Reply to Referee #1

I have revied the manuscript entitled *Temporal patterns and potential drivers of $CO_2$ emission from dry sediments of a large river*. The authors perform several GHG measured with different techniques in the riparian area of a river, during different periods along a year. They complemented these measures with several other variables related to the sediment characteristics. Although I think the content of the study is novel and interesting and the topic is relevant for this journal, my mayor concern relays in the spatial scale of the study. It was performed in a specific reach of a large river, with very specific environmental characteristics. I think this limitation in the spatial scale should be acknowledge and taken in account while discussing the results.

Thank you for the constructive review

**General comments:**

#1. In the introduction, the objective of the study was presented as the determination the origin of the $CO_2$ emitted by the dry sediment, saying that a possible source would be the seeping of ground water. When saying "seeping of ground water" the first thing that came to my mind was the presence of a ground water source (aquifer) in the catchment.

However, in this case, the term "seeping water" wanted to refer to the distance of the dry sediment to the flowing water in the river channel and to the saturated layer. I think this should be clear since the very beginning, to clearly understand the purpose of the different measures that were performed and the experimental design in general.

We agree that we were not clear enough at this point. In a revised manuscript we will explain the hypothesis by Mallast et al about groundwater as a source of $CO_2$ in more detail in a similar way as in Mallast et al.: "Compared with the river system, the response of the groundwater system to drought is delayed (Peters, Bier, Van Lanen, & Torfs, 2006; Tweed, Leblanc, & Cartwright, 2009). The delay results in higher groundwater level than river water level and thus in flow gradients towards the river. With flow gradients towards the river, the exposed riverbed area between groundwater and river water levels is constantly rewetted through discharging groundwater. Upon reaching the sediment-atmosphere interface, CO2dissolved in groundwater degasses. This process leads to higher $CO_2$ fluxes, a fact that is also reported by Macklin et al. (2014) for estuarine canal estate waters that tap surrounding aquifers thereby artificially creating groundwater discharge hotspots."

#2. The title of the study says "…*$CO_2$ emission from dry sediments of a large river"* but the spatial scale of the study was small, measures where not taken all along the river but in a specific reach. Taking in account the spatial scale of the study, I would change the title to make it a bit less pretentious.

We agree that the title may raise expectations that we aim to budget the entire river. We will change the title to "Temporal patterns and potential drivers of $CO_2$ emission from dry sediments **in a groyne field** of a large river".

However, we think that the study site was rather typical for the lowland part of the river Elbe. Thus, we are convinced that the results have general implications for the entire lowland part of the river and most probably also for dry sediment sites at other surface waters.

#3. The aim of the study was to elucidate the origin of the $CO_2$ emissions. The response to this question was discussed taking together all different measured variables (section 4.1). However, the relationship of all the measured variables with the aim of the study was not totally clear for me while reading the methods and results section. Due to the high number of variables, I suggest adding a small explanation of their propose in the methods section.

OK. We will add some more explanation to the methods section. For example: "**To investigate spatial variability** on 11 occasions between May and September transects of sediment respiration were additionally measured with a portable soil respiration system…"

Moreover, finally not only the origin of the emitted $CO_2$ (ground water or respiration) was addressed, but also the drivers of the magnitude of the fluxes. I think that taking in account the extend of this other aspect, it should be also mentioned in the introduction and aim of the study.

We agree that the introduction focusses too much on the source of $CO_2$. Since a similar point was also raised by reviewer #2 we will elaborate clearer hypotheses at the end of the introduction which address both sources and drivers of $CO_2$ emissions in the sense "if $CO_2$ originates from groundwater we hypothesize a low temperature dependence of $CO_2$ emissions.".

**Specific comments:**

Introduction

L41: Large rivers with high-flow are also susceptible to seasonal dry (i.e., Albarine river catchment in sud-west France, where more than 80 km representing ~25 % of the catchment and including the most downstream part are intermittent)

We agree and would re-formulate: "… which lead to low-water levels or desiccation in streams and rivers."

L55: and what about long term dynamics?

There is very little known about temporal dynamics at all. The question is "what is long term?". In rivers as the Elbe low water periods typically last for weeks-months. There are yet only few studies addressing seasonal differences by a manual chamber approach. We will re-formulate: "Few studies did address temporal variability of $CO_2$ emissions but nothing is yet known about short term dynamics of GHG emissions from dry aquatic sediments."

L65: see my general comment #1 about the use of the term "water seeping water".

See our reply above.

L75-77: related again to the general comment #1, make clear what you mean with "ground water" to clearly understand the aim of the study

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Methods

L87: Could you specify the length of the reach? Maybe it's included in figure S1 but I was unable to download the supplementary material.

There is indeed a photograph of the site in the supplement. To describe the study site better we will add a short description of those groyne fields to the method section including e.g. "Groynes extended about 50 m in to the river and distance between groynes was 1212±38 m".

