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

Ossénatou MAMADOU[1,2*], Louis GOURLEZ De La MOTTE[1], Anne De LIGNE[1], Bernard HEINESCH[1] & Marc AUBINET[1]

[1]University of Liège – Gembloux Agro-Bio Tech, TERRA, Ecosystems – Atmosphere Exchanges, Gembloux, Belgium.

[2]University of Porto-Novo, Institute of Mathematics and Physical Sciences, Porto-Novo, Bénin.

*ossenatou.mamadou@gmail.com

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 CO_2 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 CO_2/H_2O 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).

Fig. 1: The EMG-4 CO_2 gas analyzer

Method

1rst 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 ;

$$\phi = \frac{\int_0^\infty C_{ws}(f)\,df}{\int_0^\infty C_{ws}(f)\,\delta(f)\,df} \qquad (1)$$

- where $C_{ws}(f)$ is the undamped cospectral density which can be either the sensible heat cospectra (**Local correction factor, Φ_L**) or the Kaimal cospectra (**K1 and K2 correction factors, Φ_{K1} Φ_{K2}** respectively);
- $\delta(f)$ is the transfer function of the EC system calculated as the normalized ratio of CO_2 and the sensible heat cospectral densities. A nonlinear Lorentzian equation (eq. 2) was then fitted on this ratio to estimate the cut-off frequency (f_{co}).

$$\delta(f) = 1 / (1 + (f/f_{co})^2) \qquad (2)$$

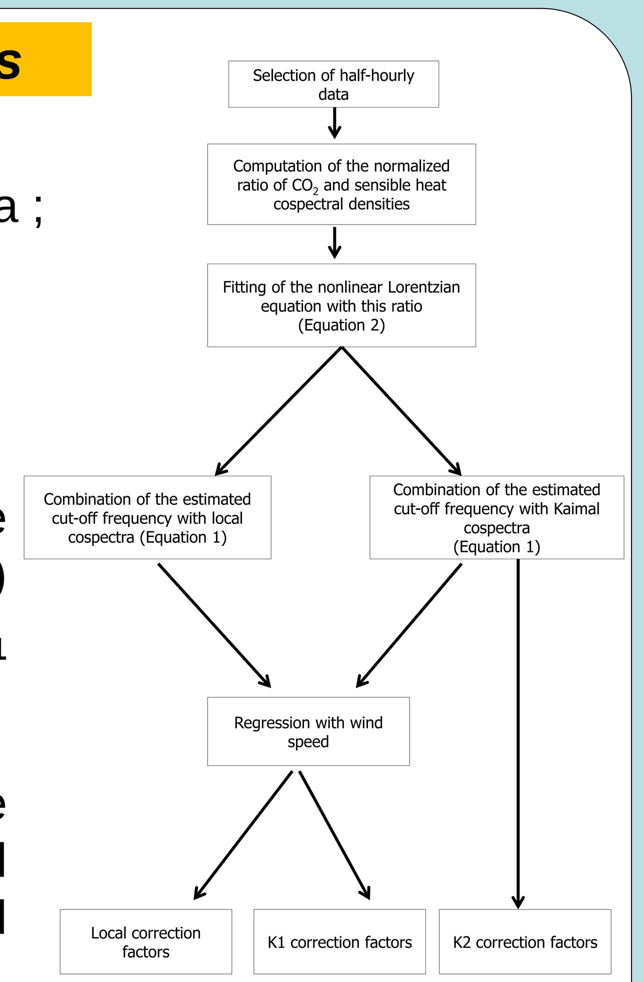

Fig. 2: Diagram of the three correction approaches developed at the Dorinne Terrestrial Observatory.

2nd step : Validation of the correction approaches

♦ Calculation of the **total chamber based TER estimates (R_{ST})** by summing **soil/grass respiration** and the **averaged cattle respiration** estimated as 1.02 µmol m^{-2} s^{-1};

♦ Statistical analysis based on the comparison of the nighttime EC fluxes (*corrected with the local approach (R_{SL}) and both Kaimal approaches (R_{SK1} , R_{SK2})*) and the total chamber based respiration measurements (R_{ST}) ;

♦ Selection of the most realistic approach to correct the high frequency losses of CO_2 fluxes from this comparison.

Results & Discussion

Shape of the cospectrum

→ The shape of the Kaimal cospectra was **more peaked in the inertial subrange** than the measured sensible heat cospectra whatever the stability conditions (Fig. 3) ;

→ By considering a transfer function with the estimated cut-off frequency (0.37±0.05 Hz), the deviation reached 9% in average between Φ_{K1} and Φ_L, and 16% between Φ_{K1} and Φ_L.

