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Air-sea gas exchange in a seagrass ecosystem— results from a ^{3}He/SF$_6$ tracer release experiment

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Revised points for Dr. Pierre Polsenaere's comments:

I thank the authors for their responses to my previous comments and the associated revised version of their MS. Most of my comments have been addressed and the revised version has been specified and improved. However, before publication in EGUsphere, significant improvement still need to be done in my opinion to improve the MS with regards to 1) the English language through an official English editing service or other options and 2) its scientific organization both for the Methods and the Results and Discussion sections. In the Methods section, there are 8 sub-sections that could easily be grouped in tracer measurements, environmental measurements (environmental variables, pCO2, etc.), tracers, Sc number, k calculations/modeling. The same effort has to be done for the Results and Discussion section with homogeneous sections and associated paragraphs, explicit titles, etc. Here are as well below, specific comments that need to be addressed to help authors improve the MS.

- We appreciate your constructive comments again.
- First, we modified figures so that readers can see them easily. For Fig. 1, we deleted the small map at upper left corner showing the location of Florida Bay. We made the bottom map bigger. We changed the shapes of Figs 3 and 4 to squares.

  For Fig. 5, we made (a)-(d) bigger. For Fig. 6, we only plotted the period when we were at measurement site so that the detailed CO$_2$ flux variability can be seen. We also calculated daily CO$_2$ flux in addition to daytime CO$_2$ flux by assuming diurnal amplitude in CO$_2$ difference is small. We discussed the variability of CO$_2$ flux as follows (section 3.3 2nd paragraph).

  "The calculated daytime CO$_2$ flux using the measured pCO$_2$ difference and modeled k in this study (Black solid line in Fig. 2e) was –5.3 ± 3.0 mmol m^{-2} day^{-1} (negative value denotes CO$_2$ flux from the air to the water) (Fig. 6b). The CO$_2$ flux varied both within a day and between days mainly due to the variability in k (Note that k(600) in Fig. 2e is filtered with 25 minutes running average). Diurnal fCO$_{2\text{water}}$ amplitude at the NOAA station (cyan diamond in Fig. 1) between 3 and 8 April 2015 was as small as 25–53 μatm, and so we calculated daily CO$_2$ flux by assuming CO$_2$ difference between air and water during the night is the mean daytime CO$_2$ difference. The calculated daily CO$_2$ flux was –7.0 ± 3.5 mmol m^{-2} day^{-1}, which was higher than daytime CO$_2$ flux because wind speed was higher during the night."

  Since summary was too short and not so clear, we modified several sentences as follows.

"Air-sea gas exchange was investigated in a seagrass ecosystem in South Florida, USA, using the ^{3}He and SF_6 dual tracer technique. The gas transfer velocity was lower than that in other coastal areas and open oceans, and commonly-used wind speed/gas exchange parameterizations overpredict the gas transfer velocities, especially when wind speeds were relatively high (> 7 m s^{-1}). A new wind speed/gas exchange parameterization was proposed ($k(600) = 0.143u_{10}^{2}$), which was able to predict the observed gas transfer velocities significantly better than existing parameterizations. This result suggests that wind is the dominant factor controlling gas exchange in the studied seagrass ecosystem, but the lower gas transfer velocity at a given wind speed was due to limited wind fetch in the study area and wave attenuation by seagrass. To assess the wider applicability of the proposed wind speed/gas exchange parameterization, more tracer release experiments are needed at similar inland ecosystems"

We reply to your specific comments below.

- We reorganized the title and paragraph as you pointed out. The reorganized titles are listed below.

1 Introduction

2 Methods

2.1 Study site

2.2 Tracer injection and measurement

2.3 Measurements of environmental variables

2.4. Gas transfer velocity calculation and $^{3}He/SF_6$ ratio modeling

2.5 Calculation of *Sc* number

3. Results and discussion

3.1 Environmental parameters

3.2 Gas transfer velocity in Florida Bay and assessment of published parameterization

3.3 Implications for biogeochemistry

4. Summary

Introduction:

l.18: Why has parameterization changed between the submitted and the revised MS?.

