

Response to the Associate Editor

Manuscript egusphere-2024-1756: “Quantifying aggregation bias in marsh carbon flux estimates caused by rhizosphere oxygen heterogeneity”

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Dear Dr Middelburg,

Thank you for these careful comments. Your comments appear below in italics, our responses in plain text.

1 Re-oxidation of reduced substances

“Re-oxidation of reduced substances (dissolved sulfide, iron sulfides, ammonium, etc) is an important sink that competes with respiration for oxygen. It is not mentioned in the manuscript.”

We agree, and added this in three places.

The Abstract now opens: “Oxygen (O₂) in marsh rhizospheres varies strongly at millimetre scales due to radial oxygen loss (ROL), re-oxidation of reduced compounds, hydrology, and sediment structure.”

In the Introduction (Sect. 1), we added: “O₂ that enters the root zone is, in addition, consumed by the re-oxidation of reduced compounds such as dissolved sulfide, iron sulfides and ammonium, which competes with aerobic respiration for O₂ and confines oxic zones to the immediate vicinity of root surfaces (Howes and Teal, 1994; Koop-Jakobsen et al., 2017).”

Section 4.4 now includes the corresponding limitation: “A related simplification is that aerobic heterotrophic respiration is treated as the only sink for O₂ in the root zone. In marsh soils, the re-oxidation of reduced compounds, including dissolved sulfide, iron sulfides and ammonium, also consumes O₂ and competes with respiration for it (Howes and Teal, 1994; Koop-Jakobsen et al., 2017; Pezeshki and DeLaune, 2012). Because the O₂ distributions are prescribed here rather than obtained from a coupled transport–reaction model, this competition is not resolved, and it affects how representative the imposed distributions are of a given marsh rather than the comparison between the uniform and the heterogeneous configuration.”

We added two references to support these statements, and now also cite Pezeshki and DeLaune (2012) in this context.

2 Units of the dissolved-phase proxy

“Line 225/226: units for dissolved proxy are missing.”

Fixed. Section 3.2 now gives the units: “the mean and variance are $\mu_{\text{gas}} = 0.0891 \text{ cm}^3 \text{ O}_2 \text{ cm}^{-3}$ and $\text{Var}_{\text{gas}} = 3.53 \times 10^{-3} (\text{cm}^3 \text{ O}_2 \text{ cm}^{-3})^2$. For the dissolved proxy [volume fraction], $\mu_{\text{aq}} = 1.97 \times 10^{-4} \text{ cm}^3 \text{ O}_2 \text{ cm}^{-3}$ and $\text{Var}_{\text{aq}} = 1.16 \times 10^{-8} (\text{cm}^3 \text{ O}_2 \text{ cm}^{-3})^2$.” We also added the unit to the caption of Fig. 2 and to the axis labels of Figs. 2b and A1.

While fixing this, we noticed the description of D_{O_2} in Sect. 2.3 was inaccurate. Like D_{gas} in the original DAMM formulation, which is dimensionless and distinct from the diffusivity in Fick’s law, our D_{O_2} is a scaling factor, not a molecular diffusivity. The Henry’s-law concentration is converted to a volume fraction using the molar volume, so the dissolved proxy shares its unit with the gas proxy. That conversion is what makes it possible to compute the unit-matched K_{M,O_2} from the ratio of the two means.

The sentence now reads: “where D_{O_2} is the diffusivity of O₂ in water, written here as a dimensionless scaling factor, consistently with D_{gas} in Eq. (4), and $C_{\text{O}_2}^* = H_{\text{cp}} P_{\text{O}_2,\text{atm}}$ is the Henry’s-law equilibrium concentration (mol m⁻³) at atmospheric partial pressure. This concentration is converted using the molar volume V_{m} , so that O₂^{aq} has units of volume fraction (cm³ O₂ cm⁻³), the same as O₂^{gas}.”

D_{O_2} is accordingly now listed as dimensionless in Table 1, with a value of 9.37×10^{-2} , and we added V_m to both Eq. (5) and Table 1. This correction doesn't change any numerical result. The Table 1 entry for V_m specifies standard conditions, and the archived analysis code has been updated so that the constants in the script are the ones listed in Table 1; the results it produces are unchanged.

3 Number of digits reported

“Line 237: mean aggregation bias of -11.71% : really so many digits?”

Corrected throughout: values above one per cent are now given as integers and values below one per cent to one or two decimals, as appropriate. The mean aggregation bias is now -12% (Sect. 3.3 and 4.3), the sensitivity ranges in Sect. 3.4 are -13% to -6% for the gas proxy and -9% to -4% for the unit-matched aqueous proxy, and the low-variance benchmark is -0.5% . We also regenerated the figures without the numerical values that used to be printed inside the panels, so these numbers now appear only in the text and captions.

4 First-order behaviour at low O_2

“Line 285: Isn't it in the equation that if $O_2 \ll K_{sat}$, then it is a first-order process?”

Yes, and we made that explicit in the Abstract, which now states that where mean $O_2 \ll K_{M,O_2}$ and the variation in O_2 is small, “the bias is negligible due to linear behaviour of the relation in these conditions.” The passage at the line you point to describes the same property of the Michaelis–Menten term, so we left its wording as it was.

5 Figure 4 and the behaviour at high O_2

“Figure 4. I do not see that bias get smaller if O_2 levels are high. Perhaps rephrase.”

You're right, and we rephrased both the caption and the text. The caption of Fig. 4 now ends: “The bias is most pronounced at intermediate relative saturation ($\text{mean}(O_2) / K_{M,O_2} \approx 1$). Over the range shown it becomes smaller towards low relative saturation, whereas at high relative saturation it remains almost constant, because the prescribed O_2 distributions retain appreciable density close to zero.”

We extended the closing sentence of Sect. 3.4 to match: “In short, the magnitude of bias increases as the system approaches the nonlinear mid-saturation regime and as O_2 variability increases, and it does not decrease again over the range of relative saturation examined here.”

6 Numbering of the appendix

“The supplementary/appendices are wrongly numbered. Some figures are missing?”

“The appendix figure numbering is wrong. Please see <https://www.biogeosciences.net/submission.html#manuscriptcomposition>, 7. Appendices. Please label the section as ‘Appendix A’ and use a consecutive figure numbering of ‘Figure A1’, ‘Figure A2’, etc.”

Corrected. We relabelled the section Appendix A and numbered the figures consecutively, Figure A1 through A7, updating all cross-references in the text. Any remaining references to a “supplement” now read “Appendix A,” since this material is an appendix.

No figures are missing. The old numbering carried over from an earlier draft that had more appendix figures; once those were removed during revision, it left gaps at S1, S4, S5 and S8. Apologies for the confusion this caused. While renumbering, we also noticed the first appendix figure, formerly Fig. S2, was never cited in the text. It's now cited in Sect. 3.2 as Fig. A1.

We also made a few grammatical corrections throughout.

We hope these changes address your comments, and thank you again for the care you've given this manuscript.

With best regards, on behalf of all co-authors,

Youssef Saadaoui

References

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Pezeshki, S. R. and DeLaune, R. D.: Soil oxidation-reduction in wetlands and its impact on plant functioning, *Biology*, 1, 196–221, <https://doi.org/10.3390/biology1020196>, 2012.