A discussion on the paper "An improved open chamber system for measuring soil CO_2 effluxes in the field"

Rayment M B *et al*., 1997

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2017/09/07

Outline

- Introduction
- Methods
- Results
- Discussion
- Inspiration

Introduction

Background

- CO_2 is responsible for the majority of the current global warming trend.
- The efflux of CO_2 from the soil surface is one of the key components of the carbon balance of an ecosystem [*Raich and Schlesinger*, 1992]. Overall, approximately 68 Pg C yr^{-1} results from global soil CO_2 emissions [*Ciais et al.*,2013].
- At present, there are four methods for measuring the CO_2 efflux of soil : eddy covariance, flux-gradient method, closed and open system.

Introduction

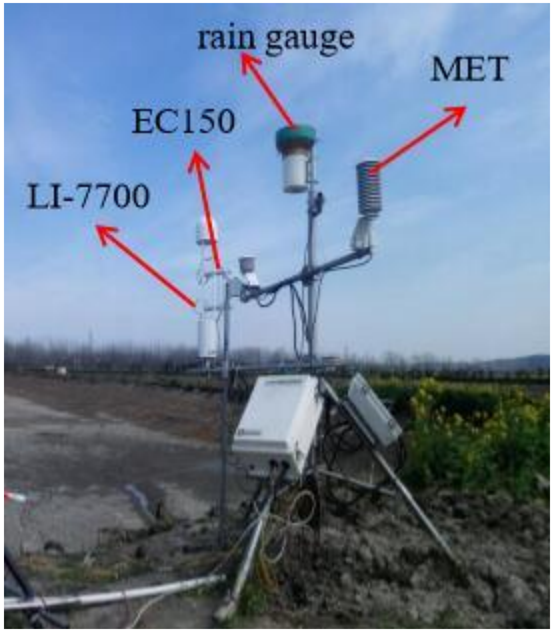
Problems faced

- Four distinct approaches have evolved, each with several variations and associated strengths and weaknesses；
- None has become recognized as the "standard" methodology, and there remains no established procedure for determining the accuracy of any one.

Introduction

Eddy covariance

Covariance between the vertical air velocity and CO_2 concentration calculated from the high-frequency time series to obtain the flux of CO_2.

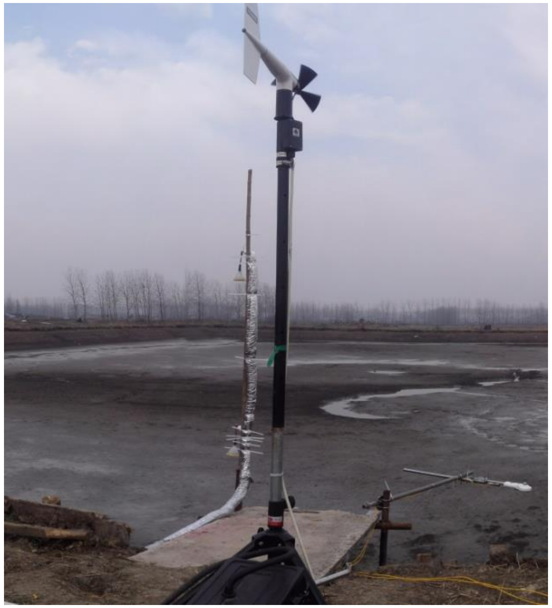


- Advantage: the soil system under observation remains completely undisturbed.
- Disadvantage: technical complexity； assumptions (a level and homogeneous upwind fetch, a zero mean vertical wind speed, and the absence of sources or sinks between the soil and the sensor).

Introduction

Flux-gradient method

$$F = c\rho_a K \frac{r_1 - r_2}{z_1 - z_2}$$



- Advantage: provide the only satisfactory method of partitioning the CO_2 source between different soil horizons;
- Disadvantage: the practical difficulty in determining accurately soil diffusivities in heterogeneous soil systems limits applicability.

