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Uncertainty of eddy covariance-derived net ecosystem CO_2 exchange over a mountain forest reduced by multiple nighttime filtering approaches, or not?

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FAIR biomet.co.at/fair-site
FWF Österreichischer Wissenschaftsfonds

Study site

FAIR site (Forest-Atmosphere-Interaction-Research)
Fluxnet-ID: AT-Mmg
Tyrol, Austria
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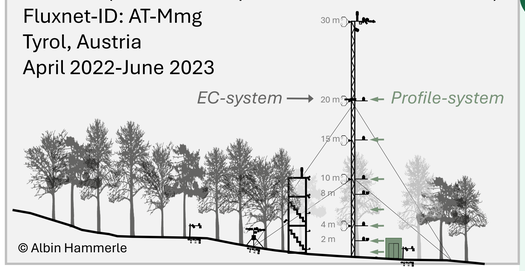


1 Filtering approaches

The general idea is to group observational data into two distinct groups and retain only one group for flux calculations (e.g., the more turbulent one). The resulting gaps are filled by a Random Forest model. We address some established methods alongside a novel machine learning method (*cluster filtering*).

u_*- and σ_w-filtering

Friction velocity (u_*) or the standard deviation of the vertical velocity (σ_w) are used as turbulence measures. Periods when the turbulence measure is below a threshold are rejected.

Ω-filtering

Ω is a physically based decoupling metric (Peltola et al. 2021):

$$\Omega = \frac{\sigma_w}{|w_{e,crit}|},$$

where $w_{e,crit}$ is a critical downward vertical velocity that an air parcel needs to overcome to reach the ground. It depends on height, leaf area index and stability. Low turbulence or high stability leads to high Ω values, suggesting a decoupled flow. Ω can be used for filtering by retaining only coupled periods.

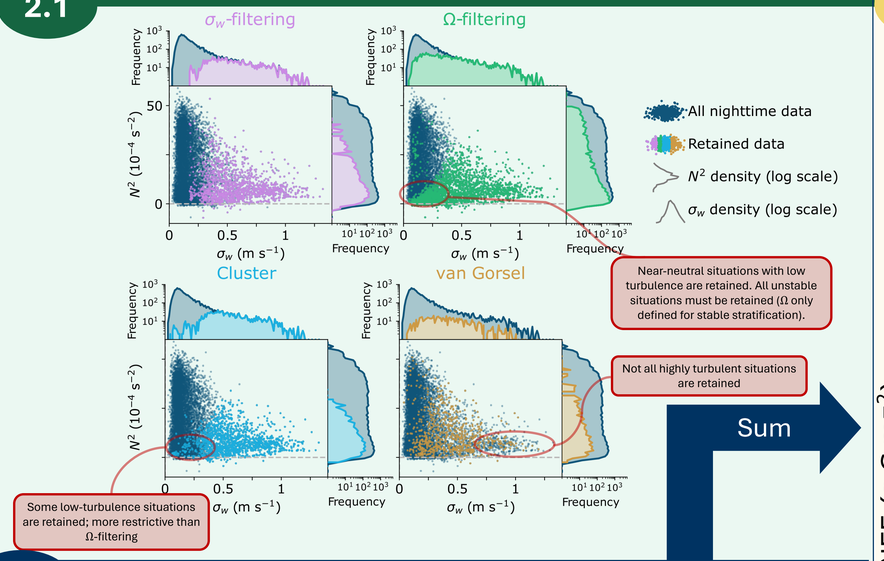
van Gorsel method

Only measurements around the typical distinct maximum in the early evening are retained.

Cluster filtering

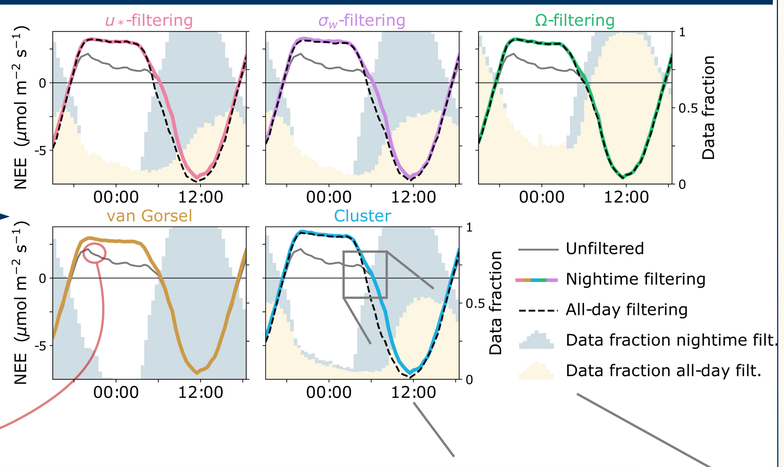
K-means clustering using vertical profiles of σ_w, temperature and wind speed as inputs is used to group observations into several distinct flow situations. Only clusters where we expect that CO_2 flux measurements are a reliable NEE estimate are retained. This is assessed by a changepoint detection (CPD) with σ_w from 20 m and the measured CO_2 flux for each cluster. If no statistically significant changepoints are found, the cluster is retained.