- It is because the equation to derive wind speed at 10 m height (u_{10}) was changed. In the previous manuscript, we calculated u_{10} by using roughness length from Cornelisen and Thomas (2009), but it turned out that the roughness length from the paper was not appropriate to our study. We are now using the equation from Amorocho and DeVries (1980) as you suggested in the present review.

l.28-32: Reformulate the whole paragraph saying first seagrasses can also emit GES (CO2, CH4) and then giving the two examples for CO2 emissions from CaCO3 production and CH4 emissions as well. In the Howard et al. (2017) study, it is not clear as it is written in the revised MS the link between the fact there is more IC than OC and the systems are CO2 sources?

- We changed the sentences as you suggested. The modified sentence is as follows(1st paragraph in section 1).

  "However, recently, the role of seagrasses in the global carbon cycle has been revisited, as carbon emissions from seagrasses were found to be large (Howard et al., 2017; Van dam et al., 2021; Schorn et al., 2021). Howard et al. (2017) examined the stock of organic and inorganic carbon in the soil of seagrass meadows in Florida Bay and southeastern Brazil, and found that the soils in both regions have more inorganic than organic carbon. They suggested that both regions are sources of CO_2 to the atmosphere by assuming 0.6 mol of CO_2 is produced when 1 mol of $CaCO_3$ is produced. Schorn et al. (2021) reported that the seagrasses in the Mediterranean Sea emit 106 μmol m^{-2} d^{-1} methane, mainly from their leaves.".

l.40: For k estimations from simultaneous EC and pCO2 measurements, you can cite this work (though no obligation at all) to support your idea: Polsenaere P., Deborde J., Detandt G., Vidal L.O., Pérez M.A.P., Marieu M., and Abril G. (2013) Thermal enhancement of gas transfer velocity of CO2 in an Amazon floodplain lake revealed by Eddy Covariance measurements. Geophysical Research Letters, 40, 1-7, doi:10.1002/grl.50291. Idem in l.50 for heat flux control on K for floodplain in Amazonia.

- Thank you for the information. We cited a paper introducing direct flux measurements alternatively (McGillis et al. 2001) when we introduce various *k* estimation methods (section 1, 2nd paragraph). The added sentence is as follows.

  "The direct flux techniques, such as the eddy covariance method, measure the CO_2 flux in the air and CO_2 concentration both in the sea and air to derive *k* (McGillis et al. 2001)."

l.56: was instead of is

- We changed from "is" to "was".

Methods:

Pink squares are illegible, please change colour.

- We did not change the color, but we made the plot bigger. We also surrounded the pink square by a black line.

Table 1 in Supplementary Material?

- We think Table 1 provides valuable information to some readers, so we will not move this table to the supplementary material.

Results and discussions:

l.314 See Abril et al. (2009) ECSS 83, 342-348 to understand how and why turbidity can affect gas exchange (authors response to previous comment)

- Thank you for letting us know the paper. This paper found that air-sea gas exchange is suppressed when turbidity has high concentration. However, the water was clear when we conducted our measurements and so we think the effect is minor.

l.316 “seagrass conditions are similar”, please specify it in the revised MS. In consequence, I still (last previous comments) think conclusions on K relationships with seagrass dynamic and distribution and extension to other seagrass systems can’t completely done here.

- Relating the vegetation and gas transfer velocity will be future study, but we consider that the proposed equation can be used on regions where seagrass density is similar to our study region. We specified “seagrass conditions are similar” by adding the information of seagrass density as follows.

  “Although the experiment was conducted over a short period of 8 days, our new parameterization, equation (7), fit the observations well; This implies that equation (7) can be applied even in different seasons and years if the wind speed is in the range of 0.12–12 m s^{-1} and seagrass conditions are similar (dominant seagrass of *Thalassia testudinum* has 63.6 (range=0–215) g dry weight m^{-2} standing crop in Florida Bay (Zieman et al., 1989)).”.