9A.1 **Eddy-covariance and chamber measured greenhouse gas emissions from a commercial cornfield**

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1. ABSTRACT

Water and nitrogen (N) use efficiencies remain generally low in corn production systems. As a result, much of the excess N applied to these ecosystems is leached to ground water and/or emitted to the atmosphere in the form of reactive N gases such as nitrous oxide (N_2O) and NO_x. The traditional static chamber technique is the standard method for point measuring of trace gas emissions in small scale field experiments, but the spatial and temporal variability make this method time consuming and labor intensive for large field scale experiments. Only recently a fast response N_2O sensor became available that makes it possible to use Eddy Covariance (EC) technique for continuous dynamic measurements of N_2O flux from large scale fields. In this study, we used the EC technique to measure N_2O, CO_2 and H_2O fluxes in a commercial cornfield in Nolensville, Tennessee that provided the field-scale accurate high frequency (seconds, minutes, or hours) results. We also used the traditional static chamber approach to ground verify N_2O emissions in the field. The results indicated that the EC measurements were reasonable compared with the corresponding chamber measurements.

2. INTRODUCTION

The United States is, by far, the largest producer of corn (Zea mays) in the world (EPA, 2009). Corn grown for grain (72.6 million acres/29.4 million hectares) accounts for almost one quarter of the harvested crop acres in this country. Corn is also an important silage crop and a popular feedstock for ethanol production (University of Nebraska, 2010). Corn-based ethanol is currently the largest source of biofuel as a gasoline substitute or additive in the United States (USDA, 2010).

Recent drought conditions and increased fertilizer cost in the southeastern United States have farmers and others interested in more efficient water and fertilizer management. However, water and nitrogen use efficiencies remain generally low in corn croplands because irrigation and N fertilizer scheduling are seldom based on the real-time soil moisture, plant water status, and N demand. Excess nitrogen and water can be applied to cornfields, resulting in a low water use efficiency of 37% and nitrogen use efficiency of 30-59% for furrow-irrigated fields (Halvorson et al., 2005). As a result, much of the excess N applied to these ecosystems is leached to ground water and/or emitted to the atmosphere in the form of reactive N gases such as nitrous oxide (N_2O) and NO_x. Nitrous oxide is the major greenhouse gas (GHG) emitted by U.S. agriculture and has 310 times the radiative forcing potential of CO_2 (CRS, 2010). The average annual N_2O emission from Cornfields in the United States ranges from 1 to 3.2 tons CO_2 equivalent per hectare (Ogle et al., 2008). The annual total N_2O emission from U.S. corn croplands is greater than 29.4 million tons CO_2 equivalents (EPA, 2009).

The traditional static chamber technique is the standard method of point measuring N_2O emissions (can be used in small plot experiments at the meter and hour scales), but the spatial and temporal variability make this method time consuming and labor intensive for field scale experiments. The use of the Eddy Covariance (EC) technique to measure N_2O emissions has the potential to continuously provide the field scale accurate instantaneous measurements (seconds, minutes, or hours). To date, aerodynamic techniques (i.e. EC) for N_2O have been used only in limited experimental settings. Only recently a fast response N_2O sensor became available that makes it possible to use this technique. We built an Eddy Covariance flux tower in a commercial corn farm in Nolensville, Tennessee to measure field scale N_2O emissions throughout the growing season, giving us the ability to fill the gap in previous studies of the N budget. We also used the traditional chamber technique to measure the N_2O emissions in the field and compared these to the EC technique.

3. MATERIALS AND METHODS

The experiment has been conducted in a commercial Cornfield in the middle of Tennessee since April 2012 and data have been collected, and and processed for more than three months. The experiment is still ongoing and will be completed after harvest (around the middle of August). The data presented were from April to June.

Experimental site and setup

The experimental site was a commercial farm that was 300 by 500 m in Nolensville, Williams County, TN (Figure 1; The farmer does not allow releasing the exact location information: latitude and longitude). The soil type is clay loam. The measurement footprint ranged from 25 to 90 m, depending on wind speed.

