Toward mesophyll conductance where it counts: on-line leaf-level carbon isotope discrimination with a new generation of field portable cavity-based optical absorption analyzer

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Introduction

- Chamber-based mass-balance approaches are used to measure the bulk CO2 exchange (i.e. carbon assimilation or respiration) of leaves in the field, and application of diffusion models to these measurements allows estimation of key parameters relevant to plant performance and stress.
- Measurement of the stable carbon isotope composition of the CO_2 exchanged with leaf provides a means to infer properties of the non-gas phase portion of the diffusive pathway, such as mesophyll conductance.
- Cavity-based optical absorption analyzers provide a novel tool to measure on-line carbon isotope discrimination during leaf-level gas exchange measurements. However, this requires careful consideration to analyzer characteristics that are typically not well-defined in manufacture specifications.

LI-7825 instrument performance

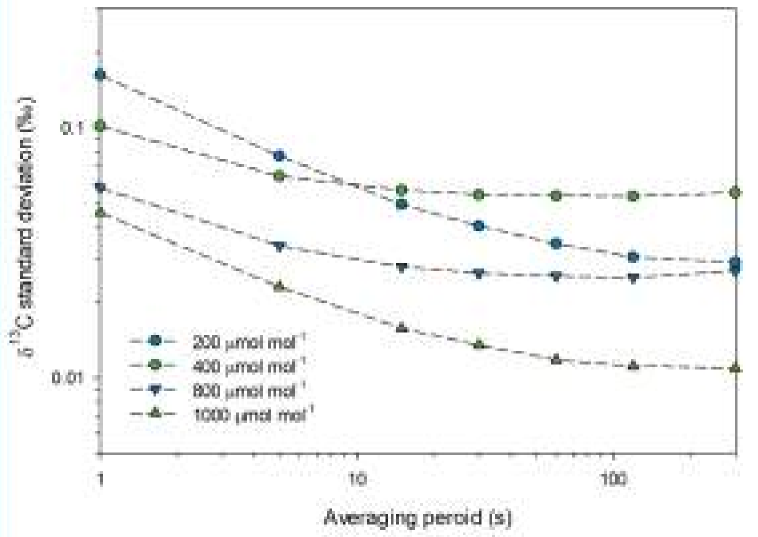


Figure 1: Impact of averaging interval on measurement precision (standard deviation) for a range of CO_2 mole fractions. Data shown here were collected at one sample per second over 30-minute intervals using the LI-6800 to generate a constant CO_2 mole fraction. The resulting precision represents the combined effects of noise introduced through the LI-6800 CO_2 control system and performance of the LI-7825.

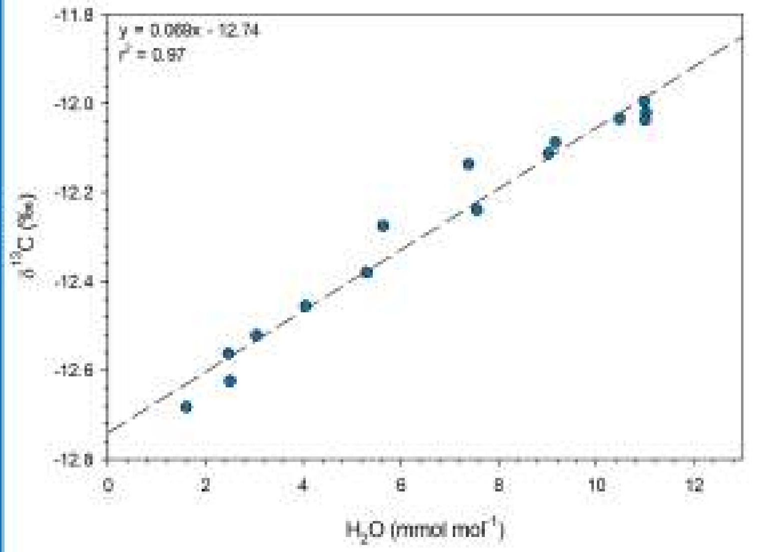


Figure 2: Dependence of $\delta^{13}C$ to H_2O mole fraction. Spectroscopic and dilution corrections are combined on the LI-7825. This combined correction was determined empirically on a population of analyzers during development to produce a generalized correction used for all LI-7825. Consequently, there is some concentration-dependent residual error (CDE) with H_2O mole fraction: 0.07 ‰ per mmol mol^{-1} for the instrument tested.

