How do soil temperature and moisture regulate N_2O flux from an urban lawn?

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Introduction: N_2O flux is one of the major components in the nitrogen cycle, and a potent greenhouse gas with a global warming potential 300 times greater than CO_2. Like agricultural fields, lawns in urban areas are also an anthropogenic nitrous oxide (N_2O) source. However, the N_2O flux from urban lawns are less studied than fluxes from agricultural fields. To better understand the seasonal dynamic of N_2O flux over urban ecosystems and how soil temperature and moisture regulate the flux, we have been measuring the flux continuously since the summer of 2019 over a lawn in Lincoln, Nebraska. The measurement was done with an automated 4-chamber multiplexer system (LI-8100A/8150) coupled with a N_2O gas analyzer (LI-7820) from Sept of 2019 to Mar 2021. Since March 2021, the flux has been measured with an 8-chamber multiplexer system (LI-8250). The flux were sequentially measured every 30 or 60 minutes. Soil temperature and moisture at each chamber at the depth of 5 cm were also measured. The grass type is a fescue with a mean vegetation height of approximately 5 cm that has not been irrigated nor fertilized.


Setup

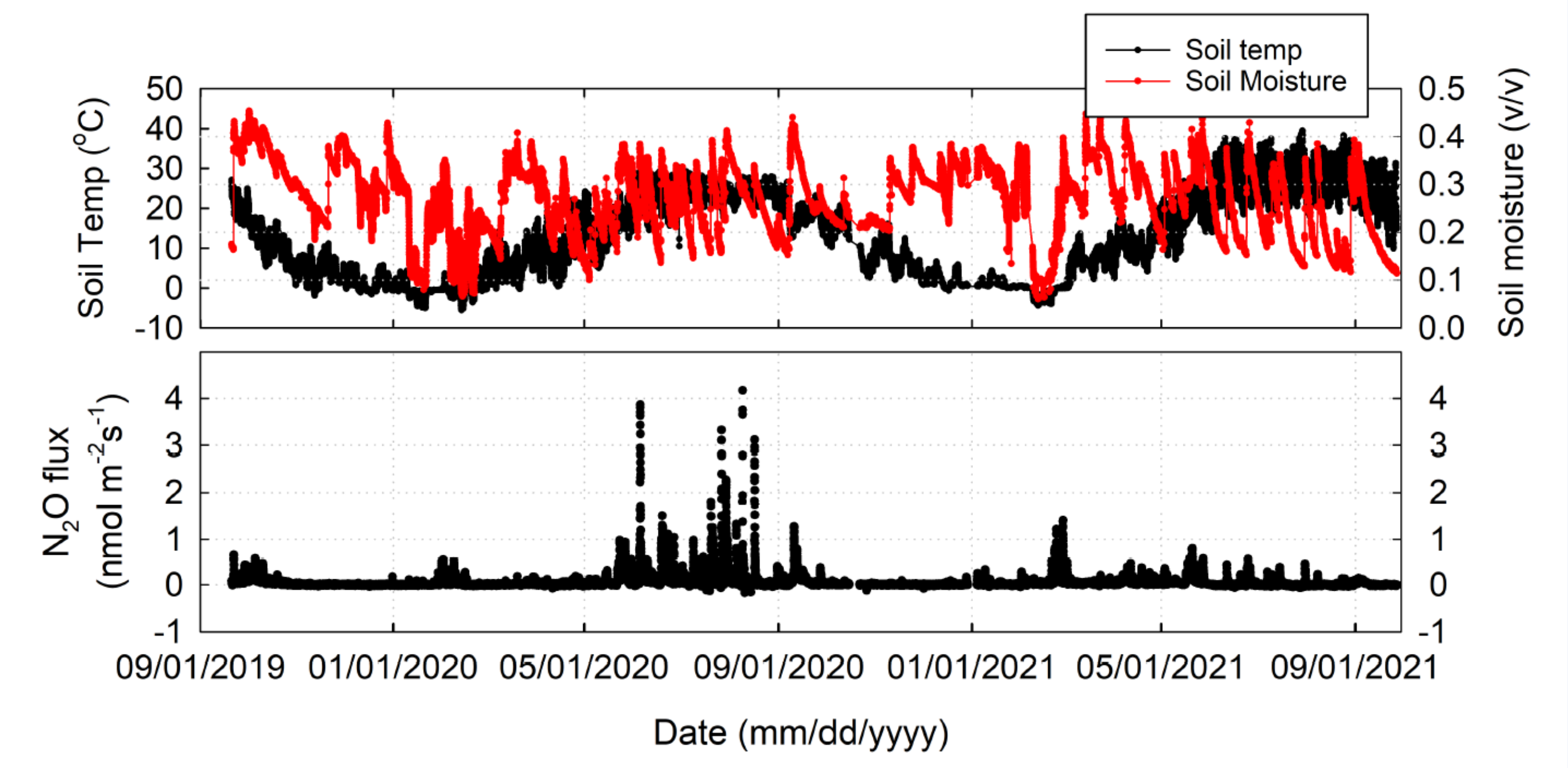
N_2O flux calculation:

$$F_{N2O} = \frac{VP(1-W_o)}{RST}\frac{dN2O}{dt}$$

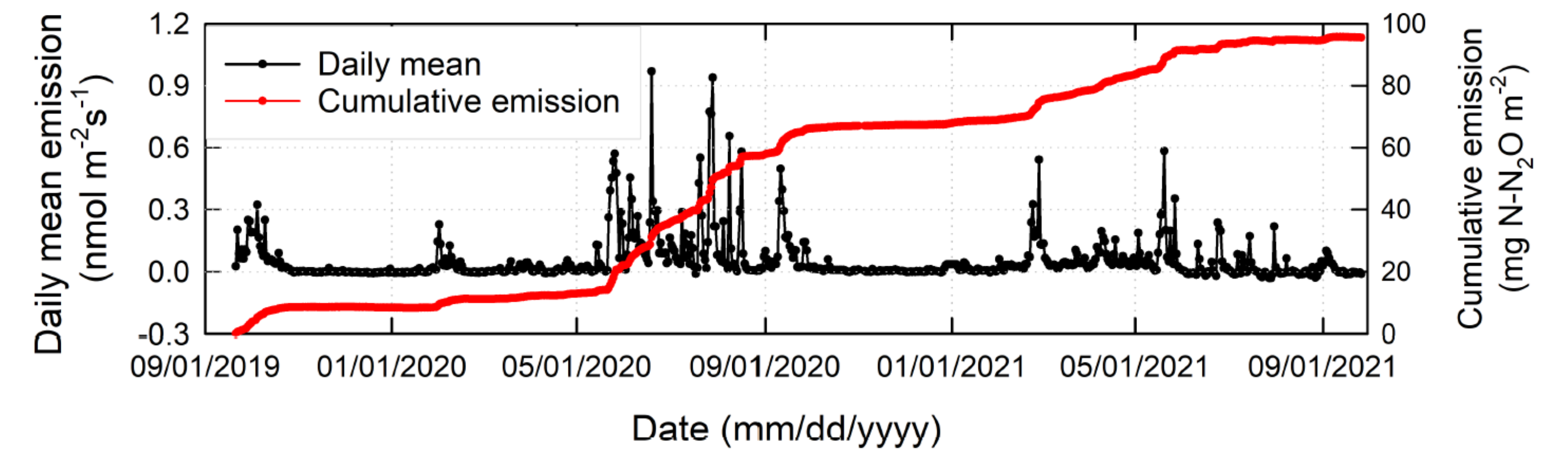
Where: F_{N2O}; soil N_2O flux (nmol $m^{-2}s^{-1}$)
V: chamber volume (m^3)
P: atmospheric pressure (Pa)
W_o: initial water vapor mole fraction (mol mol^{-1})
R: gas constant (Pa m^3 $mol^{-1}k^{-1}$)
S: soil area (m^2)
T: chamber temperature (^oK)
$\frac{dN2O}{dt}$: rate of N_2O change (nmol $mol^{-1}s^{-1}$) during the chamber closure

Results: The soil at our field site is a Sharpsburg silty clay loam (Typic Argiudall) and the ground cover is primarily fescues (*Festuca* spp.) with a mean vegetation height of approximately 5 cm. From the measured N_2O flux data from September 2019 to September 2021, we have the following preliminary results:

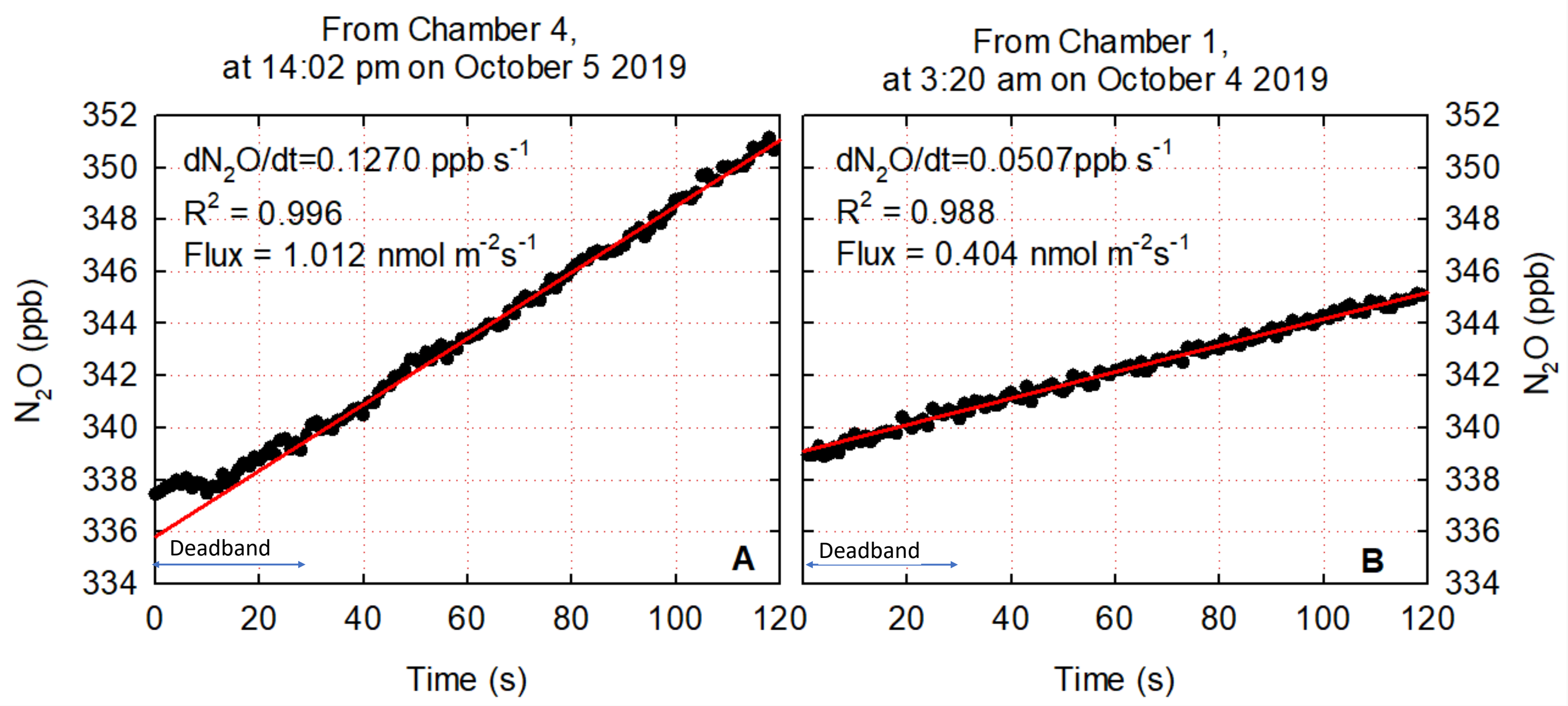
1. The flux ranged from 4.2 nmol $m^{-2}s^{-1}$ in the summer to almost zero in the winter, depending strongly on the soil moisture and soil temperature. The flux is similar to other studies over lawn ecosystems (e.g. Bijoor et al., 2008).
2. In early winter, N_2O flux almost stopped when the soil temperature at the 5-cm depth dropped below 5ºC (after October 28, 2019).
3. Rain events enhanced the N_2O flux quickly, especially in the summer when the soil moisture was below 0.2 v/v.
4. Our preliminary results seem to indicate that during the wintertime the N_2O flux increased rapidly during the ice and snow were melting (e.g. January 31 to February 15, 2020). We observed the flux jumped from zero to 0.6 nmol $m^{-2}s^{-1}$ in early February 2020 when the soil temperature was still around 0ºC. This result is consistent with data reported in the literature (e.g. Flechard et al., 2005).



