Finding the floor: Comparison of portable photosynthesis systems for measurement of small fluxes

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Introduction

- Fluxes of carbon dioxide (assimilation) and water vapor (transpiration) measured in an open flow-through gas exchange system like the LI-6400XT or LI-6800, are computed from a mass balance between the air entering the sample chamber and the air leaving the chamber.
- While the magnitude of the flux (i.e. assimilation and transpiration rates) impact the magnitude of the measured signal (ΔCO_2 and ΔH_2O, respectively), the measured signal is also dependent on flow rate through, and sample (leaf) area in, the chamber.
- Confidence in these measurements is driven by the relative magnitude of the delta between sample and reference compared to the combined noise resulting from variations in the measured parameters and the environmental control loops.

Environmental controls

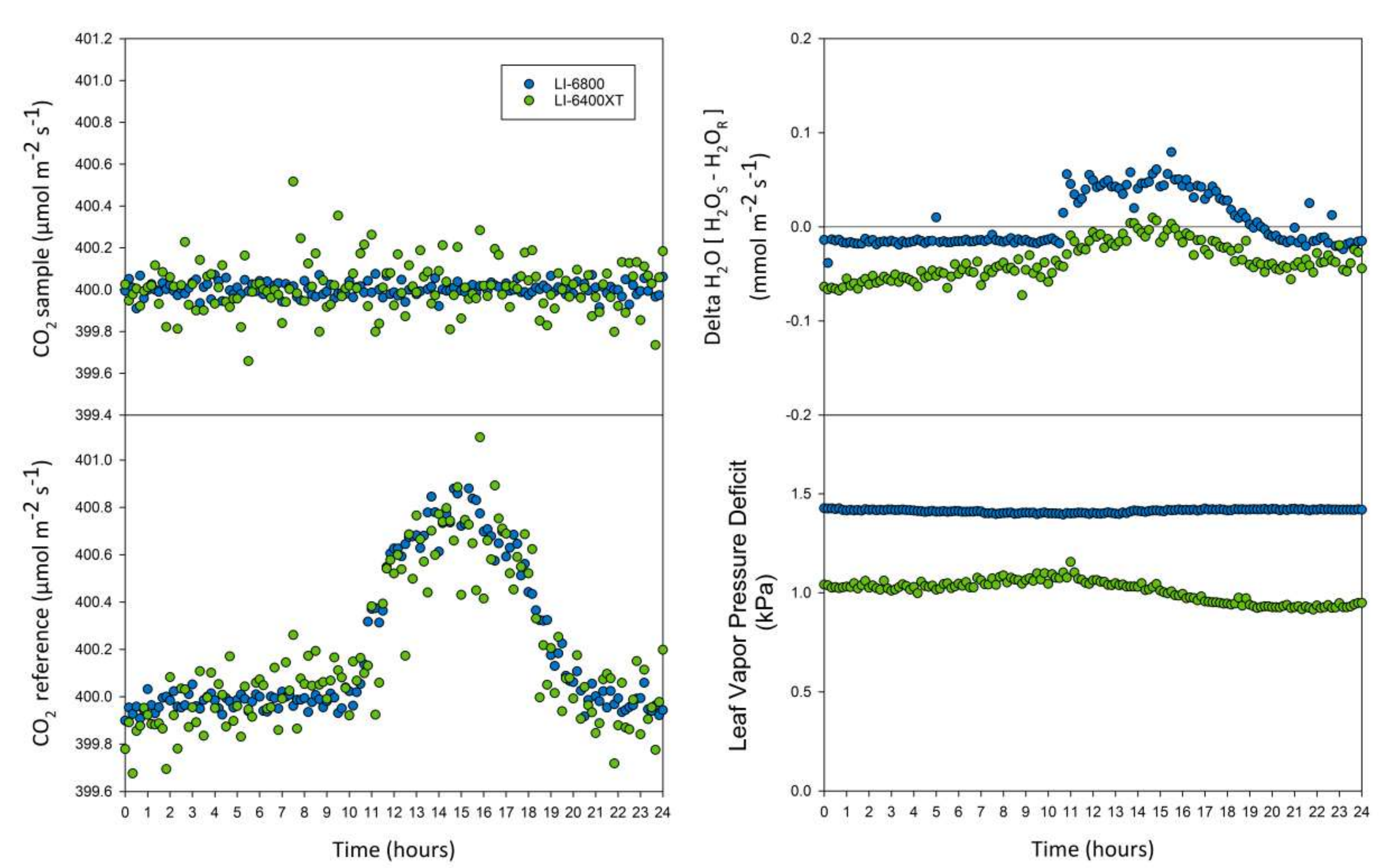


Figure 1: Environmental parameters during a 24 hour long measurement period with data points logged every 10 minutes. Both instruments were configured to control sample CO_2 at a constant value (400 µmol mol^{-1}) and set at a constant flow rate, such that the flow rate to leaf area ratio was equal between the instruments. An equal flow rate to leaf area ratio ensures that for a given assimilation rate, both instruments would report the same ΔCO_2.