Introduction

Closed system

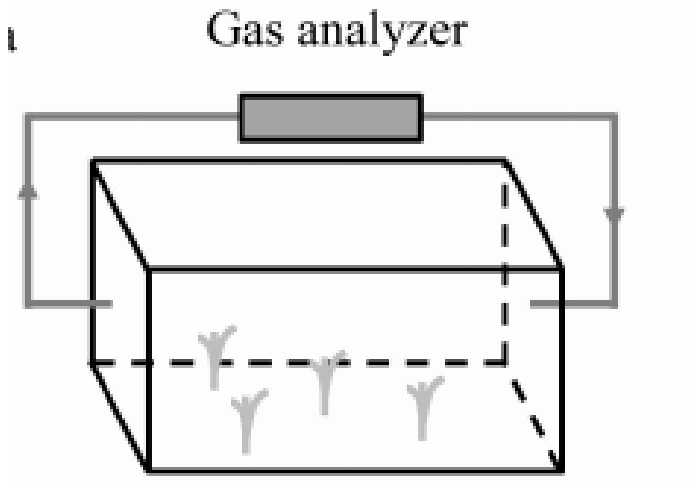


Figure 1. A closed (a) for measuring the net ecosystem exchange.[Lee, 2016]

$$F = \frac{[S_2 - S_1]h}{t\ V_m}$$

Introduction

Closed system

The accumulation rate should be determined over much shorter time period.

- Measurements at the same temporal scale as change in the environmental variable.
- Concentration increase in the chamber may lead to an underestimation of the natural flux.

Introduction

Closed system

The minimum period for measurement of soil efflux should be 24 hours.

- In order to account for changes in the diffusion properties of the soil profile.
- There is a lag period between a change in the driving variable and a corresponding change in CO_2 efflux.

Introduction

Automated closed chamber

- The sample area are more likely to be representative of non-enclosed areas;
- Drawback is the mechanical complexity.

Open system

- The pressure differentials created between the inside and outside of the chamber.

Introduction

Open system

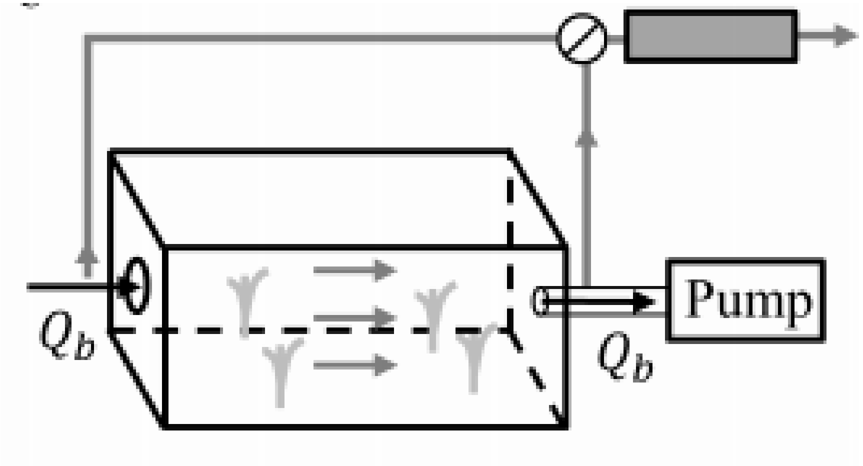


Figure 2. A dynamic canopy chamber (b) for measuring the net ecosystem exchange.[Lee, 2016]

$$F = \frac{Q\,[S_o - S_i]}{A\,V_m}$$

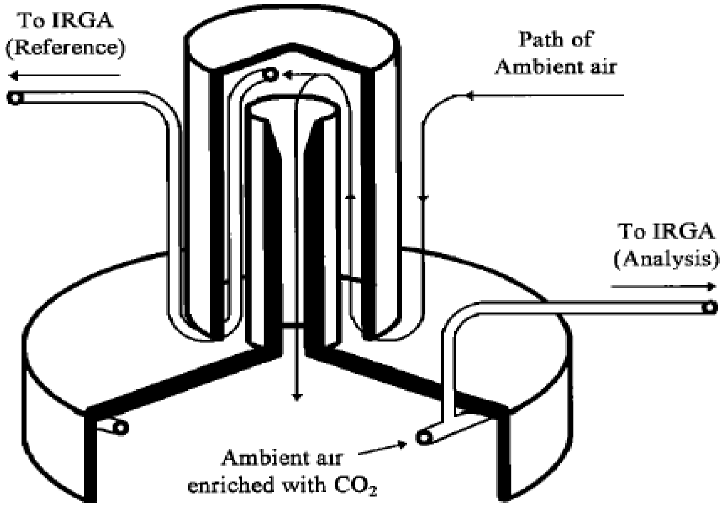
Methods

Requirements

- The flow rate of air through the chamber should be measured accurately;
- The chamber interior should be isolated from its gaseous environment;
- The chamber should allow transmission of fluctuations in atmospheric pressure through to the soil surface;
- There should be minimal pressure difference between the chamber interior and the atmosphere, eliminating any mass flow of air into or out of the chamber;

