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SPRING AND SUMMER MEASUREMENTS OF N_2O FLUX FROM AN AGRICULTURAL FIELD

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1. INTRODUCTION

Nitrous oxide (N_2O) can be produced through nitrification (the oxidation of ammonium (NH_4^+) to nitrate (NO_3^-)) and denitrification (the reduction of NO_3^- to N_2O or nitrogen (N_2)) (Olsen et al., 2003). N_2O can also be emitted as an intermediate product if conditions are suboptimum and these processes do not run to completion (Groenestein and Van Faassen, 1996). Although N_2O emissions are much lower than other greenhouse gases (Chen et al., 1995), N_2O has a large environmental impact. It is involved in the degradation and depletion of the stratospheric ozone layer (Chen et al., 1995; Groenestein and Van Faassen, 1996; Webb et al., 2000; Baggs et al., 2003) and has a global warming potential of 310 times that of CO_2 (de Boer, 2003).

Emissions of N_2O vary throughout the season but general trends do exist. Emissions have been found to be the greatest during the spring snowmelt (Olsen et al., 2003) as soils thaw (Chen et al., 1995; Grant and Pattey, 1999; Mogge et al., 1999; Maggiotto and Wagner-Riddle, 2001; Freibauer, 2003) and microbial activity increases (Maggiotto and Wagner-Riddle, 2001). The increased soil temperatures and moisture content increase N_2O emissions (Mogge et al., 1999; Baggs et al., 2003).

Field activities throughout the growing season are responsible for the other peak periods of emissions. Emissions of N_2O increase with increasing amounts of fertilizer nitrogen (Chen et al., 1995; Mogge et al., 1999; Webb et al., 2000; Baggs et al., 2003; Grant and Pattey, 2003; Freibauer, 2003) and animal manure (Olsen et al., 2003). Both of these inputs affect the processes of nitrification and denitrification and lead to changes in the fluxes of N_2O (Maggiotto and Wagner-Riddle, 2001). The use of cover crops to conserve nitrogen and to act as green fertilizer can lead to increases in the N_2O emissions when they are incorporated in the soil (Webb et al., 2000).

Climate also plays a great role. The emissions of N_2O increase with soil moisture (Chen et al., 1995; Mogge et al., 1999; Freibauer, 2003) due to rainfall (Webb et al., 2000) and soil thawing (Maggiotto and Wagner-Riddle, 2001).

In order to quantify *in situ* field N_2O emissions following typical management practices applied by crop producers, a roving flux tower measuring system was developed. It consisted of an eddy-covariance CO_2 and H_2O measuring system and a pair of gradient towers for measuring N_2O using a fast-response tunable diode laser.

The first field site selected for greenhouse gas flux monitoring was part of a dairy farm in western Quebec sown with edible peas. The study encompassed the spring snowmelt period prior to fertilization through the subsequent summer growing season and the following spring snowmelt period.

2. EXPERIMENTATION

2.1 *Field Management*

This study was conducted at the farm of a private producer in Côteau-du-Lac, Quebec, Canada. The 16 ha field was sown with corn in 2002 and received manure during the post-harvest period. The field received a low N content starter fertilizer on May 23 and 24, 2003. During this time, the field was planted with edible peas (Pisum satium var. Bolero). Harvest of the peas occurred on July 24, 2003. Following harvest, the stalks were tilled under and the field was levelled (July 30-August 4, 2003). Dairy manure was applied August 7-9, 2003 and then incorporated into the soil August 9-11, 2003 following which, a mixture of cereals was planted as green fertilizer on August 13, 2003. The cereals were tilled under as green fertilizer the following spring.

2.2 *Measurements*

N_2O fluxes were measured using the flux-gradient technique (Businger, 1986). The N_2O gradient was measured using a tunable diode laser trace gas analyzer (TGA-100, Campbell Scientific, Logan, Utah). Two pairs of inlets mounted on towers were used to continuously capture the emissions of N_2O from across the field. The two towers were positioned to capture the maximum upwind source area in the prevailing wind direction (westerly). The TDL-TGA system cycled between the towers half hourly. During post processing, data were selected from each tower based on the wind direction such that the resulting N_2O emissions came from the field of interest and not the neighboring fields. Using two pairs of intakes allowed data to be collected from the relatively narrow fields typical of the Quebec farming community.

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There were three measurement periods during this study: snowmelt 2003, growing season 2003 and snowmelt 2004.

2.2.1 *Snowmelt 2003*

The measurement system was installed in the field on March 17, 2003. Testing was conducted until March 24, 2003 after which measurements were recorded. The sampling period for the spring snowmelt ended May 8, 2004 and the equipment was removed from the field during cultivation.

2.2.2 *Growing season 2003*

The equipment was reinstalled and sampling began June 5, 2003. Sampling ended on October 5, 2003 and the equipment was removed from the field for the winter.