For water vapor the LI-6800 was set to control leaf to air VPD at 1.4 kPa. The LI-6400XT was set up with a humidifier to humidify the air stream supplied to the instrument and the desiccant scrub was adjusted to yield similar initial chamber humidity to the LI-6800.

Standard deviations used in the error analysis were computed from the 24 hour data-set . Where the data varies around a transient mean, non-linear de-trending was done prior to computing the standard deviation.

Assimilation noise analysis

The mass balance for assimilation in an open flow through system is given by:

$$A = \frac{F\left[C_r - C_s\left[\frac{1000 - W_r}{1000 - W_s}\right]\right]}{100S} \cong \frac{F\,\Delta CO_2}{100S} \qquad \text{Eq. 1}$$

where A is assimilation (µmol m^{-2} s^{-1}), F is flow (µmol s^{-1}), C_r is the incoming CO_2 concentration (µmol mol^{-1}), C_s is the outgoing CO_2 concentration (µmol mol^{-1}), W_r is the incoming H_2O concentration (mmol mol^{-1}), W_s is the outgoing H_2O concentration (mmol mol^{-1}), and S is leaf area in the chamber (cm^2).

The confidence interval half width for a given parameter, $c_x^{0.5}$, can be calculated from the standard deviation of that parameter, σ, and the desired confidence level.

$$c_x^{0.5} = \frac{3\sigma}{2} \qquad \text{Eq. 2}$$

Here we choose a 99.7% (3σ) confidence level.

Combining the confidence interval half width for all inputs in equation 1 with the respective input, allows an upper and lower confidence bound to be defined for assimilation:

$$A_{upper} = \frac{(F + c_f^{0.5})\left[(C_r + c_{Cr}^{0.5}) - (C_s - c_{Cs}^{0.5})\left[\frac{1000 - (W_r + c_{Wr}^{0.5})}{1000 - (W_s - c_{Ws}^{0.5})}\right]\right]}{100S} \qquad \text{Eq. 3}$$

$$A_{lower} = \frac{(F - c_f^{0.5})\left[(C_r - c_{Cr}^{0.5}) - (C_s + c_{Cs}^{0.5})\left[\frac{1000 - (W_r - c_{Wr}^{0.5})}{1000 - (W_s + c_{Ws}^{0.5})}\right]\right]}{100S} \qquad \text{Eq. 4}$$

where A_{upper} and A_{lower} are the upper and lower bounds, $c_F^{0.5}$, $c_{Cr}^{0.5}$, $c_{Hr}^{0.5}$, $c_{Cs}^{0.5}$ and $c_{Hs}^{0.5}$ are the confidence interval half widths for flow, incoming CO_2 and H_2O concentrations, and outgoing CO_2 and H_2O concentrations, respectively.