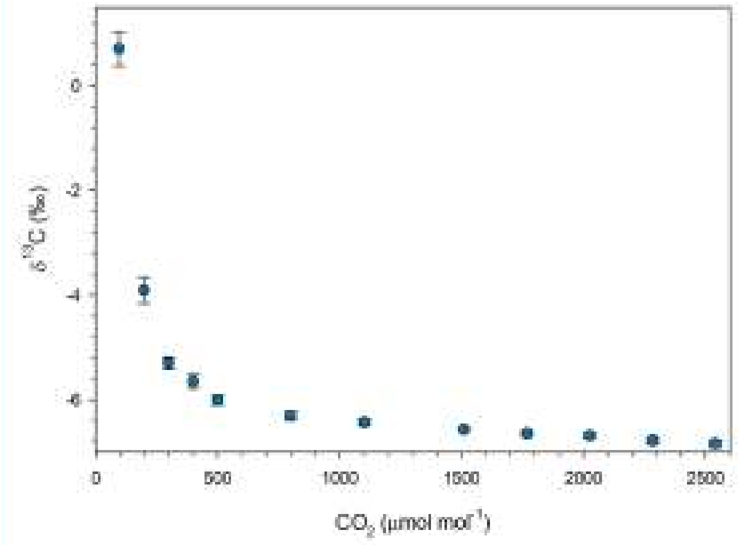


Figure 3: Dependence of $\delta^{13}C$ to CO_2 mole fraction. Error bars are one standard deviation for a five second averaging interval. Typical CDE of the LI-7825 to CO_2 is <0.1 ‰ per 100 µmol mol^{-1} at concentrations >400 µmol mol^{-1}. Data here show a residual error of 0.05 ‰ per 100 µmol mol^{-1} for the specific instrument tested.

Want to learn more about the LI-7825?

On-line leaf-level isotopic discrimination

For an open-flow through gas exchange system, like the LI-6800, leaf-level isotopic discrimination (Δ_{obs}) is calculated from the difference between the isotopic ratio of CO_2 in the air before it interacts with the leaf (δ_{13c_i}) and that after it interacts with the leaf (δ_{13c_o}), as scaled by ξ :

Equation 1:

$$\Delta_{obs} = \frac{\xi(\delta_{13c_o} - \delta_{13c_i})}{1 + \delta_{13c_o} - \xi(\delta_{13c_o} - \delta_{13c_i})}$$

Where ξ is calculated from the CO_2 mole fraction of the air before (X_{c_i}) and after (X_{c_o}) it interacts with the leaf:

Equation 2:

