

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

(See citations in following responses in the preprint)

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 question 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. LI-COR 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
5670 EndIf
5671
5672 If ((S_type = FOREST) OR (S_type = SHRUB)) Then 'Forest and Shrub
5673     displacement = 2.0*h_canopy/3.0 'Forest canopy, 2/3 rule, page 116, Oke, 1987
5674     roughness = 0.06*h_canopy 'Forest canopy, Jarvis et al. (1976) and Raupach et al. (1991)
5675 EndIf
5676
5677 If ((S_type = BARELAND) OR (S_type = WATER) OR (S_type = ICE)) Then 'Bare land, water, or ice
5678     displacement = 0.0 'Default w/o canopy
5679     roughness = 0.01 'Default w/o canopy
5680 EndIf
5681
5682 If (d_user <> 0.0) Then displacement = d_user 'User preferred has a priority
5683 If (z0_user <> 0.0) Then roughness = z0_user 'User preferred has a priority
5684
5685 hght_aerdync = h_measurement - displacement
5686 EndSub 'Displacement_roughness_heights
5687

```

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.

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.