

Biogeosciences Discuss., author comment AC2
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Reply on RC2

Margaret Capooci and Rodrigo Vargas

Author comment on "Trace gas fluxes from tidal salt marsh soils: implications for carbon–sulfur biogeochemistry" by Margaret Capooci and Rodrigo Vargas, Biogeosciences Discuss., <https://doi.org/10.5194/bg-2022-101-AC2>, 2022

Comment: This is a pioneering study that compares traditional discrete low-tide gas (CO₂, CH₄, N₂O, CS₂, DMS) flux measurements from a salt marsh against continuous, high-temporal frequency measurements. The novel approach to measuring high-frequency, continuous (72-hour) fluxes of gases is capable of capturing episodic, pulse emissions that might otherwise evade discrete, low tide measurements. High-temporal flux measurements of CO₂ did not differ from discrete measurements demonstrating that daily mean low tide measurements capture the variability of this process sufficiently, whereas the episodic spikes of the other gas fluxes (CH₄, N₂O, CS₂, DMS) that were captured by high-temporal measurements were missed by discrete measurements. There was also a strong relationship between temperature and CO₂ and CH₄ fluxes. However, precautions should be taken when using daily mean low tide (discrete) values to calculate annual flux budgets or warming potentials due to differences in flux ranges despite the mean values between the two approaches generally agreeing. Overall, this study is very thorough and the sound results are presented in very clear writing.

Response: We thank the reviewer for their kind comments and support for the manuscript and the study design.

Comment: Below are comments/questions that may improve the clarity of the manuscript text and figures, along with requests for more methodological details.

L45: add "can potentially" after also. Carbon storage rates have a vast range and many factors will impact the long-term storage potential.

Response: We will include "can potentially" in line 45.

Comment: L65-72: please specify the affect these compounds have on the climate, i.e., cooling or warming effects

Response: DMS has a cooling effect on the climate. CS₂ has a warming effect, but it is a precursor to carbonyl sulfide which is a cooling gas. CS₂ has a short lifetime (~days). We will include this within lines 65-72, as well as the following references.

References

Brühl, C., Lelieveld, J., Crutzen, P.J., Tost, H.: The role of carbonyl sulphide as a source of stratospheric sulphate aerosol and its impact on climate. *Atmos. Chem. Phys.*, 12, 1239-1253, <https://doi.org/10.5194/acp-12-1239-2012>, 2012.

Charlson, R.J., Lovelock, J.E., Andreae, M.O., Warren, S.G.: Oceanic phytoplankton, atmospheric sulphur, cloud albedo and climate. *Nature*, 95(16), 655-661, <https://doi.org/10.1038/326655a0>, 1987

Thomas, M.A., Suntharalingam, P., Pozzoli, L., Rast, S., Devasthale, A., Kloster, S., Feichter, J., Lenton, T.M.: Quantification of DMS aerosol-cloud-climate interactions using the ECHAM5-HAMMOZ model in a current climate scenario. *Atmos. Chem. Phys.*, 10, 7425-7438, <https://doi.org/10.5194/acp-10-7425-2010>, 2010.

Watts, S. F.: The mass budgets of carbonyl sulfide, dimethyl sulfide, carbon disulfide and hydrogen sulfide. *Atmos. Environ.*, 34, 761-779, [https://doi.org/10.1016/S1352-2310\(99\)00342-8](https://doi.org/10.1016/S1352-2310(99)00342-8), 2000.

Comment: L82-87: it is my understanding that disentangling gas fluxes during high tide are difficult since the effluxing gases are mixing/dissolving into the flood tide waters. Perhaps this should also be mentioned here. How were gas fluxes measured when the collars were underwater from the flood tide?

Response: In line 84, we will include the following sentences: "Measurements at high tide in salt marshes are difficult due to both reduced access to the marsh platform and reduced fluxes due to mixing with the overlying water column and a decrease in the rate of diffusion through water compared to air."

With regards to flood tide at our site: The SS site rarely floods during high tide due to its distance from the tidal creek as well as the presence of a berm located adjacent to the tidal creek. As a result, the SS site floods during spring high tides and storm events. If the soils were flooded during the study period, it was minimal and measurements continued to run. To clarify the SS site's hydrology, details and references will be included in Section 2.1.

References

Hill A, Vazquez-Lule A, Vargas R. Linking vegetation spectral reflectance with ecosystem carbon phenology in a coastal salt marsh. *Agricultural and Forest Meteorology*. 307:108481 <https://doi.org/10.1016/j.agrformet.2021.108481>, 2021

Moffett, K.B., Wolf, A., Berry, J.A., Gorelick, S.M.: Salt marsh-atmosphere exchange of energy, water vapor, and carbon dioxide: Effects of tidal flooding and biophysical controls. *Water Resour. Res.*, 46(W10525), <https://doi.org/10.1029/2009WR009041>, 2010.

Seyfferth, A. L., Bothfeld, F., Vargas, R., Stuckey, J. W., Wang, J., Kearns, K., Michael, H. A., Guimond, J., Yu, X., and Sparks, D. L.: Spatial and temporal heterogeneity of geochemical controls on carbon cycling in a tidal salt marsh, *Geochim. Cosmochim. Acta*, 282, 1-18, <https://doi.org/10.1016/j.gca.2020.05.013>, 2020.

Comment: L128-133: this text reveals that the gas fluxes are measured over ~four days; this makes the use of the word "continuous" in the introduction misleading. I understand that continuous over four days is still different than discrete low tide measurements, but this should be clarified in the Introduction that this study utilizes a continuous, multi-day measurements. Perhaps it's my own bias, but to me continuous implies year-round.

