

Comment on Golkar and de Oliveira (2026): Missing eddy covariance observations undermine reported OpenET biases

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Abstract

In a recent study published in *Agricultural and Forest Meteorology*, Golkar and de Oliveira (2026) reported systematic overestimation of evapotranspiration (ET) by OpenET across US climate zones and substantial improvements through machine learning bias correction. Here, we identify substantial inconsistencies in their eddy covariance (EC) reference data that challenge these conclusions. We first identified unusually low daily mean observed ET relative to previously reported values at the same AmeriFlux sites that is traceable to numerous zero-valued observations in their comparison scatterplot, and extended periods of exactly zero observed ET in their time series. These inconsistencies led us to hypothesize that missing latent heat flux observations were treated as zero, systematically lowering the reference EC ET measurements. Our independent reconstruction of daily ET from the original AmeriFlux datasets reproduced the reported site-mean ET within 0.04 mm d⁻¹ at 20 of 22 sites when missing observations were treated as zero, providing compelling quantitative evidence that missing data were effectively incorporated as zero ET in the original analysis. We further find that the reported ET statistics are reproducible only when omitting the energy balance correction described in the original study. These inconsistencies substantially inflate apparent OpenET overestimation and call into question the reported effectiveness of the proposed bias correction. Consequently, the study's conclusions regarding seasonal and climate-dependent correction mechanisms likely largely reflect artifacts in the reference observations rather than reflecting deficiencies in OpenET. Our findings demonstrate that errors in processing observational reference data can fundamentally alter the evaluation of satellite ET performance, underscoring the importance of rigorous quality control and reproducible analysis to distinguish genuine model biases from observational artifacts and reliably assess the effectiveness of proposed ML corrections.

Keywords: evapotranspiration; eddy covariance; energy balance closure; quality control; OpenET; machine learning

1. Introduction

Golkar and de Oliveira (2026), hereafter GO26, evaluated OpenET (Melton et al., 2022) against eddy covariance (EC) observations at 22 AmeriFlux sites across the United States. They reported systematic OpenET overestimation across climate zones and substantial improvements through machine-learning (ML) bias correction using XGBoost (Chen & Guestrin, 2016). However, we identified substantial inconsistencies in their reference EC ET observations that raise concerns about the validity of these conclusions.

Three observations initially motivated our investigation: (1) mean observed ET reported in GO26's Table 1 was substantially lower than previously published values at several of the same AmeriFlux sites (Volk et al., 2024); (2) their Figure 2a contained numerous observations with exactly zero ET, even when their XGBoost-corrected predictions reached about 4 mm d⁻¹; and (3) their Figure S2 showed extended periods of exactly zero observed ET at US-UTJ site, including during the growing season. These patterns suggested that missing EC observations may have been treated as zero ET rather than excluded or otherwise appropriately handled as missing values.

We therefore reconstructed the reference EC ET observations from the original AmeriFlux datasets and examined the consequences for the reported OpenET biases and ML correction performance.

2. Reconstruction of reference EC ET and identification of missing data artifacts

We downloaded the AmeriFlux BASE datasets (Chu et al., 2023) corresponding to the 22 sites and study periods reported by GO26 (Bednarz, 2026; Bernacchi, 2025; Bernacchi et al., 2025; Biraud et al., 2026; Davis, 2025; Helseth and Johnson, 2025a, 2025b, 2025c; Inkenbrandt, 2026a, 2026b; Key and Novick, 2025; Ladig and Inkenbrandt, 2026; NEON, 2025; Rey-Sanchez et al., 2026; Rey-Sanchez et al., 2026; Schreiner-McGraw, 2026; Schuppenhauer et al., 2025; Schuppenhauer et al., 2025; Sungur and Vanloocke, 2025; Suyker, 2026a, 2026b, 2026c). We converted half-hourly latent heat flux (LE) into ET and reproduced daily and site-mean values under alternative missing-data treatments. Summing available half-hourly ET while treating missing observations and entirely missing days as zero reproduced the mean observed ET reported in GO26's Table 1 within 0.04 mm d⁻¹ at 20 of 22 sites (Figure 1a). In contrast, restricting the analysis to valid observations, applying gap filling, and correcting for energy balance closure produced substantially different estimates (Figure 1b-d). This close agreement across nearly all study sites provides compelling quantitative evidence that missing observations were effectively treated as zero ET in the original analysis, despite the authors' stated exclusion of days with more than 50% missing or gap-filled half-hourly observations and subsequently applying energy balance closure correction (GO26, page 3-4).