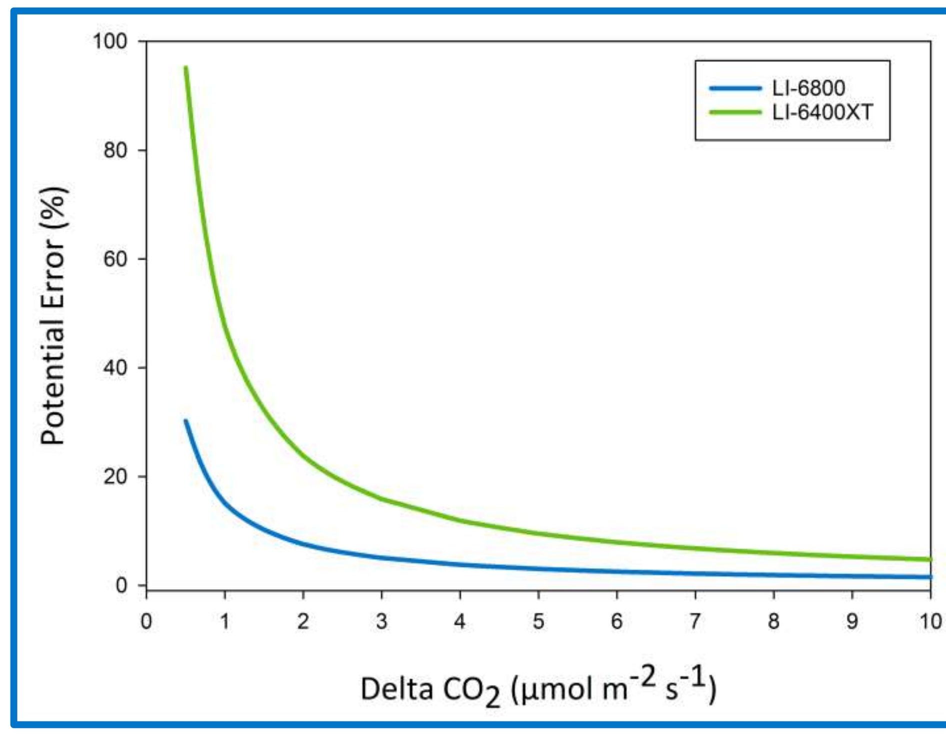


Figure 2: Modeled error in assimilation as a function of ΔCO_2. Potential error in assimilation, ψ_{error}, (%) can be computed from A and A_{lower}:

$$\psi_{error}(\%) = \frac{A - A_{lower}}{A} * 100$$

Assimilation in *Epipremnum*

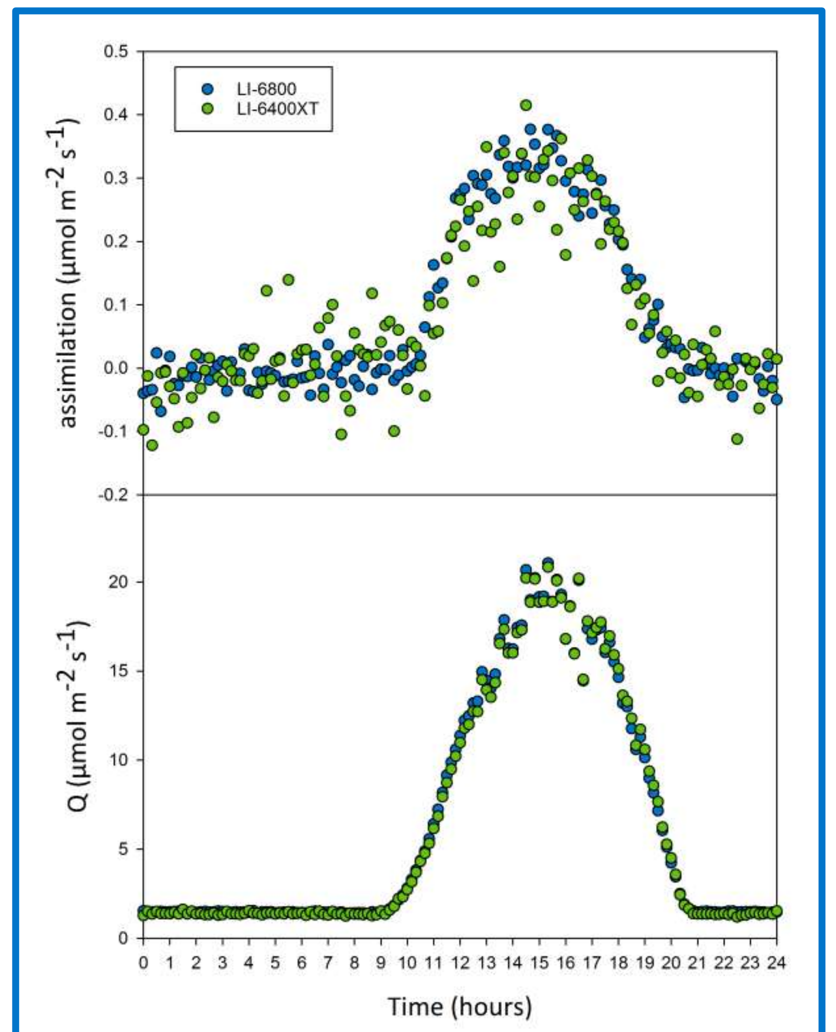


Figure 3: Assimilation and Photosynthetically Active Radiation (Q) measured in the leaf chamber over a 24 hour period for a shade grown *Epipremnum*.

