Considerations for Making Chamber-Based Soil CO2 Flux Measurements

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Abstract
The concept of chamber-based soil CO2 flux measurement can at first seem quite simple, because the only items needed for making a measurement are a chamber, a pump, a CO2 gas analyzer, and a data logging device. However, the following considerations must also be taken into account during instrument measurements design in order to have accurate flux data:

1. Maintaining chamber-pressure equilibrium with ambient air pressure
2. Ensuring good mixing of air inside the chamber
3. Dealing with an altered diffusion gradient inside the chamber
4. Minimizing disturbance to the environment.

We will discuss here how we have addressed each of these considerations.

Methods for Soil CO2 Flux Measurement

SOIL CO2, \( F_C \), can be estimated with Equation 1 using the information of chamber volume (V), soil surface area (S), air temperature (T), atmospheric pressure (P), and the rate of CO2 concentration increase inside the chamber (\( \text{d}C_C/\text{d}t \), µmol/mo/s) which has been on the soil surface for a short period of time.

\[
F_C = \frac{PV}{RTS} \frac{\text{d}C_C}{\text{d}t}
\]

(1)

Where \( R \) is the gas constant (8.314 Pa m³/K mol).

Consideration 1. Maintaining pressure equilibrium between the inside of a chamber and the ambient air pressure

Pressure equilibrium between the inside of a flux chamber and the surrounding air outside the chamber must be maintained during measurement. A simple open vent tube connecting to the chamber has often been used for chamber pressure equilibration (e.g., Hutchinson and Mosier, 1981; Davidson et al., 2002). This approach, however, is effective only under calm conditions. Under windy conditions, negative chamber pressure excursions will occur because of the Venturi effect. This will lead to underestimation of \( F_C \) and a potential chamber pressure perturbation. A mixing fan is not used on LI-8100A chambers. Good mixing is achieved through both optimal bowl-shaped chamber geometry or a mixing manifold.

Consideration 2. Ensuring good mixing.

Because only a small portion of chamber air is sent to the infrared gas analyzer to determine \( \text{d}C_C/\text{d}t \), good mixing inside the chamber is essential. To eliminate any potential chamber pressure perturbation, a mixing fan is not used on LI-8100A chambers. Good mixing is achieved through both optimal bowl-shaped chamber geometry or a mixing manifold.


Soil CO2 flux is driven primarily by the CO2 diffusion gradient across the soil surface. With the closed-chamber technique, the chamber headspace CO2 concentration (\( C_C \)) must be allowed to rise in order to obtain \( \text{d}C_C/\text{d}t \). However, raising \( C_C \) will reduce the CO2 diffusion gradient across the soil surface inside the chamber, leading to an underestimation of \( F_C \). To overcome this, a new exponential function is derived to fit the time series of \( C_C \) (Equation 2).

\[
C_C = C_s + (C_C(0) - C_s) e^{-\text{at}}
\]

(2)

where \( C_s \) is the CO2 concentration in the soil surface layer communicating with the chamber (µmol/mol), and \( a \) is a rate constant (1/a).

Our experimental data show that the underestimate of \( F_C \) from the linear approach was systematic and significant, even though the linear regression sometimes gave a very high value for the regression coefficient. Furthermore, the underestimate will be greater for porous soils that have a high conductance to gas transport. Therefore, we do not recommend using linear regression on the time series of chamber CO2 data to determine the \( \text{d}C_C/\text{d}t \).

Consideration 4. Minimizing disturbance to the environmental conditions.

For a long-term soil CO2 flux measurement, it is critical to keep conditions inside the collar as close as possible to natural environmental conditions. The impact of installation of the long-term chamber on radiation balance, wind field, and precipitation interception should be minimized. This issue was addressed carefully when designing the two long-term chambers (#100-101 and #104). Both chambers are parked away from the collar when they are not in measurement mode. The baseplate of the two long-term chambers is perforated to minimize perturbation to soil around the collar.

Also, chambers must close and open automatically and slowly. This eliminates the possibility of pushing fresh ambient air into the soil or removing soil air during the chamber closing/opening. Temperature artifacts are minimized by careful consideration of chamber materials and coatings.

Example of soil CO2 flux measurement over a soybean field in Nebraska

Figure 3 shows an example of diurnal soil CO2 flux from a soybean field at the University of Nebraska-Lincoln’s Agricultural Experimental Station near Mead, Nebraska, USA. The dataset was obtained in the middle of the growing season (July 8 to 19, 2006). The flux value and soil temperature at 5 cm depth were averaged from 16 measurements at different locations with an LI-8100 16-channel multiplexed soil CO2 flux system. The soil CO2 flux ranged from 2 to 7 µmol/m²/s and shows a strong diurnal pattern that closely follows soil temperature variations. This is because microbial respiration increases exponentially with temperature.


Soil CO2 flux is driven primarily by the CO2 diffusion gradient across the soil surface. With the closed-chamber technique, the chamber headspace CO2 concentra- 

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References