIN PROGRAM
5648 ' S_type              Surface_type
5649 ' d_user              displacement_user
5650 ' z0_user             Roughness_user
5651 ' h_canopy            height_canopy
5652 ' h_measurement       height_measurement
5653 ' displacement        d
5654 ' Roughness           z0
5655 ' hght_aerdync        z (sensing height above the ground - d)
5656
5657 Sub Displacement_roughness_heights (S_type, d_user, z0_user, h_canopy, h_measurement, displacement, roughness, hght_aerdync)
5658 ' Calculate zero-plane displacement, roughness length, and aerodynamic height
5659 ' If ((S_type = CROP) OR (S_type = GRASS)) Then 'Crop and grass
5660
5661   Select Case h_canopy
5662     Case Is = 0.0
5663       displacement = 0.0 'Default w/o canopy
5664       roughness = 0.01 'Default w/o canopy
5665     Case Is > 0.0
5666       displacement = 10.0^(0.979*LOG10(h_canopy)-0.154) 'Crop or grass canopy, Eq. 4.5, page 138 in Rosenberg et al. (1983)
5667       roughness = 10.0^(0.997*LOG10(h_canopy)-0.883) 'Crop or grass canopy, Eq. 4.4, page 137 in Rosenberg et al. (1983)
5668     EndSelect
5669   EndIf
5670
5671   If ((S_type = FOREST) OR (S_type = SHRUB)) Then 'Forest and Shrub
5672     displacement = 2.0*h_canopy/3.0 'Forest canopy, 2/3 rule, page 116, Oke, 1987
5673     roughness = 0.06*h_canopy 'Forest canopy, Jarvis et al. (1976) and Raupach et al. (1991)
5674   EndIf
5675
5676   If ((S_type = BARELAND) OR (S_type = WATER) OR (S_type = ICE)) Then 'Bare land, water, or ice
5677     displacement = 0.0 'Default w/o canopy
5678     roughness = 0.01 'Default w/o canopy
5679   EndIf
5680
5681   If (d_user <> 0.0) Then displacement = d_user 'User preferred has a priority
5682   If (z0_user <> 0.0) Then roughness = z0_user 'User preferred has a priority
5683
5684   hght_aerdync = h_measurement - displacement
5685 EndSub 'Displacement_roughness_heights
5686

```

Revision: n/a

L533-539 and Fig4: It should be noted here that installation in the field is hardly ever accurate to cm height, simply as hardware material might be different and attachment beams might vary slightly. But this is not an issue based on Fig4 as (given the scenario) even the range 5 to 6.5 m (1.5 m) still gives above 84% footprint within the area of interest.

Response

It is an experienced recommendation.

Revision

Lines 535 – 536

“The result is accurate to within a centimeter, plenty for sensor installation.”

is replaced with

“The result is accurate to within a centimeter. However, the installation in the field is hardly ever accurate in a height to centimeter, simply as hardware material might be different and attachment beams might vary slightly. Apparently, this is not an issue. Based on the scenario given by Fig. 4, even the range 5.0 to 6.5 m still gives above 84.0% footprint within the area of interest.”

L553-L555: I'm not sure I agree with this, as even with automatic quality checking, turbulent fluxes are often still subject to some issues (of course depending on the specific location), but given that

Response

Yes, flux data from non-ideal conditions often have issues. The word of “Ideal” may may not be ideal.

Revision

Line 553— 555

Revise

“these characteristics are ideally evaluated simultaneously with the computations of the flux data every interval of these data output”

to

“many users would find it convenient if these characteristics were evaluated simultaneously with the computations of the flux data every data output interval”

L725-L860: Please remove the sections (while they help to understand, they should be in the form of code comments as this allows easier use in an existing system. See also C1

Revision

Line 725— 860: Added an apostrophe (‘) before heading text to more clearly show that they are not lines of code.

Typos/Editorial suggestions

L59: The greater the footprint value, the more contribution from that location. The greater the →footprint value, the higher the contribution from that location.

Revision

Line 59: “more” is replaced with “higher”.

Fig1: Wiggly line under central CO2 text molecule in sonic indicating unknown word should be removed and “through the ECMV” is half a line below the first part of the text in the legend

Revision

Fig. 1: Corrected.

L129: Remove “the”

Revision

Revised as Referee #1 suggested.

Fig4: “arodynamic” Aerodynamic→

Revision

Fig. 4: Corrected.

L134: manifests demonstrates→

Revision

Line 134: “manifests” is replaced with “demonstrates”.

L135: at field scales at all possible field scales | of the dimensions of the spatial dimensions→→

Revision

Line 135:

1. “all” is inserted between “at” and “field”.
2. “spatial” is inserted between “the” and “dimensions”

L139/L143 the symbol for the Buckingham analysis is not the same, please unify

Revision

Line 143: “II” was replaced with Π

L147: $f(x,y)$.. $f(x,y) = \dots$ →

Revision

Line 143: “=” was inserted into Eq. (3).

L164: overbar $U(z)$ looks a bit weird (in terms of font). Check if its correct.

Revision

Line 164: Typesetting for $\bar{u}(z)$ was adjusted.

L192: eddy0covariance eddy covariance→

Revision

Line 192: Corrected.

L218: Typesetting of equation 18 appears a bit weird

Revision

Eq. (18): Typesetting was adjusted.

L263: “user onto” “user into” | “before or while” during setup or when an updated value is →→suitable

Revision

Lines 262 ~263

1. “onto” was replaced with “into”.
2. “before or while an eddy-covariance system is running” is replaced with “during setup or when an updated value is suitable”.

L265: cumulative summed up (to me cumulative implies a vector still but this will be the → sum/total)

Response

We prefer “cumulative” because the value is derived from numerical integration.

Revision: n/a

L320: overbbar U(5) again looks a bit weird.

Revision

Line 320: Typesetting $\bar{u}(5)$ was adjusted.

L335: overbbar U(5) again looks a bit weird. Also in some other places, please check all.

Response

The weird typesetting resulted from the transformation of generic Word format to template Word format of EGU journals. After adjustment, the typesetting sometimes resumes back. We checked the manuscript throughout for typesetting again.

Revision

Line 335: Typesetting was adjusted.

L355: $p \geq 32.53\%$ looks a bit weird.

Revision

Line 355: Typesetting was adjusted.

Response to

<https://doi.org/10.5194/egusphere-2025-4576-CC11>

Update and Revision

(See citations for following responses in the preprint)

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),”