Methods

Open system soil CO_2 efflux chamber



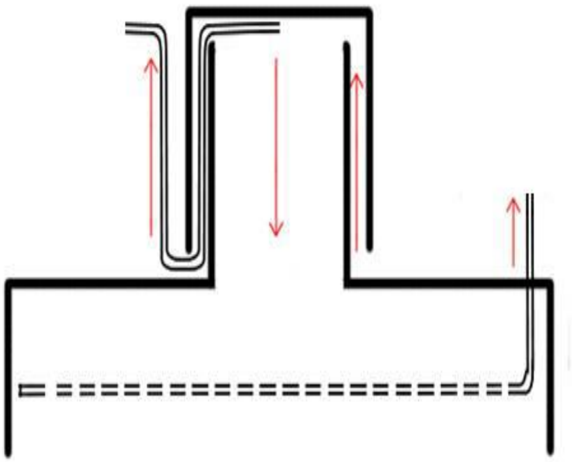


Figure 3. Schematic diagram of a section through an open system soil CO_2 efflux chamber.

Chamber diameter 280 mm
Inlet tube aperture 0 and 500 mm^2
Flow rate 1 $dm^3 min^{-1}$（±1%）

Chamber height 150 mm
Inlet tube length 150 mm

Methods

The pressure difference is a function of the flow rate of air and the length and cross sectional area of the tube.

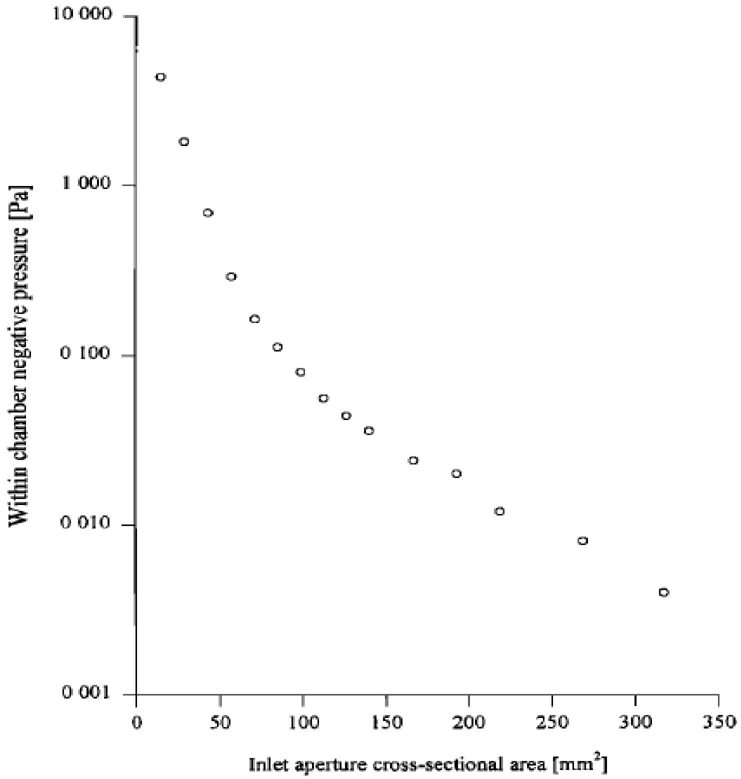


Figure 4. Effect of inlet aperture on internal chamber negative pressure (with respect to atmospheric pressure) at 1 $dm^3 min^{-1}$ flow rate.

