P1.13 SHORT-TERM CHANGES IN BELOW-GROUND CARBON DIOXIDE CONCENTRATIONS

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1. INTRODUCTION

Soils are an important component of the carbon cycle in many natural and managed ecosystems. Considerable effort is now being devoted to improving our understanding the input, storage, and removal of soil carbon. Physical diffusion of respired gaseous CO_2 is one of the main processes that removes C from the soil and Fick's law has been a useful tool to model this process. It has been recognized that in certain cases, small-scale atmospheric turbulence can enhance gaseous diffusion from a porous medium such as soil (most recently, Tackle et al. 2004). Continuous measurements of below-ground CO_2 concentrations were obtained during warm and cool seasons to examine physical and biological aspects of CO_2 in an agricultural soil. This poster will: (1) show results of these measurements; (2) demonstrate the potential effects of turbulent conditions on these concentrations; and (3) discuss the magnitude of surface flux that can be attributed to concentration storage changes.

2. RESEARCH SITE AND METHODS

Measurements were obtained from Sept. 8 - Oct. 20, 2003 and Jan. 8 - Feb. 26, 2004 at the Elora Research Station(43° 38′ N 80° 25′ W), located approximately 20 km north of the city of Guelph, Ontario, Canada. The field used in this study, planted in corn in 2003, was undergoing a conventional tillage regime as part of a larger study to examine no-till practices. The two CO_2 probes used in this study were Vaisala GMP222 solid-state infra-red sensors. The probes were installed in a fabricated 2.5 cm diameter PVC assembly that protected them from immersion in soil water while allowing a degree of spatial averaging. The probe assemblies were buried at a depth of 10 and 20 cm below the soil surface. Measurements were obtained every half hour and corrected using the procedure described in Tang et al. 2003. Measurements of soil and the CO_2 probe temperatures were obtained using copper-constantan thermocouples while atmospheric pressure and soil moisture was measured at the research farm meteorological station. High frequency 3-D wind velocity measurements were measured with a CSAT-3 sonic anemometer as part of ongoing eddy covariance measurements.

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3. RESULTS AND DISCUSSION

Below-ground CO_2 concentrations during the warmer months, shown in figure 1, generally tracked the soil temperature (not shown) exhibiting both a small diurnal trend and the effects of seasonal cooling in the early fall. Diurnal amplitude of CO_2 concentrations at the 10 and 20-cm depths was approximately 250 and 500 μmol mol^{-1} while absolute concentrations varied by a factor of 2-3.

Measurements obtained during the colder months show much lower absolute CO_2 concentrations, very little diurnal variability and much less difference in concentration between the two depths. During this period, some of the measured concentration at the 10-cm depth were higher than those at 20 cm. The 5-cm depth soil temperatures were between 0 and -0.5 °C during these measurements resulting in very low rates of biological production. During the cold season measurements a layer of snow was present which varied from 10 to 25 cm in depth.

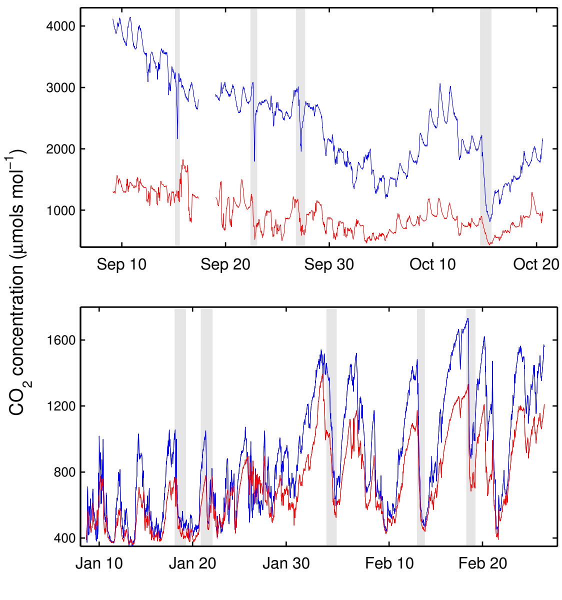

Figure 1. Time series of CO_2 concentrations measured in 2003 and 2004 at the 10-cm (red line) and 20-cm (blue line) depths. Periods where CO_2 concentrations decreased after high windspeeds and precipitation are emphasized in grey

Of particular interest is the occurrence of sudden drops in CO_2 concentration during both the warm and cool season measurements. These decreases in CO_2

concentration, observed at both the 10 and 20-cm depths, were correlated with the onset of turbulent atmospheric conditions and precipitation.

