

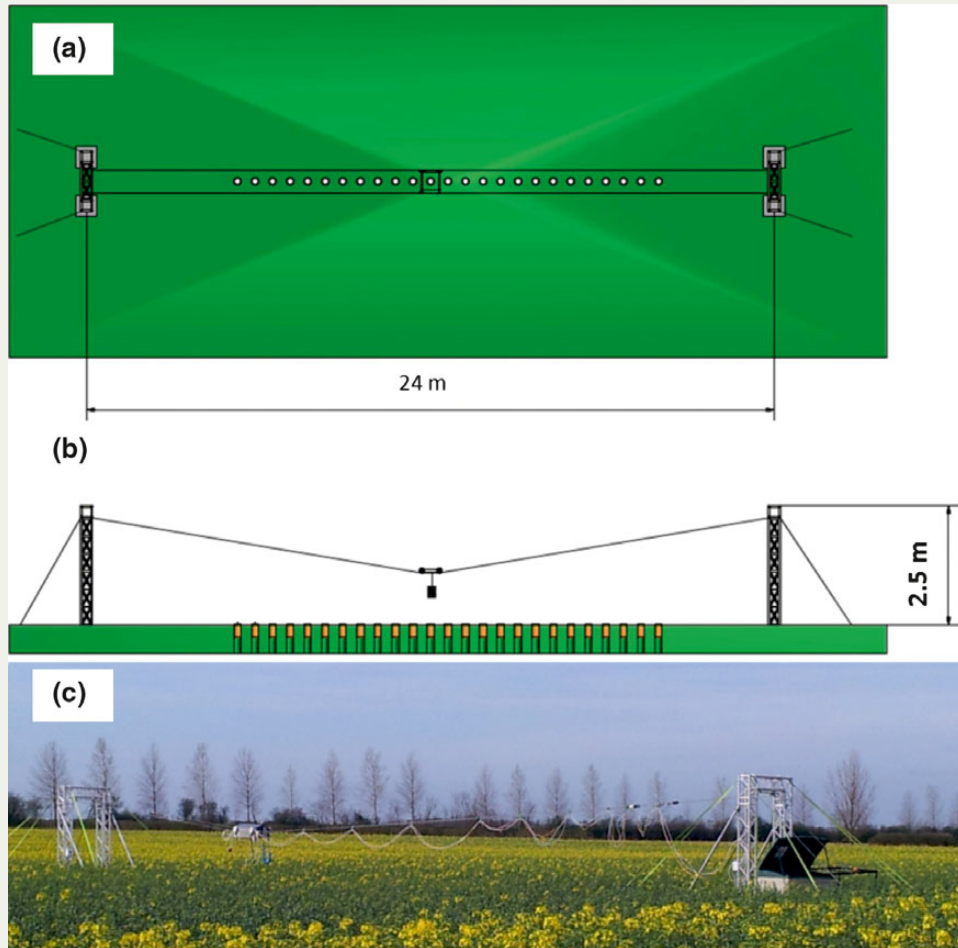
A software package for the analysis of Skyline data:

an automated flux chamber system

Peter Levy and Elisabeth Appleton
UK Centre for Ecology & Hydrology

2025-04-30

Skyline flux chamber system



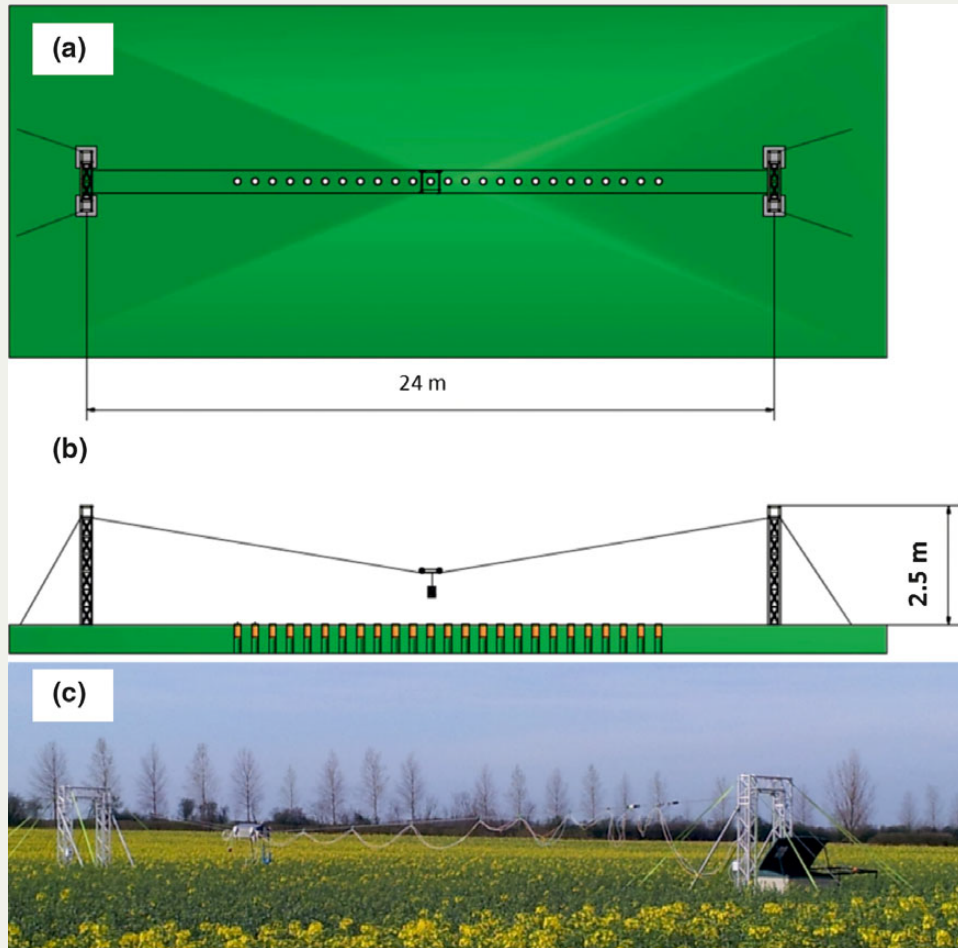
- a robotic automated flux chamber system
- 16+ chambers on transect
- measures at 1 Hz
 - CO_2
 - N_2O
 - CH_4

<https://www.youtube.com/embed/Anhxe5k6a6o>

SkyLine in action

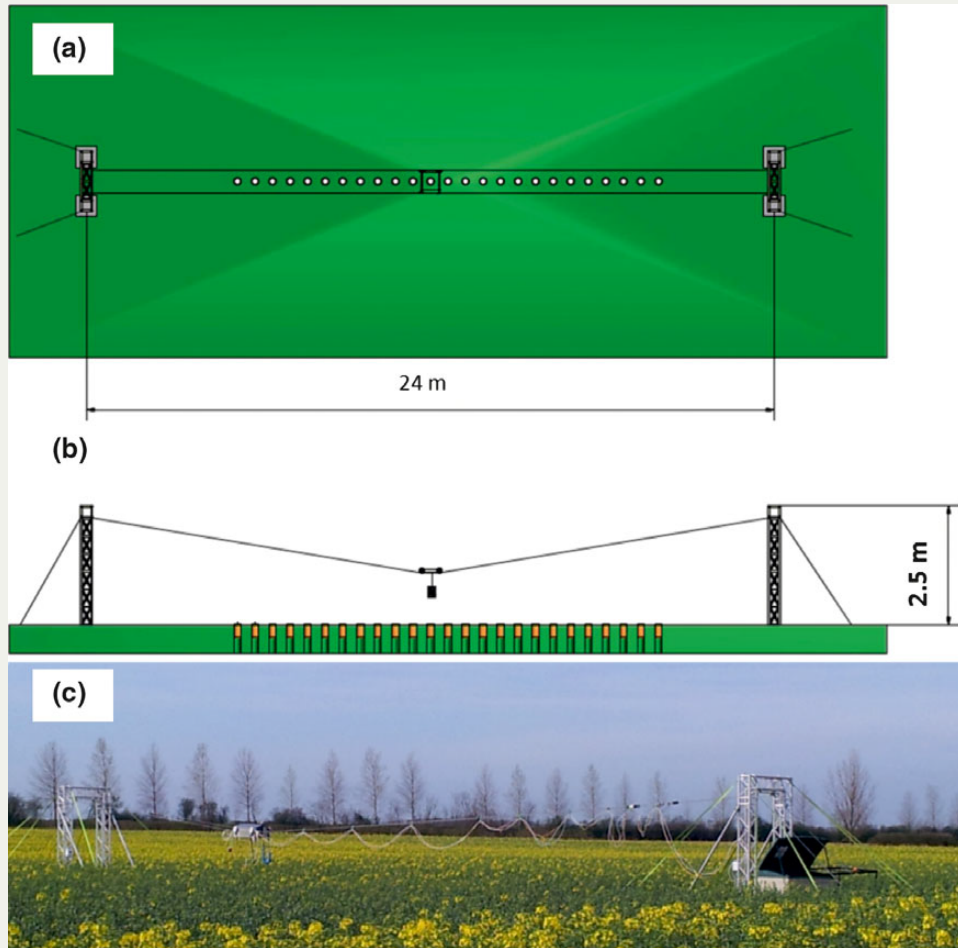


Data analysis issues



- large volume of data (>GB)
 - currently 55×10^6 records x 3 gases
 - 150 000 fluxes x 3 gases
- need to automate:
 - detecting chamber closure
 - flux calculation & QC
- no consistent meta-data

