Reduced-Cost Sensor & Node for Direct Measurements of CO_2 flux, Evapotranspiration, Sensible Heat Flux, PAR and Key Weather Parameters

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LI-COR Environmental

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INTRODUCTION

Eddy Covariance methodology has the temporal resolution and accuracy required for direct CO_2 flux measurements from ecosystems. The high cost and the complexity in this approach hinders its applicability in regulatory and commercial domains. To address these challenges, a new cost-effective solution for direct, automated, and real-time CO_2 flux measurements has been developed. The sensor, model LI-720, is part of the Carbon Node*, which provides power, mounting and connectivity to a cloud platform which provides advanced data analytics . We present here some preliminary data collected from PDR* and CDR* units in the field.

*Indicates prototype units manufactured during the PDR (Preliminary Design Review) and *CDR (Critical Design Review) process
*More information on the Carbon-Node is presented in the poster B11L-1476

DESCRIPTION OF THE SENSOR

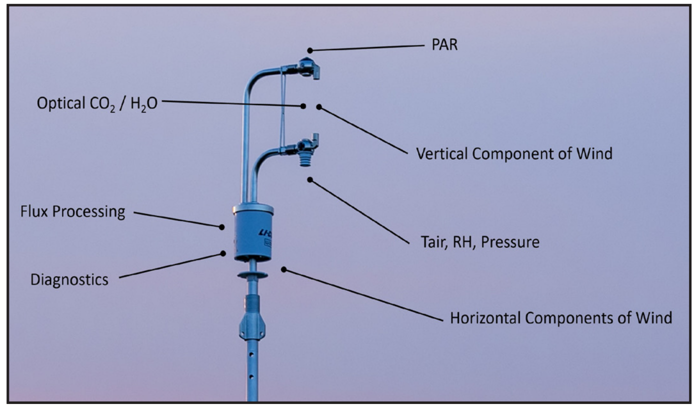

Figure 1: Image of the sensor showing the different components.

UNIQUE FEATURES OF THE LI-720

- Co-located wind and CO_2/H_2O measurements with intentionally minimized flow disturbance
- Very low power consumption (~1.5 W)
- Measures biometeorological variables such as air temperature, atmospheric pressure, relative humidity and PAR
- Compute fluxes with the collected data using standard processing algorithms with embedded custom code
- Provides raw data output via RS232 and flux output via SDI-12
- Features GPS for location and time keeping
- Tilt and orientation outputs (magnetometer/accelerometer)
- No moving parts or temperature control
- Vertical and Horizontal components of wind are measure separately in a unique geometry to minimize distortion and allow the best vertical wind measurement
- Features a broad band infrared analyzer with a modulated light source

FIELD TESTING

The prototype analyzer is being deployed at multiple sites across varying ecosystems. The data presented here include locations from Mead, NE (41.1797°N, 96.4405°W) (Soyabean), Imperial, CA and (32.8068°N, 115.4491°W) (Alfalfa), showing the comparison with a traditional EC system comprising of a Gill Windmaster sonic anemometer and a LI-COR LI-7500DS gas analyzer

