Intercomparison of lower-cost and conventional eddy covariance systems for CO_2 and H_2O flux measurements above cropland monoculture and agroforestry

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This presentation participates in OSPP
Outstanding Student & PhD candidate Presentation contest
EGU23-1527

1. Motivation

Short Rotation Alley Cropping (SRAC) agroforestry might represent a powerful nature-based solution to mitigate climate change, due to its increased carbon sequestration compared to monocropping (MC) agriculture. CO_2 and latent heat (LE) exchanges above SRAC can be studied via the eddy covariance (EC) technique, however SRAC represents a highly-heterogeneous landscape and the spatial representativity of EC is compromised. Lower-cost (LC) EC set-ups, tested in the last years with promising results [1,2,3], might provide a solution. Before widely employing LC-EC set-ups, they need to be tested against conventional EC.

2. Objectives

1) Intercompare CO_2 and LE fluxes from four LC-EC and one conventional EC above a MC cropland
2) Test if differences between LC-EC and conventional EC are smaller than differences between MC and SRAC

3. Material and methods

(a) Study site

The study site is in Wendhausen (Lower Saxony, DE). Mean annual temperature and precipitation are 9.9 °C and 618 mm. The agricultural land is divided in a MC area and a SRAC area. A map of the site is shown in **Fig. 1**. The dominant wind direction is southwest.

