Experiences using newer EC155 closed-path infrared CO_2/H_2O analyzer for measuring eddy covariance fluxes in agriculture and natural ecosystems.

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Introduction

Improved fast-response closed-path infrared CO_2/H_2O analyzers designed for use with eddy covariance (EC) flux measuring systems in remote locations promise improved performance in comparison to traditional closed-path systems. The newer-class EC155, developed by Campbell Scientific (Logan UT) in 2010, is said to offer low power consumption, low noise, a small sample cell for excellent frequency response, a slim aerodynamic shape, a heated sample intake as well as on site flux calculations. A short-term campaign was undertaken to evaluate these characteristics in terms of performance, robustness and ease of operation in three different ecosystems with varying site characteristics (Table 1) . The EC155 as part of the CPEC200 system (Campbell Scientific, Logan UT) has already been observed in a forest setting by Novick, et. al. (2013), in the following campaigns it operated independently in a soybean field and side-by-side with a LI-7000 (LI-COR, Lincoln, NE) in both a corn field and a wetland bog in Ontario, Canada (figure 2).

Table 1: Differentiating campaign parameters by ecosystem and sensor type.

Study Parameters	Soybean	Corn		Bog	
Crop Height (m)	1.15	2.85		0.2	
Largest Fluxes					
CO_2 (mg CO2/m² s)	-2.8	-2.9		-0.3	
LE (W/m²)	536.4	410.7		95.0	
Hc (W/m²)	275.5	84.5		209.0	
	CPEC	CPEC	LI-7000	CPEC	LI-7000
Length of Intake Tube (cm)	58.4	58.4	650	58.4	400
Diameter of Tube (cm)	0.95	0.95	0.32	0.95	0.40
Flow Rate (l/min)	7	7	5.5	7	17
System Height (m)	2.65	4.5		2.35	
Power Source	Solar/Battery	Line Power		Line Power	

General Performance of EC155

The EC155 is part of the CPEC200--a complete eddy covariance system that also features a CSAT3A sonic anemometer (Figure 1C) and a CR3000 data logger with a cellular modem. The data-logger program controls automatic self-calibrations and computes on-line flux calculations at the study site. As noted in figure 1A, the nightly self calibrations of CO_2 span and zero gases have very little drift about the target span (512 ppm) and zero concentrations; σ = 511.7± 1.1 ppm and σ = 0.0± 0.3 ppm respectively.

The data-logger program (CPEC200 v1.3) also provides necessary information required to ensure proper function of the CPEC200 such as battery voltage and operational flags. The CPEC200 ran autonomously in the soybean study with continuous communication being possible through the cellular modem. The modem was capable of transferring summary data and onboard flux calculations while the raw 10 Hz and 20 Hz data was stored in memory and collected weekly. The system was powered by two 85 W solar panels which were connected to two 120 Ah deep cycle batteries. As can be seen in figure 1B, this power supply was sufficient enough to power the system throughout the 99 day study period.

