Flux Calculations

Following each measurement mode, the intermediate flux data are fit with a regression, which is then used to compute the soil CO_2 flux for the target ambient CO_2 concentration (Figure 5). The cycle automatically repeats until the number of cycles specified in software are completed. Using this protocol results in accurate and repeatable soil CO_2 flux measurements. The soil flux for the measurement illustrated in Figure 5 was 6.98 µmol m^{-2} s^{-1} with a standard deviation of 0.03 for the four measurement cycles.

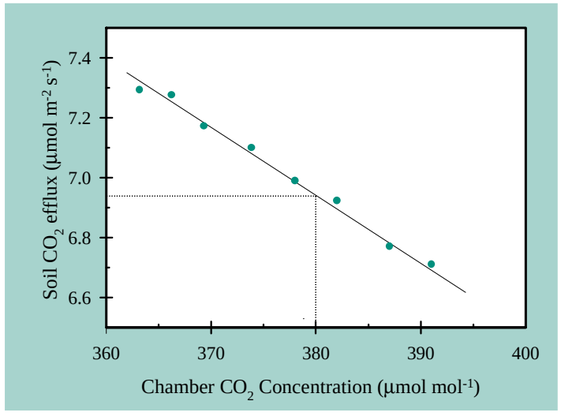

Figure 5. A plot of typical intermediate flux values. These intermediate values are used to calculate efflux at ambient conditions (380 µmol mol^{-1} in this example).

The LI-6400 console displays flux rate calculations in numeric and graphical form for evaluation in the field.

Specifications

System Volume: 991 cm^3 (zero insertion depth).
Soil Area Exposed: 71.6 cm^2 (11.1 $in.^2$).
Diameter: 9.55 cm (3.76 in.).
Air Temperature Thermocouple:
Type E: Range: ± 50 °C of reference junction.
Reference Junction: Optical housing block thermistor. Accuracy: ± 10% of temperature difference between air and sensor head reference junction with the amplifier zeroed.
Soil Temperature Probe (Type E):
Ambient Temperature Range: 0 to 50 °C.
Soil Temperature Range: ± 30 °C from ambient within the range of -20 °C to 60 °C.
Soil Temperature Accuracy: ± 1.5 °C, 0 to 50 °C.
Size: 16.50 H × 19.80 W × 10.20 D cm. (6.5 × 7.8 × 4.0").
Weight: 1.8 kg (3.75 lb).

Specifications subject to change without notice.

Ordering Information

6400-09 Soil CO_2 Flux Chamber
(Includes one 6000-09TC Soil Probe Thermocouple, one 6400-13 Thermocouple Adapter, three 6560-228 Soil Collars, one 9960-112 Gasket Kit (six gaskets for 4" collars), miscellaneous spare parts and O-Rings.

Replacement Parts

6000-09TC Spare Soil Probe Thermocouple
6560-228 Soil Collars (1 each). Three collars and instructions for making them are included with each chamber.
6560-229 Foam Gasket (one gasket for 4" collar).