$$\xi = \frac{X_{c_i}}{X_{c_i} - X_{c_o}}$$

Integration with the LI-6800

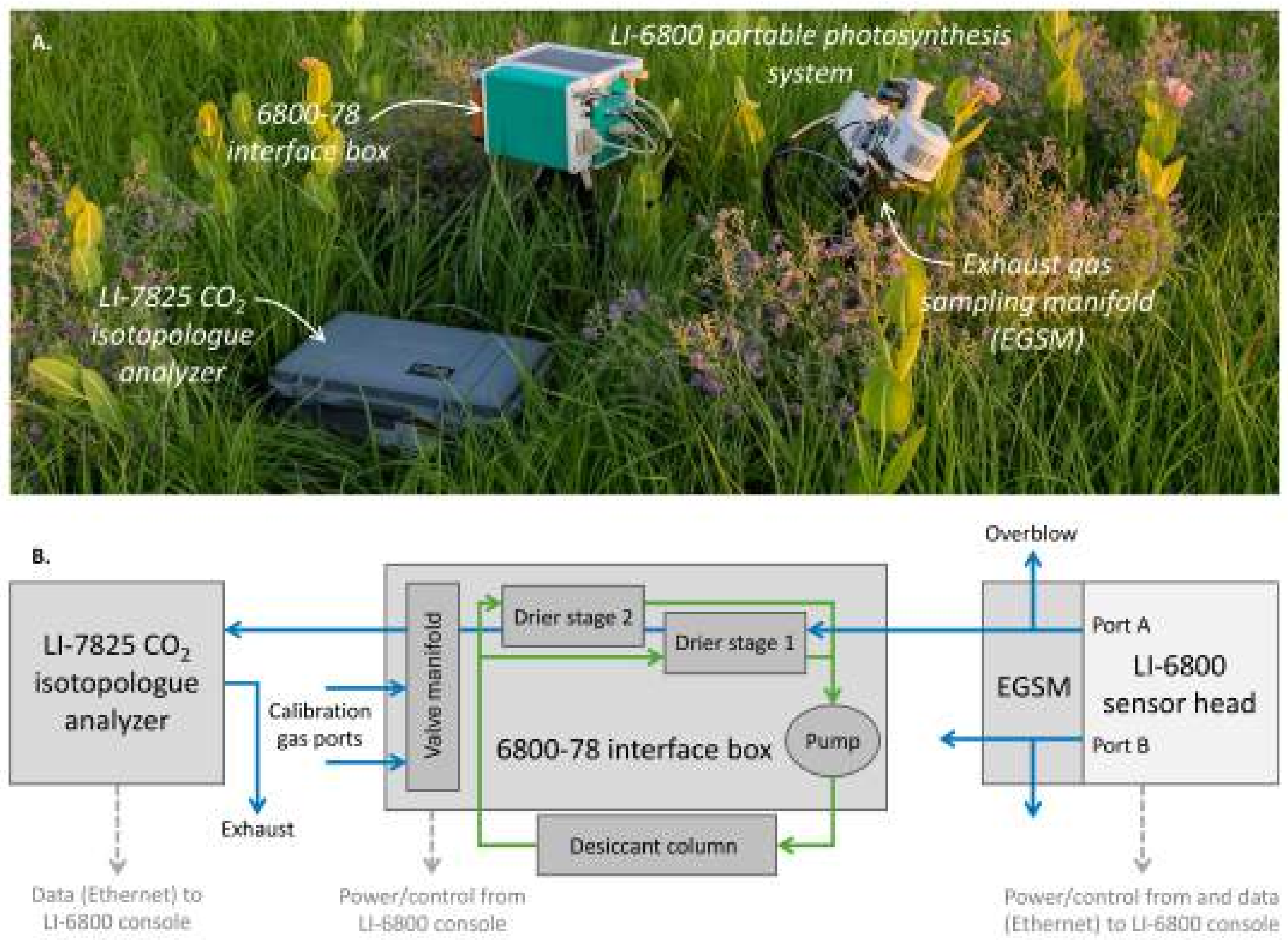
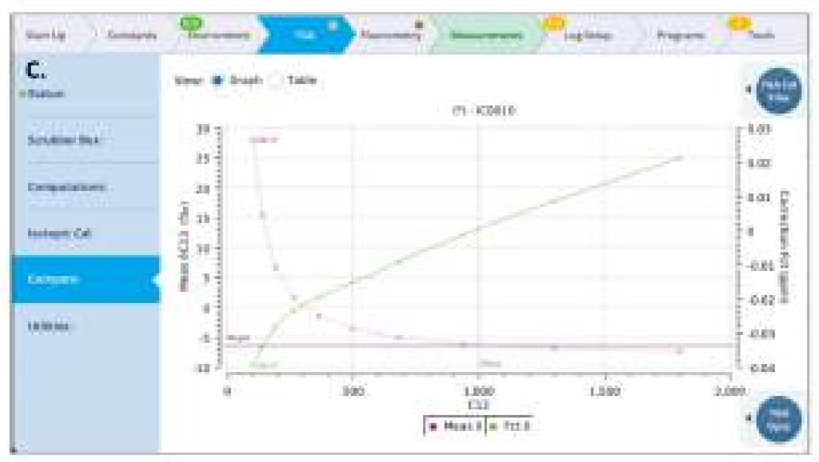


Figure 4: **A.** The integrated instrument system in a field deployment. **B.** Flow path and key functional elements. Note that the LI-7825 only samples air from exhaust port A on the LI-6800 sensor head. In normal mode this port provides exhaust air form the chamber (X_{c_o}, δ_{13c_o}). In match mode, it provides reference air (X_{c_i}, δ_{13c_i}). **C.** Example of the on-board characterization and correction for the LI-7825's CDE.



Example measurements

Figure 5: Example data from measurements on soybean (*Glycine max*).