Closer examination of the high windspeed event centered on October 15, 2003 is shown in Figure 2. During the night of the Oct. 15th accompanying the drop in barometric pressure was approximately 30 mm of rain resulting in an increase in soil volumetric water content (θ_v). Under these conditions, increases in water content would be expected to decrease the diffusivity resulting in an increase in concentration (e.g. Jassal et al., 2004). It appears that the high winspeeds occurring on Oct 15th were at least in part responsible for the decrease in CO_2.

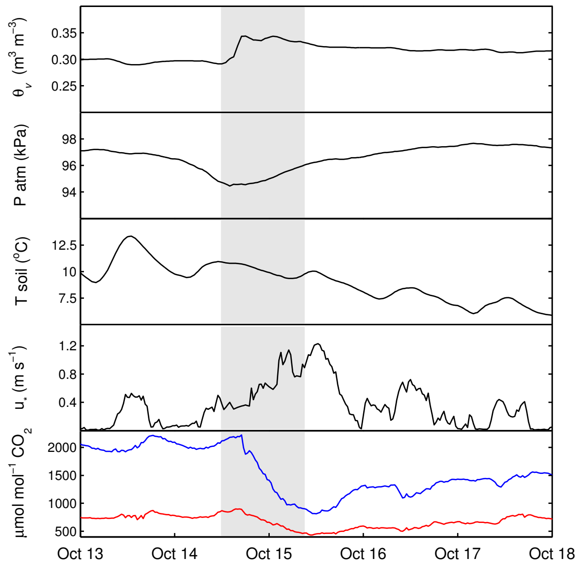

Figure 2. Time series of below-ground CO_2 concentrations measured between Oct. 13 and Oct. 18, 2003. also shown are friction velocity (from CSAT-3), 5-cm depth soil temperature, atmospheric pressure and soil volumetric water content. During the night of the 15th, approximately 30 mm of rain fell.

During the winter measurements, average air temperature was -9.1°C, the soil surface was frozen and there was very little change in θ_v. All of these factors preclude any significant moisture effect on short-term soil CO_2 concentrations. The presence of snow would have inhibited the diffusion of CO_2 from the soil by imposing an additional path length from the source to the atmosphere. Under these constraints, sharp decreases in soil CO_2 correlated with windspeed were still observed.

These changes in soil CO_2 concentrations caused by oscillatory air flow below the soil surface should, in principle, contribute to the surface CO_2 flux. A simple 2-layer slab model of gas storage in the soil can provide a first estimate on the magnitude of this effect. Assuming that: 1) soil porosity, f, in the 0-30 cm plowed layer is 0.45 m^3 m^{-3}; 2) CO_2 concentration at the surface is 365 μmol mol^{-1} and; 3) Changes in concentrations in the lower layers are neglected. With an air filled porosity, f_a, of 0.125 m^3 m^{-3} (from Figure 2), using the ideal gas law and noting ΔCO_2 at 10 and 20-cm are approximately 500 and 1400 μmol mol^{-1} respectively, a total change in storage of 2100 μmol CO_2 or an additional surface flux of only 0.03 μmol m^{-2} s^{-1} is calculated over a period of 23 hours. Repeating the analysis for the high windspeed event on the 3rd and 4th of February, 2000 results in a total ΔCO_2 of 270 μmol or an additional surface flux of 0.004 μmol m^{-2} s^{-1} over a period of 17 hours. The main difference between these two examples is the low values of f_a due to the high θ_v in the winter.

4. CONCLUSIONS

Measurements shown here demonstrate the magnitude of changes in below-ground CO_2 caused by enhanced diffusion due to atmospheric turbulence. The changes in concentrations can be quite large, in some cases decreasing by a factor of 2 or more. However, when averaged over the duration of the turbulent event, the net result on soil CO_2 flux is relatively small, particularly when compared to typical warm season soil CO_2 fluxes. The magnitude of this enhanced flux attributable to shallow storage changes alone would be very difficult to resolve using modern chamber and micrometeorological techniques. Measurements of concentration to the bottom of the soil profile would improve estimates of CO_2 storage in the soil column.

5. REFERENCES

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