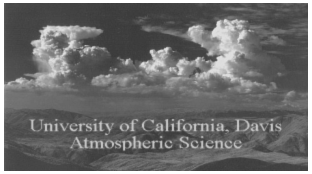
PRESSURE PUMPING EFFECTS ON SOIL EFFLUX MEASUREMENTS OF CO_2 AND O_2



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INTRODUCTION

Climate change models predict relatively large air temperature increases in the next century, caused by green house gases such as CO_2. These concentrations of CO_2 are continuing to rise annually and fossil fuel emissions are a major source of the atmospheric CO_2. Although the North American terrestrial ecosystems are estimated to be a major sink of carbon (one to two Pg carbon per year, see Pacala et al., 2001), agricultural soils are significant sources of CO_2 efflux back into the atmosphere. Therefore the measurement and modeling of soil CO_2 efflux is an important component in understanding the role of terrestrial ecosystems in sequestering carbon. Understanding soil carbon pools and processes require accurate measurements of soil CO_2 efflux; however, if pressure pumping is important, many measurement techniques such as soil chambers may need to be modified to account for such pumping. CO_2 efflux from soils may be significantly modulated by turbulent and lower frequency pressure fluctuations (Auer et al., 1996; Massman et al., 1997), although there are some reports that this term may have a small influence on the isotopic ratio of the oxygen component of CO_2 (Stern et al., 1999). This has implications both in terms of a basic understanding of CO_2 efflux and the measurement of CO_2 exchange.

METHODS

Experiments are being carried out in an agricultural transect used for growing maize (corn). In our study, we measured the barometric pressure at 10 Hz at the soil surface, 10 cm, 20 cm, and 40 cm depths by use of fast response pressure transducers (Omega Engineering, Inc., Model PX2670). Measurements began in the fall of 2003, over bare soil, and continued through planting and growth of maize. We are in the process of conducting the use of O_2 concentration measurements, simultaneously with CO_2 measurements to estimate soil efflux. In this method, an independent assessment of the Respiratory Quotient (*RQ*) would have to be made, and then the gradients of both gases in the soil would be measured. This goes beyond the method involving the soil gradients, revisited recently by CO_2 (Tang et al., 2003). Tang et al. (2003) used a diffusion transfer coefficient *D* which was estimated, using quasi-theoretical methods and assumptions regarding the physical characteristics of the soil or using soil chamber measurements to back-calculate *D*. The basic equations are,

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2} + S$$

$$\frac{\partial O}{\partial t} = aD\frac{\partial^2 O}{\partial z^2} - \frac{S}{R_Q}$$

where *C* is the CO_2 concentration, *O* is the O_2 concentration, *D* is the CO_2 diffusion coefficient through the soil, *a* is the ratio of the O2 diffusion coefficient to that for CO_2, *S* is the source of CO_2, *t* is time, and *z* is the depth. Recently, fast response data were logged on laptop computers with dataloggers attached. A three-dimensional ultrasonic anemometer (Campbell Scientific Inc. CSAT-3) was placed approximately 1 m above the soil surface or canopy to measure the velocity and temperature at 10 Hz. The efflux of CO_2 from the soil was measured by direct eddy-covariance by use of a fast response Licor-7500 open path CO_2 sensor. The experimental data are being examined for the effects of turbulence on pressure perturbations at the surface and the indicated depths. We report on preliminary biomicrometeorological measurements which are used to establish a probable relationship between pressure perturbations and soil CO_2 efflux from the total net ecosystem exchange. Statistical analysis of the standard deviation, skew, and kurtosis of the turbulence and pressure signal are being examined as well as the effects of these parameters on the theoretical equations.

Standard Deviation at the Surface and Depths of 10 cm, 20 cm, and 40 cm, at the Corn Field Site

Depth	Standard Deviation (Volts)
Surface	15.2
10 cm	13.6
20 cm	11.7
40 cm	7.3

Figure 1: Pressure Attenuation with Depth for the Surface and 20 cm at Corn Field

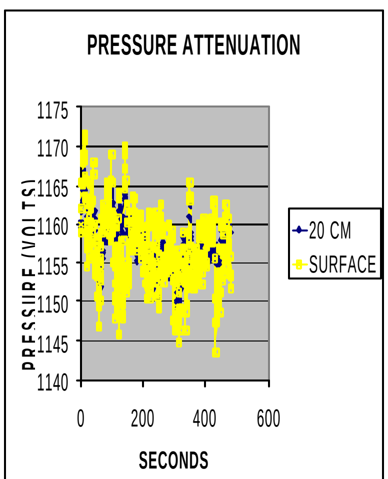


Figure 2: CO_2 Flux Time Series for Four Days in the Month of August Measured by Direct Eddy-Covariance for a Fully Mature Corn Field