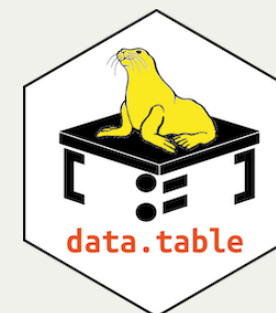
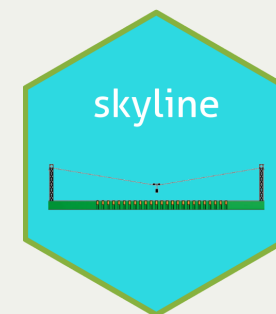
Aims



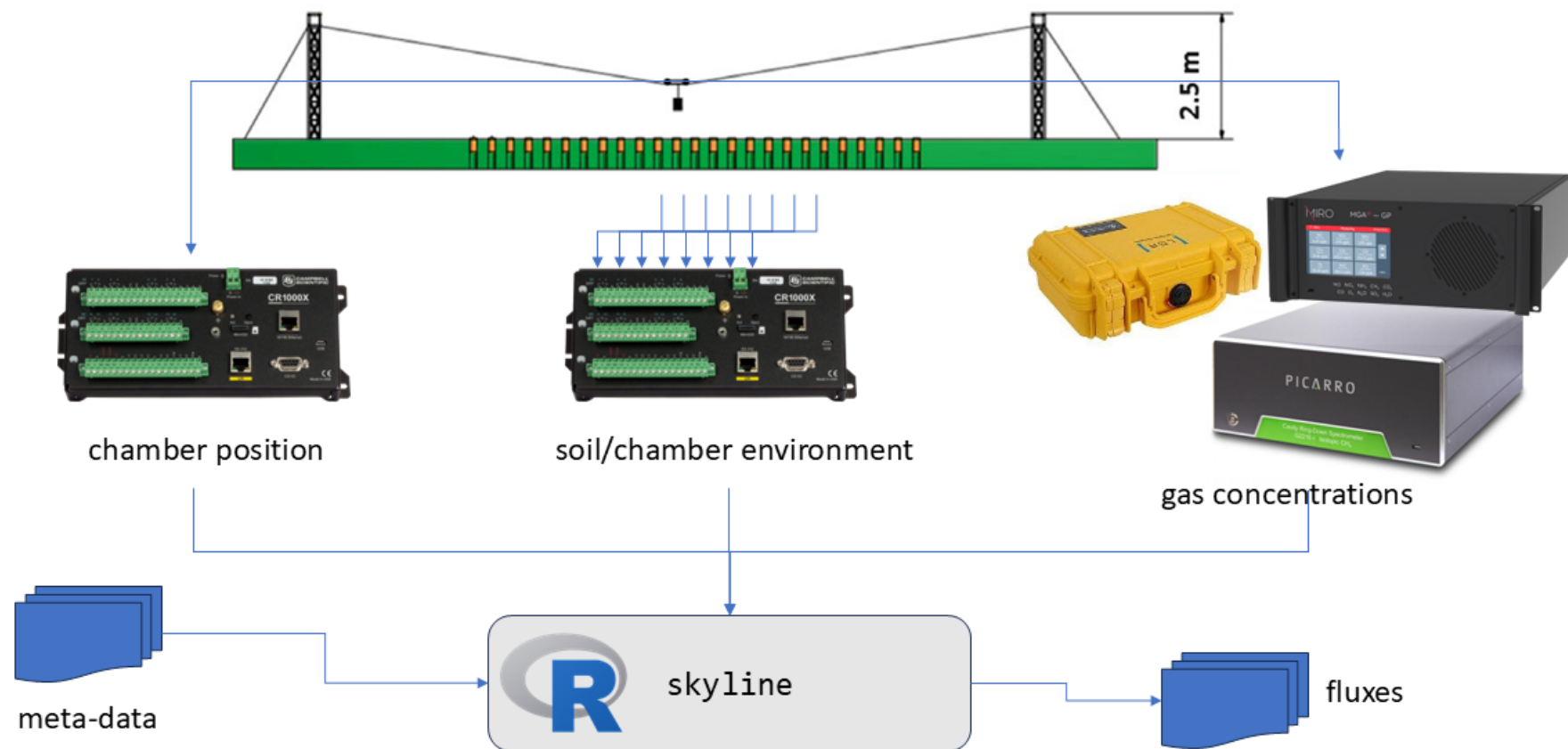
- develop generic code for data handling
- consistent meta-data, inputs and outputs
- **reproducible** workflow from raw data to statistical analysis

Technical details

- written as an R package
 - <https://github.com/NERC-CEH/skyline>
- uses `targets` for reproducible workflow
 - <https://docs.ropensci.org/targets/>
- uses `data.table` for computational efficiency
 - <https://r-datatable.com>
 - very fast for large datasets (in millions)

