fluxtools: interactive Shiny tool for QA/QC and code generation of Ameriflux eddy-covariance data

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Summary

Eddy covariance data processing requires extensive quality control (QA/QC) to identify and remove implausible or erroneous half-hourly flux data before submission to public data repositories such as Ameriflux (AmeriFlux Management Project 2025). *Fluxtools* (Key 2025) is an R [4.5.0; R Core Team (2025)] *Shiny* (Chang et al. 2024) application built with *Plotly* (Sievert et al. 2024) and *dplyr* (Wickham et al. 2023) packages designed to streamline this workflow by providing interactive visualization, year-based filtering, and on-the-fly R code generation for specified data removal. Users can visually flag anomalous data points (i.e., periods of sensor failure, physically implausible data), accumulate multiple cleaning steps, inspect R^2 values before and after data cleaning via base R's *lm()* function, and export a zipped folder containing a cleaned .csv file and a full R script that records every decision. *Fluxtools* significantly accelerates the QA/QC workflow, ensuring transparent, reproducible, and shareable data cleaning suitable for final dataset preparation and repository submission.

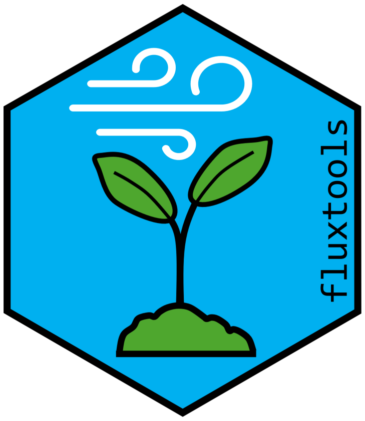


Figure 1: *Fluxtools* hex logo

Key features:

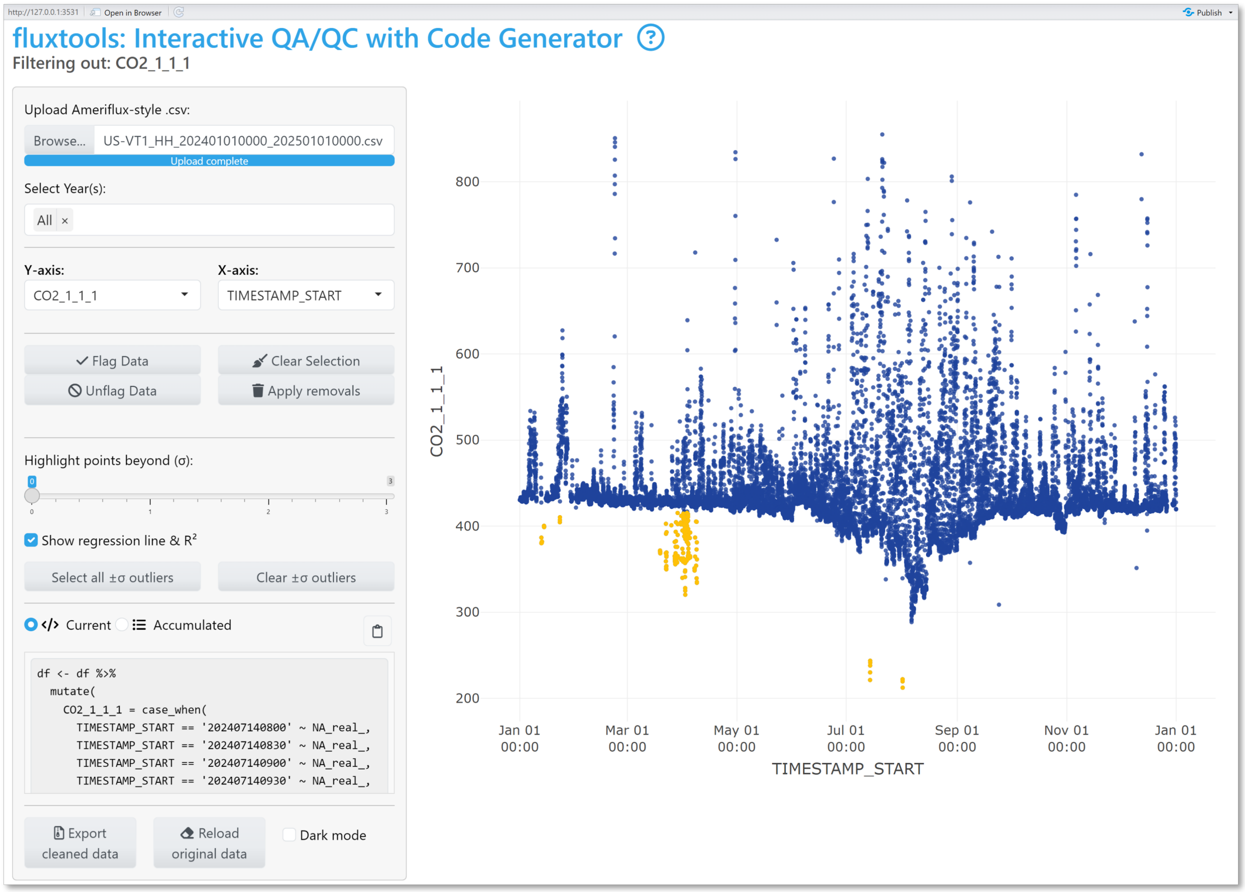
Interactive Plotly Scatterplots: Plot any numeric or time variable; hover mouse over data points to see timestamps and values; export plots as .png directly from the app

