Using the Eddy Covariance Method and Chambers to Characterize Spatial and Temporal Trends in Emissions of the Greenhouse Gas Nitrous Oxide over a Barley Field in the Inland Pacific Northwest

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Background: Nitrous oxide emission from agricultural soils

•N_2O is a greenhouse gas with 300 times the global warming potential of CO_2 on a 100-year time horizon
•It is also a chief ozone depleting substance in the stratosphere
•N_2O is produced as a byproduct of the soil microbial processes nitrification and denitrification:

Nitrification: $NH_4^+ \rightarrow N_2O \rightarrow NO \rightarrow NO_2^- \rightarrow NO_3^-$
Denitrification: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

•Agricultural soils are the largest single source of N_2O, due to the increase in available N from fertilizers
•N_2O is difficult to measure due to
  • spatial and temporal variability of emissions
  • relatively low concentration (ambient background~320 ppb)

Study Objectives:

This study is part of a larger effort to monitor carbon and nitrogen cycling over a range of agricultural sites in the Northwest. An integral part of achieving this goal is to establish a baseline for the exchange of the greenhouse gases CO_2 and N_2O. For this study, we were focused on the following objectives:

1. To characterize the flux of N_2O following fertilization and planting of a typical agricultural field in the IPNW
2. To compare results between chambers and micrometeorological techniques
3. To strategically use results from different measurement types to scale the emissions spatially and temporally

Site Description:

• Private farm located outside of Moscow, ID
• Growing spring barley, planted 2 May 2013
• Fertilized with a mix of anhydrous ammonia, ammonium phosphate, and physol for a total of 100 kg N/ha on 1 May 2013
• Figure 1b shows a satellite image of the site
  •Red ring: 100m radius around the tower or the approximate daytime footprint
  •Red dots: approximate chamber locations
  •Orange rectangle: diesel generator powering instruments

Measurements:

•Eddy Covariance:
  •10Hz wind speed and direction: 3D sonic anemometer
  •10Hz CO_2 concentration open path infrared gas analyzer (IRGA) (both Campbell Scientific)
  •10Hz N_2O measured with closed path tunable diode laser (TDL) (Los Gatos Research)
•Chamber Flux:
  •four automatic static chambers, model LI-8100 (Licor Biosciences)
  •1Hz N_2O measured with closed path TDL (Los Gatos Research)

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Measurements: Integrating Methods

Pros:
• Low detection limit
•Not subject to data loss due to ambient conditions (i.e. low turbulence)

Cons:
•Only measure small, discreet areas
•Only measure each chamber once every two hours
•May disturb soil

Pros:
•Continuous measurements
•Integrates whole-field scale
•Minimal site disturbance

Cons:
•Subject to data loss, esp. at night
•Higher detection limit

Measurement Footprint:

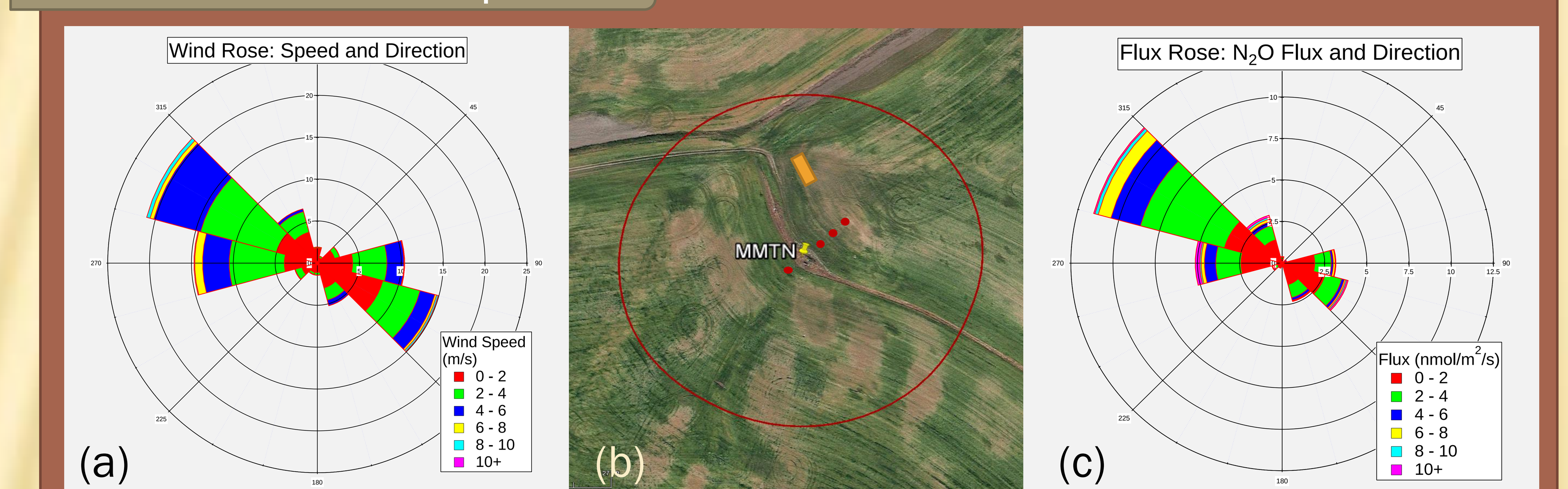

Figure 1: Polar plots showing (a) wind speed and direction, or fetch, of the tower measurements, and (c) the magnitude of the N_2O fluxes from given wind sectors. The middle image (b) shows the tower site and the locations of the chambers. These figures show that (1) the west by northwest sector was predominately measured by the tower, (2) the chambers were not in the tower footprint, and (3) the generator was only rarely upwind of the tower.

Measurement Theory

Chambers:

·The chamber volume (V, m³) and surface area (A, m²) are known, and the change in gas concentration (ΔC, nmol/m³) is measured for a set period of time (Δt, s). Using this information, emission rate can be calculated as:

$$\frac{\Delta C}{\Delta t} * \frac{V}{A}$$

Tower-based Eddy Covariance:

·Measuring correlations between gas concentration and vertical winds (i.e., updrafts and downdrafts) allows for calculation of emissions or uptake from the surface by the following equation:

$$F_{gas} = \overline{w'c'}$$

·w' = fluctuating part of the vertical wind; c' = fluctuating part of the gas concentration; over bar indicates taking the mean.

Results: What is representative?