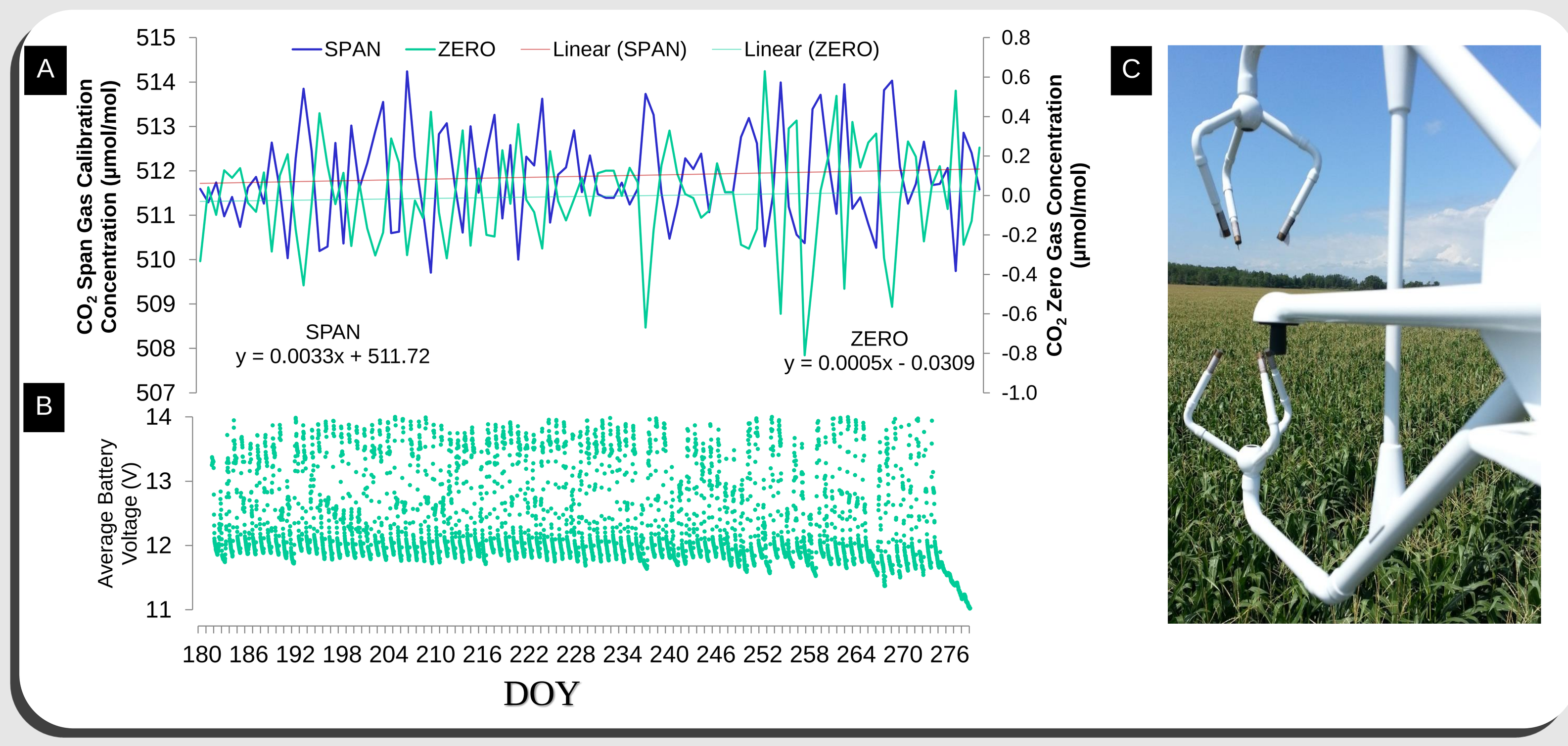

Figure 1. A. Daily system calibration of CO_2 and zero CO_2 concentrations. B. Half hourly average battery voltage over 99 day study period from two 85W solar panels and two 120 AH deep cycle batteries. C. Sonic anemometer and EC155 heated intake.