Flexible point selection: Select data points via box, lasso, or by standard-deviation ( ) cutoffs. *See Fig 2* for interface and data selection example

On-the-fly R code generation: The *Preview* pane shows selected timestamps and values; ready-to-copy R code using *dplyr's case_when(… ~ NA)* snippets generate in the *current* code box automatically; *add current selection* adds code to the *accumulated* code box for easy and continuous data selection

Before/after R² diagnostics: When numeric variables are compared against each other, a linear regression generates a R² value. Automatically computes post-removal R² value where selected data points are dropped to see step comparisons. *See Fig 3* for an example of the *Fluxtools* interfacing using the ± outliers selection tool. The top (red) R² is for all data points and the bottom R² (orange) is when selected points are dropped from the linear regression model

Export a cleaned .csv file and R script: *Apply removals* in-app (converting data points into *NA*s for selected timestamps) and download both a cleaned .csv file and a comprehensive R script documenting each data removal step



fluxtools: Interactive QA/QC with Code Generator

Filtering out: CO2_1_1_1

Upload Ameriflux-style .csv: US-VT1_HH_202401010000_202501010000.csv

Upload complete

Select Year(s): All

Y-axis: CO2_1_1_1

X-axis: TIMESTAMP_START

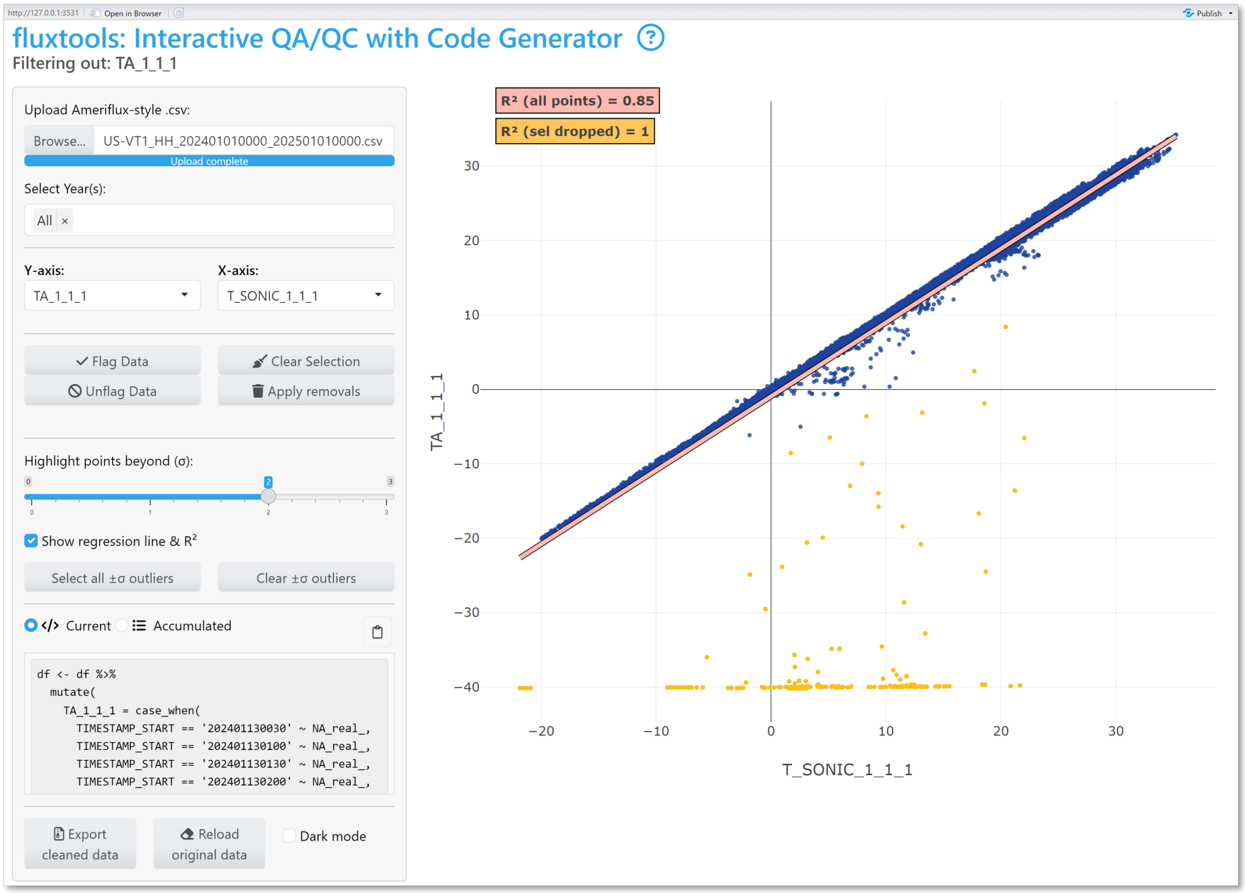
Highlight points beyond (σ): 0

☑ Show regression line & R²

● Current ○ Accumulated

```
df <- df %>%
  mutate(
    CO2_1_1_1 = case_when(
      TIMESTAMP_START == '202407140800' ~ NA_real_,
