

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 CO₂ 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

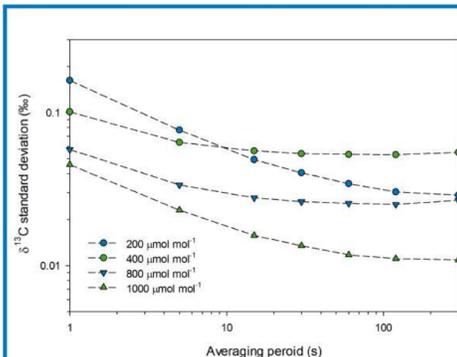


Figure 1: Impact of averaging interval on measurement precision (standard deviation) for a range of CO₂ mole fractions. Data shown here were collected at one sample per second over 30-minute intervals using the LI-6800 to generate a constant CO₂ mole fraction. The resulting precision represents the combined effects of noise introduced through the LI-6800 CO₂ control system and performance of the LI-7825.

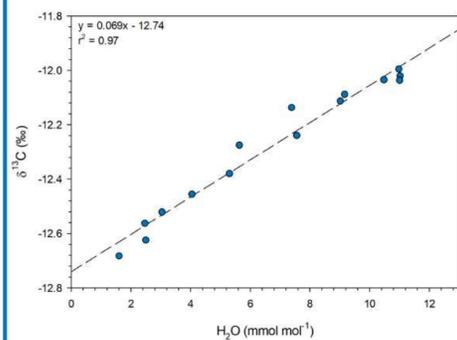


Figure 2: Dependence of δ¹³C to H₂O mole fraction. Spectroscopic and dilution corrections are combined on the LI-7825. This combined correction was determined empirically on a population of analyzers during development to produce a generalized correction used for all LI-7825. Consequently, there is some concentration-dependent residual error (CDE) with H₂O mole fraction: 0.07 ‰ per mmol mol⁻¹ for the instrument tested.

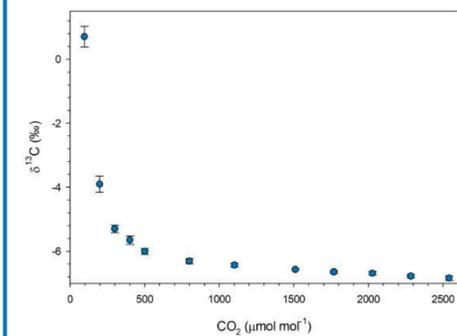


Figure 3: Dependence of δ¹³C to CO₂ mole fraction. Error bars are one standard deviation for a five second averaging interval. Typical CDE of the LI-7825 to CO₂ is <0.1 ‰ per 100 μmol mol⁻¹ at concentrations >400 μmol mol⁻¹. Data here show a residual error of 0.05 ‰ per 100 μmol mol⁻¹ for the specific 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 CO₂ 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 :

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

Where ξ is calculated from the CO₂ mole fraction of the air before (X_{c_i}) and after (X_{c_o}) it interacts with the leaf:

$$\text{Equation 2: } \xi = \frac{X_{c_i}}{X_{c_i} - X_{c_o}}$$

Integration with the LI-6800

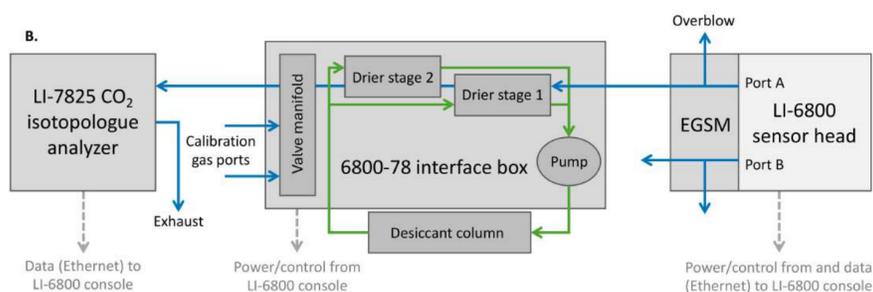
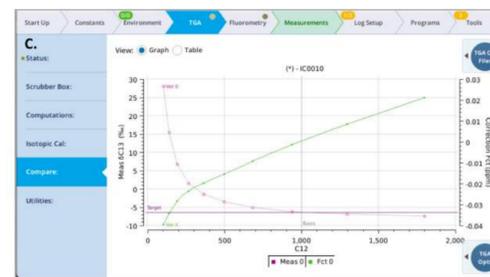


Figure 4: A. The integrated instrument system in a field deployment. B. Flow path and key functional elements. Note that the LI-7825 only samples air from exhaust port A on the LI-6800 sensor head. In normal mode this port provides exhaust air from the chamber (X_{c_o} , δ_{13c_o}). In match mode, it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

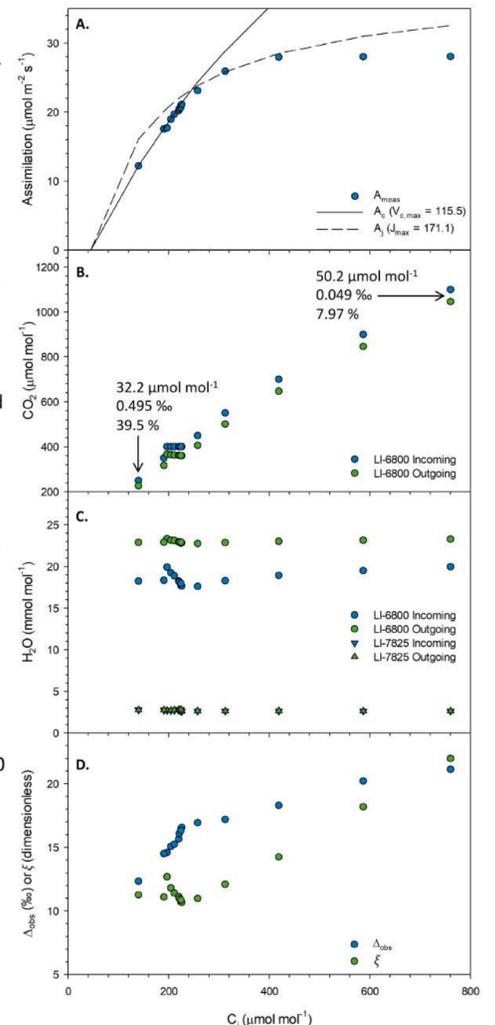
A. Response of assimilation to internal CO₂ mole fraction with fits to the carboxylation (A_c) and electron transport (A_t) limited regions of the curve.

B. CO₂ 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. H₂O 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 δ¹³C to that measured at 400 μmol mol⁻¹ using the incoming measurements. Measurements were made at constant light (1500 μmol m⁻² s⁻¹ PPF), 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 H₂O and CO₂, this can be addressed by drying the airstream before the LI-7825 with the 6800-78 and by characterizing the CO₂ 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.