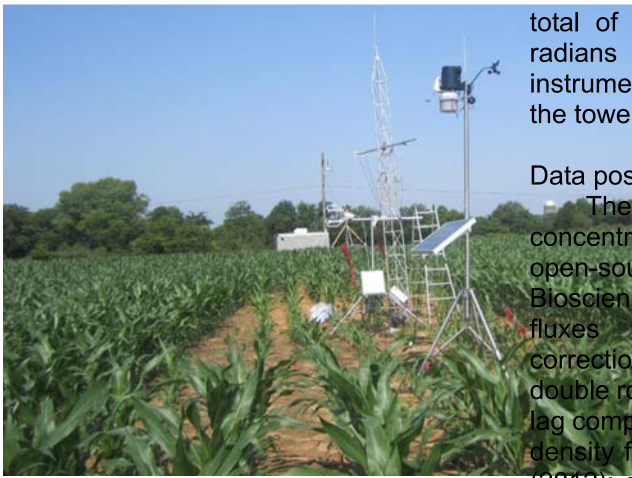

Figure 1. The experimental site.

A weather station (Vantage PRO2 Plus, Davis Instruments, Vernon Hills, IL 60061) was set up in the middle of the field that measured 30-minute rainfall, wind speed, direction, relative humidity, and solar radiation.

A CO_2 and H_2O flux EC measurement system, including a CSAT3-A anemometer, was set up in the middle of the field (Campbell Sci, Logan, UT 84321). The instruments measured 10 Hz 3-D wind velocities and CO_2 and H_2O concentrations. The instruments were kept 1.3 m above canopy by raising them as plants grew. Two soil heat flux disks (HFP01SC, Hukseflux, Manorville, NY 11949) were buried 2 cm beneath the soil surface to minimize heat flux divergence (Mayocchi and Bristow, 1995). A Hukseflux four-component net radiometer was mounted at the canopy top (h = 1.3 m above canopy) to measure Rn (NR01). Two Campbell Sci. Water Content Reflectometer (CS616) and two Averaging Soil Thermocouple probes (TCAV were buried at 10 and 25 cm to measure soil moisture and temperature.

A sampling tube (6 mm inner diameter, 50 m length) was set to sample the air at the middle of the field and was connected to an N_2O analyzer (QCL-TILDAS-76 Ambient Air Monitor Aerodyne Research Inc.) in a trailer that provides working temperature with an air conditioner. The tube tip was 20 cm away from the sonic anemometer. The analyzer provides 10 Hz N_2O and H_2O concentrations.

A Campbell Scientific CR3000 data logger was used to record all the data.

Chamber measurements of N2O emissions (30-minute interval) were obtained during the growing season on different days to compare to the EC data. A total of eight chambers were evenly (45° radians each) deployed around the instrument tower. Each was 30 m away from the tower in the radial direction.

Data post-processing

The 10 Hz wind velocities and gas concentrations were analyzed using open-source EddyPro 3.0 software (LI-COR Biosciences, Lincoln, NE). The 30-minute fluxes were calculated. The flux corrections included: axis rotation using double rotation, detrending, block-averaging, lag compensation, maximum covariance and density fluctuation according to Burba et al. (2012); spectral correction as per Moncrieff et al. (1997); high-pass filtering correction from Moncrieff et al. (2004); low-pass filtering correction using the approach of Moncrieff et al. (1997); and despiking and raw data statistical screening from Vickers and Mahr (1997).

4. RESULTS

Energy balance

When u* was greater than 0.2 m/s, the energy balance was calculated. The average balance was -0.5%, calculatred as [Rn-LE-G-H]/Rn, where Rn is net radiation, LE is latent heat flux, G is soil heat flux, and H is sensible heat flux (Figure 2).

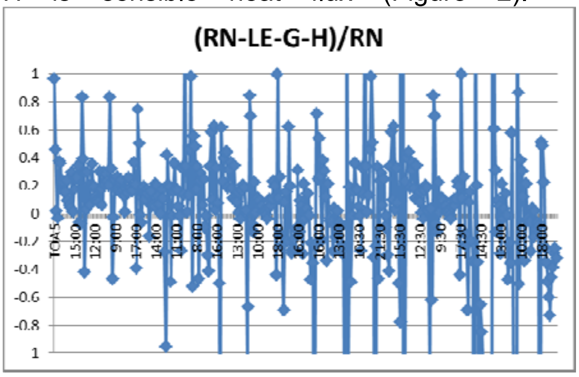

Figure 2. Sample energy balance plot when u* was greater than 0.2 m/s.