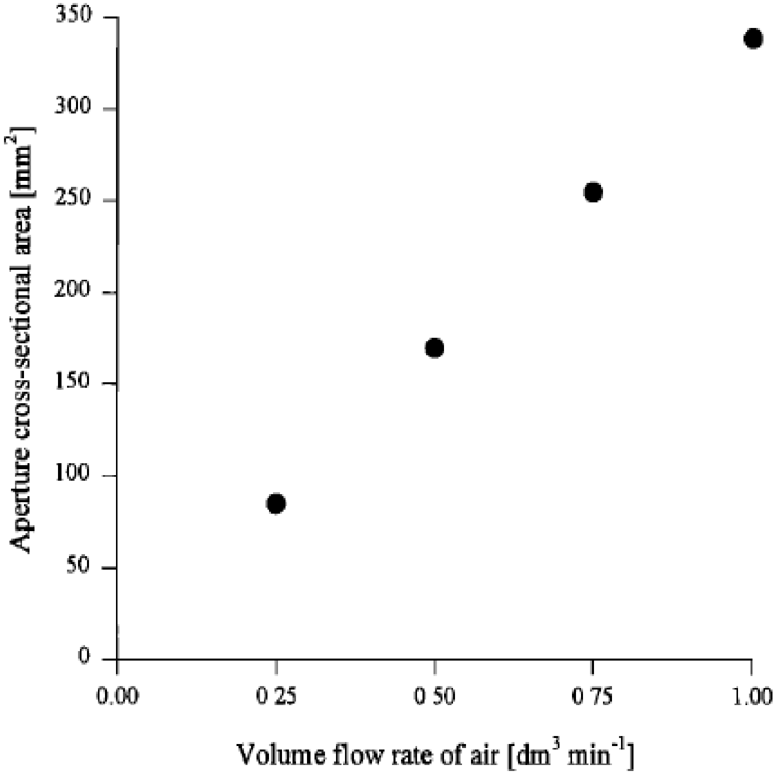
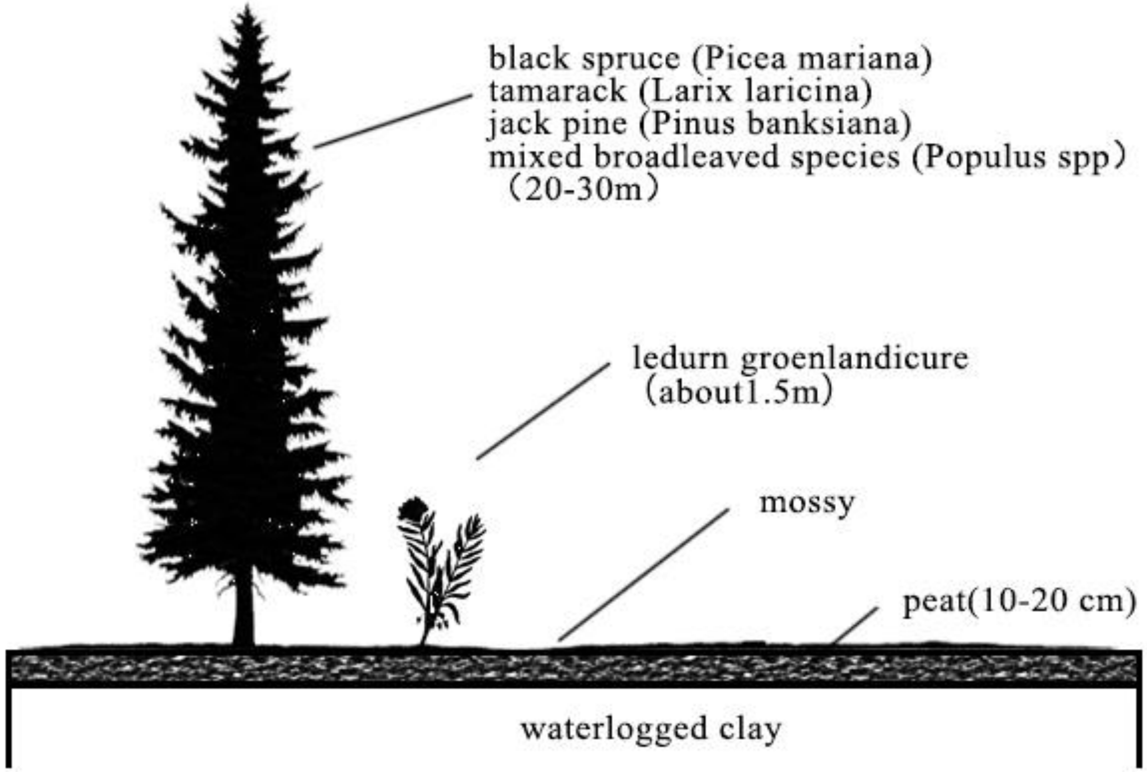