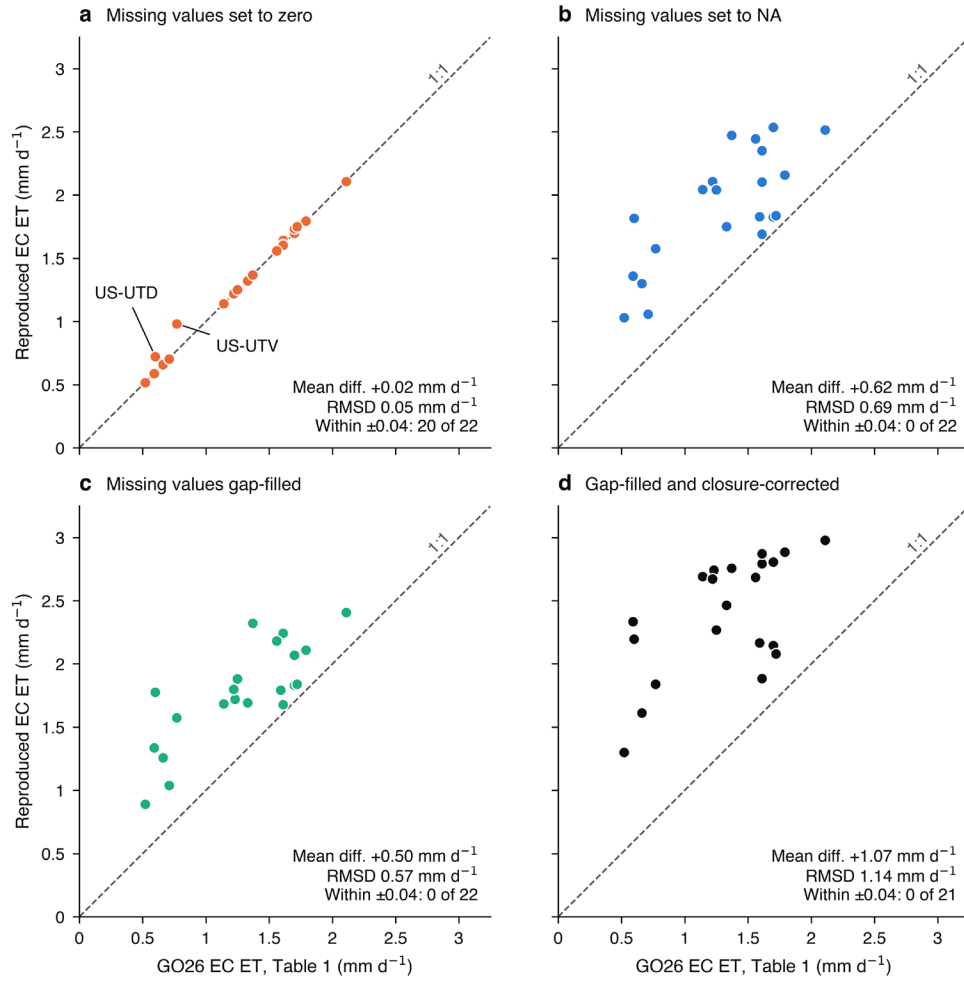


Figure 1. Mean daily ET at the 22 AmeriFlux sites studied by GO26, as reported in their Table 1 (x-axis) and as reproduced here from the AmeriFlux BASE data (y-axis); each point is one of 22 sites. (a) Missing half-hourly LE observations and entirely missing days treated as zero. (b) Missing observations excluded: daily means of the valid half-hourly observations on days with at least 50% valid half-hours, averaged over those days and missing values set to NA. (c) As in (b), with the missing half-hours of those days gap-filled from the mean diurnal cycle of a 15-day moving window. (d) Like (c), on the days with all energy balance components (net radiation, sensible and soil heat flux; 92% of the days in (c) at the sites shown). Here, the Bowen ratio closure correction described by GO26 (Twine et al., 2000) was applied with flux-data-qaqc version 0.5.0 (Volk et al., 2021) without screening the daily correction factors and leaving out days with corrected $\text{LE} \leq -100$ or $\geq 850 \text{ W m}^{-2}$. Soil heat flux (G) was set to zero at the three sites whose BASE files contain no G measurements (US-IAB, US-MN1, US-MN2). US-WT1, which has no net radiation measurements, is omitted from (d). Panels (a)–(c) are not corrected for energy balance closure. Dashed lines are 1:1. At the two labeled sites in (a), the BASE versions examined here contain more LE observations than the earlier versions GO26 appear to