      TIMESTAMP_START == '202407140830' ~ NA_real_,
      TIMESTAMP_START == '202407140900' ~ NA_real_,
      TIMESTAMP_START == '202407140930' ~ NA_real_,
```

☐ Dark mode



fluxtools: Interactive QA/QC with Code Generator

Filtering out: TA_1_1_1

Upload Ameriflux-style .csv: US-VT1_HH_202401010000_202501010000.csv

Upload complete

Select Year(s): All

Y-axis: TA_1_1_1

X-axis: T_SONIC_1_1_1

Highlight points beyond (σ): 2

☑ Show regression line & R^2

● Current ○ Accumulated

```
df <- df %>%
  mutate(
    TA_1_1_1 = case_when(
      TIMESTAMP_START == '202401130030' ~ NA_real_,
      TIMESTAMP_START == '202401130100' ~ NA_real_,
      TIMESTAMP_START == '202401130130' ~ NA_real_,
      TIMESTAMP_START == '202401130200' ~ NA_real_,
```

☐ Dark mode

R² (all points) = 0.85

R² (sel dropped) = 1

Statement of need

High-frequency (10 Hz; data recorded 10 times per second) eddy covariance measurements generate large datasets that must be carefully aggregated into half-hourly fluxes, using careful quality assurance and quality control (Burba 2021). At this high frequency, intermittent periods of sensor drift or failure are common, making manual data cleaning an integral part of the workflow. Tools like *EddyPro* (LI-COR Biosciences 2021) converts raw 10Hz data into half-hourly fluxes, while R packages like *REddyProc* (Wutzler et al. 2024), and Python tools like PyFluxPro (Isaac 2021), automate u*-threshold filtering, gap-filling, and flux partitioning. These tools excel at bulk data processing but offer no interactive means to inspect or carefully remove outliers that that require a human eye.