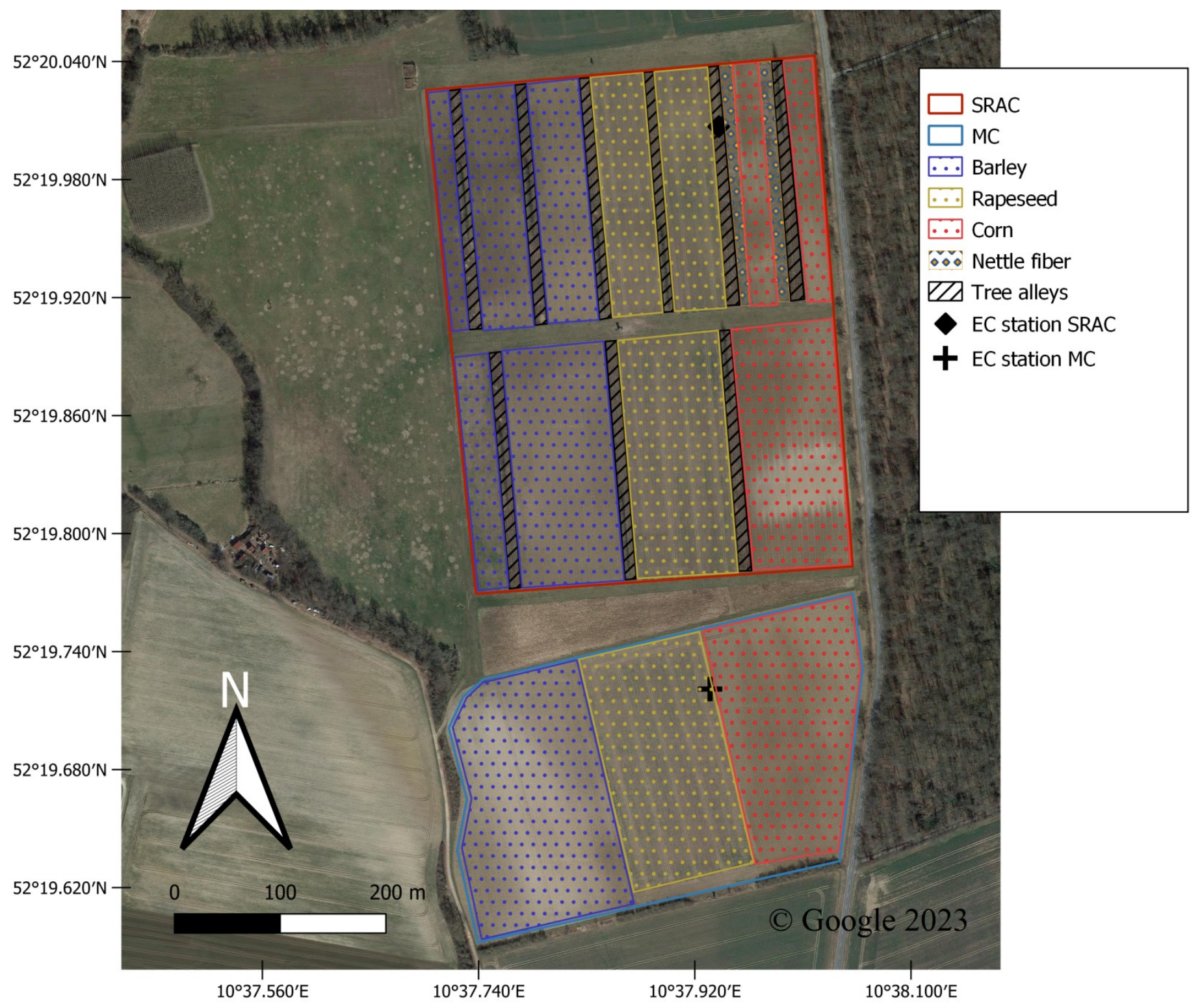


Fig. 1: Map of the experimental site, with land cover information and the location of the EC stations.

(b) Experimental set-up

In the MC, three LC-EC (LC-EC-I, LC-EC-II and LC-EC-III) and one conventional EC set-ups were installed. In the SRAC, one LC-EC set-up was installed. **Table 1** shows differences across set-ups. Each station was equipped with all the main meteorological sensors.

	f (Hz)	CO_2	H_2O	3D wind field	Flow rate ($L \cdot min^{-1}$)	Tube length (m)
LC-EC	2	GMP343 (Vaisala Oyj, Helsinki, FI)	HIH-4000 RH cell (Honeywell, Charlotte, USA)	Usonic-3 Omni (Metek GmbH, Elmshorn, DE)	2	3 (LC-EC-I) 3.5 (LC-EC-II) and 4 (LC-EC-III)
Conventional EC	20	Li-7200 (Licor Inc., Lincoln, USA)	Li-7200 (Licor Inc., Lincoln, USA)	Usonic-3 Omni (Metek GmbH, Elmshorn, DE)	15	1

Table 1: LC-EC and conventional EC set-ups.

(c) Flux computation and data analysis

- Pre-processing: (i) calculation of H_2O concentration from relative humidity (RH) following [3] and (ii) correction of CO_2 measurements for pressure, RH and temperature for the LC-EC; (iii) time lags estimation.
- Fluxes were calculated with EddyPro 7.0.9 and filtered according to standard quality checks.
- Post-processing: statistical comparison between set-ups and analysis of flux differences according to turbulence characteristics.