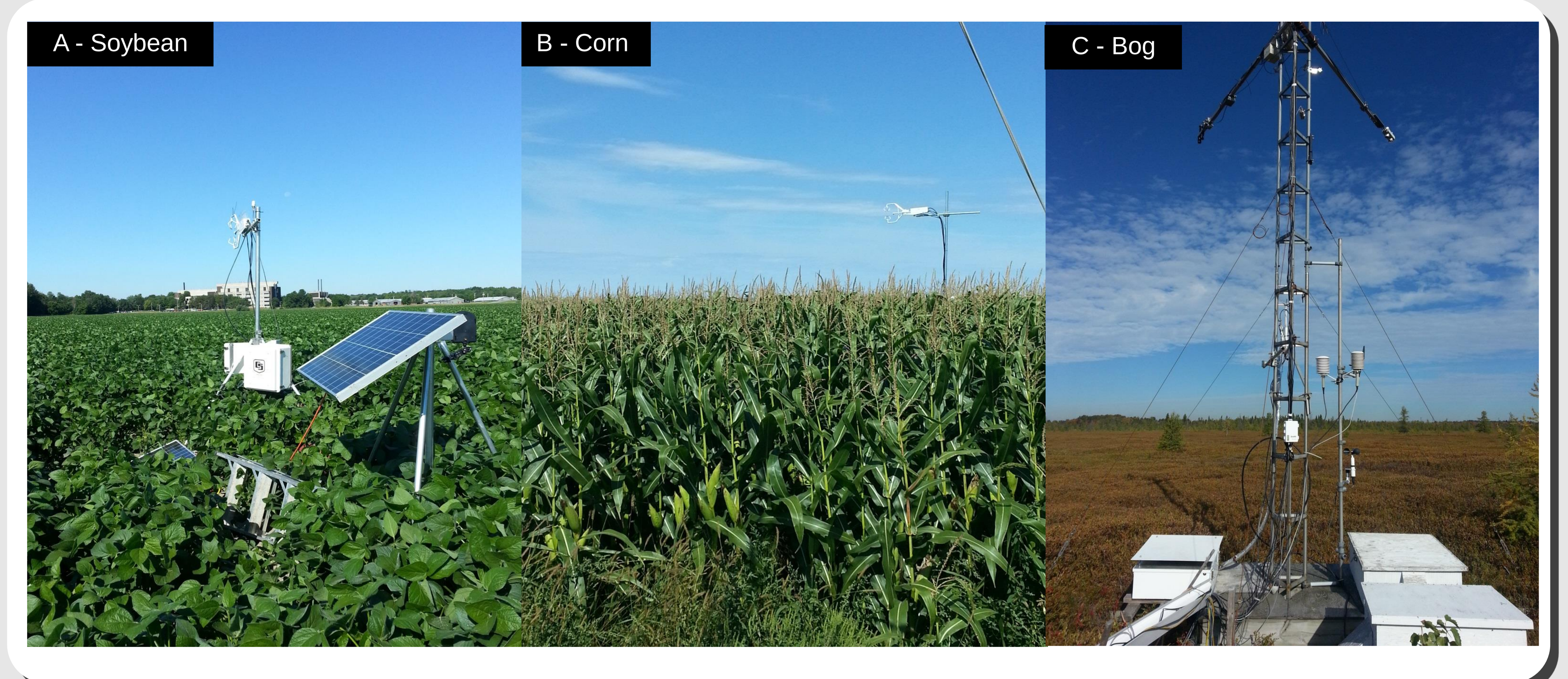

Figure 2. Deployment of CPEC 200 in three different eco-systems. A. Soybean field B. Corn field C. Bog site.