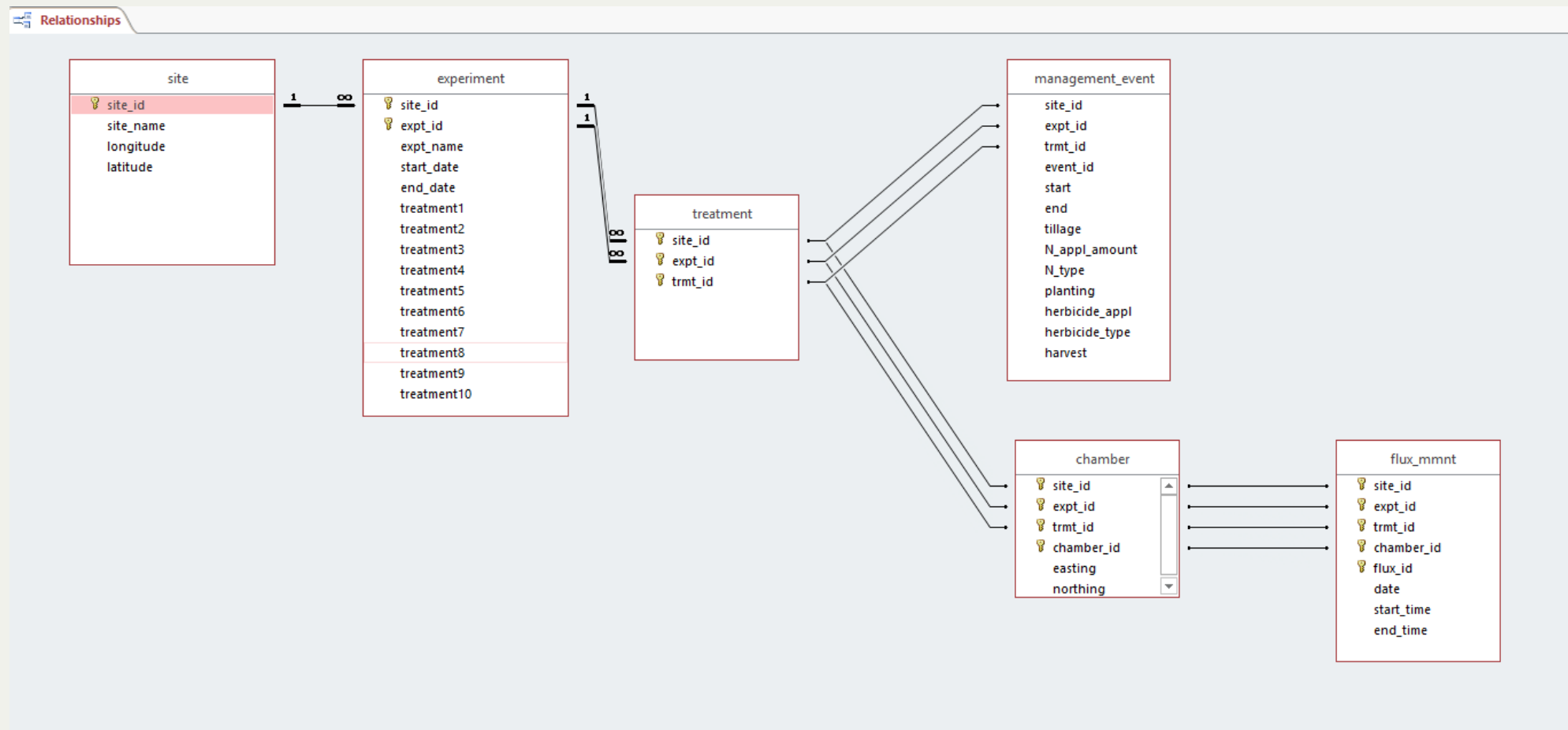


Data flow

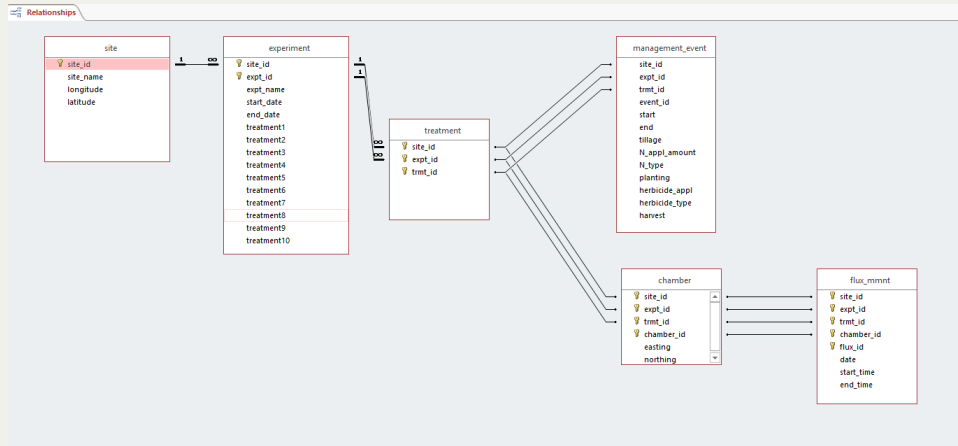


Meta-data

Relational database model



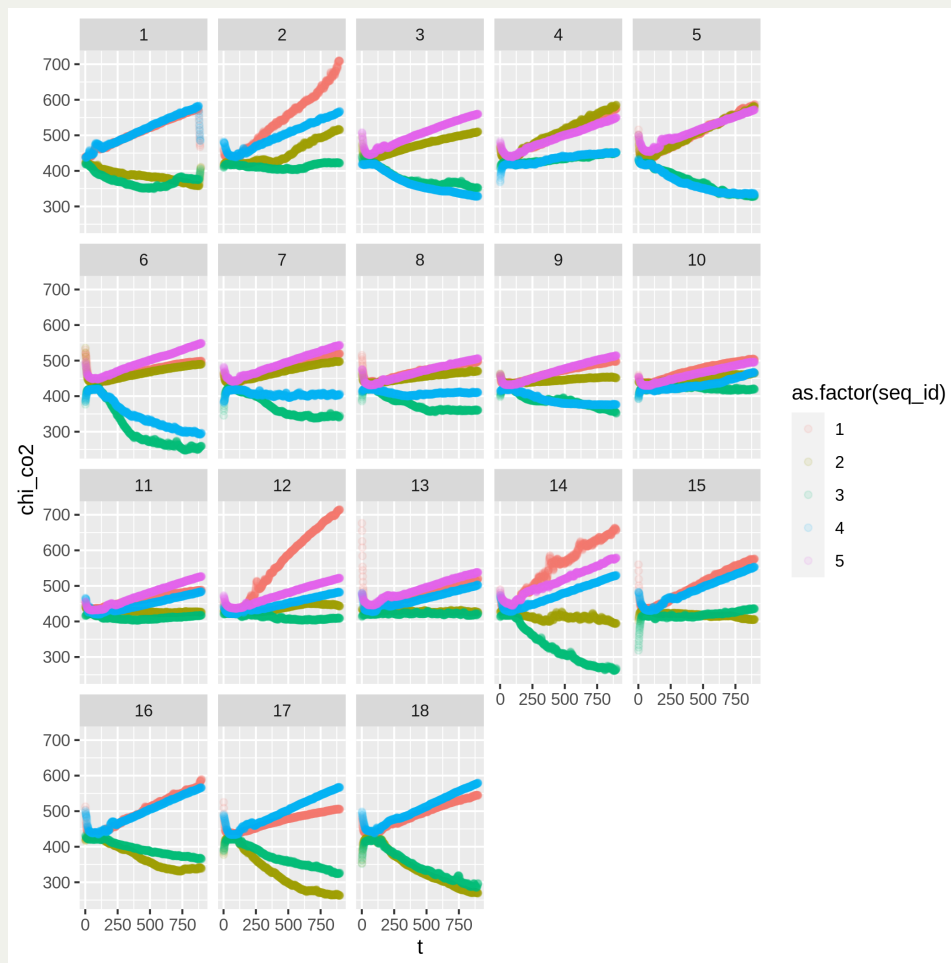
Meta-data



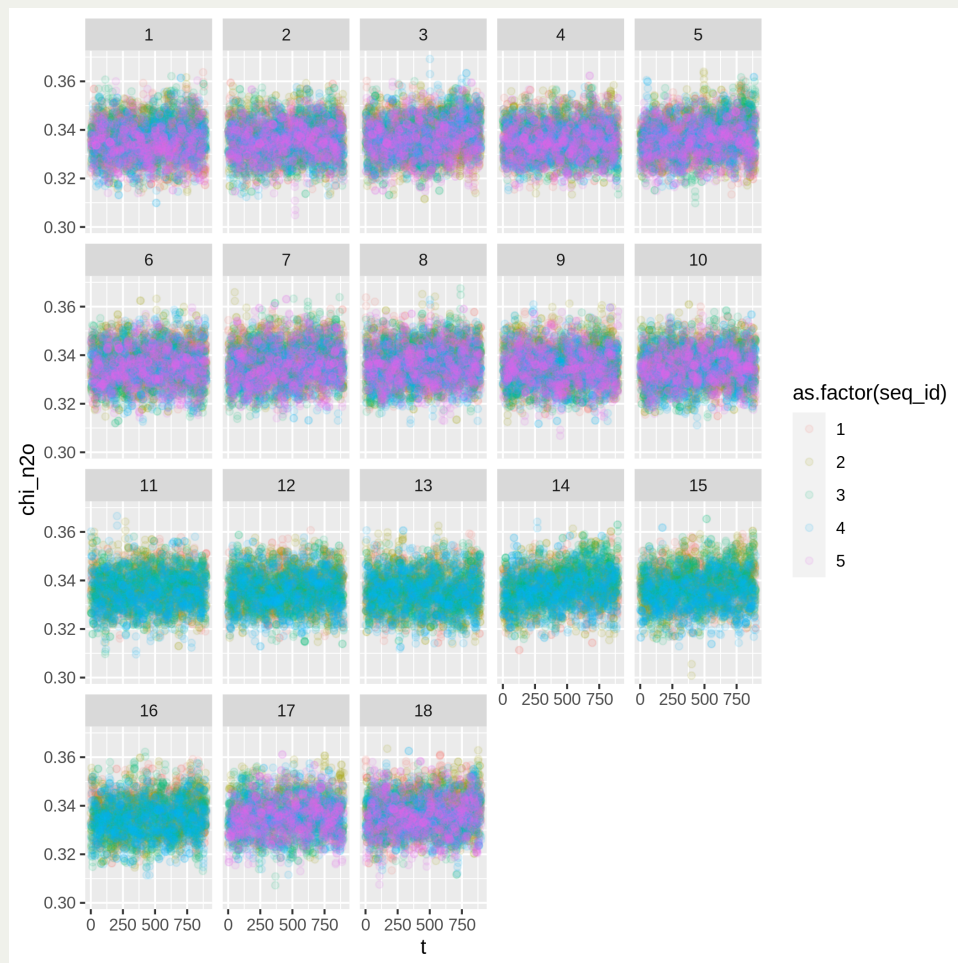
- each flux associated with a chamber
- each chamber associated with a treatment
- each treatment associated with n management events
- experimental design feeds through to analysis
- enforces consistent naming