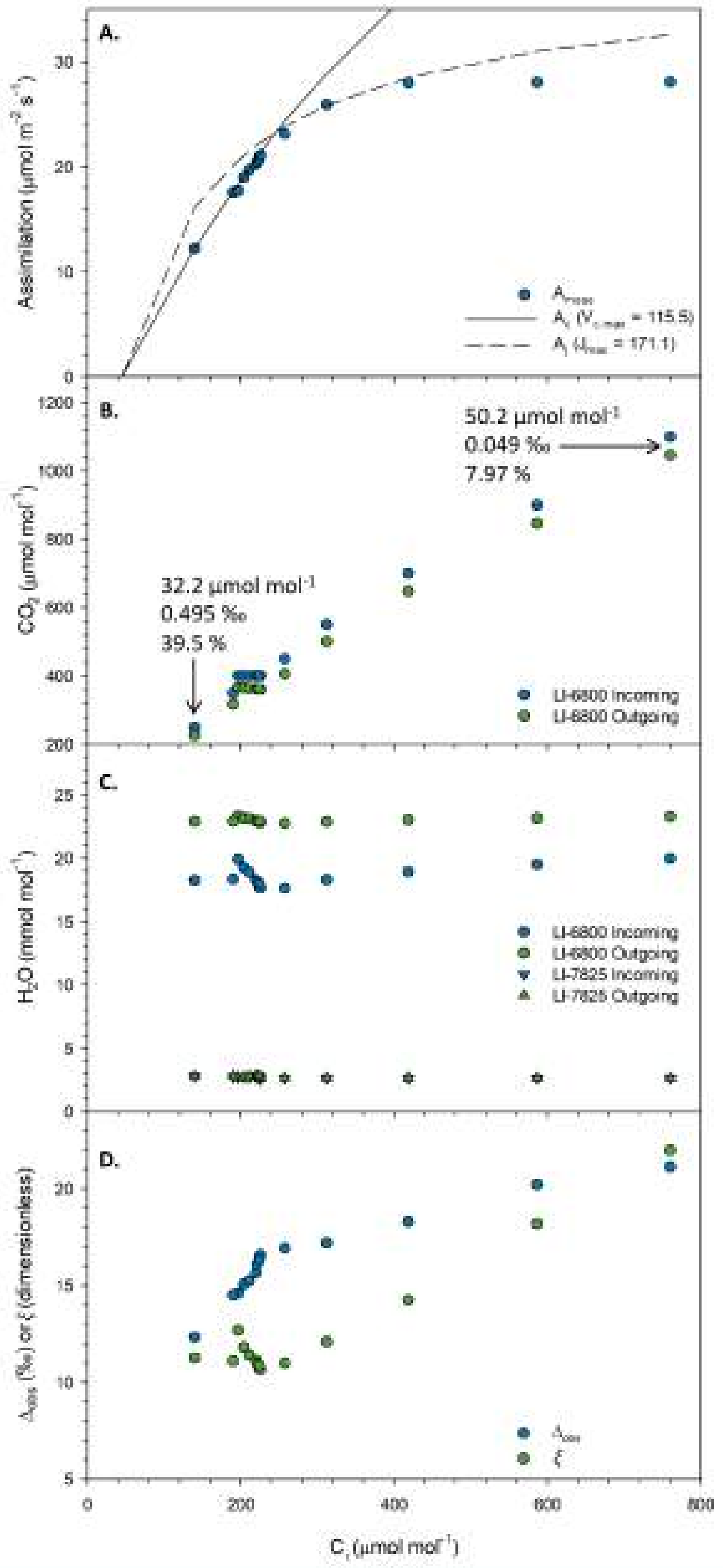
A. Response of assimilation to internal CO_2 mole fraction with fits to the carboxylation (A_c) and electron transport (A_j) limited regions of the curve.

B. CO_2 mole fraction of the incoming and outgoing airstreams as measured by the LI-6800. Callouts give $X_{c_i} - X_{c_o}$ and how much correcting for CDE changed $\delta_{13c_o} - \delta_{13c_i}$, both as an absolute (‰) and relative value (%), at the lowest and highest C_i.

C. H_2O mole fractions of the incoming and outgoing airstreams as measured by the LI-6800 (circles) and LI-7825 (triangles) using a prototype 6800-78 interface box.

D. Discrimination and ξ observed during these measurements. Uncertainty in Δ_{obs} (estimated following Ubierna *et al* 2018 using the standard deviation for a 120 second averaging interval) ranged from 0.8 % at 1050 µmol mol^{-1} to 5.5 % at 360 µmol mol^{-1}.

Note that all CDE corrections were done by adjusting $\delta^{13}C$ to that measured at 400 µmol mol^{-1} using the incoming measurements. Measurements were made at constant light (1500 µmol m^{-2} s^{-1} PPFD), leaf temperature (26 C) and vapor pressure deficit (1.0 kPa) in a 6800-02A 3x3 leaf chamber.



Conclusions

- This work demonstrates application-specific performance of the LI-7825 integrated with an LI-6800 for leaf-level carbon isotope discrimination measurements.
- While there is some CDE to both H_2O and CO_2, this can be addressed by drying the airstream before the LI-7825 with the 6800-78 and by characterizing the CO_2 dependence and correcting measurements on-board the LI-6800.
- Uncertainty estimates are quite low for Δ_{obs} (5.5 % or less) for the example measurements, suggesting good performance of the LI-7825 under these measurement conditions.

References

Ubierna, Nerea, Meisha-Marika Holloway-Phillips, and Graham D Farquhar. "Using Stable Carbon Isotopes to Study C 3 and C 4 Photosynthesis: Models and Calculations." *Photosynthesis: Methods and Protocols*, 2018, 155–96.

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