Review of "Advancing N_2O flux chamber measurement techniques in nutrient-poor ecosystems"

Triches et al. 2025, Atmospheric Measurement Techniques

Overview

This study investigates the quantification of low nitrous oxide (N_2O) fluxes in nutrient-poor, sub-Arctic ecosystems using a fast-responding portable gas analyser (PGA, Aeris-N_2O) combined with a custom-built flux chamber system. The authors conducted laboratory tests to assess the instrument's signal stability, noise characteristics, and water vapor interference, and performed field experiments at a sub-Arctic peatland. Chamber closure times ranging from 3 to 10 minutes were systematically varied under both light and dark conditions, and fluxes were calculated using both linear and non-linear models. In addition, the high-frequency PGA data were downsampled to simulate gas chromatograph (GC) measurements, and the impact of reduced sampling frequency on parameter uncertainty and flux estimates was evaluated.

I would like to thank the authors for providing the data and code for this study.

The paper is well written and is suitable for publication in Atmospheric Measurement Techniques. I have three general comments regarding the uncertainty analysis, the simulation of GC measurements, and the model assumptions.

General comments

1. The analysis of the instrument stability and noise characteristics seems to suffer from repetition of several values that are very close to each other (see figure below). As a result, the Allan deviation analysis shows correlated noise up to 30 seconds averaging period. When the repeated values are removed, the Allan deviation shows a more realistic white noise behavior. These repeated values need to be removed before any further analysis. Note that they are not identical but they are very close to each other.