Typical data for 1 day

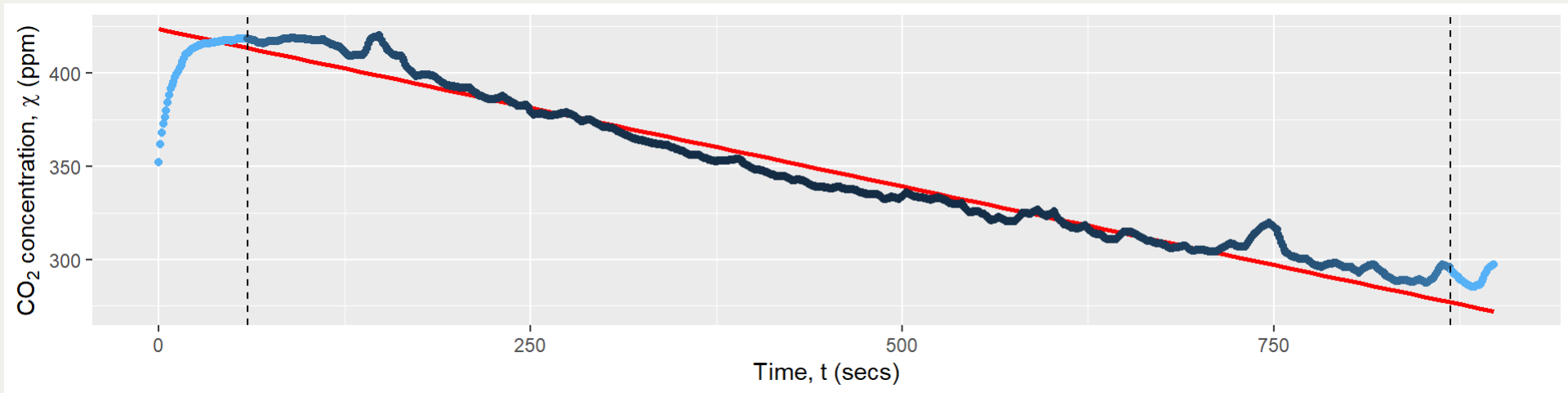
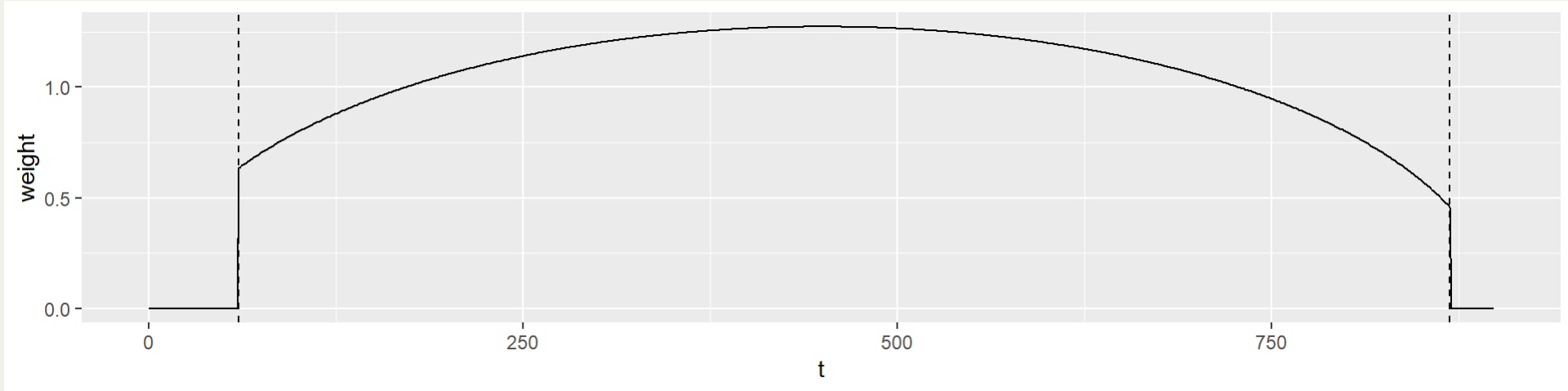
CO₂



N₂O

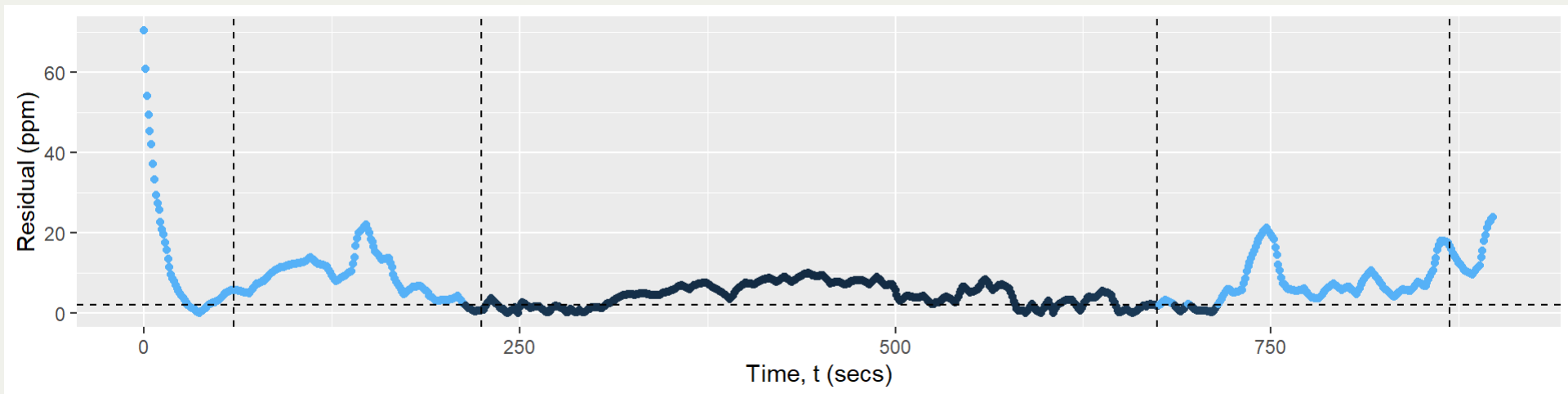
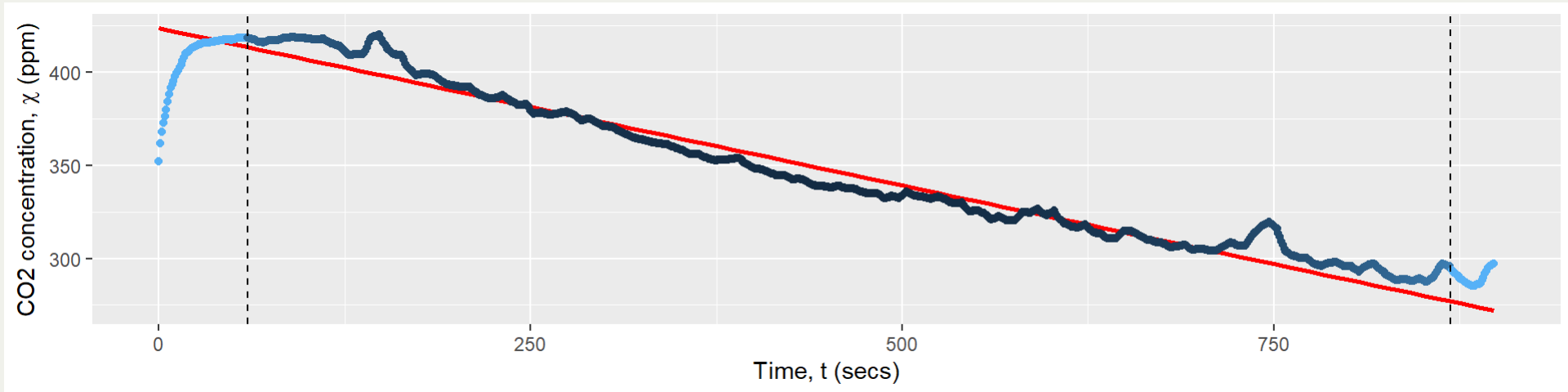