Figure 2: Deployment of the sensor at Mead, NE

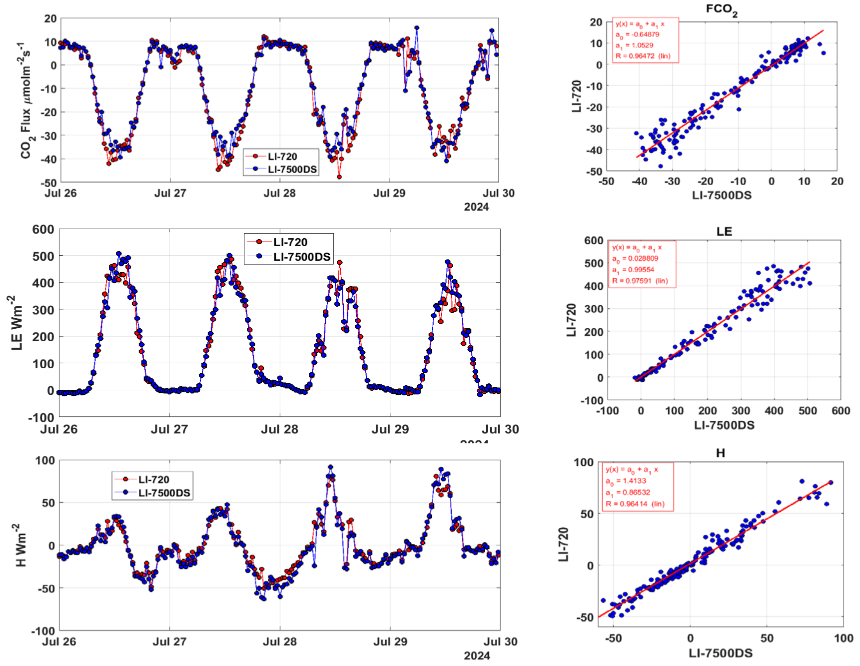

Figure 3: Comparison of CO_2 flux, Latent heat and Sensible heat flux between the LI-720 and a traditional EC system at Mead, NE

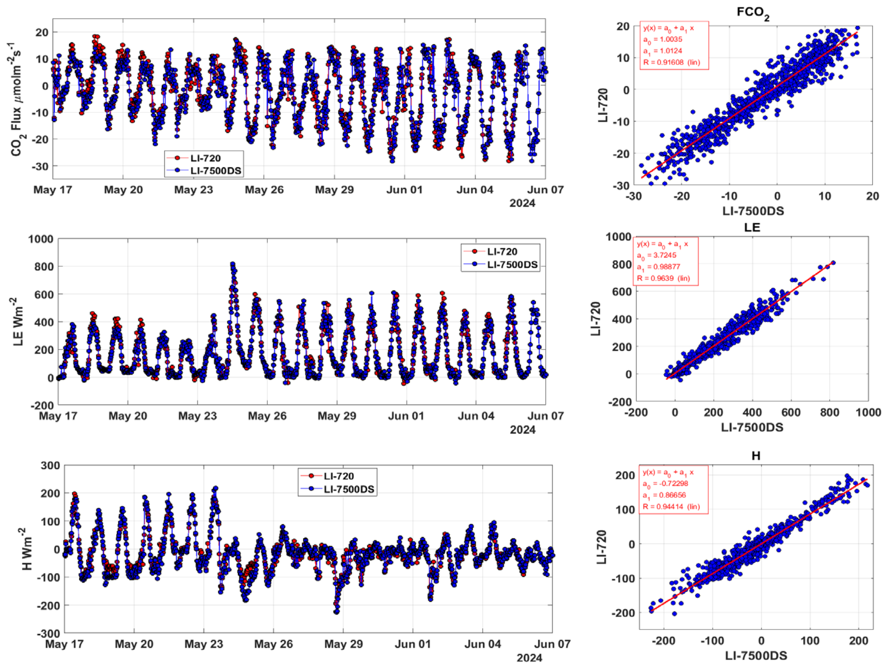

Figure 4: Comparison of CO_2 flux, Latent heat and Sensible heat flux between the LI-720 and a traditional EC system at Imperial, CA