4. Results and discussion

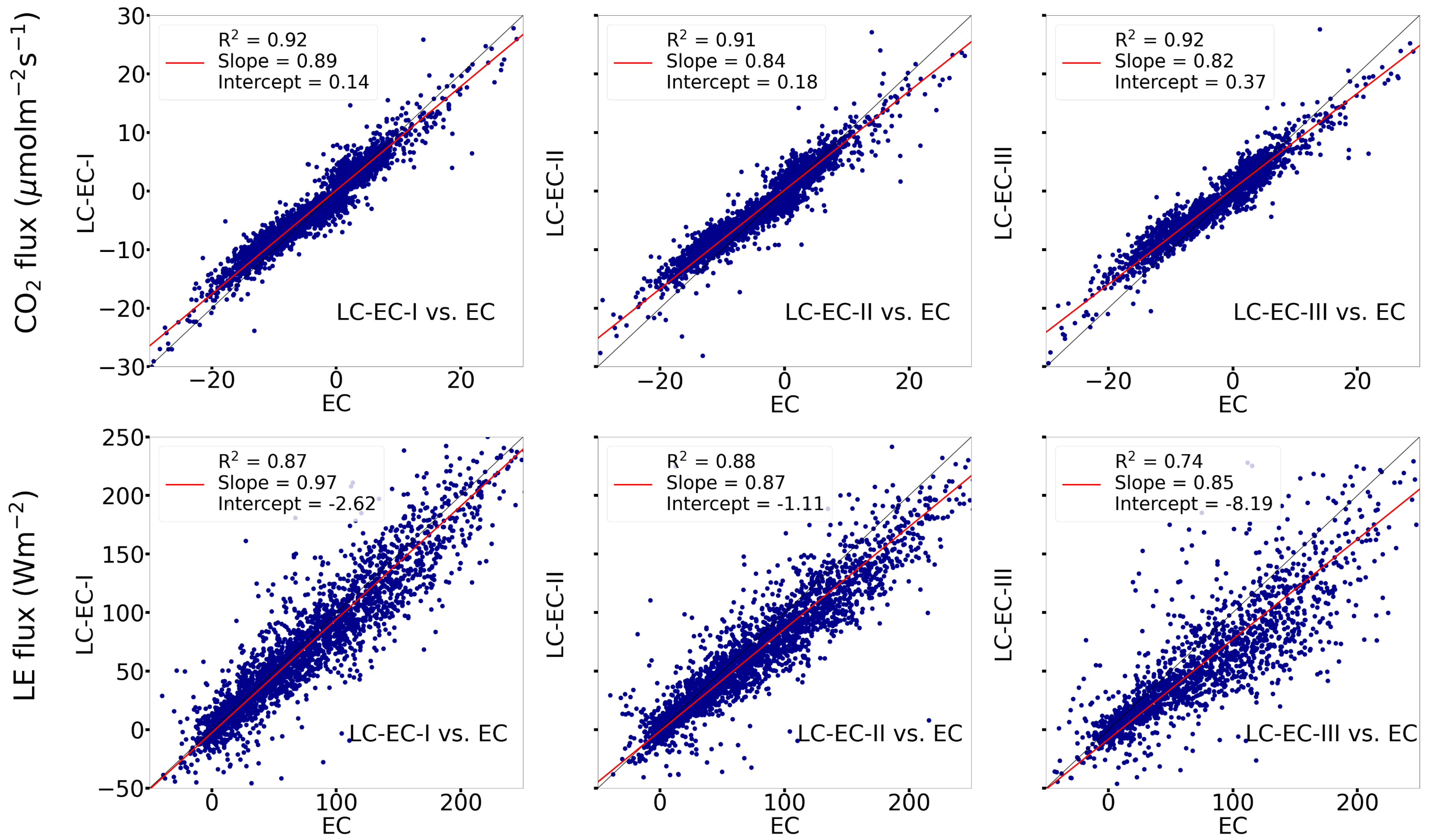