Deadband identification 1



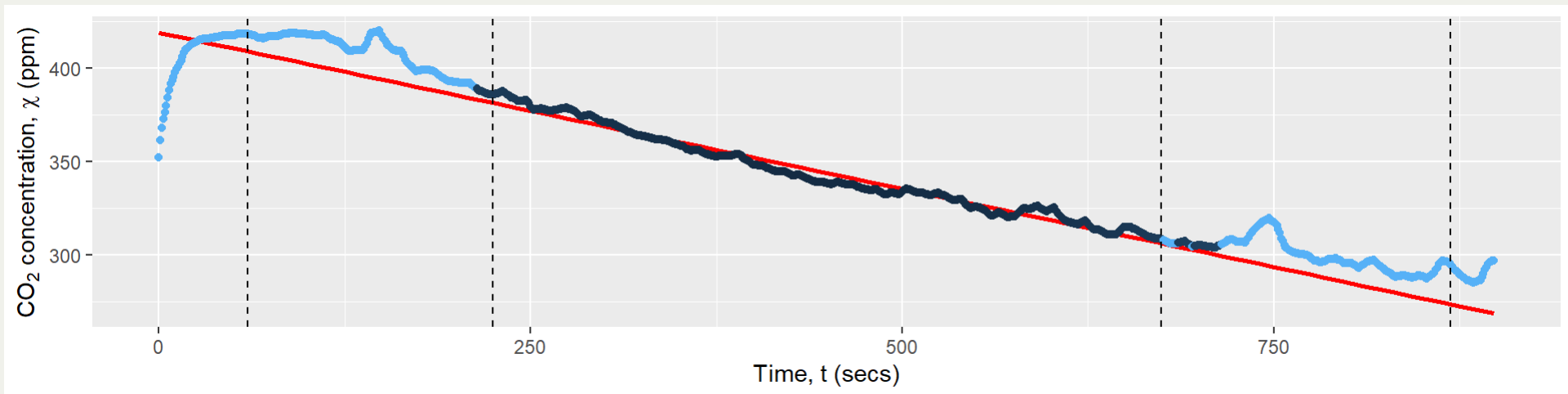
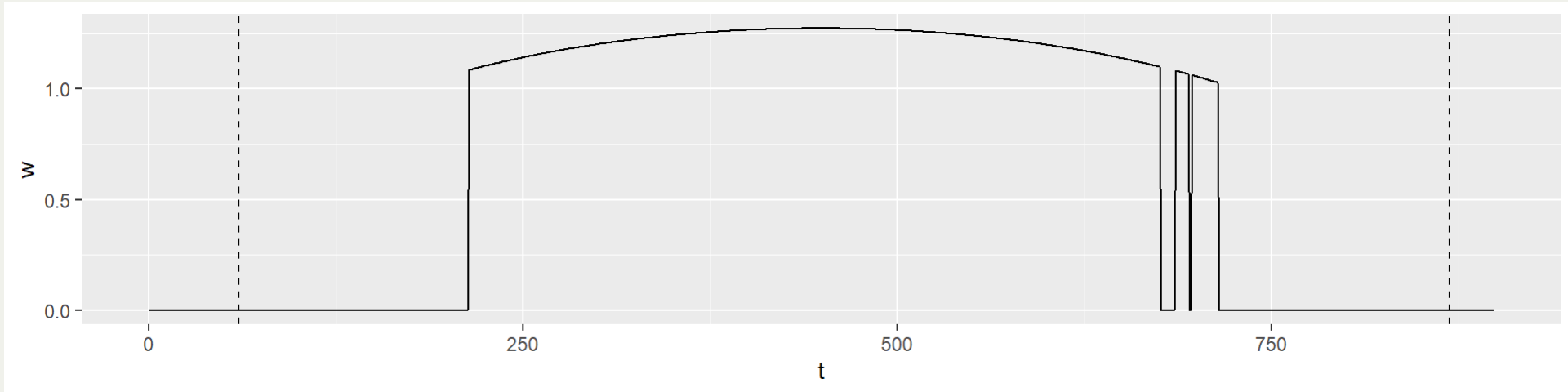
β function provides weights for regression on CO₂

Deadband identification 2



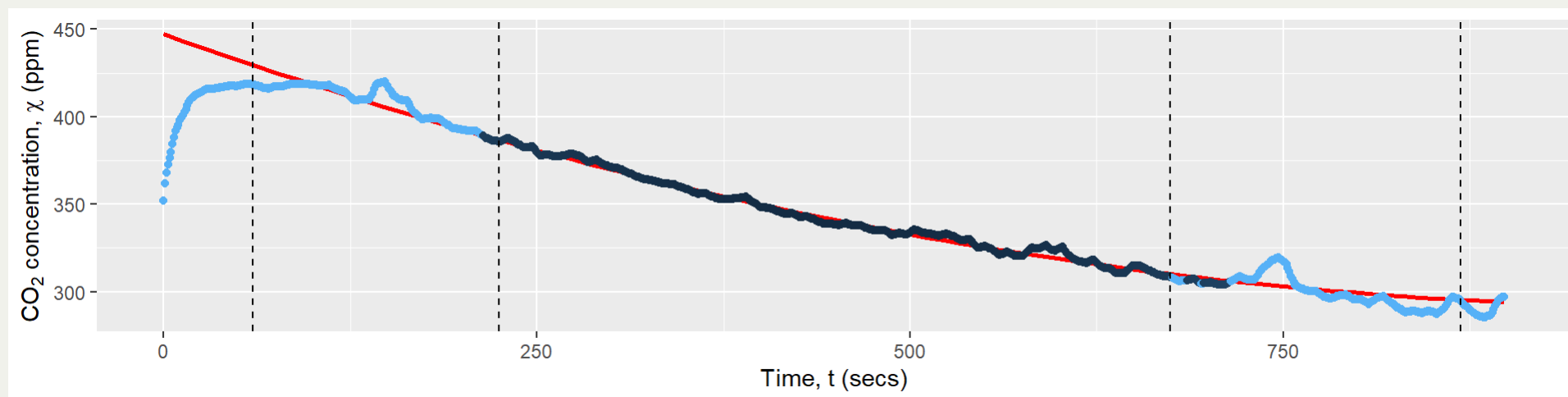
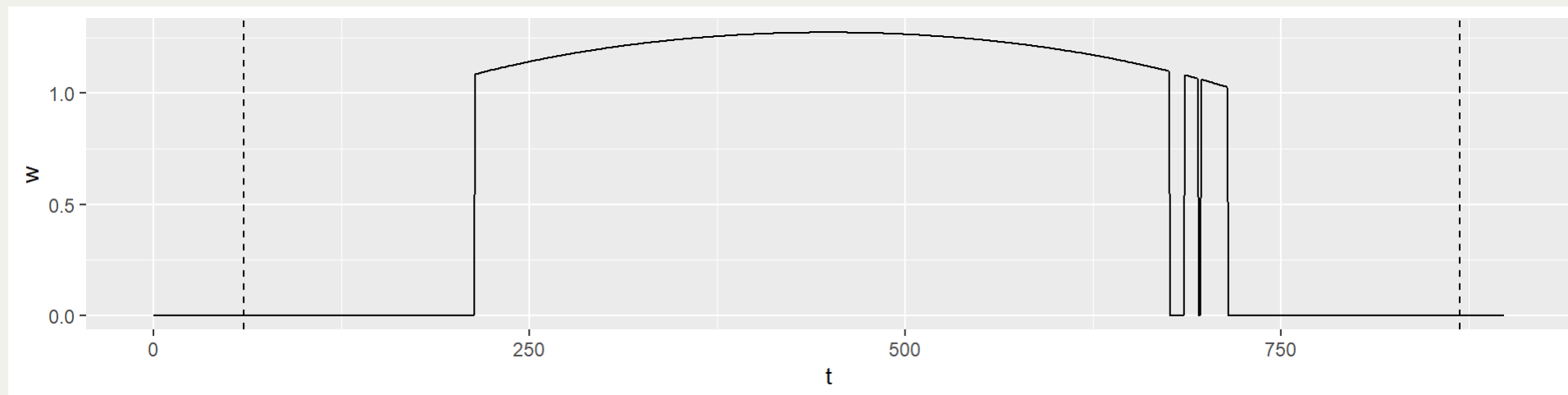
Thresholding on residuals in first & last quarters