Diurnal N_2O and CO_2 concentration

Figures 3 and 4 show typical diurnal N_2O and CO_2 concentration variations. When u*>0.2 m/s, N_2O was higher during daytime and lower during nighttime because soil temperature was larger during daytime. But when u*<0.2 m/s during the nighttime, drainage apparently occurred and N_2O had very high values

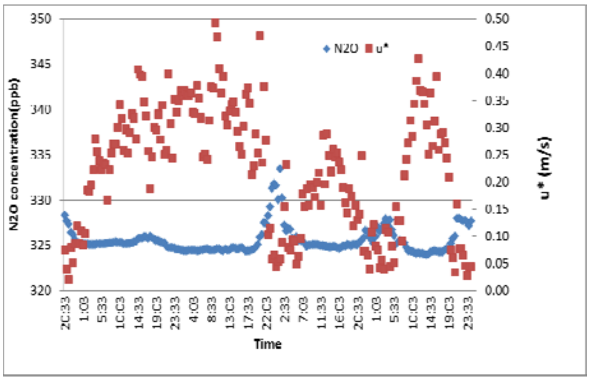

Figure 3. Diurnal N_2O concentration variation.

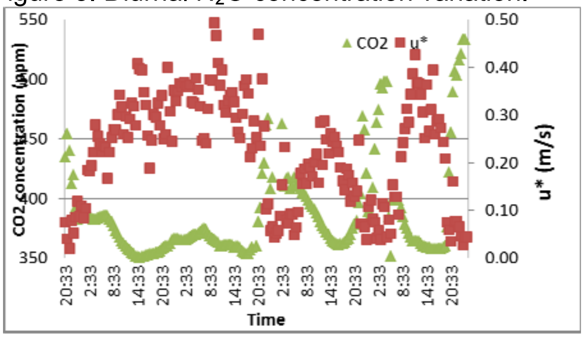

Figure 4. Diurnal CO_2 concentration variation.

When u*>0.2 m/s, CO_2 concentration was smaller during the daytime than during nighttime because corn plants assimilated CO_2 during the daytime. When u*<0.2 m/s, CO_2 concentration was very high at night.

Diurnal N_2O and CO_2 fluxes

Figures 5 and 6 show the diurnal N_2O-N and CO_2 fluxes variation. When u*>0.2 m/s, N_2O-N emission was higher during daytime (hotter soil temperature) and CO_2 flux was lower during daytime (photosynthesis and assimilation).

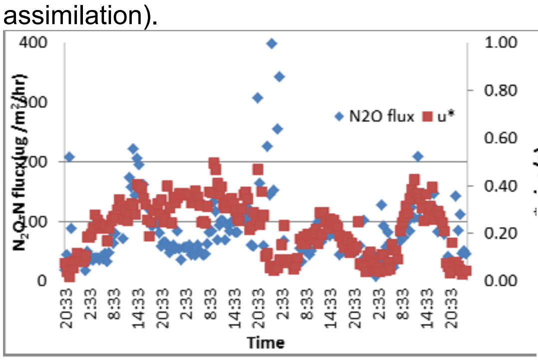

Figure 5. Diurnal N_2O-N flux variation.

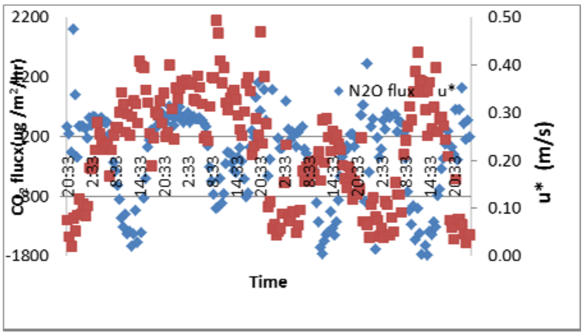

Figure 6. Diurnal CO_2 flux variation.

Seasonal N_2O and CO_2 emissions/fluxes

Figures 7-10 show the seasonal variation of N_2O and CO_2 emissions/fluxes. The corn was planted on April 9, 2012. After the fertilizers were applied, the N_2O emissions were not increased until rainfall was received on April-16. The largest emissions occurred a few hours after rainfall events. Therefore, soil moisture was an important factor regulating N_2O emissions.

From April 9 to May 12, the plants were small, and CO_2 assimilation was low (Figure 10). When the plants grew larger, CO_2 assimilation increased. After the plants were tasseling on June 17, the plants grew slowly and drought condition occurred. Therefore, CO_2 assimilation decreased.

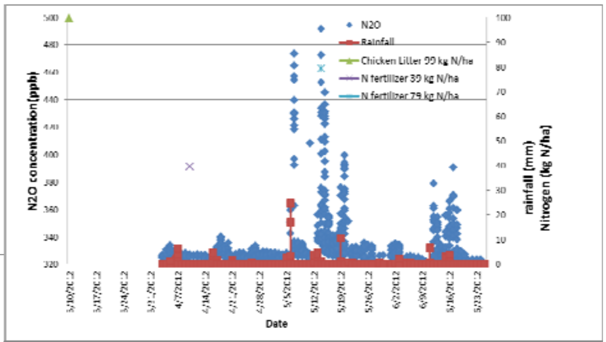

Figure 7. Seasonal N_2O concentration variation.