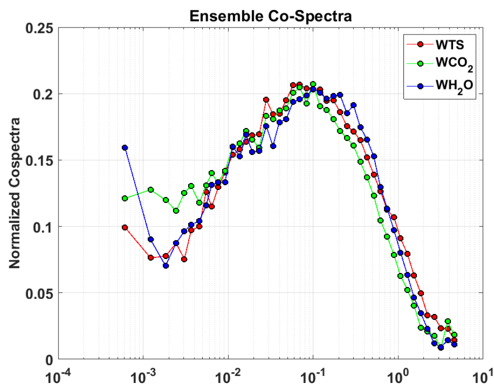

Figure 5: **Ensemble co-spectra comparison between fluxes**

Figure 6: **LI-720 sensor deployed on a Carbon-Node**

FLUX PROCESSING SCHEME

Raw Data	U, V, W, Tsonic (vertical), Tsonic (Horizontal), CO_2, H_2O, Tair, Pressure, RH
Remove implausible values	Large spikes are removed
De-spiking	(Mauder *et al*, 2013) using Median Absolute Deviation
Time align U and V with W	Using cross covariance between vertical and horizontal Tsonic
Two-Dimensional Rotation	For tilt correction
Compute fast air temperature	Correct sonic temperature iteratively using mean air temperature
Compute fast air molar volume	Compute Fast H_2O mole fraction iteratively using RH probe and analyzer H_2O
Compute fast mixing ratios	Using fast molar volume and CO_2 / H_2O mole fractions
Compute covariances	Covariance between W and H_2O / CO_2 mixing ratios are computed
Frequency response correction	Massman, 2000, 2001 methodology is implemented
Compute Fluxes	Buoyancy correction applied to heat flux
Compute turbulence parameters	Fraction velocity, stability parameters and others are computed
QA/QC Flags	Based on Mauder and Foken 2004 (0, 1, 2)

PRELIMINARY SPECIFICATIONS

Variable	Preliminary specification
CO_2 Measurement	Calibration Range: 0 to 1500 µmol mol^{-1} Accuracy: Within 1.5% of reading Zero Drift (per °C): ±0.15 ppm typical, ±0.3 ppm maximum RMS Noise (typical @ 400 µmol mol^{-1} CO2): @10 Hz: 1.0 ppm Direct Sensitivity to H2O (mol CO2 mol^{-1} H2O): ±2.00E-05 typical, ±4.00E-05 maximum
H_2O Measurement	Calibration range: 0 to 60 mmol mol^{-1} Accuracy: Within 1.5% of reading Zero drift (per °C): ±0.03 mmol mol^{-1} typical, ±0.05 mmol mol^{-1} maximum RMS noise (typical @ 10 mmol mol^{-1} H_2O): @10 Hz: 0.05 mmol mol^{-1} Direct sensitivity to CO_2 (mol H_2O/mol CO_2): ±0.02 typical, ±0.05 maximum
Wind Measurement	Measurement Axes: U, V, W Measurement Range: 0 – 30 m s-1 (Horizontal Wind Conditions) Offset at Zero Wind: ±0.06 m s-1 RMS Noise: <0.1 m s-1 @ 5 m s-1, <0.15 m s-1 @ 15 m s-1 Sonic Temperature Accuracy: ± 0.2°C Maximum offset at 20°C
Biomet Measurements	Photosynthetic Photon Flux Density: Range: 0-3000 µmol m -2 s -1, Accuracy: ±5% of reading Cosine Correction: Corrected up to 75° angle of incidence. Biomet Air Temperature Range: -40 - 60°C Accuracy: ±1.5°C – No load conditions Atmospheric Pressure Range: 50 – 110 kPa Accuracy: ±0.5 kPa typical Biomet RH Range: 0-100 % - non-condensing Accuracy: ±1 % typical

CONCLUSIONS

- The LI-720 is a low power, low-cost sensor primarily meant for carbon and water flux measurements.
- The sensor is designed for ease of use with only a single output cable and provides both high frequency raw data and processed fluxes.
- Supporting biometeorological data such as PAR, air temperature, relative humidity and atmospheric pressure required for gap filling and flux processing are also provided.
- Preliminary field data indicates a performance very similar to a traditional Eddy Covariance systems.
- The LI-720 sensor coupled with a Carbon-Node™ provides an end-to-end solution for quantifying carbon budgets with automated outlier detection and gap filling.

REFERENCES

Massman, W. J. 2000. A simple method for estimating frequency response corrections for eddy covariance systems. Agricultural and Forest Meteorology, 104: 185-198.

Massman, W. J. 2001. Reply to comment by Rannik on "A simple method for estimating frequency response corrections for eddy covariance systems." Agricultural and Forest Meteorology, 107: 247-251.

Mauder, M. and T. Foken. 2006. Impact of post-field data processing on eddy covariance flux estimates and energy balance closure. Meteorologische Zeitschrift, 15: 597-609.

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