Deadband identification 3



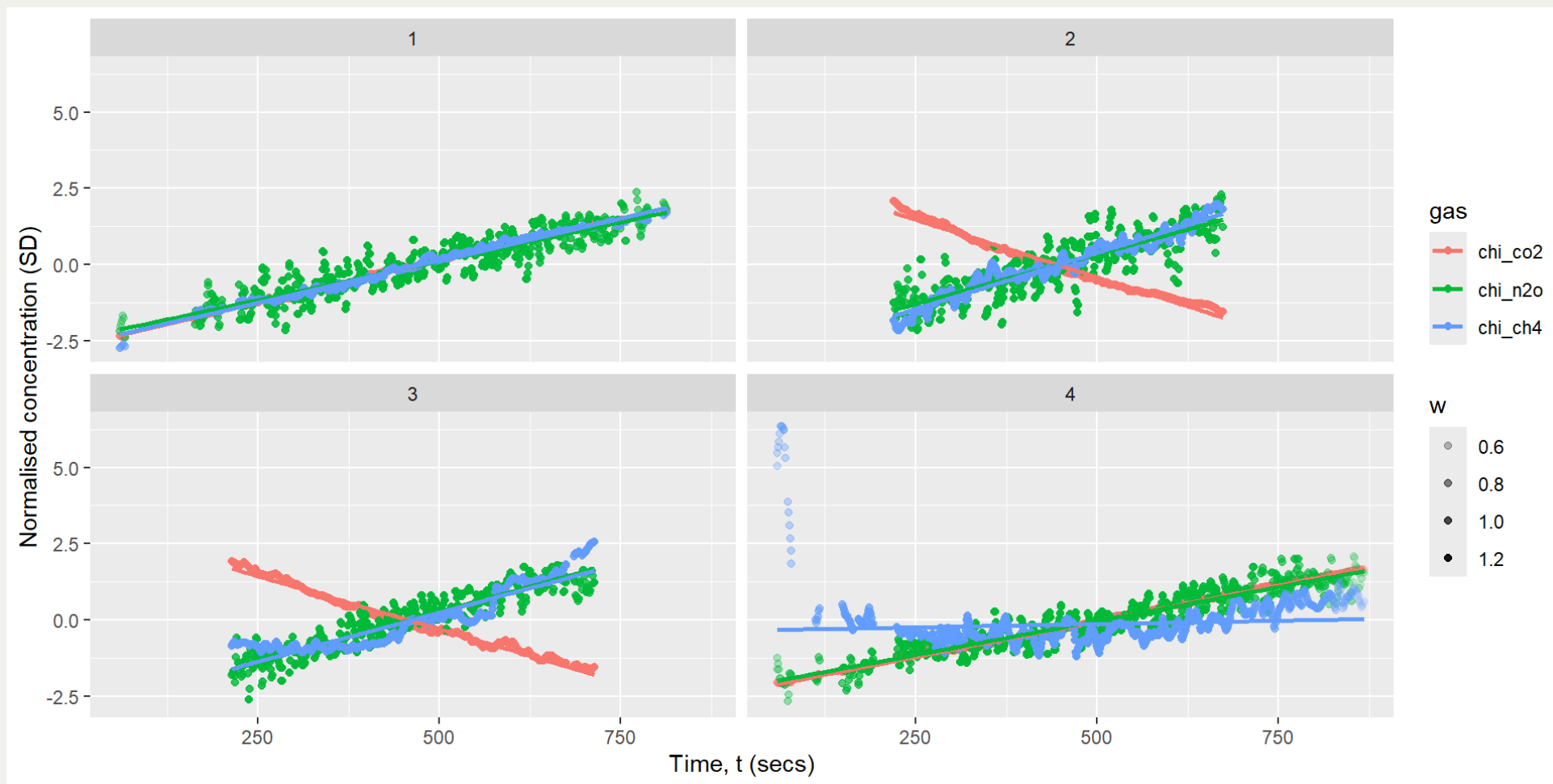
Re-weighted regression on CO₂

Flux calculation 1



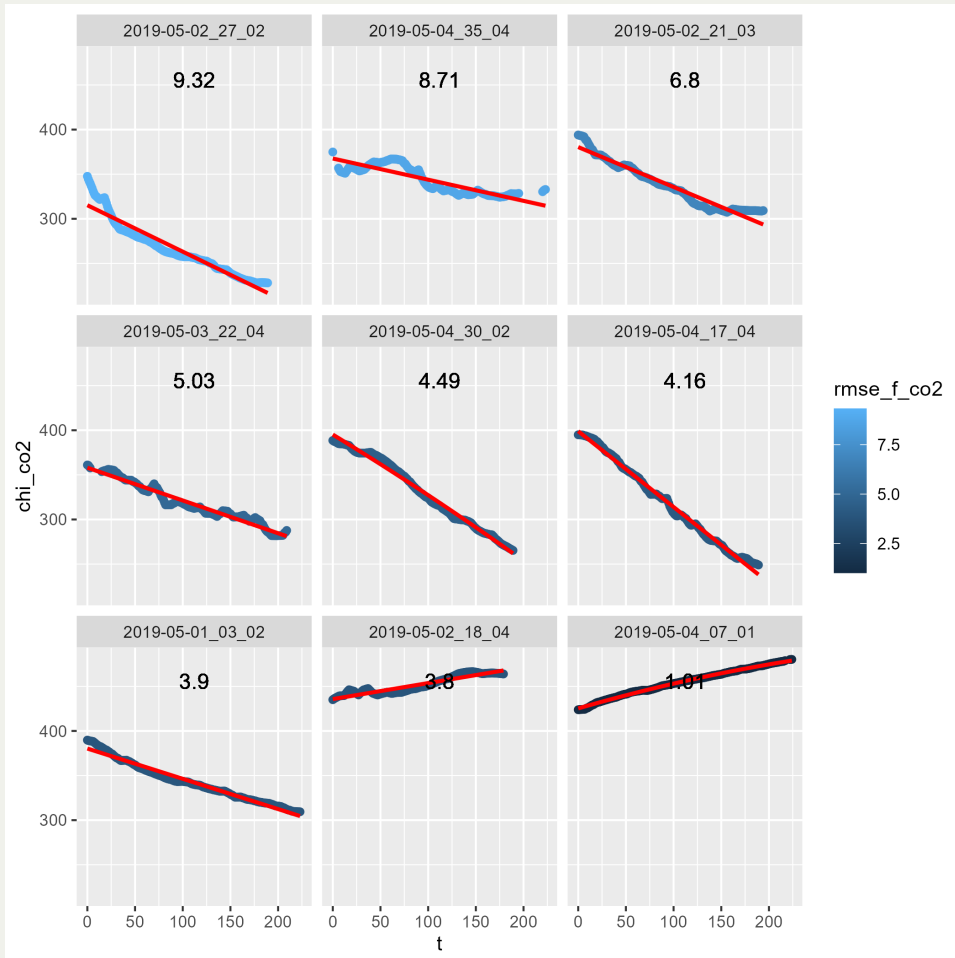
Nonlinear regression on re-weighted data

Flux calculation 2



Same weighting applied to N_2O and CH_4

Quality control



- r^2 not useful
- low flux $\rightarrow$ low r^2
- thresholding on RMSE for CO₂ flux
- exclude N₂O & CH₄ fluxes based on CO₂ RMSE
- or compare with analytical uncertainty:

<https://connect-apps.ceh.ac.uk/chamberuncertaintytool/>

Flux partitioning

Photosynthesis, $P = \alpha\sqrt{Q}$

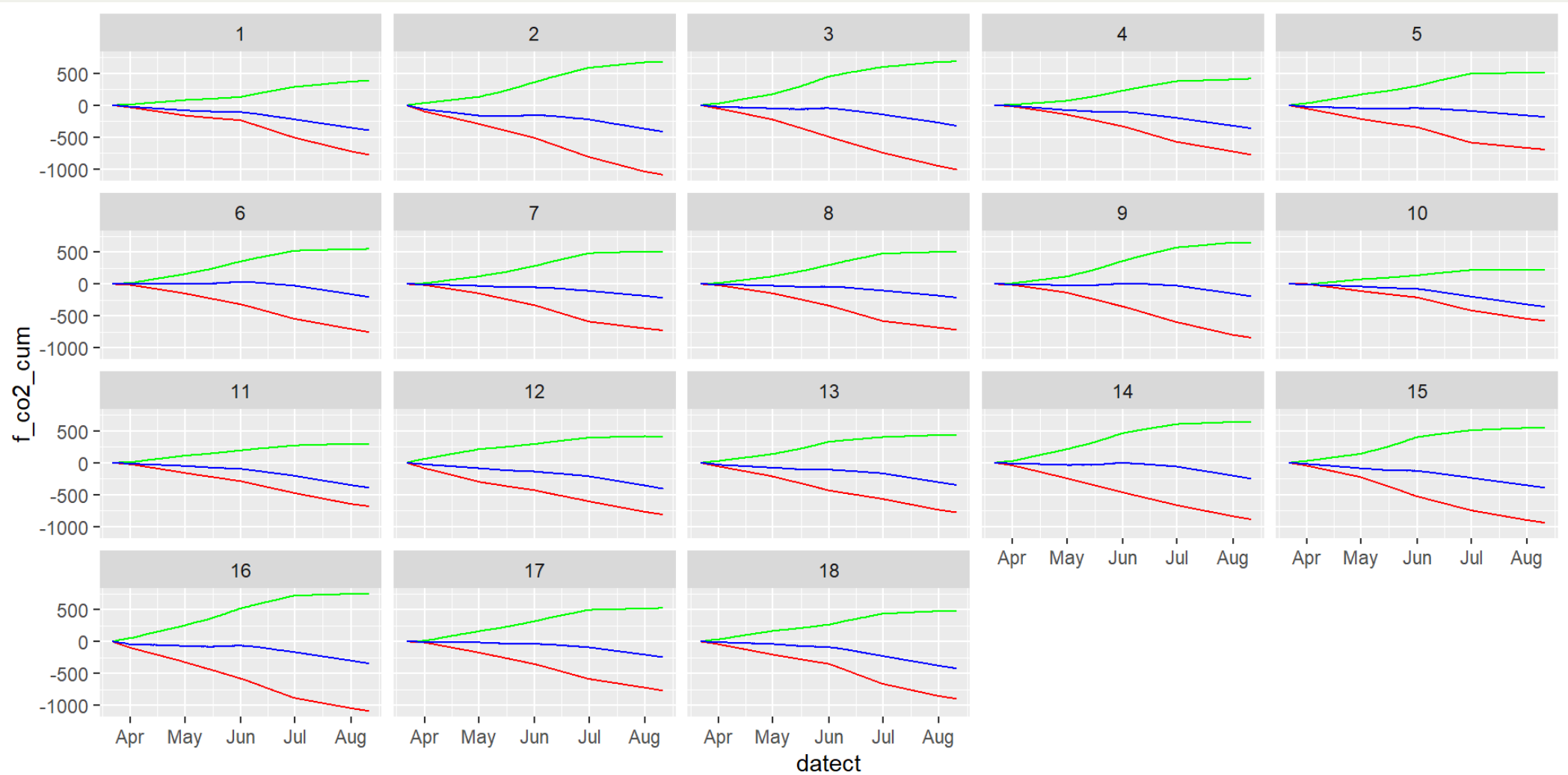
Respiration, $R = R_{10} + k_T\Delta T$

Net flux, $F_{\text{co}_2} = \alpha\sqrt{Q} + R_{10} + k_T\Delta T$

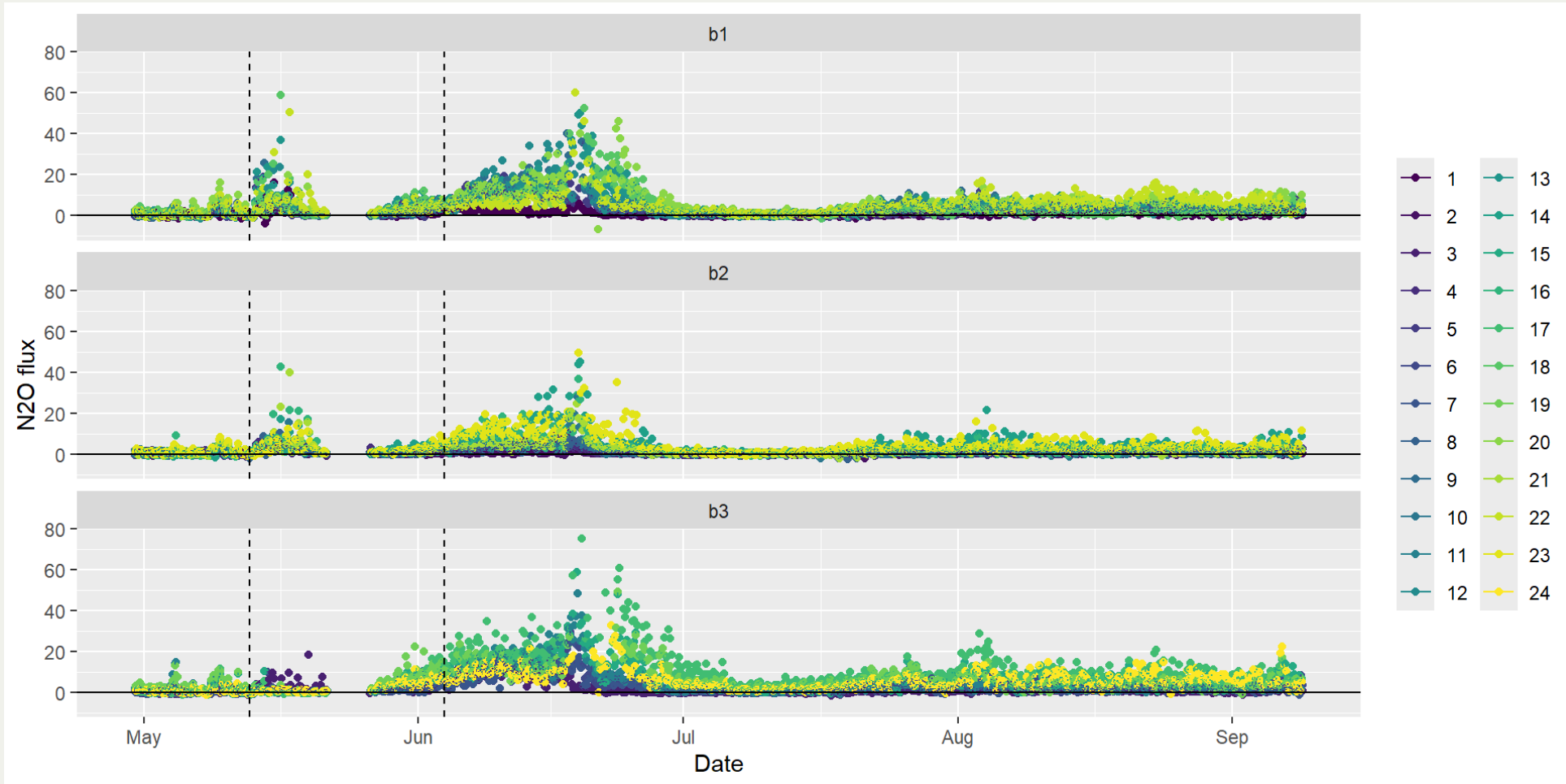
```

1 form <- formula(f_co2 ~ sqrt(PPFD_IN) + dTA)
2 dt[, R_10 := coef(lm(form, data = .SD))[1], by = .(chamber_id, month)]
3 dt[, lue   := coef(lm(form, data = .SD))[2], by = .(chamber_id, month)]
4 dt[, k_T   := coef(lm(form, data = .SD))[3], by = .(chamber_id, month)]
5 dt[, f_co2_pred := lue * sqrt(PPFD_IN) + (R_10 + k_T * dTA)]
6 dt[, P := lue * sqrt(PPFD_IN)]
7 dt[, R := R_10 + k_T * dTA]
```