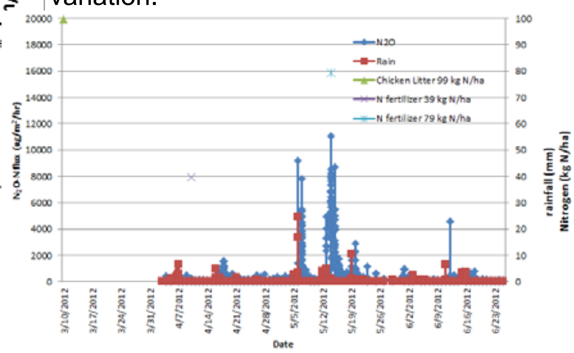

Figure 8. Seasonal N_2O-N flux variation.

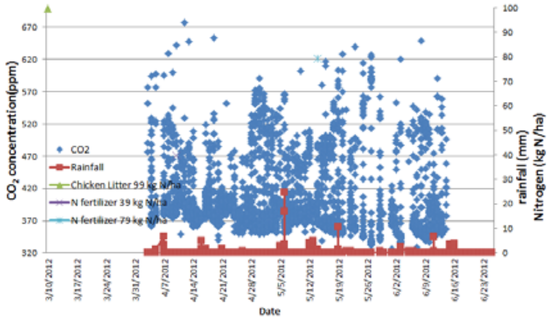

Figure 9. Seasonal CO_2 concentration variation.

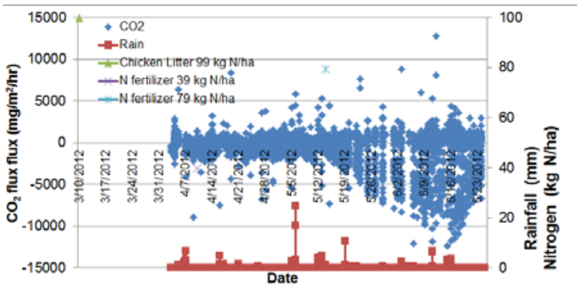

Figure 10. Seasonal CO_2 flux variation.

The total seasonal N_2O-N emission

The total seasonal N_2O-N emission was calculated by integrating the N_2O-N flux over the whole season, including when u*≥0.2 m/s and u*<0.2 m/s.

The N_2O-N fluxes when u*<0.2 m/s were calculated using regression equations. The equations were deduced using the N_2O-N flux data when u*≥0.2 m/s. The data used were divided into nighttime (from 19:00 to 8:00 ***) and the daytime (from 8:00 to 19:00) for regression analysis at different plant stages. The stages included after planting and before the first application of nitrogen URAN-32-0-0, after the first application of nitrogen and heavy rainfall events, during heavy rainfall season, after the second application of URAN-32-0-0, and during other periods. In the regressions, the N_2O-N flux was the dependent variable, and the independent variables were 10-cm soil moisture and temperature. The determination coefficient R^2 values were above 0.6, and the p values were smaller than 0.001.

The N_2O-N emission from the cornfield was 29 g/ha/day (3.5 kg/ha/120 days).

Chamber vs. EC measurements

Currently, although we only have limited chamber data, Figure 11 shows that the EC measurements were reasonable compared with the chamber data.

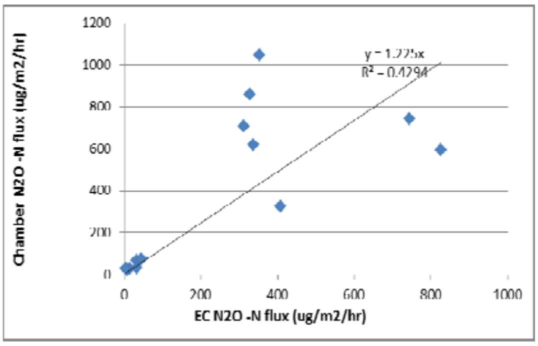

Figure 11. Chamber vs EC N_2O-N flux measurements.

5. CONCLUSION

The N_2O and CO_2 measurements from the EC system were reasonable. The N_2O-N emission from the commercial cornfield was 29 g N_2O-N/ha/day (3.5 kg/ha/120 days).

6. ACKNOWLEDGMENTS

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