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Eddy covariance carbonyl sulfide flux measurements with a quantum cascade laser absorption spectrometer

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Background: Eddy covariance (EC) carbonyl sulfide (COS) flux measurements have been suggested as a novel way of estimating ecosystem gross primary productivity. While an increasing number of publications report EC COS flux measurements using quantum cascade laser absorption spectrometers (QCLAS), a thorough analysis of the limitations and required corrections for these systems has not yet been conducted.

The **objective** of this study is to critically examine and validate the performance of a QCLAS commonly used to quantify COS fluxes.

Fig. 1: FLUXNET site Neustift (AT-Neu).

Study site and methods: EC flux measurements (Gill R3IA sonic anemometer and Aerodyne miniQCL) were conducted at the FLUXNET site Neustift (AT-Neu), a managed temperate mountain grassland in Austria, during 2015.

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I: Laser absorption spectrometers are known to be affected by laser drift, which causes an overestimation of the EC and needs to be removed. We used Allan variance plots for quantifying laser drift and for selecting a suitable time constant (ca. 50 s) for a recursive high-pass filter in order to correct for laser drift.

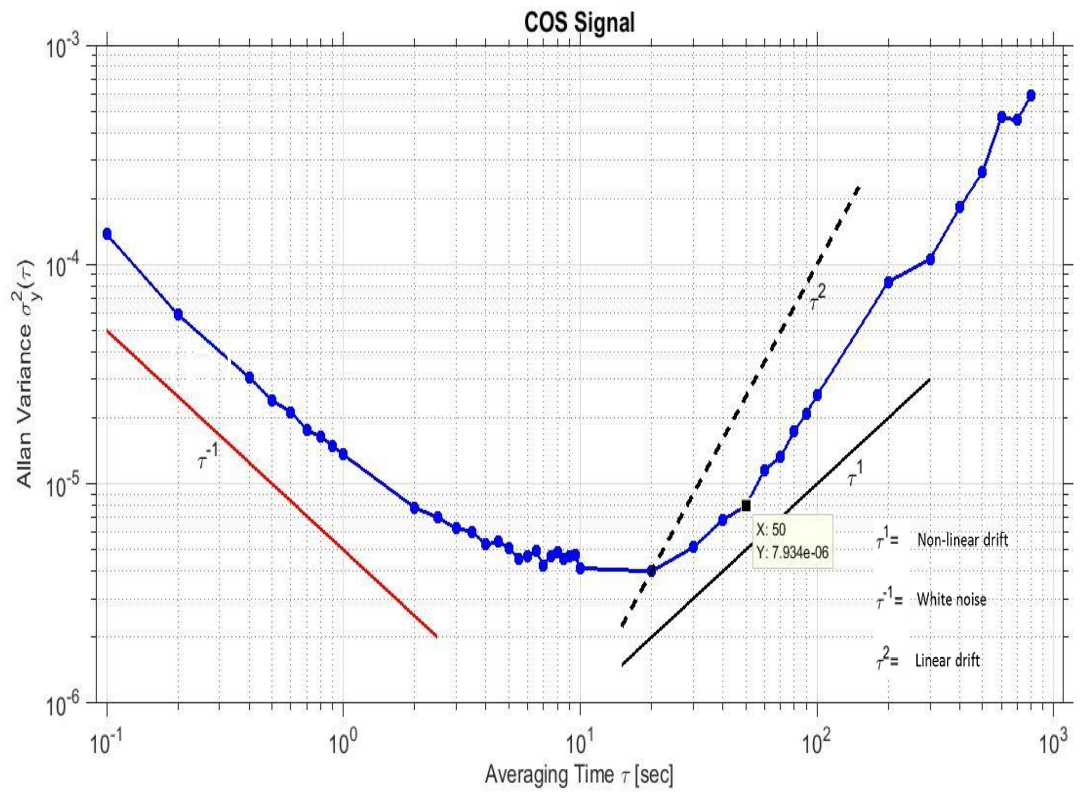

Fig. 2: Example Allan variance plot for COS. The time series was obtained under ambient conditions in the instrument hut in the field by feeding pressurized air from a cylinder to the QCLAS.

The system is dominated by white noise up to 11 s and starts to drift in an approx. linear fashion at around 50 s.