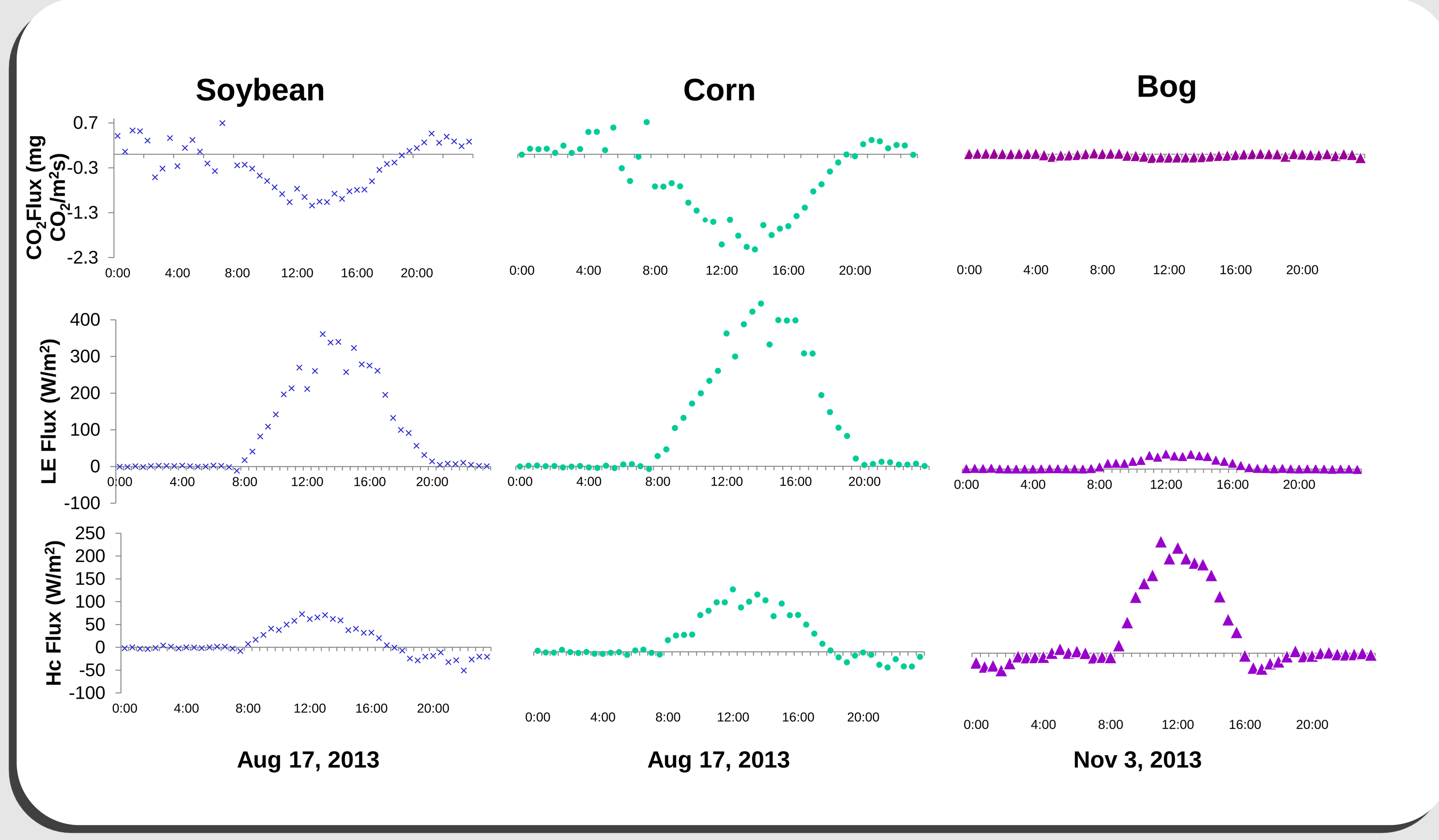

Figure 3. CPEC200 onboard flux calculation data from each study site under ideal conditions.