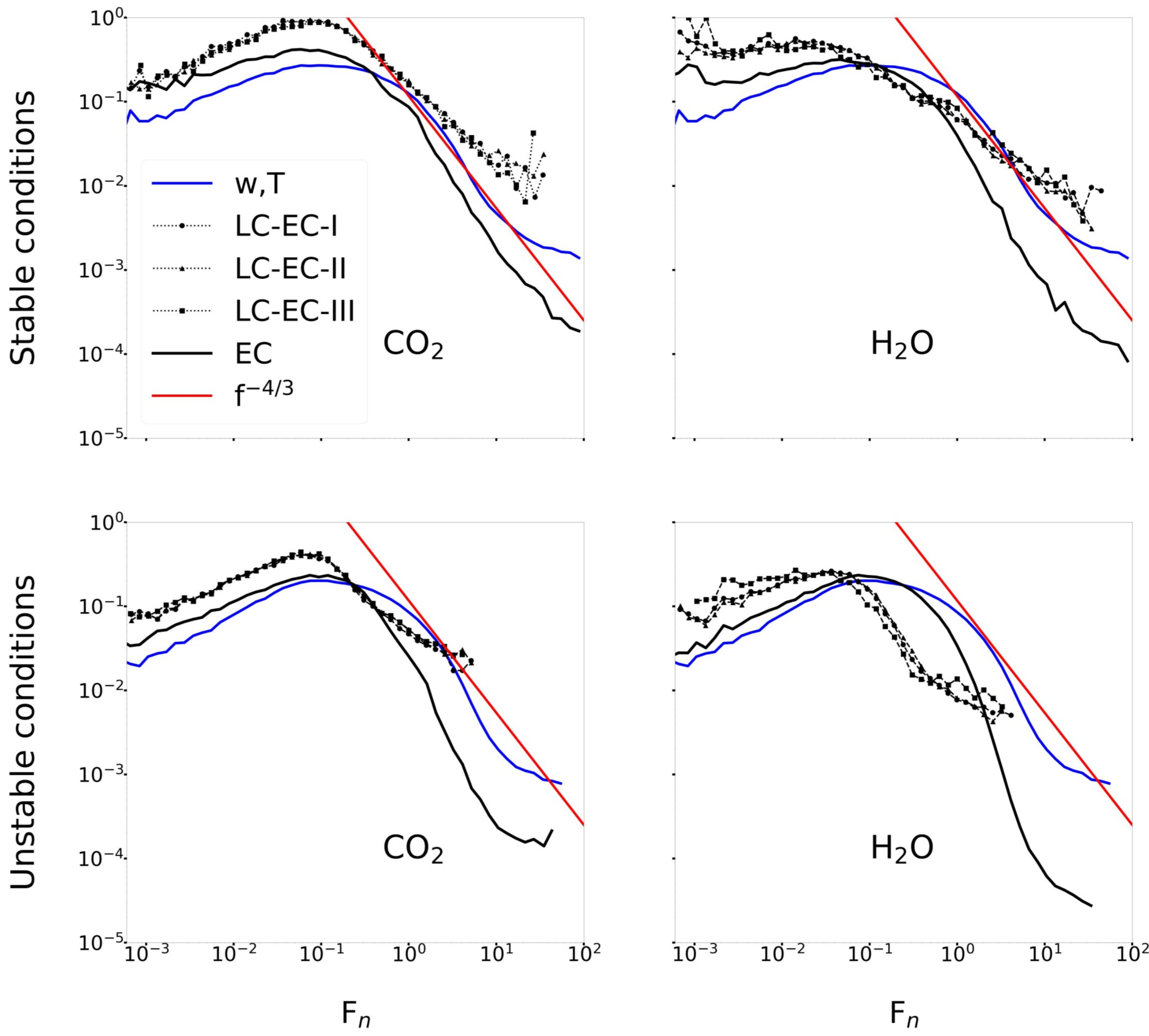