Response: We agree that the use of "continuous" can imply different things. Here "continuous" denotes that the measurements were performed in an automatic and continuous way until the instruments were shut down for each campaign. We will clarify in the introduction in line 102 that continuous measurements lasted ~72 hours. At this moment it is not possible to perform long-term continuous measurements because of electrical power limitations and damage to the instruments due to the high salinity content in the environment. We will also discuss this in more detail in a revised version.

Comment: L135-137: could benthic microalgae be present on the sediment surface? Were gas chambers darkened to prevent photosynthesis? Were plant stems trimmed down to the sediment surface or pulled out completely? Could remaining plant structure in the sediment act as "straws" or conduits of gas exchange? If plants were completely removed (i.e., pulled out or cut to below the surface), was the sediment surface disturbed?

Response: Here are the answers to the above five questions:

- We did not see the presence of dense microbial mats on the sediment surface. However, microalgae not forming mats could have been present but were not evident with a "naked eye".
- Chambers were opaque. We will clarify that in line 137.
- Plant stems were clipped to the sediment surface. We will clarify that in lines 135-137.
- It is entirely possible that the plant structure in the sediment could act as "straws" for transport of gases to the atmosphere. However, plant stems were trimmed on a frequent enough basis, such that stem diameters were reduced, minimizing the effects of plant-mediated transport of trace gases. That said, we will discuss this mechanism in a revised version of the manuscript.
- Plants were not completely removed to minimize disturbance to the sediment surface. These plants have dense thick rhizomes and removing them will represent a major disturbance to the soil structure. Therefore, careful clipping was the most effective approach. Finally, our measurements of CO₂ and CH₄ fluxes were comparable to manual measurements performed with chambers of different sizes and including different components of vegetation in this wetland (Hill et al 2022)

Reference

Hill, A. C., and R. Vargas. 2022. Methane and carbon dioxide fluxes in a temperate tidal salt marsh: Comparisons between plot and ecosystem measurements. *Journal of geophysical research. Biogeosciences* 127. <http://doi.org/10.1029/2022JG006943>

Comment: L140: what was the volume of a chamber? Did this warrant an internal fan to homogenize gases while measuring?

Response: The chamber volume was 4071.1 cm³. LICOR soil chambers do not have fans included in their design. As per the website

(https://www.licor.com/env/products/soil_flux): "mixing is achieved through a bowl-shaped chamber and air inlet/outlet positioning." Therefore, the chambers were designed to homogenize gases during chamber closure. These are "industrial type" autochambers and have been extensively engineered to address changes in pressure and to maximize flow for measurements.

Comment: L155-158: The description of the QAQC is a bit too brief. There seems to be a lot of steps packed into this sentence. It would help the reader to have each step in a sentence, at least, with more description. I recognize that every step of QAQC cannot be divulged in detail, but the current state of this sentence is far from reproducible.

Response: We have followed previously published QA/QC protocols but lines 155-158 will be rewritten as follows: QAQC included several steps. First, all values due to instrumental errors such as an insufficient chamber closure seal were removed. These errors were identified by the SoilFluxPro software. Second, the R^2 for the linear and exponential fits of trace gas emissions were compared and the fit with the higher R^2 was chosen. Third, all fluxes that occurred when the R^2 of CO_2 was <0.90 were removed. Low R^2 's indicate that the soil micrometeorological conditions were not stable during the measurement. Finally, all negative CO_2 fluxes were removed since they were likely erroneous".

Comment: L216: salinity should be reported as unitless

Response: Salinity is a measure of the amount of salt per unit volume (e.g., gr/L) and it is usually expressed as ppt (part per thousand).

Comment: Figure 2: the text reporting mean, UCI, and LCI is too small. Please enlarge. Define UCI and LCI in the figure caption.

Response: We thank the reviewer for catching that we forgot to define the UCI and LCI in the figure caption. We will include the following definitions: UCI = upper 95% confidence interval, LCI = lower 95% confidence interval. We will enlarge the mean, LCI, and UCI in the figure as best we can.

Comment: Figure 4: is it possible to produce higher resolution figures so the density curves do not look pixelated? The grey color is not included in the legend or described in the caption. It needs to be. I assume this is where overlap occurs. If so, it appears the N_2O fluxes are completely and perfectly overlapped, which was not mentioned in the text.

Response: We noticed that the R code for the graph produces pixelated density curves, but we will see if there is an alternate code for density plots that is less pixelated. We will include the color of the overlap between continuous and discrete measurements in the next version of the figure. N_2O fluxes had similar means for both the continuous and discrete measurements. We will point-out the density curve the discussion of N_2O in lines 516-525.

Comment: Figure 5: if I understand this correctly, this plot compares the continuous

measurement (over 72 hours) to the discrete measurement (one hour before and after low tide). If so, the time frames should be mentioned in the figure caption and/or text to remind the reader how exactly the comparison is made.

Response: The description by the reviewer is correct. We will explicitly mention the study's definition of continuous and discrete in the appropriate legends (i.e., Fig. 4, 5, and 6, Table 1 and 2).

Comment: L366-368: it may be useful to mention the findings of McTigue et al. 2021 (doi: 10.3389/fmars.2021.661442) that demonstrate the relationship between CO₂ production and temperature is a function of the activation energy required to breakdown salt marsh sediment organic matter.

Response: We will include the reference in the preceding paragraph which discusses the role of temperature in CO₂ fluxes (e.g., line lines 349-352).

Comment: L387: "pore water" should be one word, as is used throughout the rest of the manuscript

Response: Thank you for catching that – it will be corrected.

Comment: L568: remove the comma after "temporal"

Response: Thank you for catching that – the comma will be removed.