Figure 5. Effect of flow rate on the maximum intake aperture area above which a loss of CO_2 occurred against the mass flow of air into the chamber.

Methods

Field Tests

Extensive field tests were carried out at the southern study area old black spruce site of the BOREAS project in Saskatchewan, central Canada during 1994 and again in 1996.

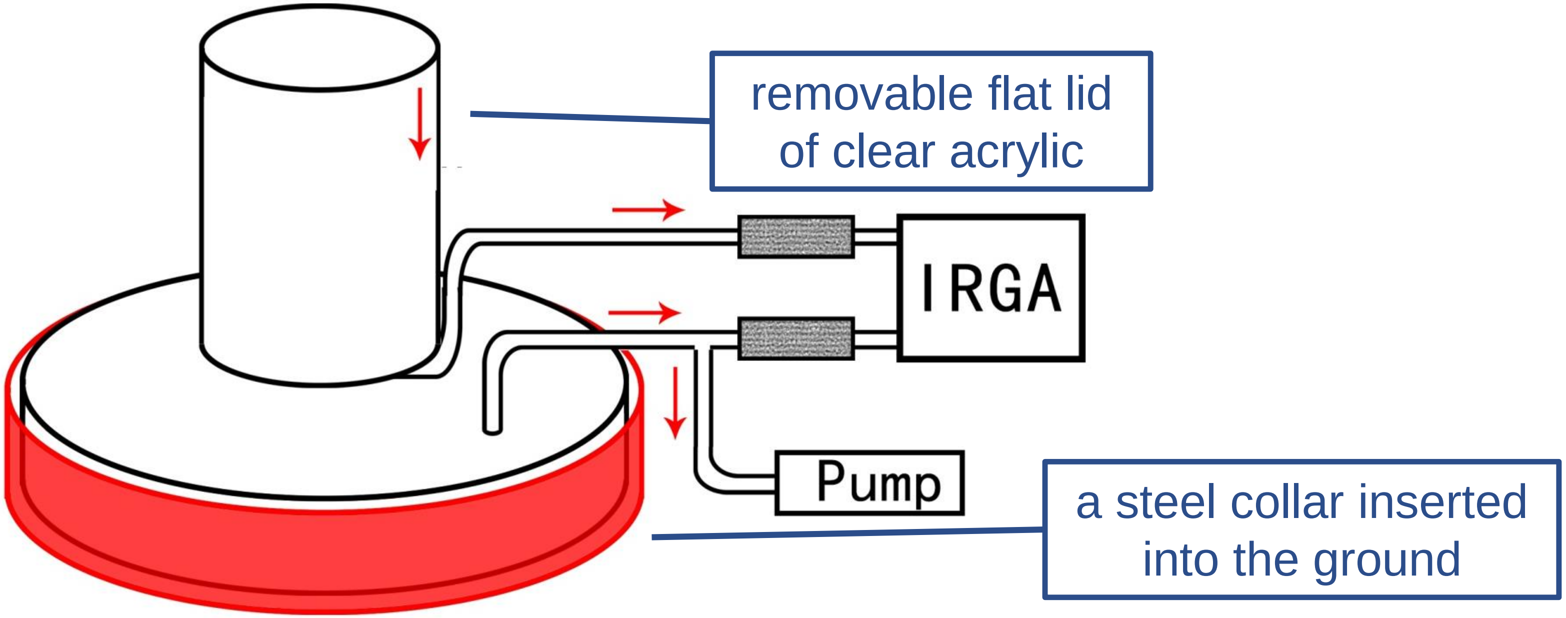


Methods

The chamber used in the field

- A fixed circular intake tube of length: 150 mm
- Internal cross-sectional area: 340 mm^2;
- A mass flow controller: 1 $dm^3 min^{-1}$;
- A rigid cover was constructed to fit over the intake tube.