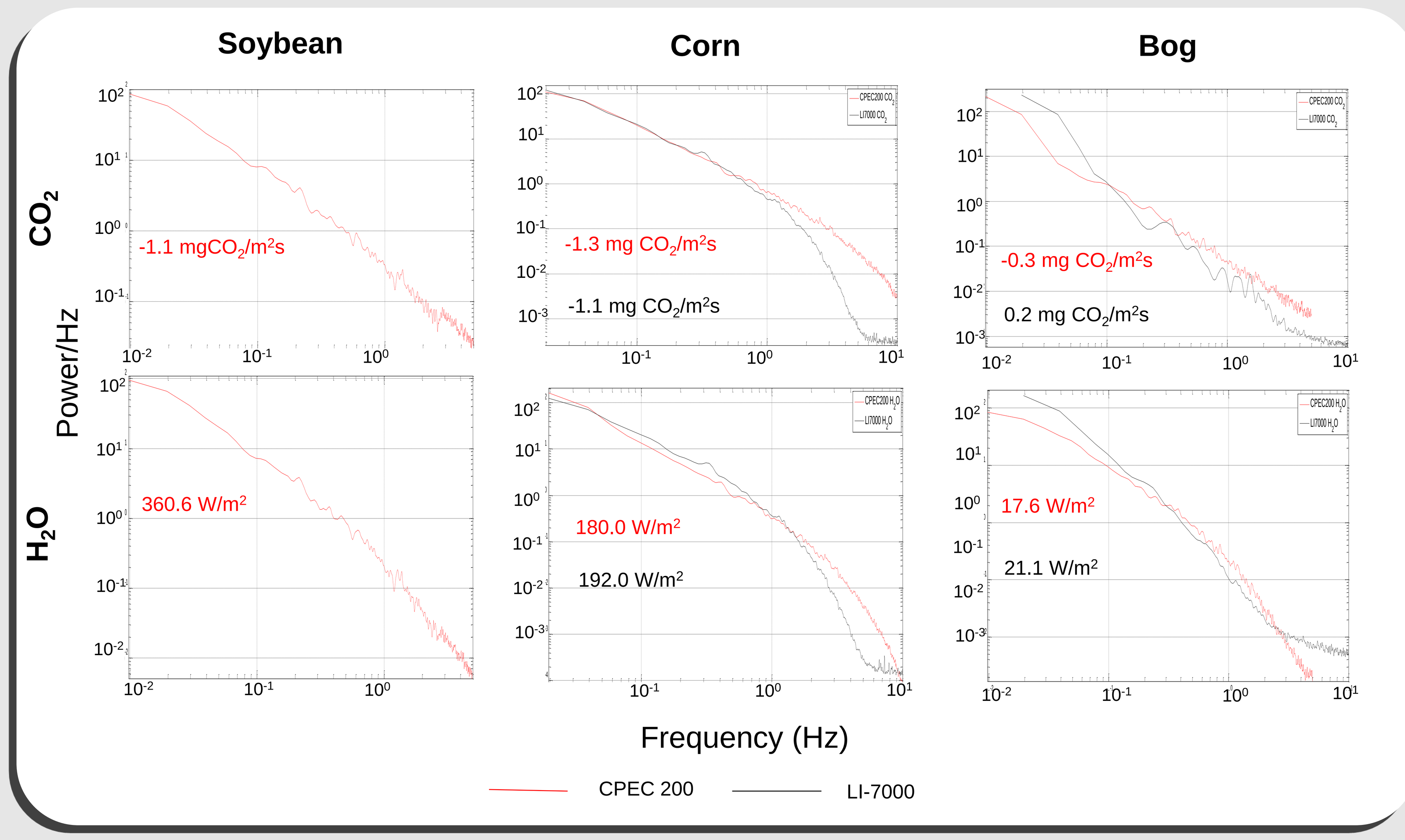

Figure 4. Power spectral density of CO_2 and H_2O- detrended and normalized for Soybean , Corn and Bog site. Flux calculations provided for specific spectra.

Spectral Analysis

The CPEC 200 system was deployed in three environments with contrasting vegetation and system heights. Flux data was acquired during the peak growing season in the soybean and corn fields and for approximately five weeks during cooler autumn weather at the bog site. At both the corn and bog, the CPEC200 was co-located with an EC system equipped with a LI-7000 infrared gas analyzer. Each of the LI-7000 had two different models of sonic anemometers; an HS-50 in the corn study and a R3-50 in the bog study (Gill Instruments, Lymington, Hampshire, UK). The CPEC200 was situated within 20 m of the LI-7000 flux system in the corn field and off-set on the same tower in the wetland bog site (Figure 2B and C). Flux measurements from each site are provided in Figure 3 from the CPEC200 system only, from days with high incoming solar radiation and some wind driven turbulence.

A comparison of power spectral results for corrected CO_2 and H_2O densities between the CPEC200 and LI-7000 systems at all sites (Figure 4) showed strong similarities at frequencies less than 1 Hz but the LI-7000 setup showed greater loss of power (power/Hz) as the frequency increased most likely due to damping within the longer, small-diameter sample tubes. The spectral density for CO_2 at the bog is not ideal but it should be noted that at the time of the campaign the maximum flux recorded was -0.27 mg CO_2 m^{-2} s^{-1} (Table 1).

On Board CPEC 200 Fluxes

The CPEC 200 onboard calculated fluxes are corrected for time lags by the data logger. These results were compared to post processed raw data. Post processing was carried out using EddyPro (EP) (LI-COR, Lincoln, NE), a software package used for processing eddy covariance data. CO_2, latent heat (LE) and sensible heat (Hc) fluxes were all compared to post-processed fluxes from 10 Hz data and results can be seen in Figure 5. The post-processed data went through seven levels of processing using information specifically configured for the CPEC in each environment and the default Vickers and Marht (1997) EP settings for data processing: level 1 (unprocessed), level 2 (despiking), level 3 (crosswind correction), level 4 (angle-of-attack correction), level 5 (tilt correction), level 6 (time lag compensation) and level 7 (detrending). Two 24 hour periods were analyzed; the first having a relatively low friction velocity (u_* <0.2 ms^{-1}) and the second having a high u_* (>0.2 ms^{-1}). The on-board calculated fluxes and the post-processed data generated by EP is generally poor over a 24- hour period when there is a low u_*. The relation is very strong, however, for all three fluxes (r2= >0.98) during a 24 hour period when u_* is above 0.2 ms^{-1}.