have processed. Mean diff., mean of reproduced minus reported ET; RMSD, root-mean-square difference.

We further examined the daily time series presented in GO26. At US-UTJ, 206 of 353 daily observations shown in their Figure S2 were exactly zero, corresponding to dates without available LE measurements in the AmeriFlux BASE dataset examined here. At US-UiC, reconstructed daily ET (i.e., zero-filled daily sums) reproduced 360 of 361 observations in their Figure 8 within 0.02 mm d^{-1} , including days with incomplete flux records. These results provide strong evidence that many zero-valued reference EC ET observations reflect data unavailability rather than measured absence of evapotranspiration.

3. Implications for OpenET biases and ML correction

Treating missing EC observations as zero systematically lowers the observational reference and consequently inflates apparent OpenET overestimation. Using the 742 site-months at 21 sites with at least 20 days that pass GO26's 50% filter and have all energy balance terms, we found that the monthly bias of the current OpenET ensemble (collection 2.1) decreased from $+0.51 \text{ mm d}^{-1}$ against zero-filled ET to $+0.17 \text{ mm d}^{-1}$ against the daily means of the valid observations. Applying the Bowen ratio closure correction described by GO26 (Twine et al., 2000) to these means, without screening the daily correction factors as in flux-data-qaqc (Volk et al., 2021), changed the bias to -0.43 mm d^{-1} . Because LE is missing mostly at night at several sites, we also gap-filled the missing half-hours from their mean diurnal cycle, a step GO26 do not describe; the bias was then $+0.30 \text{ mm d}^{-1}$ before and -0.24 mm d^{-1} after the same Bowen ratio closure. For reference, the energy-balance-ratio (EBR) closure of flux-data-qaqc gave -0.22 mm d^{-1} on the gap-filled means of the same site-months. Moreover, the current OpenET collection evaluated against measured monthly ET at 36 cropland stations of the Volk et al. (2023) benchmark dataset (2016–2022; closure-corrected eddy covariance at 32 stations and weighing lysimeters at four) gives an ensemble bias of -0.22 mm d^{-1} . Thus, the direction and magnitude of the inferred OpenET bias depend strongly on the treatment of the reference observations. Notably, applying each closure correction changes the inferred bias from overestimation to underestimation, highlighting the importance of consistent EC reference-data processing.

The missing-data artifacts also affect the reported benefits of ML bias correction. For US-UTJ, digitizing the observations and predictions presented in GO26's Figure S2 reproduced the reported XGBoost reduction in root-mean-square error (RMSE) of approximately 52.8%. However, excluding the zero-valued reference observations reduced the apparent RMSE improvement to approximately 0.5%. This example demonstrates that a substantial apparent improvement in ML performance can arise from fitting or evaluating against erroneous reference observations rather than correcting genuine OpenET biases. Although this site-specific analysis

does not establish the magnitude of this effect across the full dataset, it raises substantial concerns about the reported overall improvements and their interpretation.

4. Additional methodological and reproducibility concerns

Beyond the treatment of missing EC observations as zero, several aspects of GO26 warrant further clarification.

Energy balance correction. GO26 stated that EC observations were corrected for energy-balance closure using Bowen ratio preservation method (Twine et al., 2000). However, their reported site-mean daily ET values were reproducible only with uncorrected turbulent fluxes and missing data counted as zero, whereas applying energy balance closure correction produced substantially different values (Figure 1d). This discrepancy raises questions about whether the described correction was consistently implemented in the observations used to calculate the reported statistics and evaluate OpenET.