Methods



Ambient air sampled at the open end of the intake tube, and air drawn through the chamber were analyzed for CO_2 concentration using an infrared gas analyzer (Li 6252, LiCOR Inc., Lincoln, Nebraska) in differential mode.

A solenoid-based, gas-switching system enabled two collars to be sampled alternately, each chamber being sampled for 5 min, with the first minute of each measurement being ignored to allow for total flushing of the tubing and IRGA.

Methods

TEST 1

- Six collars were inserted at randomly chosen locations.
- After at least one day, the chamber was placed in position.
- CO_2 efflux from the collar was measured over two or three diurnal cycles using infrared gas analysis (IRGA).
- The removal of chamber lids for a minimum of 6 days between measurements.
- Two collars remained in the same location, and the rest were measured on two, three, or four occasions before being moved to a new location.

TEST 2

- Six pairs of collars were inserted along a 10 m transect, and simultaneous measurements were made by dynamic closed system and open system.

Results

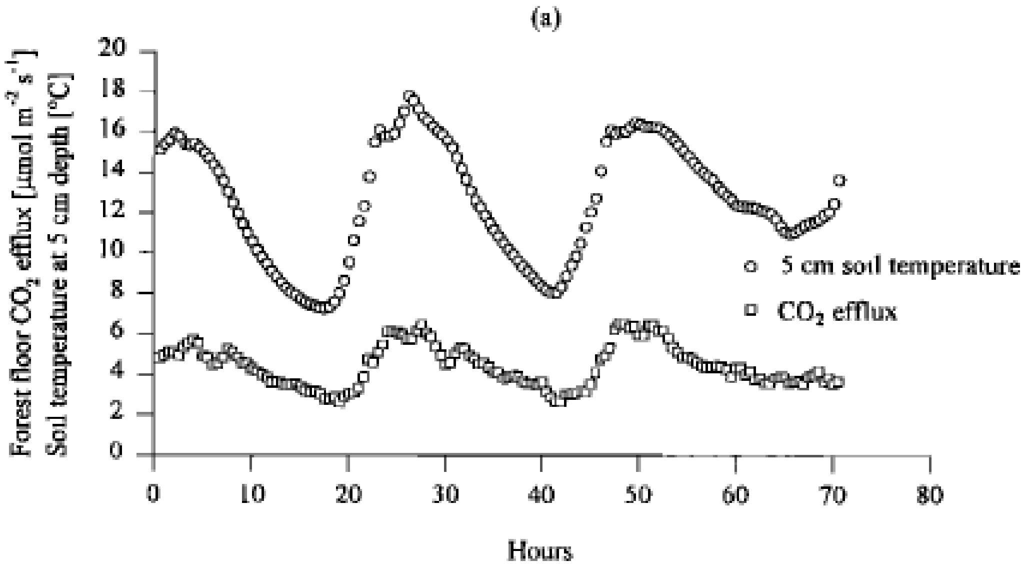
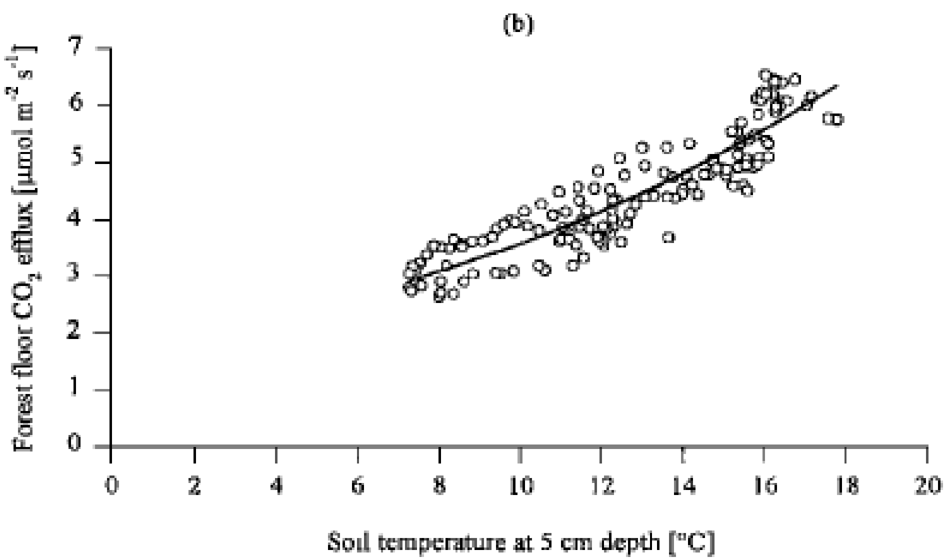