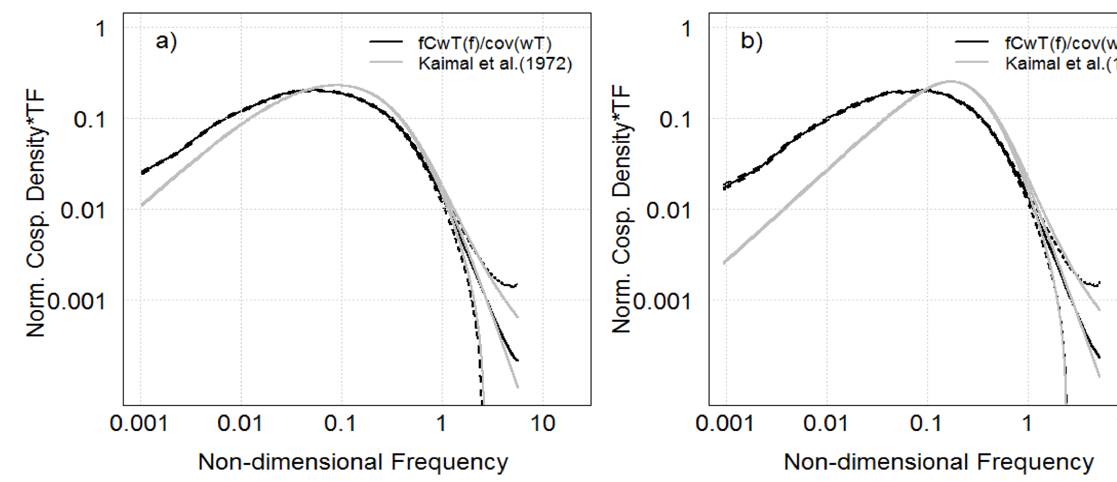

Fig. 3 : Normalized sensible heat cospectra (black colors) and Kaimal cospectra (grey colors), considering a Lorentzian transfer functions with a cut-off frequency of 0.37 Hz during unstable (a) and stable (b) conditions.

Evaluation of the correction procedure

→ In the common temperature range, the average total chamber – based TER (R_{ST}) was closer to the EC fluxes corrected using the local approach (R_{SL}) than to the others (Fig. 4).

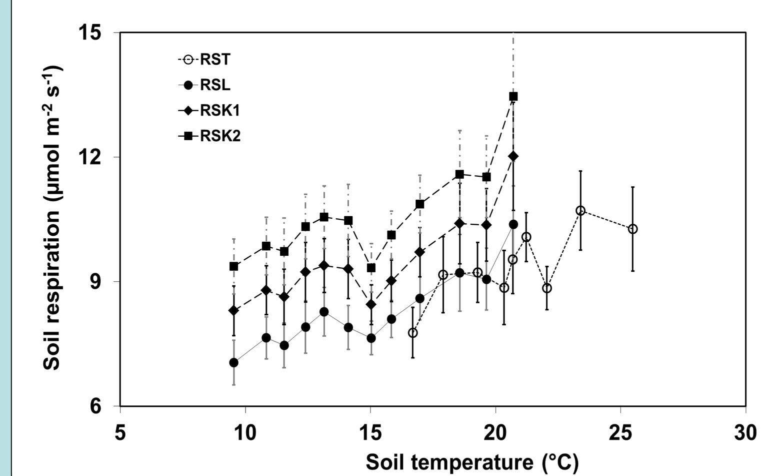

Fig. 4: Relationship between total ecosystem respiration and soil temperature for the corrected EC data (closed symbols) and for chamber-based TER estimates (open symbols): R_{SL} (black circles) , R_{SK1} (black diamonds) and R_{SK2} (black squares).

→The normalized differences (u_{obs}) between R_{ST} and R_{SL} 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.

	Temperature class	R_{SL}- R_{ST}	R_{SK1}- R_{ST}	R_{SK2}- R_{ST}
Difference	16 20	0.38 0.57	1.43 2.04	2.55 3.38
u_{obs}	16 20	0.96 (p=0.33) 1.62 (p=0.055)	3.55 (p<0.001) 4.76 (p< 0.001)	6.19 (p<0.001) 6.81 (p<0.001)

Tab. 1: Results of the comparison at similar temperature between total chamber-based (R_{ST}) and eddy covariance TER estimates corrected with different approaches (R_{SL}, R_{SK1} and R_{SK2}) ; p represents the probability level.

Impact of the reference cospectrum choice on annual CO2 fluxes

→ 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).