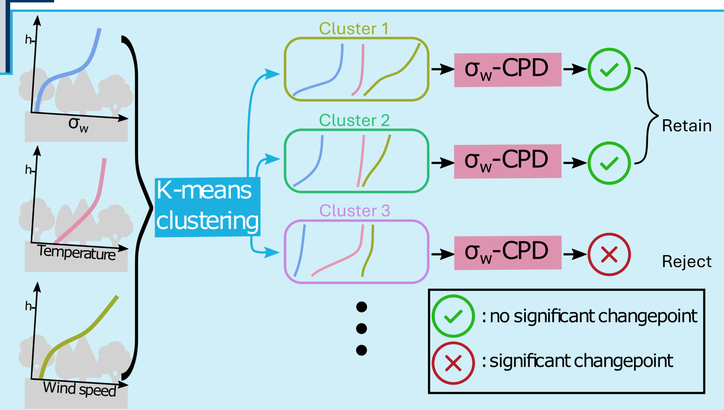
2.1 Which type of data is retained? (Stability & Turbulence)



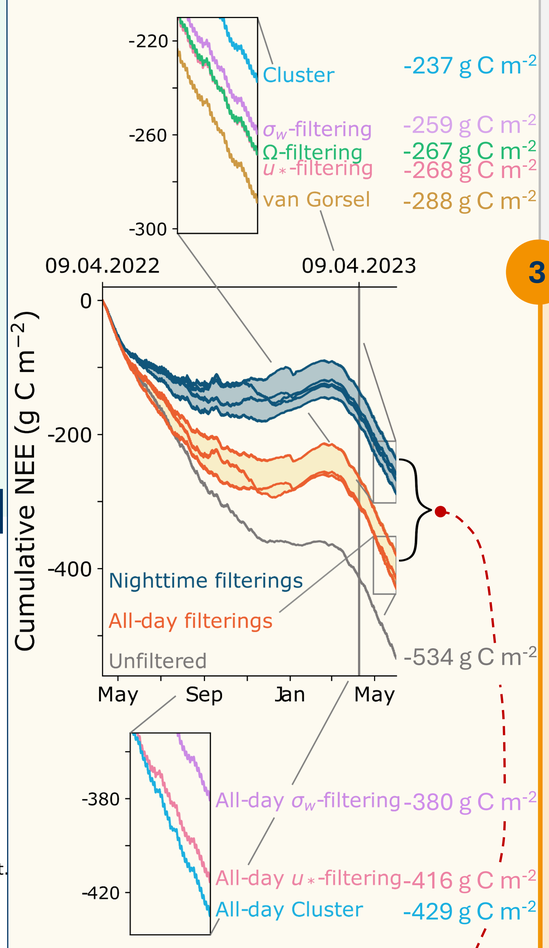
2.2 Mean daily NEE cycles (filtered and gapfilled) & retained data fraction

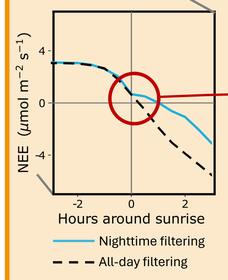
Gapfilling (Random Forest)





2.3 Cumulative Budget





Nighttime or all-day filtering?

It really makes a difference! There is no a priori reason to not filter also for daytime. After sunrise, all-day filtering leads to a more plausible NEE evolution without a step change, as is the case for pure nighttime filtering. If all-day filtering is applied, the van Gorsel method (by design) and Ω-filtering to some extent (as Ω is only defined for stable situations), become less attractive alternatives.

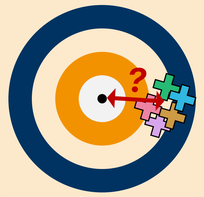
Background

Experimentally, net ecosystem CO_2 exchange (NEE) estimation often relies on eddy covariance measurements. Under stable, low-turbulence nighttime conditions, the measured flux may not be representative of the NEE, as unmeasured fluxes (e.g., advection) can become relevant, leading to an underestimation of nighttime respiration. Measuring three-dimensional advection is very challenging and not realistically feasible for long-term measurements. Consequently, a common practice is to filter out periods when we can expect that the measured flux is an unreliable NEE estimate to avoid a selective systematic error.

3 Conclusions

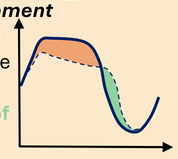
Is uncertainty really reduced?

While we have good agreement (high precision), we cannot assess uncertainty (accuracy) without an independent estimate.



Uncertainty unknown; but good agreement

The different filterings do not only agree on the budget estimates, they also agree on the underestimation of nighttime respiration and the underestimation of morning carbon uptake compared to the unfiltered NEE.



Advantages and limitations of the approaches

u_*- and σ_w: ↑ requires little information
↑ well established
↓ problems during decoupled periods

Ω: ↑ includes stability → can handle decoupled periods
↓ fails for daytime filtering

van Gorsel: ↑ requires no additional measurements
↓ misses turbulent periods in the later night
↓ cannot handle daytime data by design

Cluster: ↑ can use an unlimited number of input variables
↑ can be easily extended to daytime
↓ needs more testing for different sites
↓ improvements in cluster number selection and cluster evaluation needed

What next?

- Improve process understanding (e.g., via observational campaigns combined with high-resolution numerical modeling)
- Compare eddy covariance-derived estimates with those obtained from biometric approaches

References

Peltola, O., Lapo, K., Thomas, C.K., 2021. A Physics-Based Universal Indicator for Vertical Decoupling and Mixing Across Canopies Architectures and Dynamic Stabilities. Geophys. Res. Lett. 48. doi:10.1029/2020GL091615.

van Gorsel, E., Leuning, R., Cleugh, H.A., Keith, H., Suni, T., 2007. Nocturnal carbon efflux: Reconciliation of eddy covariance and chamber measurements using an alternative to the u*-threshold filtering technique. Tellus B 59, 397. doi:10.1111/j.1600-0889.2007.00252.x.