Figure 6. (a) Three-day-long time course of forest floor CO_2 efflux (squares) and soil temperature at 5 cm depth (circles). (b) Same data as Figure 4a with efflux plotted as a function of temperature, and fitted exponential function.



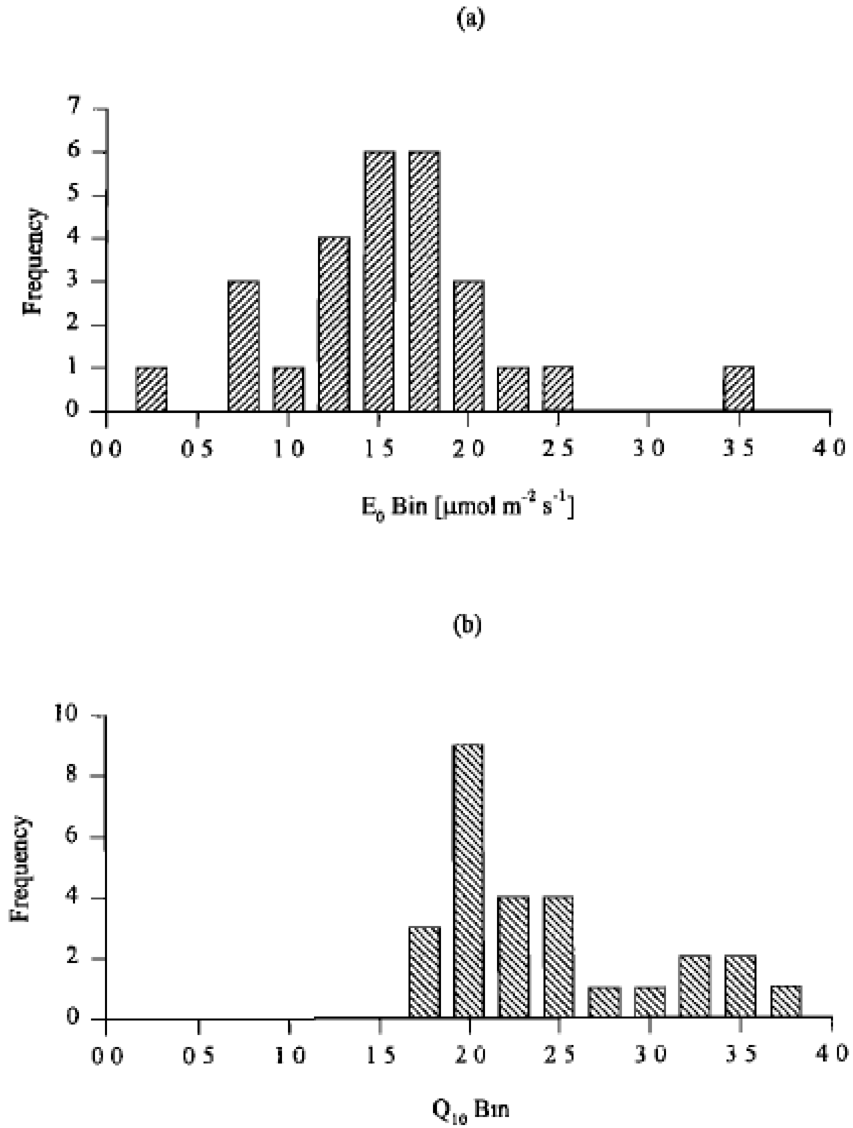
$$E = ae^{bT}$$

$$E_0 = a$$

$$Q_{10} = e^{10b}$$

Results

Spatial variability



E_0 mean value:
1.72umol $m^{-2}s^{-1}$
standard deviation:
0.12umol $m^{-2}s^{-1}$

Q_{10} mode:
2 to 2.25

Figure 5. Spatial heterogeneity of (a) calculated basal rate and (b) temperature quotient of forest floor CO_2 efflux measured over a 4-week period at the BOREAS old black spruce site in summer 1994.

