Unexpected sensitivity of the annual net ecosystem exchange to the high frequency loss corrections in a grazed grassland site in Belgium

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Objective & Strategy

The impact of the reference cospectrum choice on the annual carbon balance was investigated at the Dorinne Terrestrial Observatory (DTO). To reach this goal, we:

- **Compare** three high frequency loss correction approaches of CO2 fluxes, all based on the Monin-Obukhov similarity;
- **Evaluate** them by comparing the nighttime eddy covariance (EC) fluxes, corrected with each approach, with fluxes measured from a 4-month period of soil/grass respiration measurement campaigns at the DTO;
- **Quantify** the impact of the correction approaches on the annual carbon balance by using 4 years of EC measurements.

The Dorinne Terrestrial Observatory

- An intensively grazed experimental grassland site in Belgium;
- EC fluxes measured with a closed-path CO2/H2O gas analyzer IRGA (LI-7000) and a sonic anemometer (CSAT3) at rate of 10 Hz since 2010;
- Soil/grass respiration measured with a dynamic closed soil chamber (Fig. 1).

Method

1st step : Computation of correction factors

- The general procedure is illustrated in Fig. 2;
- The correction factor was computed as (eq. 1) for each 30 min data:

  \[ \phi = \int_0^\infty C_{WS}(f) \delta(f) df \]

  (1)

  - \( C_{WS}(f) \) is the undamped cospectra density which can be either the sensible heat cospectra (Local correction factor, \( \Phi_S \)) or the Kaimal cospectra (K1 and K2 correction factors, \( \Phi_{K1} \) and \( \Phi_{K2} \) respectively);
  - \( \delta(f) \) is the transfer function of the EC system calculated as the normalized ratio of CO2 and the sensible heat cospectra densities. A nonlinear Lorentzian equation (eq. 2) was then fitted on this ratio to estimate the cut-off frequency (\( f_c \)).

  \[ \delta(f) = 1 / \left(1 + (f/f_c)^2 \right) \]

  (2)

2nd step : Validation of the correction approaches

- Calculation of the total chamber based TER estimates (\( R_{EC} \)) by summing soil/grass respiration and the averaged cattle respiration estimated as 1.02 (\( \mu \)mol m\(^{-2}\) s\(^{-1}\);
- Statistical analysis based on the comparison of the nighttime EC fluxes (corrected with the local approach (\( R_{LS} \)) and both Kaimal approaches (\( R_{SK1} \) and \( R_{SK2} \))) and the total chamber based respiration measurements (\( R_{EC} \)) ;
- Selection of the most realistic approach to correct the high frequency losses of CO2 fluxes from this comparison.

Results & Discussion

Shape of the cospectrum

- The average flux difference between L and K1 or L and K2 amounted to 412 and 209 g C m\(^{-2}\) y\(^{-1}\) for GPP (Fig. 5a), 562 and 280 g C m\(^{-2}\) y\(^{-1}\) for TER (Fig. 5b) and 150 and 71 g C m\(^{-2}\) y\(^{-1}\) for NEE (Fig. 5c);
- The relative differences ranged from 9% to 19% (GPP) and 14 to 27% (TER) between L and K1 and between L and K2, respectively;
- The choice of reference cospectrum change the site from being a net C sink to being a weak net C source (Fig. 5c).

Evaluation of the correction procedure

- In the common temperature range, the average total chamber – based TER (\( R_{EC} \)) was closer to the EC fluxes corrected using the local approach (\( R_{LS} \)) than to the others (Fig. 4);
- The normalized differences (\( H_{LS} \)) between \( R_{LS} \) and \( R_{EC} \) are not significant (p > 0.05) while they are highly significant (p < 0.001) for \( R_{SK1} \) and \( R_{SK2} \) (Table 1);
- This suggested clearly that the local approach gave compatible estimates.

Main findings & Recommendation

- The shape of the measured cospectra differed from the theoretical prediction, although the site could not be considered ‘difficult’ (in the sense used by Finnigan, 2008);
- The choice of the reference cospectrum was found to affect significantly, both nighttime and daytime fluxes CO2 fluxes;
- The choice of Kaimal cospectra reversed the CO2 balance from a C sink to a C source;
- We finally encourage site PIs to check the cospectrum shape at their sites and, if necessary, compute frequency correction factors on the basis of local cospectra rather than on Kaimal cospectra.

References

- Mamadou, O., Gourlez de la Motte, L., De Ligne, A., Heinrich, B., Aubinet, M. Unexpected sensitivity of the annual net ecosystem exchange to the high frequency loss corrections in a grazed grassland site in Belgium. (in review in Agric. For. Meteorol.)

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