EGU21-515
https://doi.org/10.5194/egusphere-egu21-515
EGU General Assembly 2021

Quantifying nitrous oxide emissions in space and time using static chambers and eddy covariance from a temperate grassland

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Nitrous oxide (N_2O) is a potent greenhouse gas (GHG), with a global warming potential (GWP) of 265 relative to carbon dioxide (CO_2) and a lifespan of over 100 years. Where N input from fertilizers exceeds plant demands, hotspots of N_2O can be produced releasing short-lived pulses of N_2O from the soil that exhibit disproportionately high rates of emissions relative to longer periods of time, known as hot moments. Hotspots and hot moments of N_2O are sensitive to changes in agricultural management and the environment making it difficult to accurately quantify N_2O emissions with low uncertainties. This study investigates the methods used to quantify N_2O emissions in time and space, using both static chambers (SC) and eddy covariance (EC) techniques.N_2O fluxes were measured from both techniques from an intensively managed grassland site under four fertilizer applications of calcium ammonium nitrate (CAN) in 2019. EC measurements of N_2O were gap-filled by using a simple linear empirical model that incorporated environmental and management data. SC N_2O fluxes were calculated using the arithmetic method and Bayesian statistics via Markov Chain Monte-Carlo (MCMC) simulations to account for the log-normal distribution of fluxes measured. N_2O emissions were weakest in winter for both techniques (-3.27 µg N_2O-N m^{-2} hr^{-1} for SC and -3.9 µg N_2O-N m^{-2} hr^{-1} for EC). Following fertilizer application, daily averaged N_2O emissions peaked in March (538.89 µg m^{-2} hr^{-1} for SC, 491.18 µg m^{-2} hr^{-1} for EC) and April (117.91 µg m^{-2} $hr^{-1}$for SC and 306.90 µg m^{-2} hr^{-1} for EC). Delayed peaks in N_2O emissions following fertilizer application occurred in June (101.03 µg m^{-2} hr^{-1} for SC and 814.76 µg m^{-2} hr^{-1} for EC) and October (417.14 µg m^{-2} hr^{-1} for SC and 313.22 µg m^{-2} hr^{-1} for EC) and these high emissions events coincided with dry periods followed by rainfall events. EC and SC measurements were most comparable when emissions were > 115 µg m^{-2} hr^{-1}, when the flux footprint of half-hourly EC flux measurements overlapped with the position and time of SC measurements and when the number of chamber replicates were ≥ 15 on a given sampling day. Where the chamber sample size was small (n ≤ 5), the Bayesian method produced large uncertainties (> 25,000 µg m^{-2} hr^{-1}) due to the inability to constrain an arithmetic mean from a log-normally distributed data set. Annual cumulative N_2O fluxes from EC and SC by the arithmetic and Bayesian method, were 3.35(± 0.5) kg N ha^{-1}, 2.98 (± 0.17) kg N $ha^{-1}$and 3.13 (± 0.24) kg N ha^{-1} respectively. Emission factors from EC and SC by the arithmetic and Bayesian method were higher than the Intergovernmental Panel on Climate Change (IPCC) default value of 1%, at 1.46%, 1.30%

and 1.36%, respectively. Our study highlights that disparities exist between SC and EC in quantifying N_2O fluxes from a managed grassland and we recommend constraining disparities by utilizing a SC sample size > 5 and by accounting for the log-normal distribution of N_2O flux data to accurately estimate N_2O flux uncertainty.