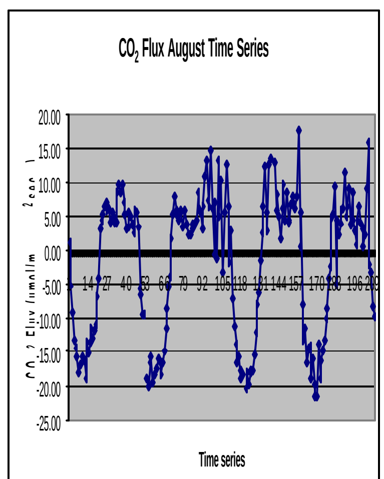


Figure3:Standard Deviation (Pa) at 40 cm vs. Standard Deviation of Vertical Velocity (m/s)

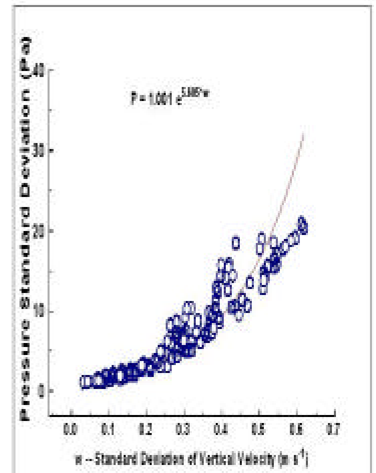
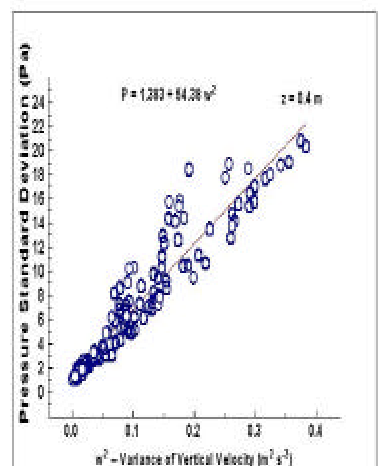


Figure 4: Standard Deviation (Pa) at 40 cm vs. Variance of Vertical Velocity (m^2/s^2)



Results

Results for a pressure sensor show turbulent patterns superimposed on longer frequency patterns, probably associated with turbulent coherent structures (Figure 1). Examination of the standard deviation of the pressure signal as a function of depth revealed a decrease in amplitude with depth (Table 1). A damping depth D could be fit to the data for the standard deviation of pressure, s (z), from the equation:

s (z) = s (0) exp(-z/D)

The second pressure experiment, run at the same site as the south tower of the Rolston Kearney project in August and September of 2004 revealed similarities to the first pressure experiment done at the Campbell Tract. The geometric mean damping depth of 72 cm was quite similar to the Campbell Tract and Takle et al. (2004).
In addition, turbulence data taken at this site were related to the pressure fluctuations. There was a clear relationship between the standard deviation of pressure fluctuations and the variance and standard deviation of the vertical velocity (see Figure 3 and 4). Although an exponential fit can be made to the relationship, the pressure is also closely related to the variance of the vertical velocity (see Fig. 4).

Discussion

The standard deviation of the pressure tracks the variance of the vertical velocity in a linear fashion (Figure 11), which is compatible with Bernouilli's equation and Poisson's pressure equation. These pressure variations with depth can easily be substituted into the above transport equations for CO_2 in the soil.
These results are important because they establish on a preliminary basis, when scientists can expect soil chambers to yield more accurate measurements comparable to eddy-covariance methods. They also could help in improved chamber design. Soil efflux measurements are important because agricultural soils may be important sources of CO_2 efflux. CO_2 efflux is important because terrestrial ecosystems are potentially major sinks of carbon, but this is influenced by the source nature of agricultural soils. Climate change models predict relative large air temperature increases in the next century, caused by greenhouse gases such as CO_2.

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1) PRESSURE PUMPING EFFECTS ON SOIL EFFLUX MEASUREMENT OF CO_2 and

2) SIMULTANEOUS CARBON DIOXIDE AND OXYGEN MEASUREMENTS TO IMPROVE SOIL EFFLU ESTIMATES

Table 3: Standard deviation at depths of 10 cm, 20 cm, and 40 cm, at the Turkovich site

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