Fig. 2: Comparison of lower-cost EC (y-axis) against EC (x-axis) for CO_2 (top row) and LE (bottom row) at the MC site.

- 1:1 plots show a good agreement of LC and conventional EC (**Fig.2**), with slopes ranging from 0.82 to 0.89 and R^2 above 0.9 in the case of CO_2, and from 0.85 to 0.97, with R^2 of 0.74 to 0.88, in the case of LE.



- Slope and peak of conventional EC co-spectra follow the sonic temperature co-spectra and the theoretical slope of $f^{-4/3}$ much closer than the LC-EC (**Fig.3**)
- The three LC-EC set-ups show faster energy content decrease in the high-frequency range. They behave similarly for CO_2, while for H_2O there are big discrepancies across them, especially for the LC-EC-III.

Fig. 3: Co-spectra of conventional EC and LC-EC, for CO_2 and H_2O. The sonic temperature co-spectra (blue) and the theoretical line of $f^{-4/3}$ (red) are shown for reference.

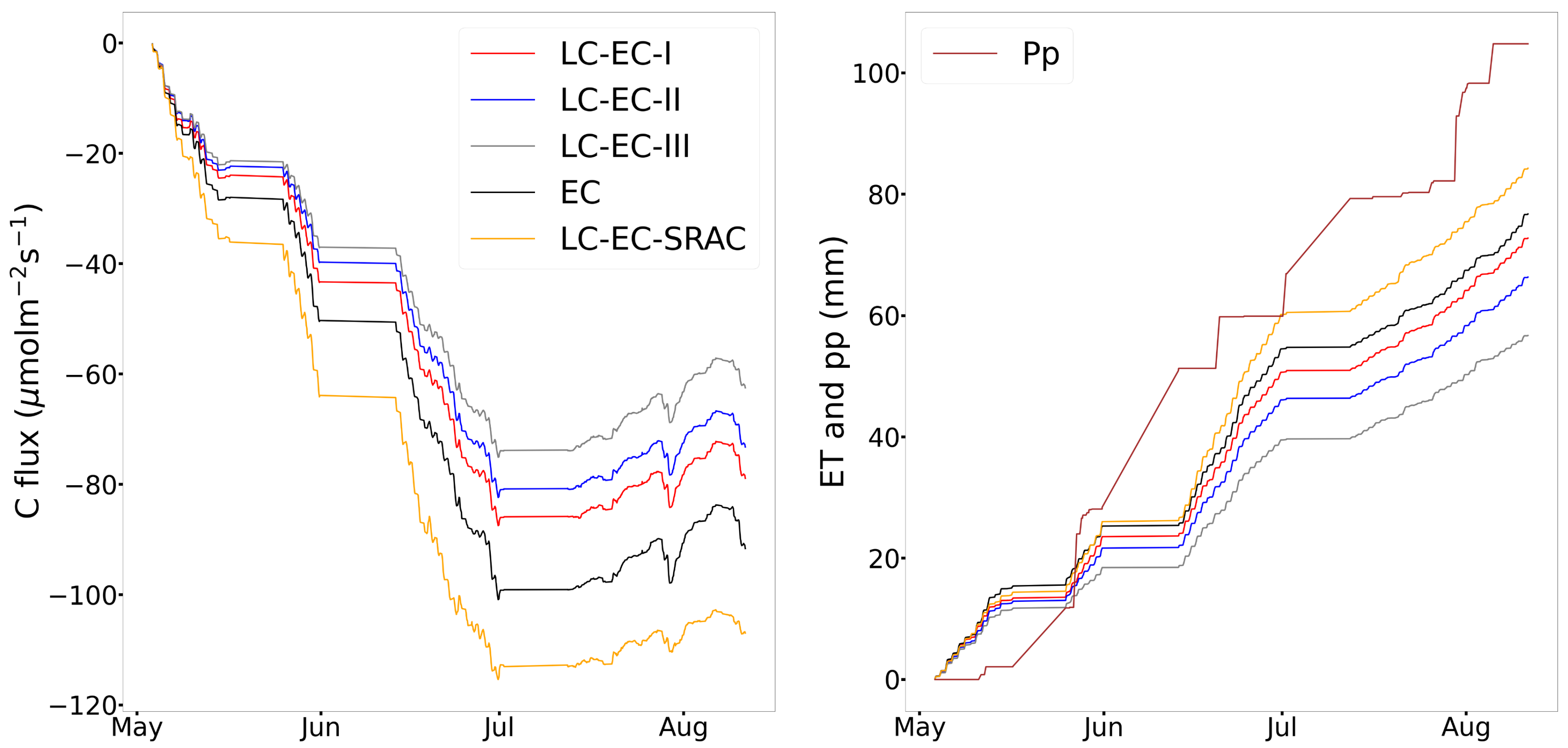


Fig. 4: Cumulative sums of CO_2 and ET fluxes for all four set-ups in the MC and SRAC across the measurement campaign (March to August 2022). Precipitation is plotted together with ET for reference.

- In accordance with the 1:1 plots, the different LC-EC in the MC underestimate the conventional EC cumulative sums at different rates (**Fig.4**).
- For CO_2, differences in cumulative sums across LC-EC set-ups in the MC are smaller than differences between SRAC and MC. The difference between LC-EC and conventional EC in the MC is around 50% to the difference between MC and SRAC.
- For ET, the differences between SRAC and MC are of the same order as the difference between LC-EC and conventional EC in the MC.

5. Conclusions

- LC-EC setups perform well compared to conventional EC, in agreement with the results from [1] and [2]. All LC-EC set-ups reproduce the ecosystem dynamics and are capable of detecting ecosystem differences (**Obj. 1**).
- The variability across LC-EC set-ups in the MC is smaller than the variability across SRAC and MC (**Obj. 2**).
- The higher spectral attenuation of the LC-EC leads to higher spectral correction factors, which increases the uncertainty in the LC-EC fluxes.
- The LC-EC set-ups could be applied to address the spatial replication problem in EC, but more investigation is needed on the corrections during data analysis.
- A set-up that minimizes frequency attenuation with e.g., higher flow rate and shorter tube length could reduce the need of corrections and improve the performance of the LC-EC.

References

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Abstract

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Acknowledgments
This study was founded by the German Ministry of Education and Research (BMBF), through the BonaRes initiative, project SIGNAL. We thank the team of the Bioclimatology Department for the technical support.

Sharing is encouraged