Results

Methodological intercomparison

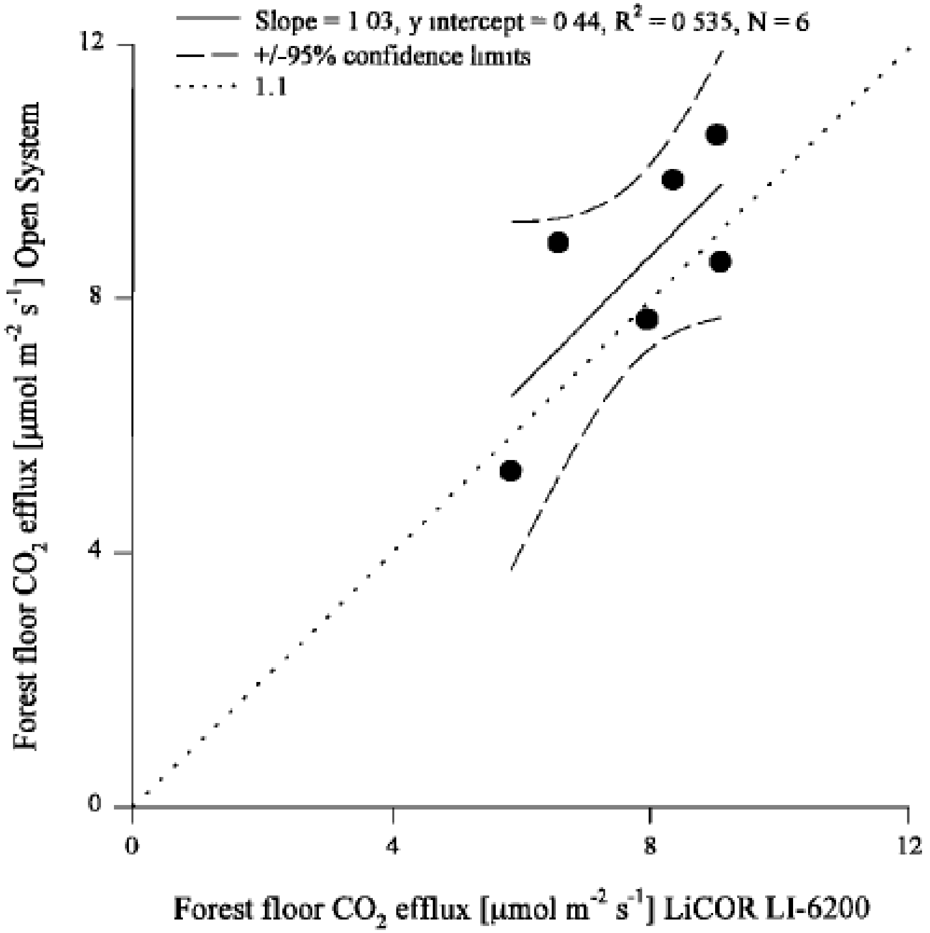


Figure 7. Comparison of forest floor CO_2 efflux as measured using the open system technique described here and using the LiCOR soil chamber.

Discussion

- The system was robust, and aside from collar placement and insertion, the only maintenance necessary was the renewal of the drying columns and calibration of the IRGA;
- The agreement between open and closed systems is encouraging and the open system provides a means of making time series measurements in a much less labor-intensive way;
- Generally the open system gave results slightly higher than the closed system. R. G. Striegl suggests that chamber measurements are subject to around a 10% underestimation of the natural soil efflux;
- Condensed water falls back to the moss surface contributing to the apparently higher rates measured with the open system, but no condensation occurred within the chambers in this study.

Inspiration

- The scheme to determine the flow rate of air through the chamber .
- The pressure differential created between the inside and outside of the chamber deserve attention.
- Whether it is necessary to open the chamber at regular intervals during the measurement.
- The spatial difference of CO_2 flux deserves attention.
- Influence of transparency of chamber on results

Thanks for your attention!