What we measured: time series of fluxes, meteorological & soil variables

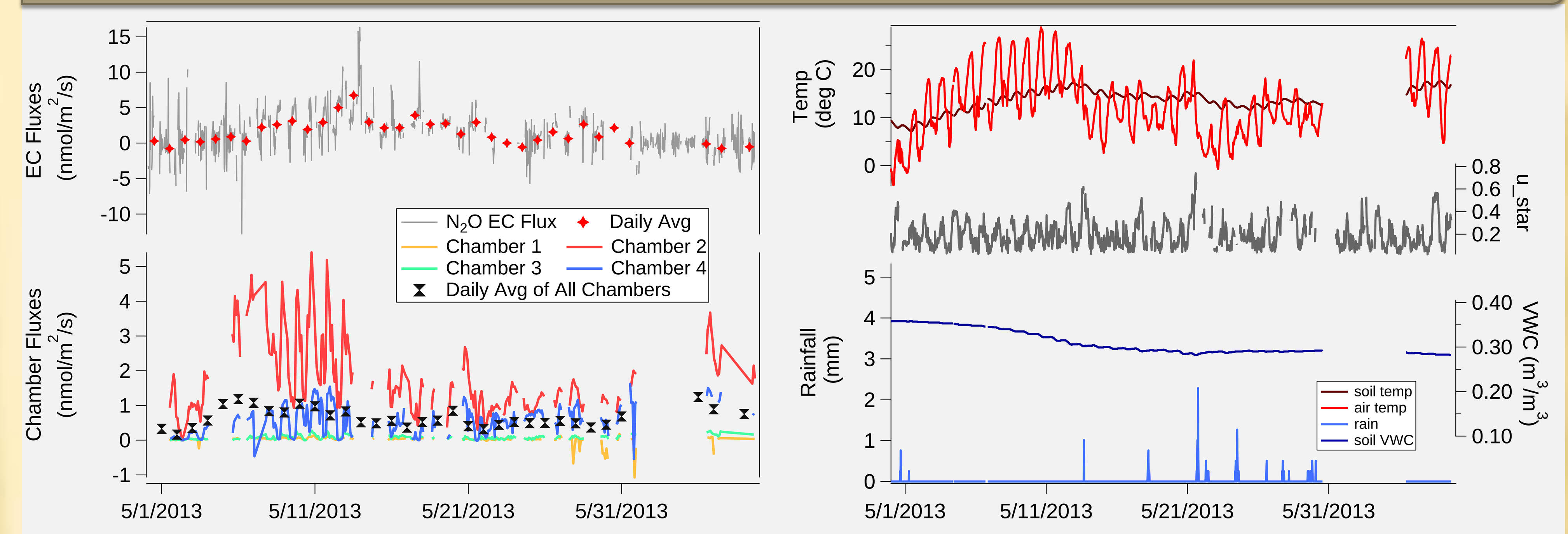

Figure 2: Time series of fluxes, meteorological parameters, and soil conditions. The plot on the left shows half hour eddy covariance N_2O fluxes on the top axis. Periods that did not fulfill stationarity and/or sufficient turbulence were filtered, as were statistical outliers. Chamber fluxes are on a two-hour time step. The plot on the right shows parameters that may affect N_2O production. Emissions increase along with soil temperature, peaking after the first rain event following fertilization. U_{star} is an measure of turbulence, and values <0.3 (usually nighttime) indicate poor measurement quality.

Comparing Emission Magnitudes: Daily Averages

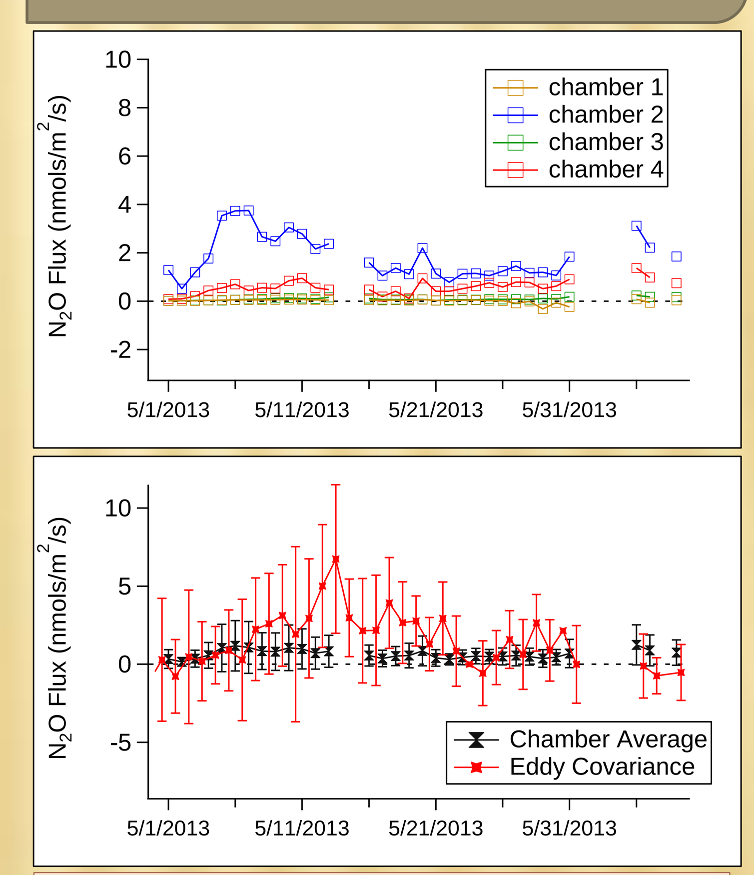

Figure 3: Daily averages of N_2O fluxes. Bars are one standard deviation from the mean, and indicate the daily range.