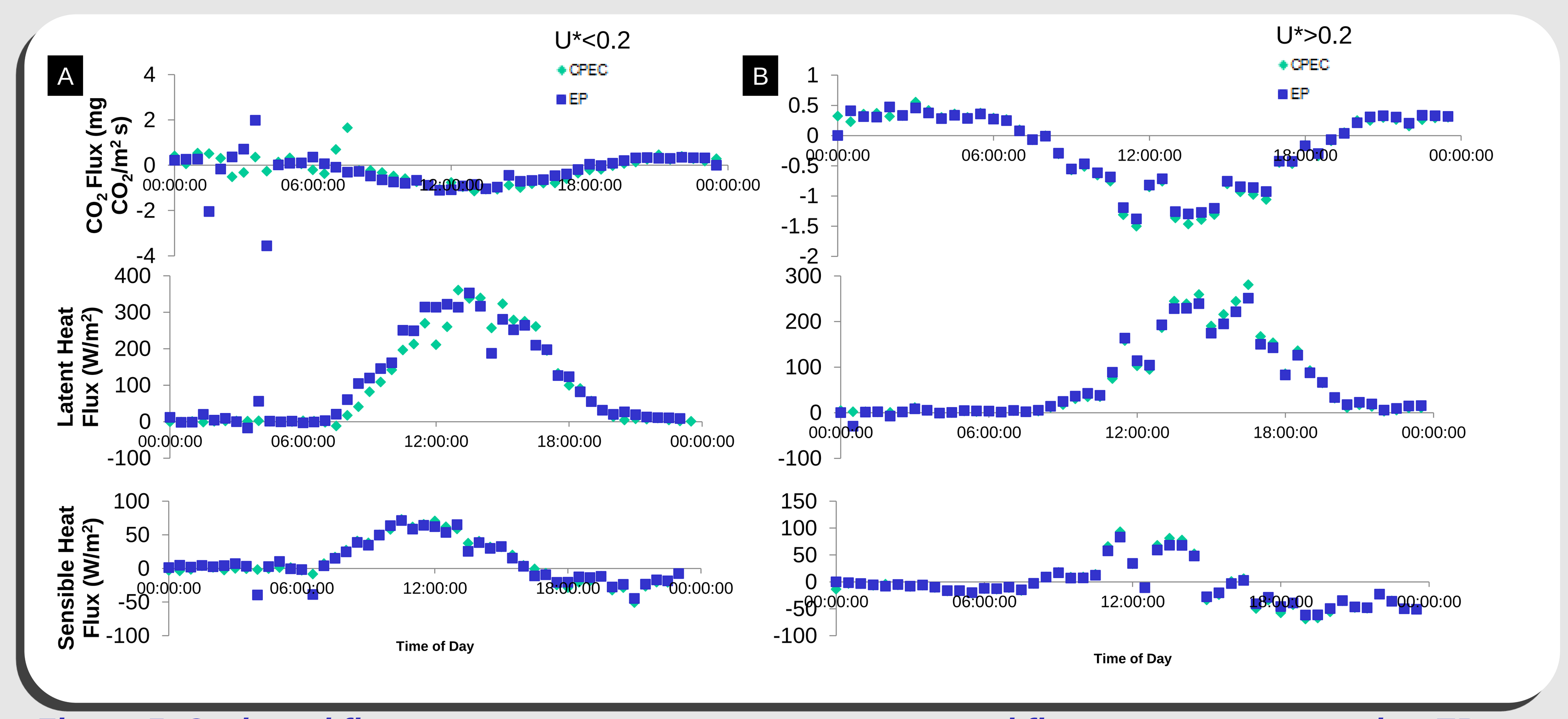

Figure 5. On-board flux measurements versus post-processed flux measurements using EP software. A. Represents a 24-hour period with low U (<0.2 ms^{-1}) B. Represents a 24-hour period with high U* (>0.2 ms^{-1})*

Experiences

Overall, the study showed that the EC155/CPEC200 is a reliable system with operational capabilities surpassing typical closed-path systems. The system functioned very well on battery and solar power, it provided reliable daily self-calibrations, is highly mobile and was stable in three separate environments. It also provided reasonable non-spikey on-board flux calculations which could be collected efficiently through remote communication. The EC155/CPEC 200 system appears to be a good instrument for deployment in both and agricultural and wetland setting. Still required for future consideration is the need for testing winter performance and long-term evaluation.

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