Equalizing Pressures Between A Soil CO_2 Flux Chamber and the Ambient Air Under Windy Conditions

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Introduction

- It is important to be able to measure soil CO_2 flux accurately in order to understand ecosystem carbon balance.
- Soil CO_2 flux is driven primarily by diffusion from soil, which is a porous medium; therefore, it is sensitive to very small changes in pressure.
- Wind can cause pressure fluctuations that alter CO_2 flux. Various authors (Davidson, et.al, 2002; Hutchinson and Livingston, 2001; Hutchinson and Mosier, 1981) have recommended using vent tubes to equalize pressure between chambers and the surrounding air. Others (Conen and Smith, 1998) have suggested that, due to the venturi effect, such vents introduce more errors than they solve and recommend against using vents.

Purpose

- We show that wind can cause negative pressure excursions in vented chambers, which lead to large over-estimates in soil CO_2 flux; but pressure excursions are even worse in unvented chambers.
- We show a new vent design that avoids these problems.

Theory

- According to the Bernoulli equation, for a free air stream,

$$P + \tfrac{1}{2}\rho v^2 + \rho g h = constant$$

Static pressure + dynamic pressure + gravitational pressure = constant.

- At constant height, when wind speed increases, dynamic pressure increases as the square of wind speed and static pressure declines an equal amount to keep the sum constant.
- Thus, still air inside a vent tube will have a higher static pressure than moving air outside a vent tube. Air will flow out of the chamber down this pressure gradient, reducing pressure in the chamber and drawing CO_2 out of the soil (Conen and Smith, 1998).
- Thus, soil CO_2 efflux is over-estimated when the open end of a vent tube is exposed to wind.

The Problem

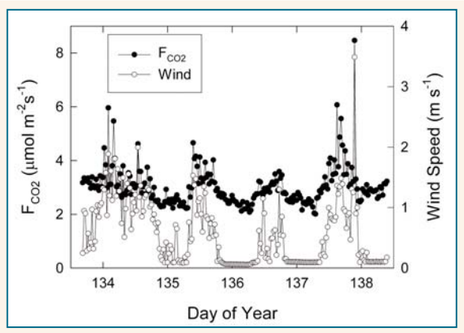


Figure 1. Soil CO_2 flux is highly correlated with wind events. Wind can cause 2- to 3-fold increases in the apparent flux. Soil CO_2 flux was measured with the LI-COR LI-8100 Automated Soil CO_2 Flux System. Wind speed was measured 0.5 m above the ground with an RM Young Model 81000 3D sonic anemometer. Measurements were made over a Sharpsburg Clay Loam soil in Lincoln, Nebraska, USA, in May 2004.

Hypothesis

In vented soil chambers, wind causes negative pressure fluctuations that lead to over-estimates of CO_2 flux.

Test 1

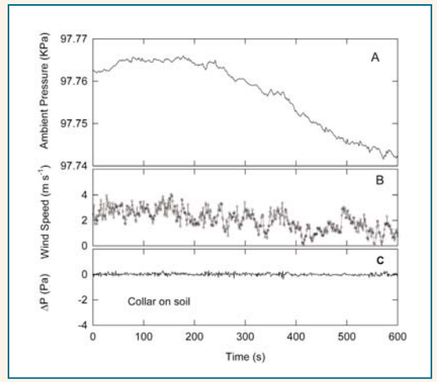


Figure 2. When a vented chamber was placed on a collar inserted into the soil, wind *did not* cause substantial differences between pressure in the chamber and static pressure at the soil surface outside the chamber. Differential pressure was measured with an Omega model PX 653 differential pressure sensor.

Test 2

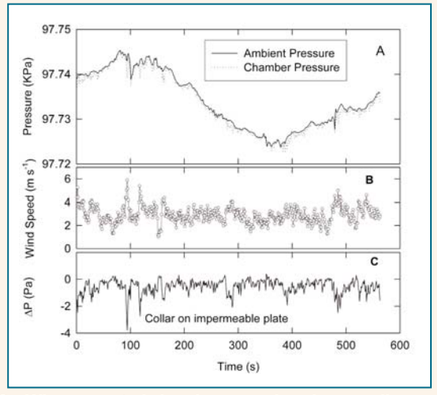
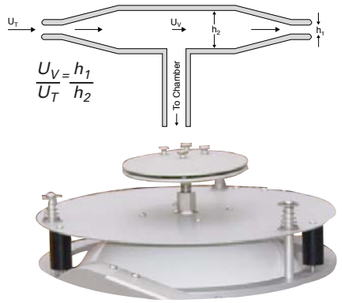


Figure 3. When a vented chamber was placed on a collar sealed onto an impermeable aluminum plate, wind *did* cause substantial pressure differences between the chamber and soil surface outside the chamber.