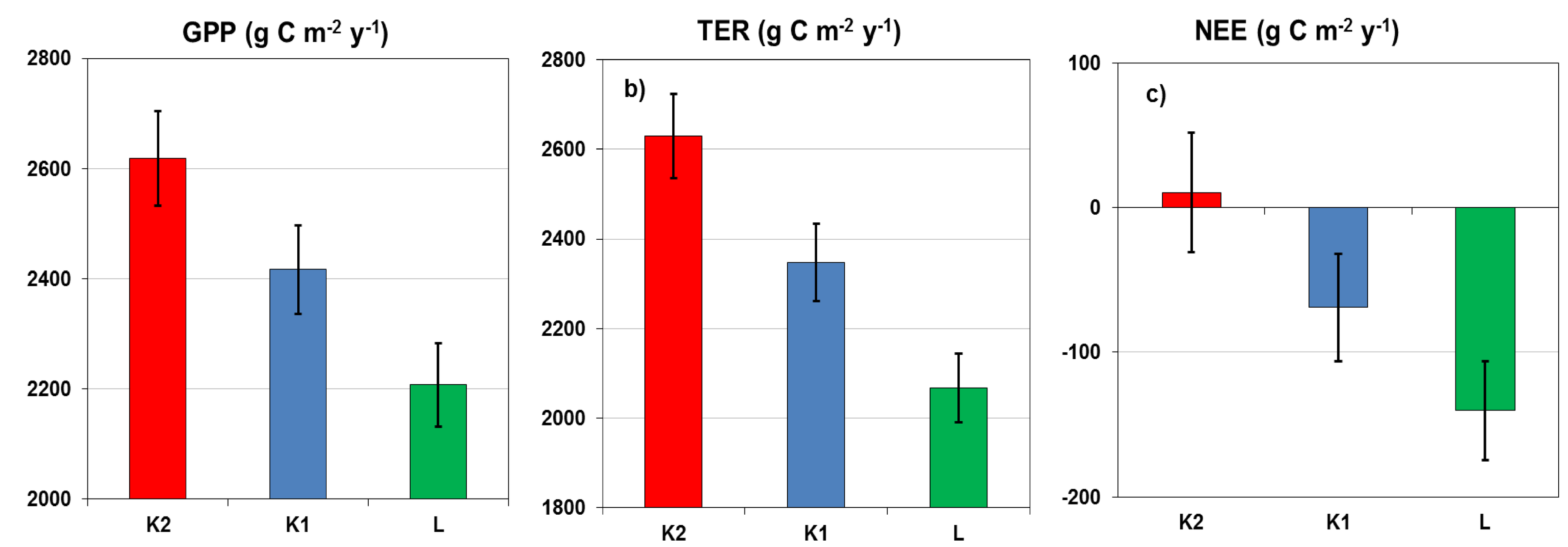

Fig. 5 : The 4-year (2011-2014) average and their standard errors of the annual estimates of (a) gross primary productivity (GPP, g C m^{-2} y^{-1}), (b) total ecosystem respiration (TER, g C m^{-2} y^{-1}) and (c) net ecosystem exchange (NEE, g C m^{-2} y^{-1}) corrected with the local (L, green color,) first (K1, blue color) and second (K2, red color) Kaimal approaches, respectively, at the Dorinne Terrestrial Observatory (DTO) .

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 CO_2 fluxes ;

♠ The high frequency loss corrections were more **realistic when based on local** ;

♠ The choice of Kaimal cospectra **reversed the CO_2 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

- Gourlez de la Motte, L., Jérôme, E., Mamadou, O., Beckers, Y., Bodson, B., Heinesch, B., Aubinet, M., Carbon balance of a long-standing and intensively grazed grassland in southern Belgium,(submitted to Agric. For. Meteorol.)
- Jérôme, E., Beckers, Y., Bodson, B., Heinesch, B., Moureaux, C., Aubinet, M., 2014. Impact of grazing on carbon dioxide exchanges in an intensively managed Belgian grassland. Agric. Ecosyst. Environ. 194, 7–16.
- Mamadou, O., Gourlez de la Motte, L., De Ligne, A., Heinesch, 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.)

Aknowledgments

This research was funded by the Service public de Wallonie, Direction Générale Opérationnelle de l'Agriculture, des Ressources naturelles et de l'Environnement, Département du Développement, Direction de la Recherche, Belgium. Project no. D31-1235, January 2010 to December 2011. Project no. D31-1278, January 2012 to December 2013. Project no. D31-1327, January 2014 to December 2015. We thank Alain Debacq, Fred Wilmus and Henri Chopin for their technical assistance and Louise Maroun for making soil chamber measurements. The authors also would also like to thank the farmer, Adrien Pâquet, for his collaboration, which was essential to the implementation of the study.