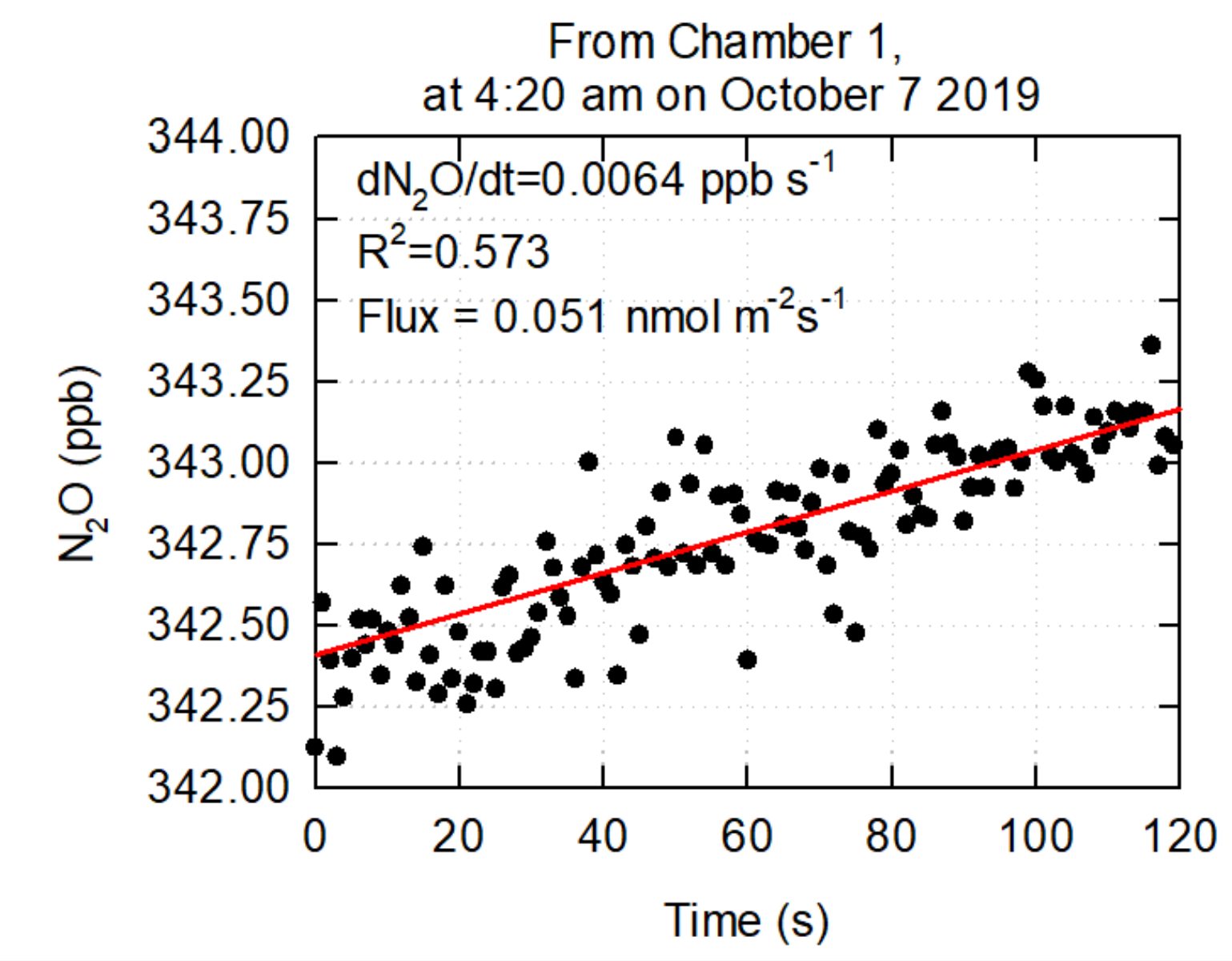
5. Based on the flux data over our entire study period, the cumulative N_2O emission is 95.62 mg N-N_2O m^{-2} (0.956 kg N-N_2O ha^{-1}). The cumulative emission from the present study site is relatively lower as compared with other studies from similar ecosystems. For example, Townsend-Small and Czimczik (2011) report an annual total emission rate of 1.0 to 3.0 kg N-N_2O $m^{-2}yr^{-1}$ from an urban turf study in Irvine, California.



Example of time series N_2O concentration: With an 8100-104 Long-Term Chamber (chamber volume of 5973 cm^3 and soil area of 318 cm^2), linear regression coefficients were normally higher than 0.9 when the N_2O flux was higher than 0.1 nmol $m^{-2}s^{-1}$. See two examples below:



Based on our seasonal long-term N_2O flux data, this configuration of a closed chamber system can resolve a minimum flux as low as 0.05 nmol $m^{-2}s^{-1}$. A typical example is shown at right. Over the two minutes observation, chamber N_2O concentration increased by approximately 0.768 ppb. This is about 3 times the precision of this N_2O analyzer (~0.3 ppb). This gives us enough confidence in the slope estimation using linear or exponential regression.



Conclusions

1. Our study site with fescue vegetation in Lincoln, Nebraska, is primarily a weak N_2O source. Depending on the soil temperature and moisture, the emission rate ranges from zero in the wintertime to 4.2 nmol N_2O $m^{-2}s^{-1}$ in the summer.
2. Large pulse of N_2O emission is observed during the thawing of frozen soil in early spring.
3. Rain events enhance the N_2O emission quickly, especially during summertime when soil moisture is below 0.2 v/v.
4. With our current instrument setup, the minimum detectable nitrous oxide flux is approximately 0.05 nmol $m^{-2}s^{-1}$.

References

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Flechard C.R., et al., 2005. By-directional soil/atmosphere N_2O exchange over two mown grassland systems with contrasting management practice. Global Change Biology, 11: 2114-2127.

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