Flux partitioning

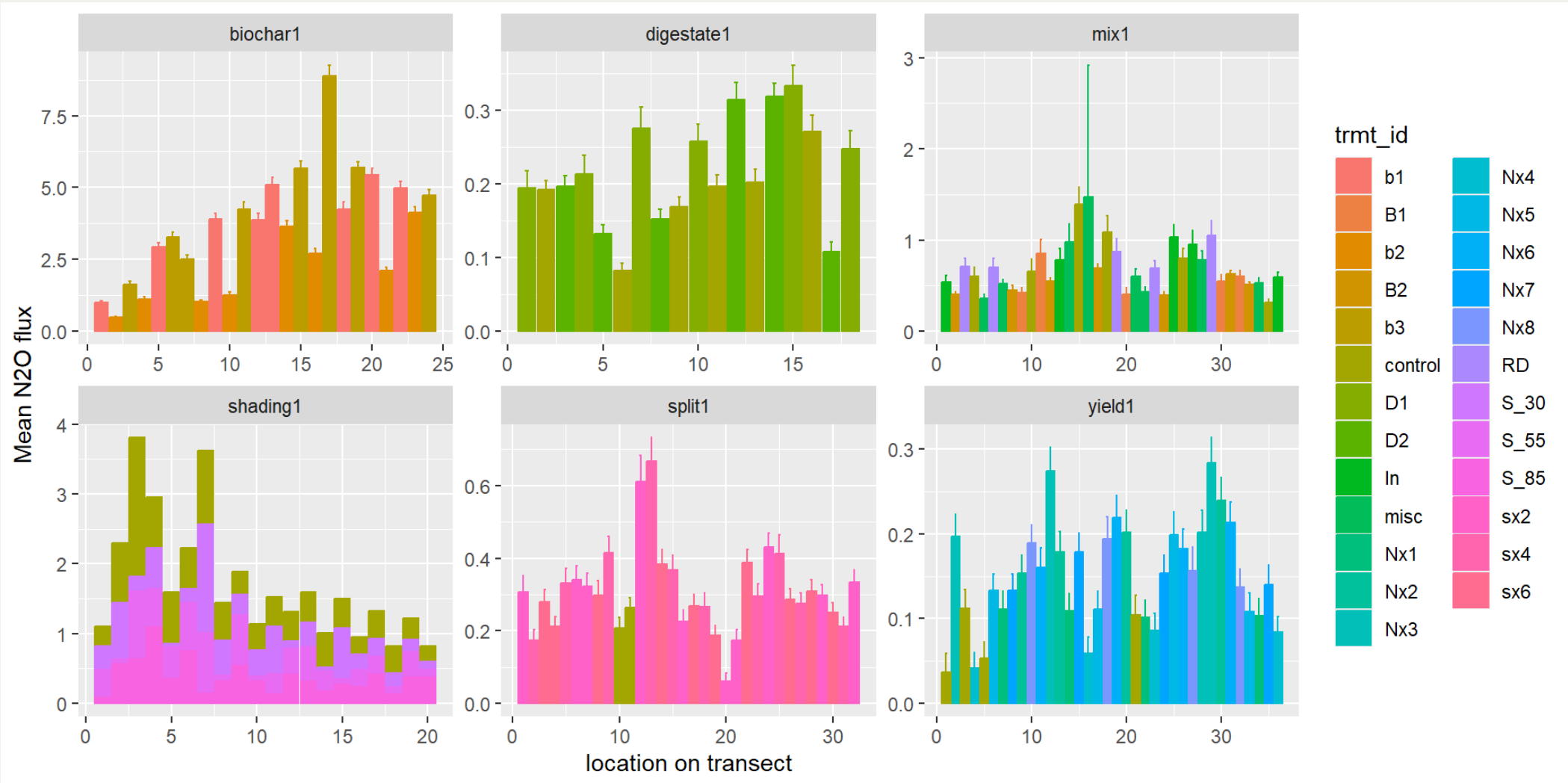


Results

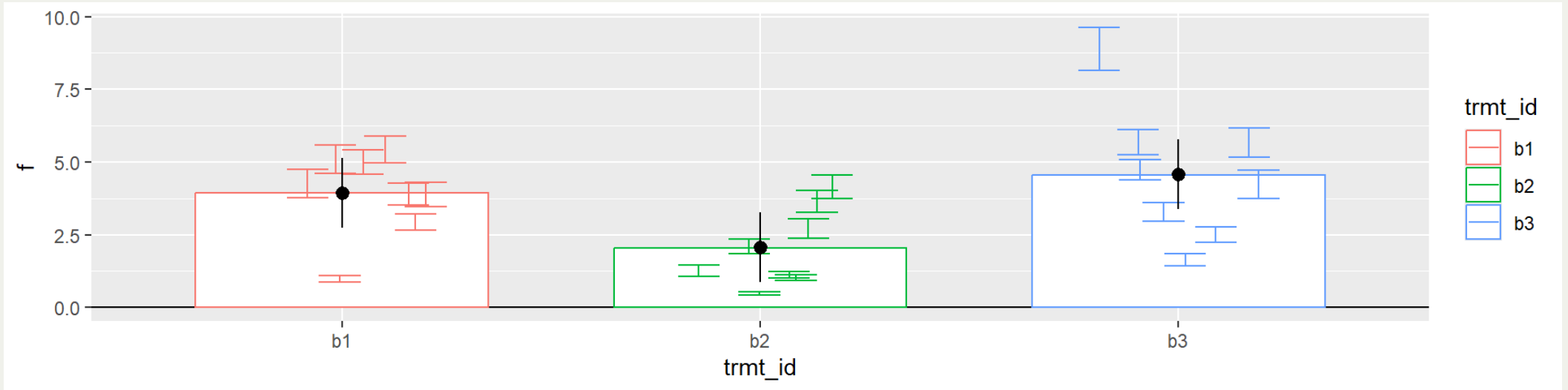


Full growing season time series

Results

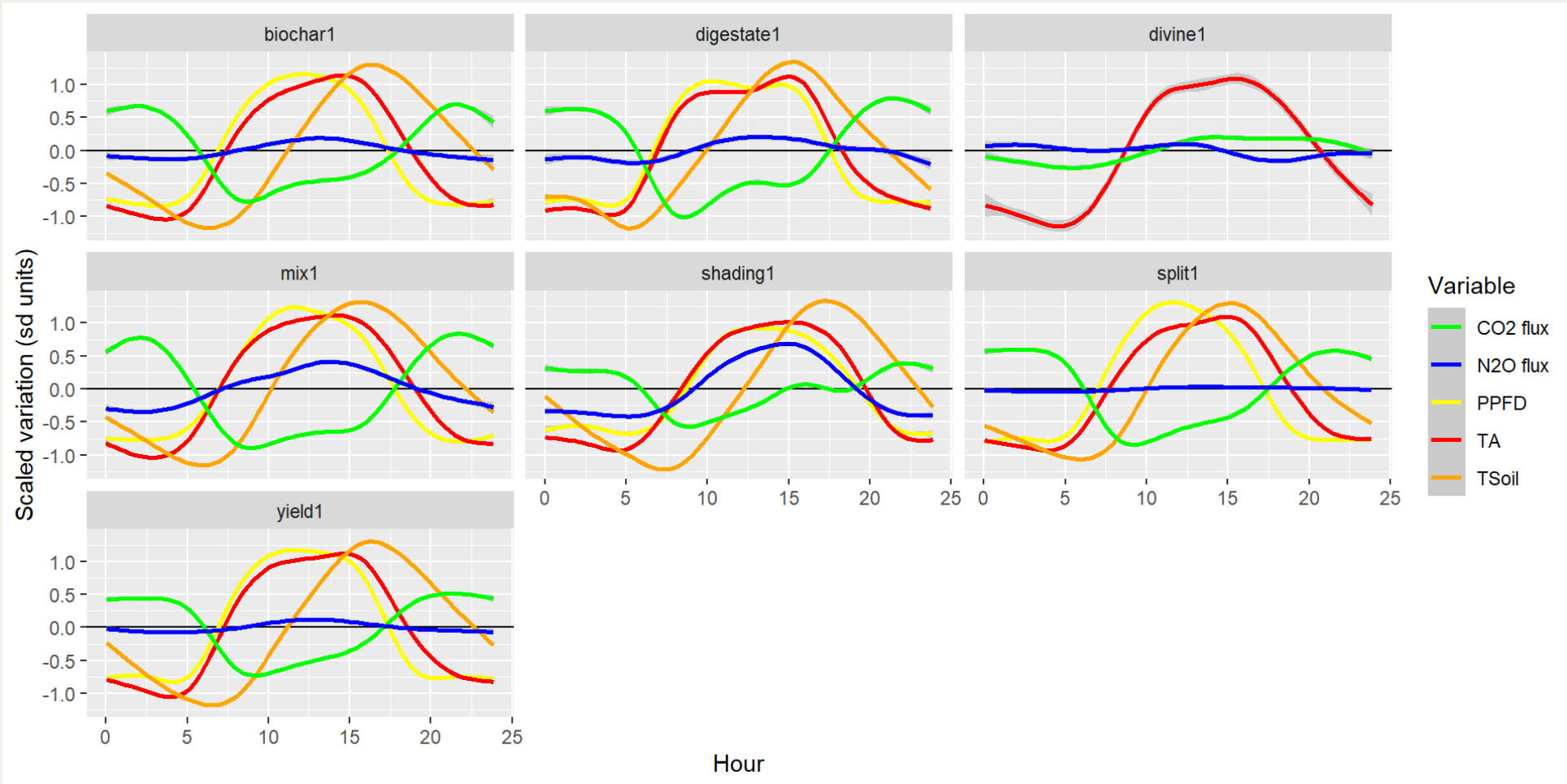


Results



- high spatio-temporal variability
- low statistical power (true positive rate)
- Bayes factor better than p values

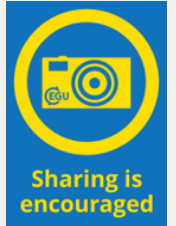
Results



Diurnal cycle in N₂O flux is less than expected

Summary

- skyline R reproducible data pipeline
- handles large data volumes automatically
- adding Bayesian analysis / uncertainty
- extensible to other systems
- available on GitHub for collaboration:
 - <https://github.com/NERC-CEH/skyline>
- contact: plevy@ceh.ac.uk



Analytical uncertainty

European Journal of Soil Science 

METHODS ARTICLE | [Open Access](#) | 

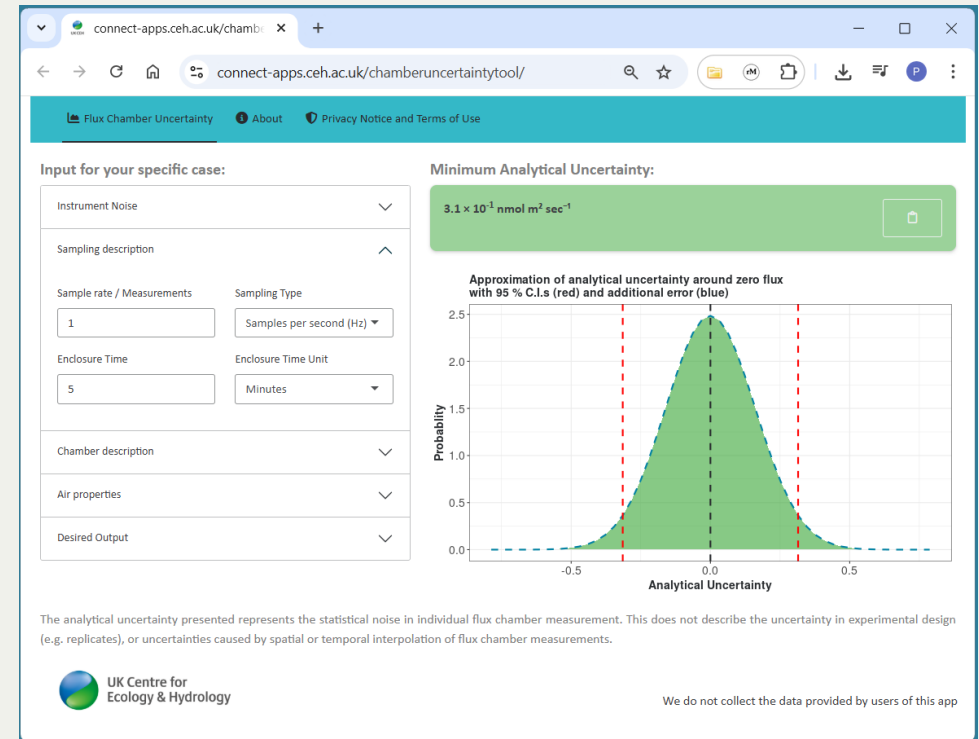
Characterisation of Analytical Uncertainty in Chamber Soil Flux Measurements

Nicholas Cowan  Pete Levy, Maddalena Tigli, Galina Toteva, Julia Drewer

First published: 10 April 2025 | <https://doi.org/10.1111/ejss.70104>

Funding: This work was supported by the NERC National Capability Science: International Award 'Options for Net Zero Plus and Climate Change Adaptation' (Grant Ref: NE/X006247/1).

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<https://doi.org/10.1111/ejss.70104>

<https://connect-apps.ceh.ac.uk/chamberuncertaintytool/>