We will also add a Google-Earth image showing the groynes around our study site:


L96: I don't understand what do you mean with "the chambers measured hourly $CO_2$ fluxes". Did you measure 5 minutes intervals during a period of 1 hour?

We measured for 5 minutes. The chamber was then opened and the system waited for 55 minutes before starting the next measurement. We will reformulate to: "The chambers measured $CO_2$ fluxes once every hour. Each flux measurement lasted 5 minutes and between flux measurements the chambers were open for 55 min."

L111: Why were these periods chosen? Looking at Figure 1, there were also other time-frames in which the water level was lower than in those selected periods

The river level changed quite dynamically. It was our aim to cover as much low water periods as possible without losing the instruments. Since prediction of water level changes was related to some uncertainty and there were also logistic and time constraints due to the travel distance we did not place the chambers immediately but to be on the safe site a few days later. We mostly removed the chambers very shortly before they would have been flooded. In one instance there was already river water entering the chambers when we removed them in the last second. To deal with such dynamics was a rather high effort and to capture these periods was a challenge. We see that it would always be desirable to have more data or longer time periods, but this was not possible in this first study.

What the reviewer probably asks is, why we did not place chambers at all water level positions during low water levels consistently. E.g. at beginning of September we did not put chambers at the 95 cm position. The reason is that we were most interested in the lower lying sediment areas and we speculated that the river level would further drop and we would then move chambers further down. Unfortunately, that summer did not show such a clear low water period as the preceding years.

There were a few periods during high water level when the chambers were placed high up just to put them in a safe place. However, these rarely flooded sites were not the focus of our research and we did not intend to monitor those sites.

All in all we hope that Figure 1 and the explanation in L.99-103 sufficiently explain why those measurement periods were chosen.

L152: The significance of the acronym “Bq” is not specified

Bq is the SI derived unit for radioactive decay (Becquerel). Since the text explains that we are measuring radiactive decay we did not think it was necessary to specify this more. To clarify, we specify that Bq means radioactive decay we will add to the method section: “The counts were measured over one hour and averaged, with a standard deviation of one sigma **and expressed as decays per second [Bq]**.”

L154: How/Where (flowing channel? ground water?) were these water samples taken?

Will be changed to “300 mL ground water samples (2.3.3)”

L189: The significance of the acronym “g-dw” has not been specified

Will be changed to “… rates of respiration per gram dry weight [µmol g-dw d-1] were converted to fluxes by multiplying with sediment…”

L207: For how long were the drying and the ignition?

Will be changed to: “…after drying for at least 2 days to constant weight at 105 °C and loss on ignition (LOI) at 550°C, respectively.”

L252-253: As the variability of the data shows a temporal pattern, it would be interesting to analyse the potential drivers of this changes.

Indeed, the pattern is very interesting and motivated us to follow up on this study. The discussion can be found in section 3.1.1 and most illustrative when discussing Figure 4.

L268: And what about precipitation? Why didn't you include it in the mixed model?

Precipitation and moisture showed considerable co-linearity. We decided to keep moisture because it was measured directly at the site while precipitation data were from a weather station.

Figure 3. The way the hour is indicated in legend (0-20) seems a bit estrange

We will change the color scale to cover 0-24 h.

Results

Related to the general comment #3, at a first reading only the section 3.2.1 of the results seems directly related to the current aim of the study (source of the CO2).

As explained above we will rewrite the introduction and expand the aim of the study by including the drivers underlying the fluxes and patterns.

Discussion

The first point of the discussion (4.1) perfectly addresses the aim of the study and summarises all the results obtained. I really like the way it's written, very clear and direct.

Thanks.

In relationship with the general comment #2, along the discussion, the influence of different factors (dependence of temperature, sediment characteristics, thickness of the unsaturated layer...) in the CO2 emissions were discussed. However, although performed in a big river, the spatial scale of the study was small. Those factors can substantially change along the river, from the headwaters (typically at higher altitude, with more forested and closer riparian areas) to downstream areas (wider reaches, less forested riparian areas, more exposed to solar radiation). I think this spatial scale (together with the already addressed temporal scale) should be at least mentioned in the discussion.

We agree. We will address the spatial scale both in the methods and the discussion in more detail. We thought that talking about a "river" would already make clear that the study is not about "headwaters". We will clarify that this study is not about headwaters but about the lowland section and that we focus on a (typical) groyne field. Although it is a rather small scale of observation, the chosen goyne field is representative for large sections of the river. The entire river upstream of km 130 has been modified by groynes (Bussmann et al. 2022) – thus, the site can be considered typical for the lowland part of River Elbe from km 130 to km 580.

**Typing errors:**

L207: repeated words: loss after

Will be deleted

L243: May

Will be corrected.