II: Cospectral and spectral analyses showed low-pass filtering (mainly related to tube attenuation and QCLAS time response) in the x-y frequency range, followed by an increase in cospectral power due to QCLAS instrument noise. We thus decided to filter for QCLAS noise using a low-pass finite-response (FIR) filter and back-corrected for this filter and the general low-pass filtering by adopting a transfer function approach from Aubinet et al. (2001).

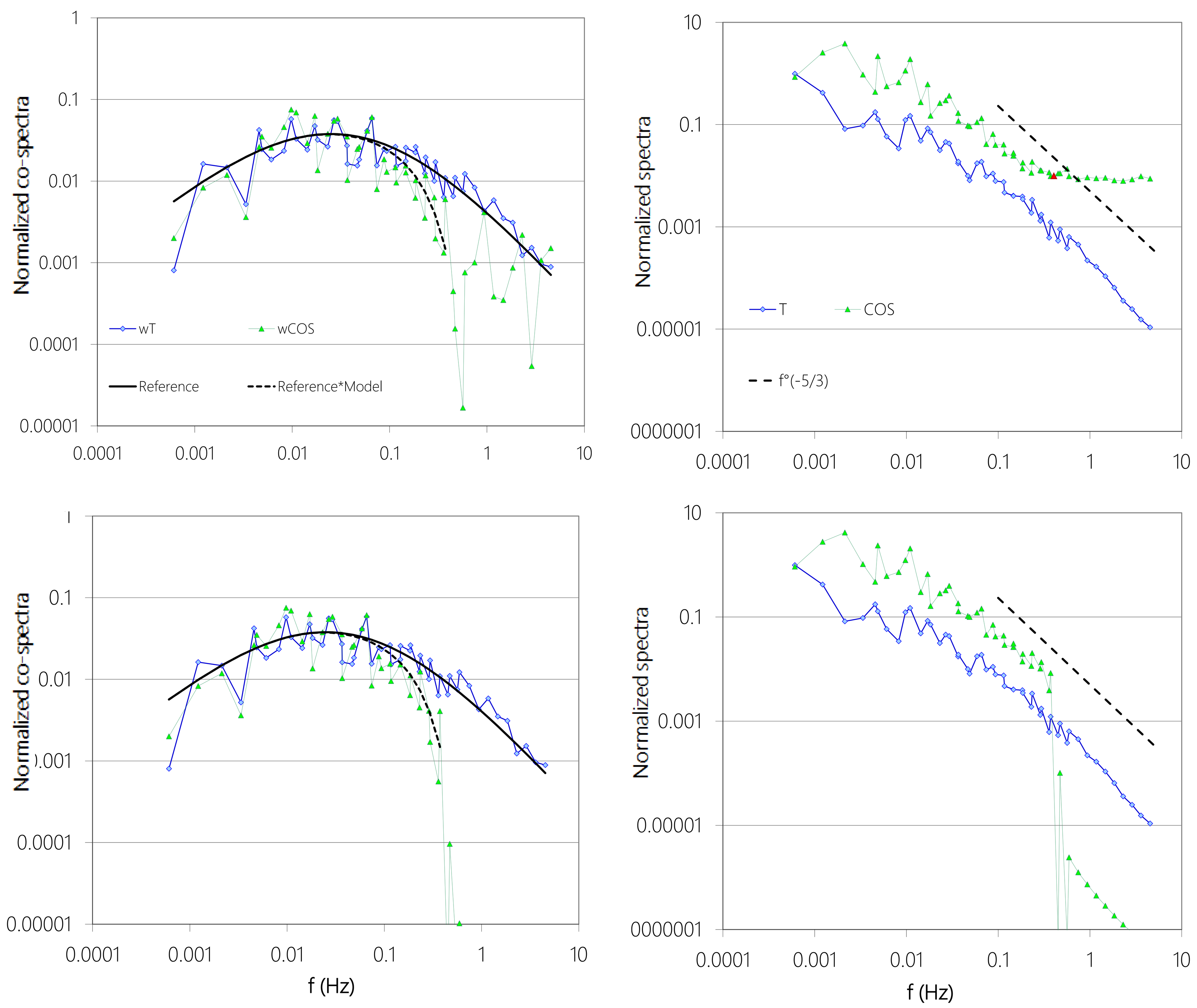

Fig. 3: Co-spectra (left panels) and power spectra (right panels) before (upper panels) and after (lower panels) application of the FIR filter. The onset of QCLAS noise is indicated by a red triangle. Solid and dashed lines in the cospectral plots indicate the reference model and the attenuated reference model, the integrated ratio of which yields the low-pass filtering correction factor (x in this case).