Machine learning validation. The reliability of ML correction also depends on the independence of training and testing data, particularly when observations exhibit temporal autocorrelation or originate from geographically clustered flux towers (Shi et al., 2022). GO26 described several validation approaches, including site-based and temporally blocked evaluation, and reported that predictor imputation parameters were estimated from training data. Nevertheless, our sensitivity experiments with a GO26-like XGBoost correction of OpenET at the cropland stations of the Volk et al. (2023) benchmark indicate that estimated XGBoost improvements can vary considerably with the validation strategy, ranging from 9% to 26% RMSE reductions. More importantly, the apparent inclusion of zero-valued reference observations raises concerns about whether the reported improvements reflect genuine predictive skill. Independent reproduction of the reported results, including the reference-data filtering, training and testing partitions, and validation procedures, is therefore needed to establish the robustness and generalizability of the reported ML improvements.

Supplementary information and reproducibility. GO26 refers to supplementary tables that we could not locate among the publicly available article materials examined. The authors also stated that all analysis code, trained models, and feature-engineering scripts would be made publicly available upon acceptance. However, these materials were not publicly accessible as of October 16, 2026, despite the article's acceptance on October 7, 2026, and online publication on October 13, 2026. Their unavailability limits independent reproduction of the observational processing, energy balance closure correction, and ML evaluation, particularly given the substantial discrepancies identified here. We encourage the authors to release the complete analysis code, associated model artifacts, and supporting materials to enable independent verification and resolution of these concerns.

5. Conclusions

Our reconstruction provides strong evidence that missing EC observations were effectively treated as zero ET in GO26, reproducing the reported mean observed ET within 0.04 mm d⁻¹ at 20 of 22 AmeriFlux sites. This treatment substantially underestimated reference EC ET and inflated apparent OpenET biases. This artifact also calls into question the reported effectiveness of ML bias correction. The additional inconsistency between the reported ET statistics and the described energy balance closure correction further complicates interpretation of the findings. We recommend reassessing the original study using appropriately quality controlled and processed EC observations, with consistent validation procedures. Such reassessment is necessary to distinguish genuine OpenET model deficiencies from artifacts introduced during reference data processing and to establish the robustness of the proposed ML corrections.

Data statement

All reconstruction scripts, sensitivity analyses, and supporting results are publicly available on GitHub (<https://github.com/Open-ET/openet-bias-correction-comment-afm>) and archived on Zenodo (Kim et al., 2026; <https://doi.org/10.5281/zenodo.23383493>). The AmeriFlux BASE data (AmeriFlux CC-BY-4.0) products were accessed from the AmeriFlux data portal (<https://ameriflux.lbl.gov>) on [10/15/2026].

Declaration of generative AI use

The authors identified potential methodological issues in the original study and used Claude (Anthropic) to assist in developing and refining code to investigate these issues and independently reproduce the reported results. All code, analyses, and interpretations were reviewed and verified by the authors, who retain full responsibility for the findings and conclusions. The analysis code is publicly available on GitHub to support transparency and reproducibility.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this comment.

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US-UiC, US-UiG, US-VT1, US-WT1, and US-xSL. In addition, funding for AmeriFlux data resources was provided by the U.S. Department of Energy's Office of Science.

Author contributions

Yeonuk Kim: Conceptualization, Investigation, Writing – original draft, Visualization. **Sayantana Majumdar:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – review and editing. **John M. Volk:** Conceptualization, Investigation, Writing – review and editing. **Peter ReVelle:** Conceptualization, Writing – review and editing. **Todd Caldwell:** Writing – review and editing. **Justin Huntington:** Conceptualization, Writing – review and editing, Visualization, Funding acquisition.