- Apparently, when a vented chamber was placed on a collar in the soil, air leaving the chamber in response to wind was balanced by air drawn from the soil, so little or no pressure effect was observed. Air drawn from the soil has high CO_2 content, leading to overestimates of the flux (Xu, et.al, 2005, data not shown).
- *Measuring pressure in a chamber placed on soil can lead to the erroneous conclusion that pressure fluctuations are not a problem precisely when wind is causing the artifacts we are trying to avoid.*

The Solution

Figure 4. We designed a new vent (patent pending) based on the Bernoulli equation that reduces the speed of wind as it passes over the vent opening, thus increasing the static pressure of the air at the vent opening, and eliminating the pressure difference between chamber and air.



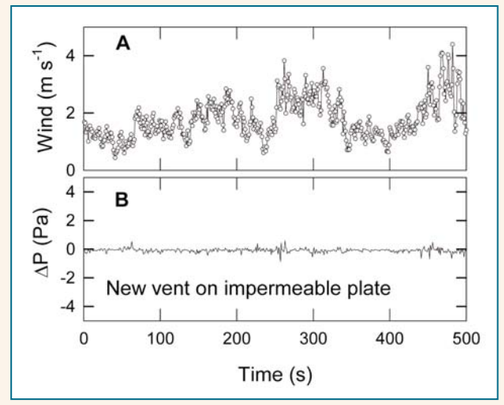


Figure 5. The new vent virtually eliminates pressure differences due to wind when the chamber is placed on a sealed plate.

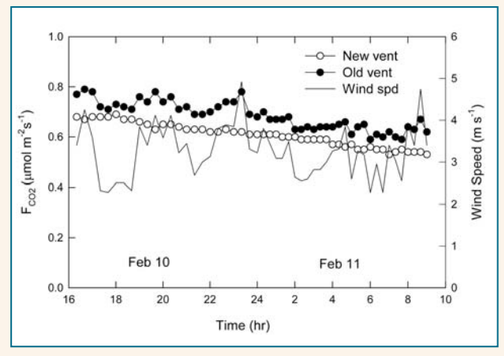


Figure 6. The new vent greatly reduces artifacts in measured soil CO_2 flux due to wind. Soil CO_2 flux was measured on loamy sand soil in Ft. Lauderdale, Florida, USA in February 2005.

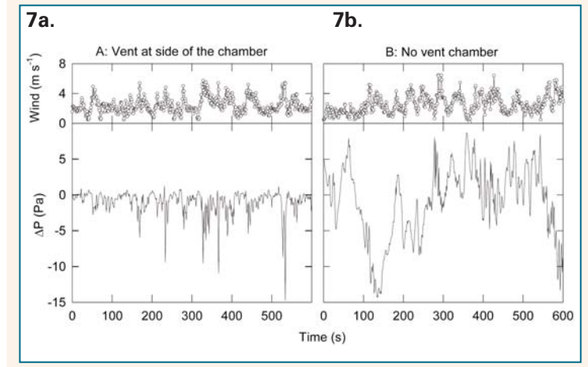


Figure 7. The new vent performs better than our original vent (Figure 3), or a simple tube vent (Figure 7a), or no vent (Figure 7b).

Conclusions

- When chambers are placed on soil, wind-generated static pressure gradients between the chamber and outside air can cause serious errors even when measured differences are well under 1 Pa.
- Wind-generated pressure differences can only be accurately estimated when chambers are placed on an impermeable base, such as an aluminum plate.
- Pressure differences are larger and longer lasting in non-vented chambers than they are in vented chambers.
- A new vent design (patent pending) is presented that avoids wind-generated artifacts in measured soil CO_2 flux.

Literature Cited

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