III: An independent validation of entire post-processing chain was provided by comparison to CO_2 (and H_2O – not shown) eddy covariance fluxes measured routinely at the study site, since the QCLAS also quantifies these two compounds. The lowest systematic bias, mean absolute error and highest fraction of explained variance was obtained for fluxes calculated by linear detrending.

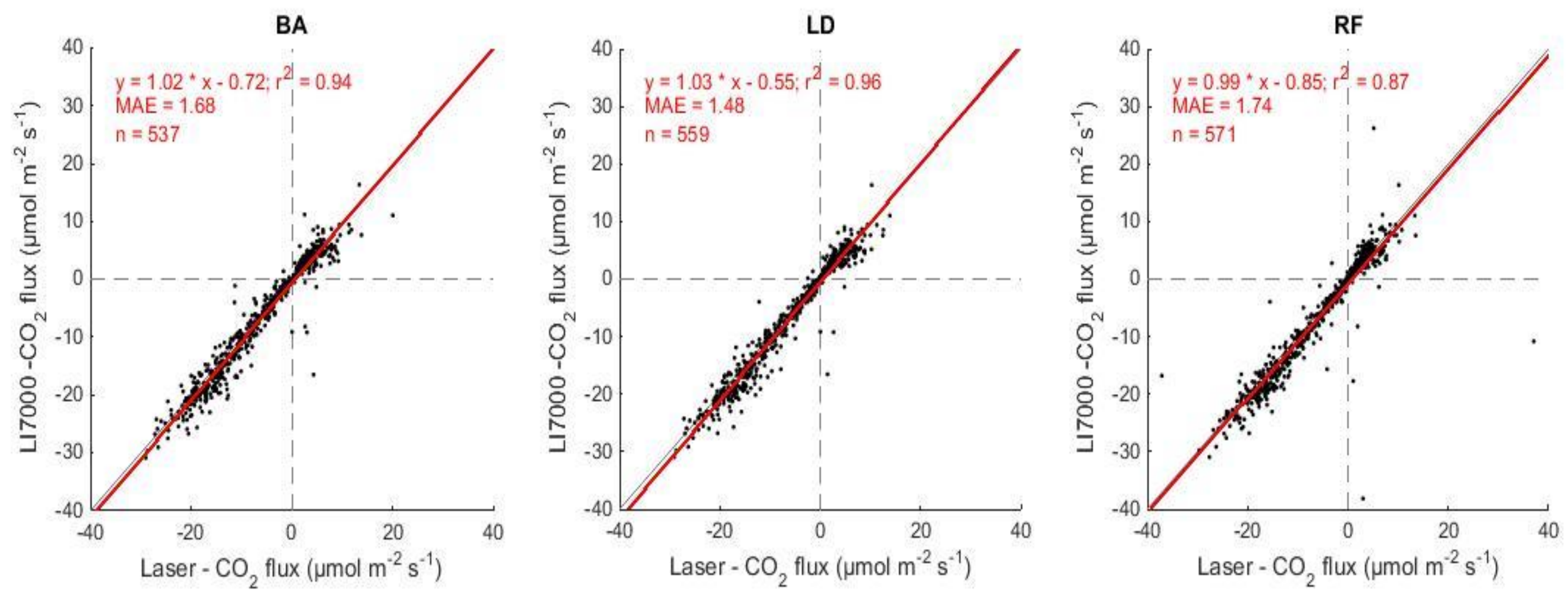

Fig. 4: Correlation between IRGA (Li-7000) and QCLAS CO_2 fluxes using block averaging (left panel), linear detrending (middle panel) and a recursive filter with a 50 s time constant (right panel).

Summary and conclusions:

- A commonly used QCLAS for COS eddy covariance flux measurements was shown to be affected by laser drift, low-pass filtering and high-frequency noise.
- Approaches to deal with these problems were developed and tested.
- An independent validation for CO_2 fluxes suggest that our post-processing chain produces unbiased flux estimates.
- We conclude that, provided the appropriate corrections are made, the employed QCLAS can be used for defensible COS flux measurements.

Reference: Aubinet et al. (2001). Long term carbon dioxide exchange above a mixed forest in the Belgian Ardennes. Agricultural and Forest Meteorology 108, 293-315.