References

- Bednarz, C., 2026. AmeriFlux BASE US-WT1 Kress, TX no-till cotton and grain sorghum production, Ver. 4-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2407207>.
- Bernacchi, C.J., 2025. AmeriFlux BASE US-UiG University of Illinois Maize-Soy 2, Ver. 1- 5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2574375>.
- Bernacchi, C.J., Blakely, B., Moore, C., Pederson, T., 2025. AmeriFlux BASE US-UiC University of Illinois Maize-Soy, Ver. 2-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1846665>.
- Biraud, S., Fischer, M., Chan, S., Torn, M., 2026. AmeriFlux BASE US-ARM ARM Southern Great Plains site- Lamont, Ver. 15-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1246027>.
- Chen, T., & Guestrin, C. (2016). XGBoost: A Scalable Tree Boosting System. Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 785–794. <https://doi.org/10.1145/2939672.2939785>
- Chu, H., Christianson, D.S., Cheah, Y.-W., Pastorello, G., O'Brien, F., Geden, J., Ngo, S.-T., Hollowgrass, R., Leibowitz, K., Beekwilder, N.F., Sandesh, M., Dengel, S., Chan, S.W., Santos, A., Delwiche, K., Yi, K., Buechner, C., Baldocchi, D., Papale, D., Keenan, T.F., Biraud, S.C., Agarwal, D.A., & Torn, M.S. (2023). AmeriFlux BASE data pipeline to support network growth and data sharing. *Sci. Data*, 10, 614. <https://doi.org/10.1038/s41597-023-02531-2>
- Davis, K., 2025. AmeriFlux BASE US-NSb NASA HAQ - SJV West Irrigated Cotton, Ver. 1- 5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2574380>.
- Golkar, M.K., & de Oliveira, L.A. (2026). Diagnosing and correcting OpenET satellite evapotranspiration across U.S. climate zones: Error decomposition, explainable AI, and uncertainty quantification. *Agr. Forest Meteorol.*, 391, 111524. <https://doi.org/10.1016/j.agrformet.2026.111524>

- Helseth, C., Johnson, J., 2025a. AmeriFlux BASE US-MN1 Morris: Corn-Soybean with Cover Crops, Strip Tillage, Ver. 2-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2407204>.
- Helseth, C., Johnson, J., 2025b. AmeriFlux BASE US-MN2 Morris: Corn-Soybean-Wheat with Cover Crops, Minimal Tillage, Ver. 2-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2407205>.
- Helseth, C., Johnson, J., 2025c. AmeriFlux BASE US-MN3 Morris: Corn-Soybean, Conventional Tillage, Ver. 2-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2407206>.
- Inkenbrandt, P., 2026a. AmeriFlux BASE US-UTD UFLUX Dugout Ranch, Ver. 2-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2531148>.
- Inkenbrandt, P., 2026b. AmeriFlux BASE US-UTJ UFLUX Bluff, Ver. 3-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2531150>.
- Key, K., Novick, K., 2025. AmeriFlux BASE US-VT1 Vermillion Tributary Paired Cropland – Site 1 (Corn/Soy; No Cover Crops), Ver. 4-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2567994>.
- Kim, Y., Majumdar, S., Volk, J.M., ReVelle, P., Caldwell, T.G., & Huntington, J.L. (2026). Code and data for: Comment on Golkar and de Oliveira (2026): Missing eddy covariance observations undermine reported OpenET biases (Version 1.0.0) [dataset]. Zenodo. <https://doi.org/10.5281/zenodo.23383493>
- Ladig, K., Inkenbrandt, P., 2026. AmeriFlux BASE US-UTV UFLUX Desert View, Ver. 4-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2531152>.
- Melton, F.S., Huntington, J., Grimm, R., Herring, J., Hall, M., Rollison, D., Erickson, T., Allen, R., Anderson, M., Fisher, J.B., Kilic, A., Senay, G.B., Volk, J., Hain, C., Johnson, L., Ruhoff, A., Blankenau, P., Bromley, M., Carrara, W., Daudert, B., Doherty, C., Dunkerly, C., Friedrichs, M., Guzman, A., Halverson, G., Hansen, J., Harding, J., Kang, Y., Ketchum, D., Minor, B., Morton, C., Ortega-Salazar, S., Ott, T., Ozdogan, M., ReVelle, P.M., Schull, M., Wang, C., Yang, Y., Anderson, R.G., 2022. OpenET: Filling a Critical Data Gap in Water Management for the Western United States. *J. Am. Water Resour. Assoc.* 58, 971-994. <https://doi.org/10.1111/1752-1688.12956>
- NEON (National Ecological Observatory Network), 2025. AmeriFlux BASE US-xSL NEON North Sterling, CO (STER), Ver. 10-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1617735>.
- Rey-Sanchez, C., Wang, C.T., Szutu, D., Hemes, K., Verfaillie, J., Baldocchi, D., 2026. AmeriFlux BASE US-Bi2 Bouldin Island corn, Ver. 21-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1419513>.
- Rey-Sanchez, C., Wang, C.T., Szutu, D., Shortt, R., Chamberlain, S.D., Verfaillie, J., Baldocchi, D., 2026. AmeriFlux BASE US-Bi1 Bouldin Island Alfalfa, Ver. 16-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1480317>.
- Schreiner-McGraw, A., 2026. AmeriFlux BASE US-Mo1 LTAR CMRB Field 1 (CMRB ASP), Ver. 5-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1870588>.
- Schuppenhauer, M., Biraud, S.C., Chan, S., 2025. AmeriFlux BASE US-RGB Butte County Rice Farm, Ver. 5-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1870591>.
- Schuppenhauer, M.R., Biraud, S.C., Chan, S., 2025. AmeriFlux BASE US-RGA Arkansas Corn Farm, Ver. 4-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1880913>.