2. The comparison with GC simulation is not rigorous enough in my opinion. Report-

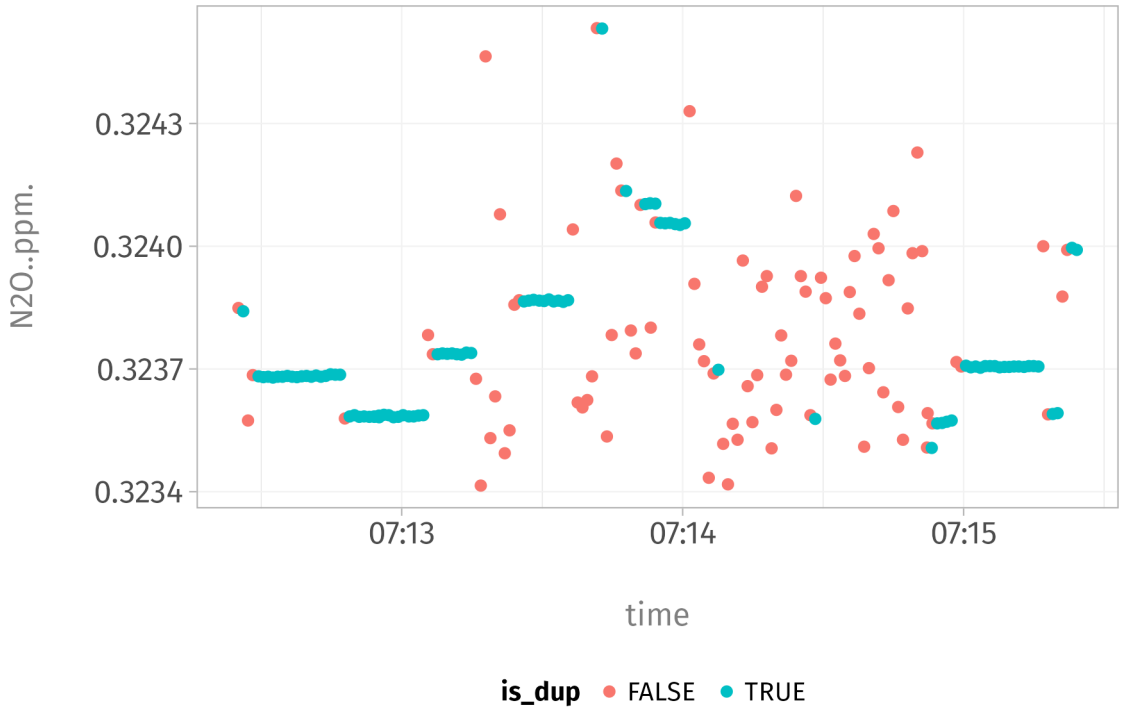

Figure 1: A random sample of 2 minutes from the lab test time series

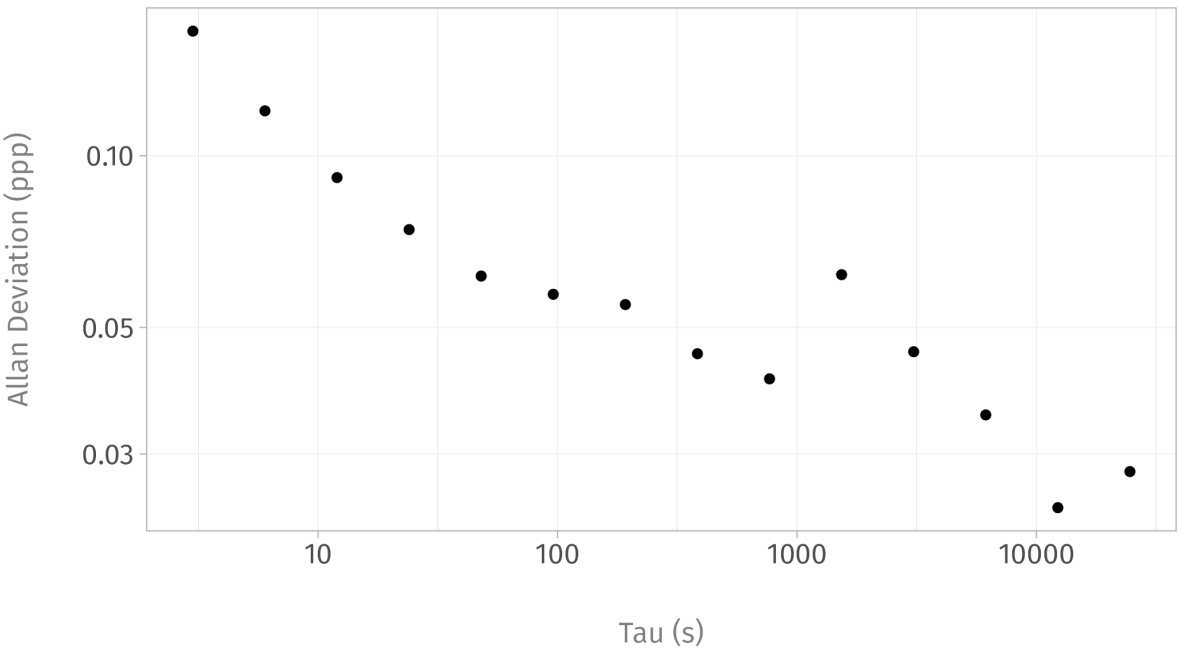

Figure 2: Corrected Allan deviation after removing duplicates

ing underestimation from a downsampled time series needs stronger justification. An increase in uncertainty from a fewer number of sampling points is expected and can be assessed from theory. That being said, a Monte Carlo simulation is also a valid approach to explore the increased uncertainty. However, in that case the subsampled time series should be taken from what is believed to be the true value of concentration (i.e. from the fitted model) and then noise can be added to it based on known GC uncertainty e.g. (Lebegue et al. 2016) (Rapson and Dacres 2014). Then the fluxes calculated from simulated GC measurements can be compared to PGA measurements.
If the authors' argument is that there is more than just downsampling and that the concentration inside the camber fluctuates not only due to noise, then a justification needs to be provided for this argument. In that case taking mean downsampled PGA measurements is reasonable but needs explicit discussion of the uncertainty.

3. It appears that both the LM and HM models assume that flux at the soil-air interface remains constant over time (time invariant). However, the study mentions that N_2O fluxes change as the concentration gradient evolves within the chamber. Could the authors discuss this assumption more explicitly and its potential implications for flux calculations? Are there metrics that the authors recommend to assess the violations of this assumption?