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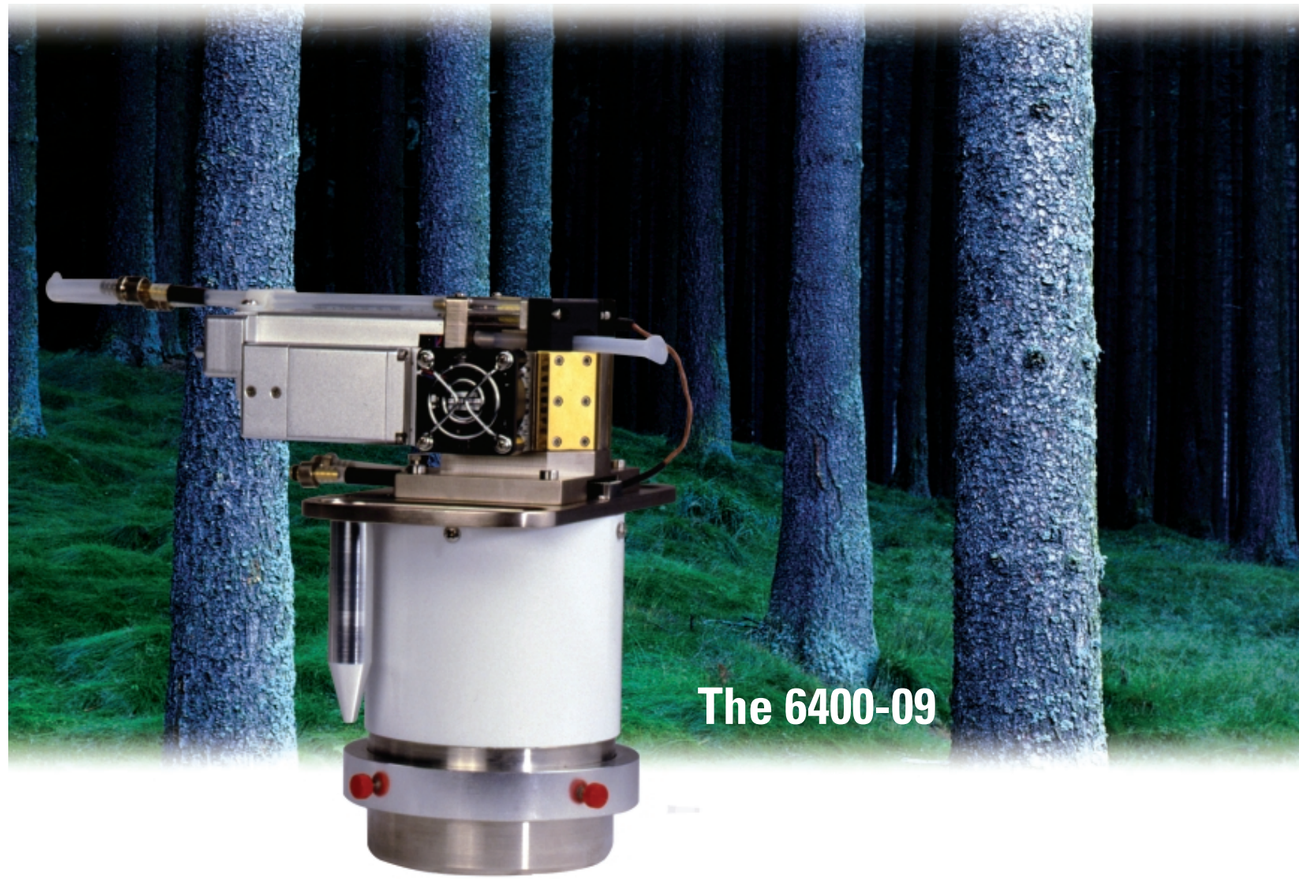
Soil CO_2 Flux Chamber



LI-COR Biosciences

Accurate Soil CO_2 Flux Measurements

Accurately measuring soil CO_2 flux can be challenging, even under the best of conditions. Factors that influence the soil CO_2 flux rate include chamber pressure, method of mixing the chamber air, chamber CO_2 concentration, and dilution effects of water vapor. LI-COR understands these challenges. For more than a decade we have been perfecting the science of measuring soil CO_2 flux using chamber methods. The 6400-09 Soil CO_2 Flux Chamber and the LI-6400 Portable Photosynthesis System combine to create the best system available for measuring soil CO_2 flux.

Effects of Chamber CO_2 Concentration

The movement of CO_2 out of the soil is primarily in response to the concentration gradient between the soil and the ambient atmosphere. Chamber CO_2 concentration should not be allowed to build up too far above ambient CO_2 concentration, or the flux will be underestimated. In the LI-6400, the chamber concentration is automatically scrubbed to just below an ambient target, and then measured as it rises to slightly above ambient. This protocol maintains the CO_2 concentration gradient to within a few ppm of the natural, undisturbed value (Figures 2 and 4).

Effects of Pressure

Soil CO_2 concentration may be many times greater than ambient CO_2 concentration. In addition, soil is a porous medium, so movement of air into or out of soil, which can be caused by extremely small pressure differentials, can greatly enhance or suppress soil flux. The 6400-09 Soil CO_2 Flux Chamber employs a pressure equilibration tube that eliminates the development of pressure differentials and at the same time avoids chamber leaks.

Thorough Mixing

Air in the chamber headspace must be thoroughly mixed in order to correctly sample the chamber CO_2 concentration. However, mixing must be achieved without causing localized pressure gradients. The 6400-09 uses a fan to push air through a perforated manifold to distribute and thoroughly mix the air in the chamber without developing localized pressure gradients or ventilating the soil surface (Figure 3).

Dilution Corrections

When a closed chamber is placed on a moist soil surface, water vapor concentration in the air increases, causing a proportionate decrease in the air CO_2 partial pressure. This

Figure 1. *The CO_2 and H_2O analyzers in the LI-6400 sensor head are connected directly to the soil chamber for fast response.*

may underestimate the CO_2 flux. The need for a dilution correction is especially acute if the rate of increase of humidity is large in comparison to the rate of increase of CO_2 concentration. This happens with wet soils on dry sunny days, when chamber air temperature and water vapor rise rapidly. The LI-6400 measures the rate of increase of water vapor at the same time it measures CO_2, and automatically applies a dilution correction. This results in consistently accurate data.