- Shi, H., Luo, G., Hellwich, O., Xie, M., Zhang, C., Zhang, Y., Wang, Y., Yuan, X., Ma, X., Zhang, W., Kurban, A., De Maeyer, P., & Van de Voorde, T. (2022). Evaluation of water flux predictive models developed using eddy-covariance observations and machine learning: a meta-analysis. *Hydrol. Earth Syst. Sci.*, 26, 4603-4618. <https://doi.org/10.5194/hess-26-4603-2022>
- Sungur, G.A., Vanloocke, A., 2025. AmeriFlux BASE US-IAB Iowa State University NE tower, Ver. 1-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/2567982>.
- Suyker, A., 2026a. AmeriFlux BASE US-Ne1 Mead - irrigated continuous maize site, Ver. 20-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1246084>.
- Suyker, A., 2026b. AmeriFlux BASE US-Ne2 Mead - irrigated maize-soybean rotation site, Ver. 20-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1246085>.
- Suyker, A., 2026c. AmeriFlux BASE US-Ne3 Mead - rainfed maize-soybean rotation site, Ver. 20-5. AmeriFlux AMP (Dataset). <https://doi.org/10.17190/AMF/1246086>.
- Twine, T.E., Kustas, W.P., Norman, J.M., Cook, D.R., Houser, P.R., Meyers, T.P., Prueger, J.H., Starks, P.J., & Wesely, M.L. (2000). Correcting eddy-covariance flux underestimates over a grassland. *Agr. Forest Meteorol.*, 103, 279-300. [https://doi.org/10.1016/S0168-1923\(00\)00123-4](https://doi.org/10.1016/S0168-1923(00)00123-4)
- Volk, J.M., Huntington, J.L., Allen, R.G., Melton, F.S., Anderson, M.C., & Kilic, A. (2021). flux-data-qaqc: A Python package for energy balance closure and post-processing of eddy flux data. *J. Open Source Softw.*, 6(66), 3418. <https://doi.org/10.21105/joss.03418>
- Volk, J.M., Huntington, J., Melton, F.S., Allen, R., Anderson, M.C., Fisher, J.B., Kilic, A., Senay, G.B., Halverson, G., Knipper, K., Minor, B., Pearson, C., Wang, T., Yang, Y., Evett, S.R., French, A.N., Jasoni, R.L., & Kustas, W.P. (2023). Development of a benchmark eddy flux evapotranspiration dataset for evaluation of satellite-driven evapotranspiration models over the CONUS. *Agr. Forest Meteorol.*, 331, 109307. <https://doi.org/10.1016/j.agrformet.2023.109307>
- Volk, J.M., Huntington, J.L., Melton, F.S., Allen, R., Anderson, M., Fisher, J.B., Kilic, A., Ruhoff, A., Senay, G.B., Minor, B., Morton, C., Ott, T., Johnson, L., Comini de Andrade, B., Carrara, W., Doherty, C.T., Dunkerly, C., Friedrichs, M., Guzman, A., Hain, C., Halverson, G., Kang, Y., Knipper, K., Laipelt, L., Ortega-Salazar, S., Pearson, C., Parrish, G.E.L., Purdy, A., ReVelle, P., Wang, T., & Yang, Y. (2024). Assessing the accuracy of OpenET satellite-based evapotranspiration data to support water resource and land management applications. *Nat. Water*, 2, 193-205. <https://doi.org/10.1038/s44221-023-00181-7>