Comparing Emission Patterns: Diurnal Averages

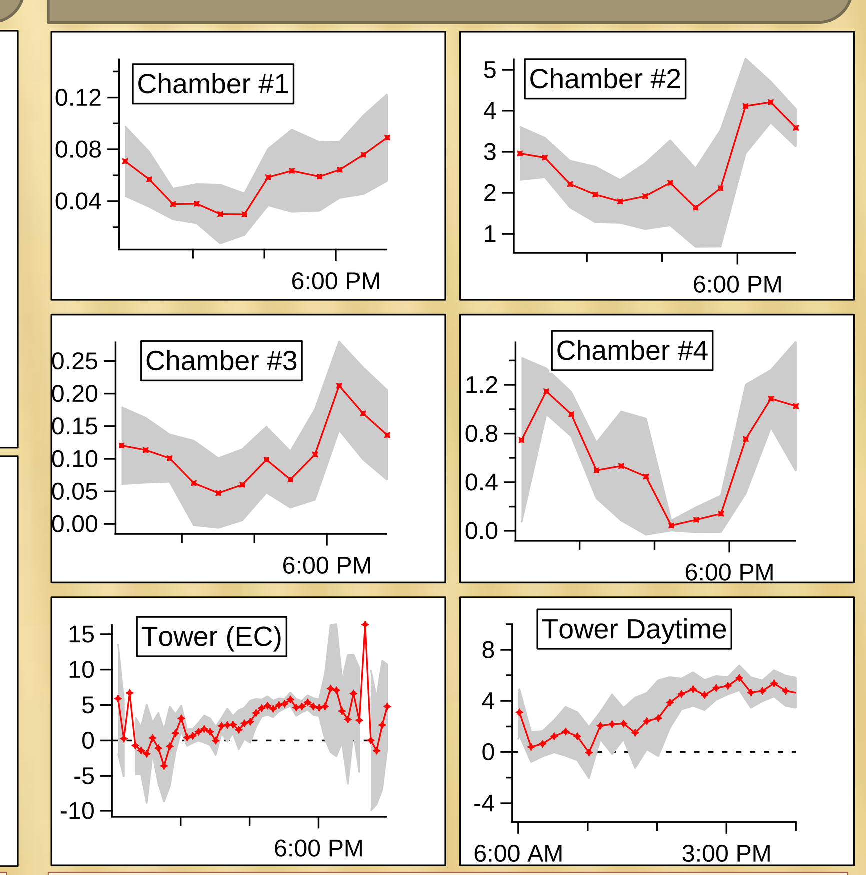

Figure 4: Diurnal averages (in $nmol_{N_2O}/m^2/s$) for the seven-day maximum flux period (5/7-5/14).

Comparing Total Emissions

Table 1: Integrated total fluxes for the month-long measurement period

	kg N/ha	% of fert N
Ch #1	0.008	0.01%
Ch #2	1.5	1.49%
Ch #3	0.072	0.07%
Ch #4	0.464	0.46%
Ch Avg	0.529	0.52%
Tower	1.01	1.00%

Discussion:

The final estimate of total N_2O emission during the "hot moment" period following fertilization ranges from less than 0.5 kg N/ha to 1.5 kg N/ha. These numbers fall within the IPCC Tier 1 estimate of N_2O emissions as 1.25±1% of the total fertilizer applied. However, the magnitude of the EC measurements coupled with the chamber pattern of enhanced night time emissions suggests underestimation of total emissions.

To better understand the spatial and temporal variability of N_2O emissions during this period, we plan to analyze night time emissions using box modeling, and investigate source heterogeneity using a footprint analysis.