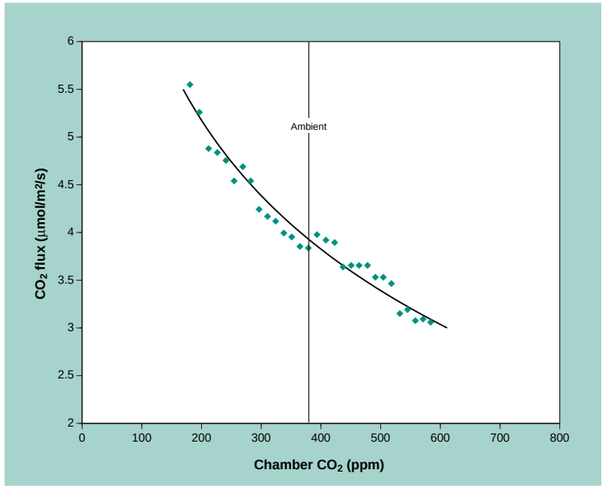


Figure 2. *Soil CO_2 flux dependency on chamber CO_2 concentration.*

Sampling Automation

Due to the natural spatial heterogeneity of soil, CO_2 flux measurements require extensive sampling. The LI-6400 introduces a new level of sampling repeatability and accuracy that can easily be achieved with the LI-6400's unique software and hardware automation controls.

OPEN™ Software

Switching from photosynthesis to soil CO_2 flux measurements is easy with the LI-6400's OPEN software. You can quickly configure OPEN for any LI-6400 accessory by simply picking the chamber accessory from a list.

Four parameters are entered from the LI-6400 keypad to control the automatic measurement:

1. Ambient CO_2 concentration (380 µmol mol^{-1}, in the example in Figure 4).
2. The CO_2 change that determines the upper and lower set points ($\Delta CO_2 = \pm 5$ µmol mol^{-1} from ambient in Figure 4).
3. Depth of the chamber in the soil (or above the soil, if using collars).
4. Number of measurement cycles.

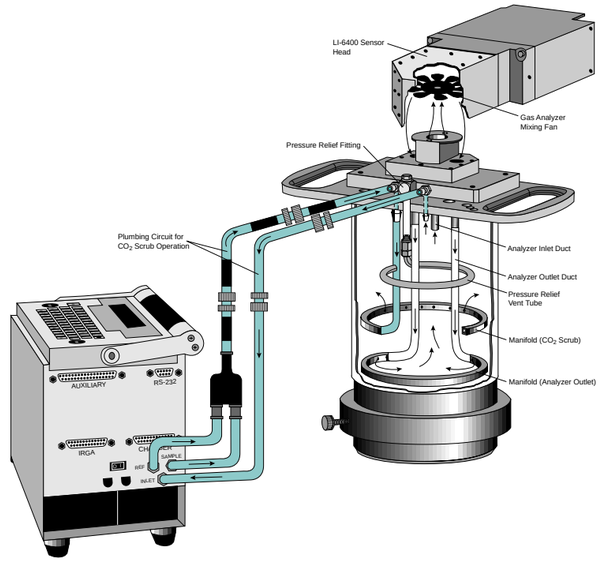


Figure 3. *Schematic showing path of air flow between 6400-09 and LI-6400 console. A fan pushes air through a perforated manifold to thoroughly mix the air.*

Measuring Ambient CO_2

Before starting a series of measurements, ambient CO_2 is measured by laying the soil chamber on its side on the soil surface, near the location where the chamber will be inserted.

Mounting the Chamber

Chamber handles (Figure 1) make it easy to press the 6400-09 into the soil or to slip it into a soil collar already in the soil. The preferred method, however, is to use soil collars, which makes repeated sampling easier and also prevents disturbing of the soil.

Automated Cycling Protocol

The measurement protocol is fully automated. Each time the chamber is placed at a new location, simply press the "Start" function key and a new measurement cycle is triggered.

Drawdown Mode

The LI-6400 enters drawdown mode after the "Start" key is pressed. Air is pumped from the chamber through the soda lime CO_2 scrubber and back into the chamber. The system software automatically stops the pump and enters measurement mode after the CO_2 concentration drops to just below the set point (Figure 4).

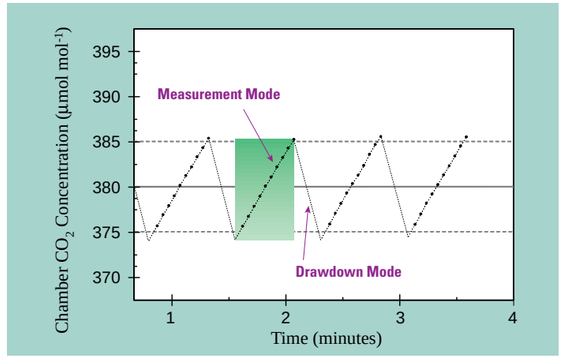


Figure 4. *Data from a measurement with four cycles.*

Measurement Mode

During measurement, the CO_2 concentration of the chamber air rises from the low set point, passing through the target ambient CO_2 concentration, to the high set point. Every two to three seconds, a flux is computed based on a running average of the rate of change of CO_2 concentration with time.