Specific comments

(*numbers refer to line numbers in the manuscript*)

- The title of the paper seems quite general. You might consider suggesting a more specific title that highlights the key contributions but I leave this to the authors to decide.
- 12 … "we **can** successfully detect" This sounds like you are reporting a detection limit. but you are reporting means with an uncertainty interval. I would suggest to rephrase this sentence.
- 15 MDF reported as a number with uncertainty interval is unusual. Maybe clarify what is reported here.
- 20 "..or matched the linear model. .." could you clarify this sentence.
- 21 Underestimation flux when using GC needs stronger justification see my general comment.
- 27 is the repetition of the IPCC full name necessary?
- 57 "At the same time, many of the reported N_2O fluxes were found to be below the detection limit, making it challenging to assess the magnitudes and possible uptake of these fluxes."

Not clear here which fluxes you are referring to. The phrase "possible uptake" sounds ambiguous to me. do you mean "challenging to assess the sign of these fluxes"?

- 91 the coordinates seem to be missing a dot "20.0'" instead of "200"
- 180 where is the instrument precision taken from?
- 180 Definition of MDF is somehow strange as it does not include the number of points in the time series. Also this definition is different from what what is typically reported in the literature. For example (Maier et al. 2022) defines MDF as

$$MDF = \left(\frac{PI}{t_c}\sqrt{\frac{t_c}{p_s}}\right) \times \left(\frac{V_{ch}p_{air}}{ART_{air}}\right)$$

- I think it's also important to highlight that MDF defined here is only a theoretical limit based on the instrument uncertainty and does not account for model fit or chamber artifacts.
- 194 "We used this factor because it has been previously used" I think better justification is needed here.
- 202 could you clarifies your second measurement strategy? did you take block averages or have you calculated the flux on 1-min intervals?
- 223 2500 ppm to 800 ppm seem very dry for ambient air, was their any drying involved?
- Figure 1 description needs restructuring. Move information about shape files to the end if it is needed. Also shapefile is a technical term that might not be familiar to all readers. I would suggest to use a more general term like "geospatial data" or "map data" instead.
- Looking at Figure A1. I would not say there is no drift. At least in the beginning (maybe 2, 3 hours) there is a clear drift of about 1.5 ppb. You mentioned that 5 hours were needed for the signal to stabilize, would that mean the instrument needs 5 hours in the field for the signal to stabilize? or is that a temperature or pressure artifact? this needs more discussion.
- Figure 4. is there a reason why relative humidity is chosen rather than absolute water concentration? For the analyzer, any matrix effects would be dependent on absolute water concentration rather than relative humidity.
- 240 with such large uncertainty - this is basically not statistically different from zero - I would not conclude that the site acted as a sink. What is the number after the $\pm$ in the reported fluxes? Conventionally, it should be 2*SE to give a 95% confidence interval for the mean (can you please mention this when your first report it)
- 245: is there something that supports this?

- 269: I don't understand the recommendation for 3-5 minutes since the flux is continuously increasing. Could you elaborate more on this recommendation?
- 291: why does water increase in that pattern, and why would it decrease with time? Does temperature explain this behavior?
- Figure S5, is this a differenced time series? so is this ppm per minute or is it just normalized concentration by subtracting the first H2O measurement.
- 378 again I think an explanation is needed on why GC underestimates the flux
- in the conclusion, can you extend your recommendations to cover model choice, and how to avoid chamber artifacts. I am thinking of what metrics would you recommend to assess the goodness of fit of the model or when to detect the violations of the time-invariance assumption.

References

Lebegue, Benjamin, Martina Schmidt, Michel Ramonet, Benoit Wastine, Camille Yver Kwok, Olivier Laurent, Sauveur Belviso, et al. 2016. "Comparison of Nitrous Oxide (N_2O) Analyzers for High-Precision Measurements of Atmospheric Mole Fractions." *Atmospheric Measurement Techniques* 9 (3): 1221–38. https://doi.org/10.5194/amt-9-1221-2016.

Maier, Martin, Tobias K. D. Weber, Jan Fiedler, Roland Fuß, Stephan Glatzel, Vytas Huth, Sabine Jordan, et al. 2022. "Introduction of a Guideline for Measurements of Greenhouse Gas Fluxes from Soils Using Non-Steady-State Chambers." *Journal of Plant Nutrition and Soil Science* 185 (4): 447–61. https://doi.org/10.1002/jpln.202200199.

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