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PRESSURE PUMPING OF CARBON DIOXIDE FROM SOIL

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1. INTRODUCTION

Recent interest in atmospheric increases in carbon dioxide have heightened the need for improved accuracy in measurements of fluxes of carbon dioxide from soils. Diffusional movement has long been considered the dominant process by which trace gases move from the subsurface source to the surface, although there has been some indication that atmospheric pressure fluctuations also might play a role (Clark and Waddington, 1991, and Massman et al, 1997). A related question centers on what possible influence the CO_2 measurement chamber might have on the microscale pressure field at the measurement site. We have measured carbon dioxide fluxes and atmospheric pressure fluctuations concurrently at the soil surface under conditions of natural and artificial pressure pumping with the intent of providing some answers to these questions.

2. FIELD SITE

Measurements were taken in the vicinity of an 1.2-m high (H = 1.2 m) vertical-slat snow fence (62% porosity) oriented east-west in the center of a flat, open agricultural field at the Agricultural Research and Development Center of the University of Nebraska-Lincoln near Mead, NE. The wheat crop was removed from the field in late July and the field was tilled in early August. The soil in the vicinity of the fence was packed. At the time of the measurements (16-17 September) the field surface was dry and bare with only sparse remnants of wheat straw.

3. MEASUREMENTS

Surface fluxes of CO_2 (LI-COR 6400) were taken concurrently with measurements of wind speed, high-frequency (2 Hz) atmospheric pressure fluctuations at the surface and at various depths (5, 10, and 15 cm in one experiment and 15, 30, and 60 cm in a second experiment) in the soil, and field carbon dioxide concentrations at three depths (10, 25, and 50 cm) in the soil leeward and windward of the fence. The LI-COR has a chamber of diameter 5 cm and height 15 cm and was situated on top of a 2-inch high circular collar that was depressed about 1 inch into the soil. For one experiment we placed surface pressure sensors inside and nearby outside the LI-COR measuring chamber, which was directly over the profile of soil pressure samples.

Pressure sensors were diaphragm capacitance type with a differential range of ±25 Pa, (Setra Mdl. 264 with foam filters removed from the input ports to assure fast response time). Automotive vacuum tubing connected a sensor to each soil depth (0, 5, 10, and 15 cm in one experiment and 0, 15, 30, and 60 cm in a second experiment). For 30 cm back from each subsurface sample point, tubes were horizontal and tightly packed in replaced soil, to eliminate leakage along the tube. Reference pressure for all sensors was taken at the surface, 77 m upwind of the fence.

Vertical tubes were installed in the soil at 4 locations (3 near the fence and one about 80 m distant) several weeks before the measurement program began with ports allowing air to be drawn from depths of 10, 25, and 50 cm. From each depth, one 5-ml volume was drawn with a syringe from the tube previously installed in the soil and discarded and then a second volume was extracted for analysis.

Observations were made under conditions ranging from near calm to mean wind speeds of approximately 6 m s^{-1} over a 2-day period.

4. RESULTS

The time dependence of pressure measured inside and outside the CO_2 chamber and at all

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three depths in the soil at 1.5 H in the lee of the fence (Figure 1) revealed that the phase and amplitude of the pressure fluctuations are not affected by the presence of the chamber. These fluctuations evidently are caused by pressure-inducing mechanisms of much larger scale than the CO_2 chamber.

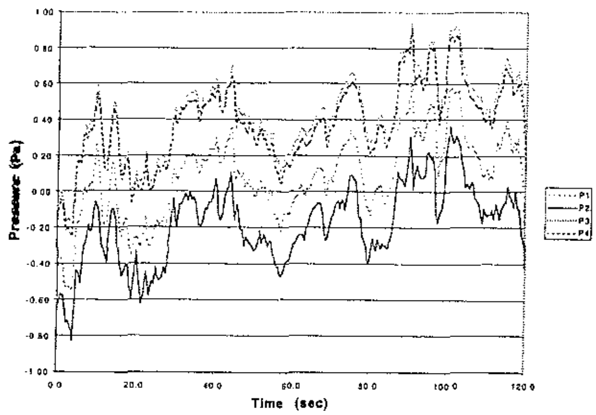

Figure 1. Time dependence of pressure fluctuations at the soil surface inside the LI-COR chamber (P1), at the surface outside the chamber (P2), at 10 cm soil depth under the chamber (P3), and at 15 cm soil depth under the chamber (P4).

An estimate was made of the surface concentration gradient of CO_2 by differentiating the curve defined by fitting a quadratic function to CO_2 concentrations from the surface and from 10 cm and 25 cm soil depths (data from 50 cm were missing from Location 2 and others showed extreme scatter that was quite unphysical) and evaluating this differential at the surface. The volume of the chamber and the flux calculated from this surface concentration gradient were used to estimate the diffusional contribution to the rate of build-up of CO_2 in the chamber for comparison with actual measurements. From 24 sample concentration gradient measurements we calculated a mean rate of build up in the chamber of 0.170 ppmV/s with a sigma of 0.074. But the LI-COR measured a buildup of about 0.7 ppmV/s, which is approximately 4 times the diffusion value. Our tentative conclusion from these measurements and calculations is that diffusion alone does not account for CO_2 fluxes from the surface under these conditions.

We evaluate the dependence of the CO_2 surface "flux", measured in ppmV/s (reporting units of the LI-COR) as a function of the pumping rate as measured by the absolute value of dp/dt as determined by changes in pressure over successive half-second intervals. Results shown in Figure 2 reveal a tendency for enhanced pumping rates to increase the soil surface CO_2 flux.

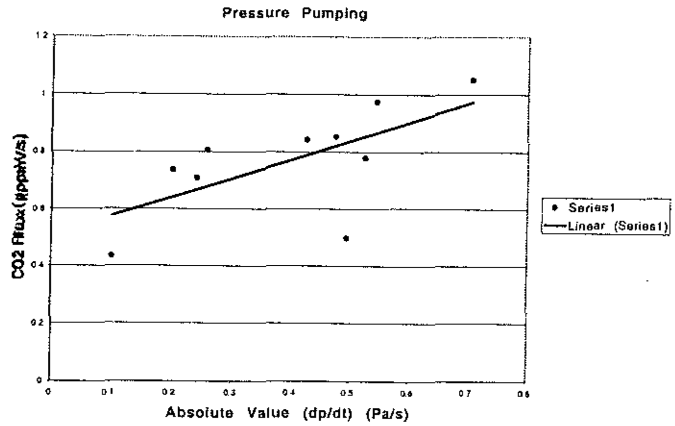

Figure 2. CO_2 flux as a function of the pressure pumping rate.

5. CONCLUSIONS

These preliminary analyses of our field data suggest that (1) the presence of the CO_2 chamber in the configuration we deployed does not adversely influence the pressure field for the measurement of surface fluxes, and (2) there is a strong suggestion that diffusional processes alone are not sufficient to explain the flux of CO_2 from the soil surface but that increasing the magnitude of pressure fluctuations will enhance soil CO_2 flux.

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