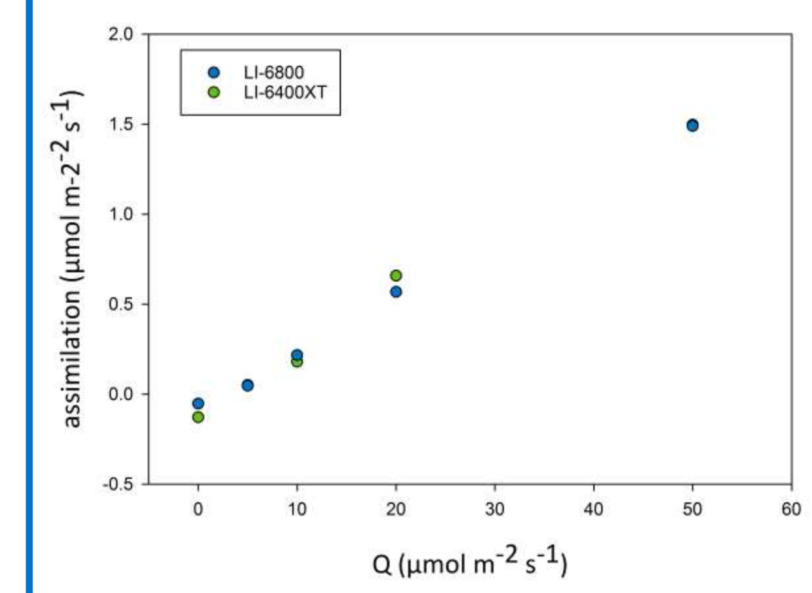
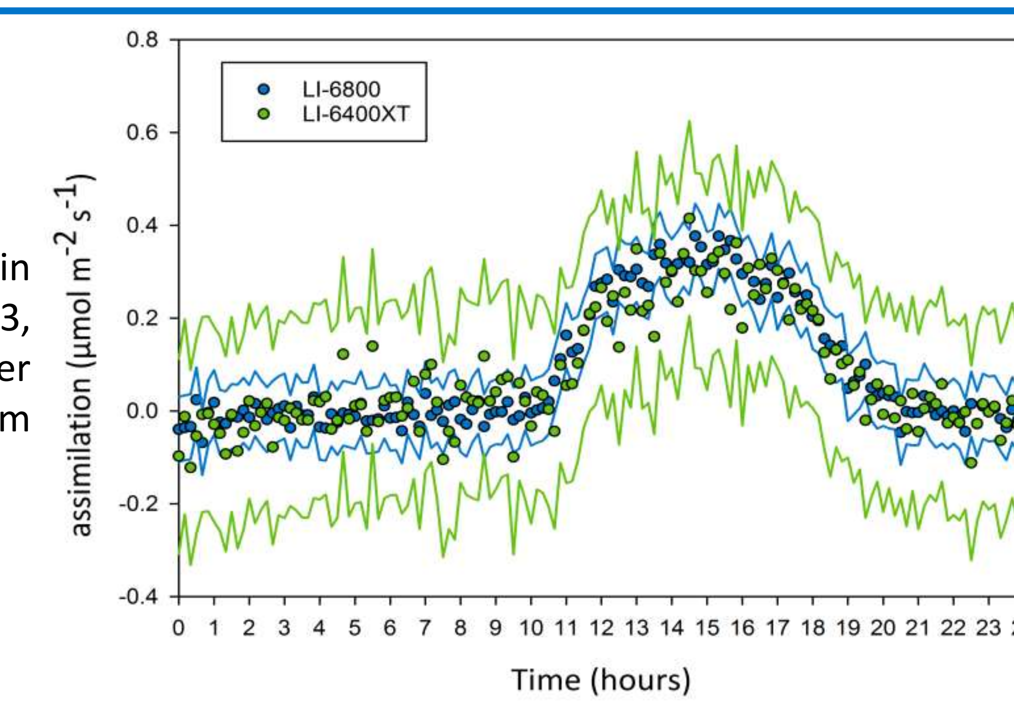


Figure 4: Initial light limited region of two light response curves measured on *Epipremnum*. Light intensity (Q) is plotted as incident PPFD measured in the chamber. The apparent light compensation points are 2.6 and 3.2 µmol m^{-2} s^{-1} for the LI-6400XT and the LI-6800, respectively.

Figure 5: Assimilation, as shown in the upper panel of Figure 3, plotted with upper and lower confidence bands computed from Equation 3 and 4.



Conclusions

- A simple analysis of noise, while not a complete accounting of measurement errors, can provide useful insights to limits of measurement precision in gas exchange measurements.
- Improvements in gas analyzer performance and environmental control loops in the LI-6800 allow for greater precision when measuring small fluxes.
- Further reductions in system noise are possible through reducing flow rates, increasing leaf area in the chamber or increasing averaging time.

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