In practice, data managers resort to custom scripts, extensive manual visualization, and fragmented documentation to detect and remove erroneous data points caused by sensor drift, malfunction, or calibration issues. These procedures are labor-intensive, prone to errors, challenging to reproduce, and lack transparency. *Fluxtools* addresses this challenge by pairing an interactive scatterplot-based interface with on-the-fly R code generation. Users can visually flag implausible half-hourly data points, automatically generate the exact *case_when(… ~ NA) dplyr* code snippets (or apply removes automatically in the app) and export a .zip file containing a cleaned .csv file plus a comprehensive R script documenting each data removal step that captures every user-made QA/QC decision.

Fluxtools streamlines and clarifies the QA/QC workflow by combining interactivity with code-based reproducibility. It promotes transparent documentation of decisions, reduces manual effort, and accelerates the preparation of flux data for repository uploads such as individual site submissions to Ameriflux. Ultimately, *Fluxtools* lowers the barriers to robust and reproducible QA/QC workflows, enabling researchers to devote less time to manual anomaly detection and more time to scientific analysis.

Code Example

Fluxtools can be installed from Github.

```r
library(fluxtools)

# Set your site's UTC offset (e.g., -5 for Eastern Standard Time)
fluxtools::run_flux_qaqc(-5)
```

Acknowledgments

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References

AmeriFlux Management Project. 2025. "AmeriFlux Data Portal." 2025. https://ameriflux.lbl.gov/.

Burba, George. 2021. *Eddy Covariance Method - for Scientific, Regulatory, and Commercial Applications*. Lincoln, Nebraska: LI-COR Biosciences. https://www.licor.com/products/eddy-covariance/ec-book.

Chang, Winston, Joe Cheng, JJ Allaire, Carson Sievert, Barret Schloerke, Yihui Xie, Jeff Allen, Jonathan McPherson, Alan Dipert, and Barbara Borges. 2024. *Shiny: Web Application Framework for r*. https://doi.org/10.32614/CRAN.package.shiny.

Isaac, Peter. 2021. "PyFluxPro." https://github.com/OzFlux/PyFluxPro.

Key, Kesondra. 2025. "Fluxtools: Interactive QA/QC for AmeriFlux Data." Zenodo. https://doi.org/10.5281/zenodo.15626645.

Key, Kesondra, and Kim Novick. 2025a. "AmeriFlux BASE US-VT1 Vermillion Tributary Paired Cropland – Site 1 (Corn/Soy; No Cover Crops)." AmeriFlux Network, Lawrence Berkeley National Laboratory. https://doi.org/10.17190/AMF/2567994.

———. 2025b. "AmeriFlux BASE US-VT2 Vermillion Tributary Paired Cropland – Site 2 (Corn/Soy; Cover Crops)." AmeriFlux Network, Lawrence Berkeley National Laboratory. https://doi.org/10.17190/AMF/2567995.

LI-COR Biosciences. 2021. “EddyCovariance Processing Software (EddyPro).” https://www.licor.com/env/products/eddy-covariance/eddypro.

OpenAI. 2025. “Introducing OpenAI O3 and O4-Mini.” 2025. https://openai.com/index/introducing-o3-and-o4-mini/.

R Core Team. 2025. *R: A Language and Environment for Statistical Computing.* Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Sievert, Carson, Chris Parmer, Toby Hocking, Scott Chamberlain, Karthik Ram, Marianne Corvellec, Pedro Despouy, Salim Brüggemann, and Plotly Technologies Inc. 2024. “Plotly: Create Interactive Web Graphics via ’Plotly.js’.” https://doi.org/10.32614/CRAN.package.plotly.

Wickham, Hadley, Romain François, Lionel Henry, Kirill Müller, and Davis Vaughan. 2023. *Dplyr: A Grammar of Data Manipulation.* https://doi.org/10.32614/CRAN.package.dplyr.

Wutzler, Thomas, Markus Reichstein, Antje Maria Moffat, and Mirco Migliavacca. 2024. *REddyProc: Post Processing of (Half-)hourly Eddy-Covariance Measurements.* https://doi.org/10.32614/CRAN.package.REddyProc.