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Uncertainty of eddy covariance-derived net ecosystem CO_2 exchange over a mountain forest reduced by multiple nighttime filtering approaches

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The assessment of net ecosystem CO_2 exchange often relies on eddy covariance systems. However, this method overlooks CO_2 advection, even if it is often non-negligible. This is especially the case under stable, low-turbulence nighttime conditions. Hence, there is a need to filter nighttime eddy covariance data for periods when advection can be expected to be non-negligible. This study evaluates both well-established and novel filtering methods at a mountain forest site in Tyrol, Austria (Forest-Atmosphere-Interaction-Research (FAIR) site, AT-Mmg). Established methods, including friction velocity (u_*) filtering, its counterpart using the standard deviation of vertical velocity fluctuations (σ_w) and an after-sunset flux maxima approach (commonly referred to as *van Gorsel method*) are applied. Additionally we use a more recent approach with a physically-derived measure of flow decoupling for filtering. With this method also stability information is taken into account, not only a turbulence scale, as in the commonly used u_* filtering. As often seen in literature, the uncorrected CO_2 flux underestimates the nighttime respiration, as it appears for all the filtering methods. Despite being based on widely differing assumptions, the various filtering approaches yielded relatively similar carbon budget estimates over 14 months of measurements (-252 to -290 g C/m^2). in contrast to the uncorrected budget of -521 g C/m$^{2.}$

Furthermore, we introduce a novel K-means clustering approach that groups flow situations into clusters based on vertical profiles of temperature, σ_w and wind speed. These clusters need then to be evaluated to determine whether they represent a flow situation in which CO_2 advection is expected to be irrelevant. Such scenarios are often Foehn periods or early-night situations with high turbulence and low stability. This approach is relatively straightforward to implement, works with an unlimited number of input variables and has the advantage that the identified periods are easy to interpret. This method results in a 14-month budget of -232 g C/m^2 for our study site.

The universality of the clustering method allows not only for an unlimited number of input variables, it can be also easily extended for the entire day. There is no a priori reason not to filter eddy covariance data during the daytime when low-turbulence situations with persistent in-canopy flows may lead to non-negligible advection, especially in complex terrain. We made an attempt of daytime filtering in this study with the clustering method, but also with some adapted

versions of the benchmark methods. All of these daytime filtering methods suggest that there is an underestimation of the CO_2 uptake in the morning for the uncorrected measurements. Filtering for both nighttime and daytime leads to a range of 14-month budgets of -451 to -359 g C/m^2.

Further analysis, incorporating different established sites, direct advection measurements or numerical simulations, could be used in future to explore the full potential of the novel clustering approach, especially with its application to daytime flux data.