2.2.3 *Snowmelt 2004*

The measurement system was installed in the field between February 27, 2004 and March 3, 2004. Testing was conducted until March 5, 2004 after which measurements were recorded. The farmer spread fertilizer (urea) on April 29, 2004 and worked the field May 8 and 9, 2004. The sampling period for the spring snowmelt ended May 12, 2004 and the equipment was removed from the field for cultivation.

2.3 *Calculation of fluxes*

The flux of N_2O (F_{N2O}) is represented by a partial derivative which is approximated by a finite difference:

$$F_{N_2O} = -K\,\rho\,\frac{\partial N_2O}{\partial z} \approx -K\,\rho\,\frac{\Delta N_2O}{\Delta z} \qquad (1)$$

Measurements at 10 Hz, averaged over 30 minutes, were taken to determine the N_2O gradients (ΔN_2O) with a TDL-TGA (Edwards et al., 2003). The half hourly values of ΔN_2O were screened according to the number of observations, the difference in pressure between the two inlets and the standard deviation of each level. Night time flux values were filtered according to the friction velocity, u*, and all 30-min flux values kept if more than 50% of the observations met the u* threshold (Pattey et al., 2002). Sensible heat and u* were measured using an ultrasonic anemometer. The sonic anemometer model (CSAT-3, Campbell Scientific, Logan, Utah) used during snowmelt 2003 was replaced by another model less sensitive to precipitation (Solent R3-HS,Gill Instruments Ltd, Lymington, Hampshire, UK) for the remainder of the study. Sensible heat flux and u* were used to calculate the coefficient of turbulent diffusivity (K ($m^2\ s^{-1}$)), which was adjusted for atmospheric stability.

3. RESULTS

3.1 *Snowmelt 2003*

Meteorological information from a standard meteorological station in the region indicated that the winter of 2002/3 was colder than normal and featured less snow cover in this area. By April 7, 2003, the soil surface was still frozen and the field had very little snow but some ice. The thaw occurred quickly and within four days, the field was muddy. The emissions resulting from the snowmelt were somewhat low (< 10 mg N_2O-N $m^{-2}\ d^{-1}$), even though parts of the field exhibited standing water. Snowmelt N_2O emissions following corn harvest in the sandy clay field were in the same range as those observed previously in a clay loam harvested corn field (Grant and Pattey, 1999).

3.2 *Growing season 2003*

Following seeding, the pea field continually generated small emissions of N_2O throughout the growing season, certainly in relation to the rhizobial activity (O'Hara and Daniel, 1985; Brady and Weil, 1999; Olsen et al., 2003). The rainfall events did not induce substantial peak N_2O emissions. The exception was a single rainfall event of 50 mm 20 days after starter fertilizer application, which generated a large emission peak (>40 mg N_2O-N $m^{-2}\ d^{-1}$). After pea harvest, the application of manure resulted in large and sustained N_2O emissions. Values ranged between 10 and 40 mg N_2O-N $m^{-2}\ d^{-1}$ for almost 10 days.

3.3 *Snowmelt 2004*

In contrast to the winter of 2003, observations on February 27, 2004 indicated that there was 20 to 30 cm of snow on the field. By March 5, 2004 the snow was melting and there was a significant amount of water in some areas. The surface had re-frozen by March 8, 2004. As in 2003, the fluxes were still fairly small, although values were a bit higher in 2004.

4. DISCUSSION

We have obtained almost annual cycles of greenhouse gas (GHG) flux using micrometeorological towers. The periods of elevated emissions of N_2O mostly occur in the spring following snowmelt as well as after the application of mineral fertilizer, manure or green manure, or following plough-down of green fertilizer. Such data will allow us to re-evaluate the coefficients used in the budget of GHG from Canada and to better understand the underlying processes which lead to the atmospheric emissions of GHG.

Although the field in Côteau-du-Lac was covered with water during the 2003 spring melt, the N_2O emissions were comparable with those observed in 1996 under similar management practices in Ottawa (Grant and Pattey, 1999). We hypothesize that the limited emissions with regard to well developed anoxic conditions can be attributed to the lighter soil texture.

The sandier soil and tile drained field allowed better drainage compared with heavier soils in the region. Emissions were a bit higher during the 2004 spring melt but still fairly small.

After seeding, we observed weak emissions after rainfall, except during the 50 mm of rain that fell which generated high N_2O emissions. Webb et al (2000) hypothesized that increased emissions following rainfall resulted from what they referred to as 'degassing' events. The rainfall rapidly fills the soil pores with water and traps the N_2O which is produced. When the drying conditions are favorable and the soil pores dry rapidly, the trapped N_2O is released. A stimulating event such as rainfall generally results in a rapid response by nitrous oxide emissions which can be detected as a large emissions peak. However, if the event is not maintained, emission levels quickly return to the previous level (Webb et al, 2003). The application of cow manure between the harvest and cereal sowing provoked large N_2O emissions for ten days.

The results of these experiments are used to verify mathematical models, to revise the coefficients used to measure greenhouse gases in Canada and to better understand the processes involved in atmospheric emissions of GHG to define the best agricultural practices.

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