List of changes made in revised manuscript

L 40 : Section about individual sources is rewritten

L 64: Sentence is rephrased to make it more comprehensible to non specialists

L65 : We improved the sentence, "...water mass movement induced by destratification, or seasonal winds, leads to shifting mixing regimes that disrupt continuity on a seasonal scale."

L 90: Coordinates figure adapted they were in degrees/seconds

L 97: Improve sentence

L 111: Revised sentence changed to "conductivity, temperature and depth”

L 151: Improve methodology: “ The samples were incubated in a temperature-controlled incubator for 72 hours in the dark, maintaining in situ temperature conditions.”

L186 We changed the text accordingly so that it is clear there was no stratification at our reference stations.

L195 + 208 + 270 Table 1 and 2 were unified and additional statement why standard deviations are not included for the reference station is added.

L310 + 319 We included the r^2 values into the main text

L392 Additional sentence to clarify water mass movement

L391: Sentence rephrased and Borges et al. (2018) included as a reference.

L 409 : typo « Thes » is corrected into The

L 422: Clarification on current dynamics and related water column properties affecting MOB

L 467: Santos (2015) included as reference

L503 + 553: Revised budget statements based on recommended reference (Rosenthether et al. 2021).

Reference list edit:

Borges AV, G Speeckaert, W Champenois, M.I. Scranton & N Gypens (2018) Productivity and temperature as drivers of seasonal and spatial variations of dissolved methane in the Southern Bight of the North Sea, Ecosystems, 21, 583–599, https://doi.org/10.1007/s10021-017-0171-7

Rosentreter JA, AV Borges, BR Deemer, MA Holgerson, S Liu, C Song, J Melack, PA Raymond, CM Duarte, GH Allen, D Olefeldt, B Poulter, TI Battin, BD Eyre (2021) Half of global methane emissions come from highly variable aquatic ecosystem sources, Nature Geoscience, 14, 225-230 https://doi.org/10.1038/s41561-021-00715-2

Santos IR., M Beck, H-J Brumsack, DT. Maher, T Dittmar, H Waska, B Schnetger (2015) Porewater exchange as a driver of carbon dynamics across a terrestrial-marine transect: Insights from coupled 222Rn and pCO2 observations in the German Wadden Sea, Marine Chemistry, 171, 10-20, https://doi.org/10.1016/j.marchem.2015.02.005

Response to Reviewer 1 comments

We are thankful for the overall positive appraisal of Reviewer 1. Below, we provide a point-by-point answer to the raised points.

L186 It migth be intersting to see / check if theres was stratification at both reference stations.

Response: the waters at our reference stations were not stratified during any of the seasons studied. We changed the text accordingly so that it is clear there was no stratification.

L221 Table 2. Why are there no standard deviations for the reference station?

Response: The standard deviations presented are calculated based on multiple sampling points during our time-series. However, in the case of the reference station, we only conducted a single sampling per season (i.e., not repeatedly for 48h as for the sampling station within the Wadden Sea), which is why standard deviations are not included.

To address this concern, we will update the table caption for Table 2 to provide a clear explanation of why standard deviations are not included for the reference station. We will also adjust table 1 accordingly so that the tables are unified. This will help to ensure that readers understand the rationale behind the absence of standard deviations in the table. Thank you for bringing this to our attention.

L259 could you give an r^2 for each corelation?

Response: We agree that including the r^2 values in the main text, in addition to the supplementary information, would enhance the clarity of our findings. We will incorporate the r^2 values into the main text.

L407 have you checked if spring or nipp tides had an accidental influence as well?

Response: We checked the timing of our sampling in relation to the lunar calendar to identify any overlap with spring or neap tide periods. Sampling occurred at around spring tide. However, we did not sample each season at different tidal regimes and cannot assess the influence of spring vs neap tides.

Response to Reviewer 2 comments

We are thankful for the overall positive appraisal and constructive comments provided by Reviewer 2, which we will address point-by-point below.

L 40 : I agree that marine emissions of CH4 are not well constrained, as stated. However, even if you take the highest estimates, the marine emission of CH4 is much lower than other natural sources of CH4 such as wetlands and lakes (Rosentreter et al. 2021). The study of the marine CH4 cycle is justified because there are interesting biogeochemical processes to understand (aerobic CH4 production) but it is not essential/urgent to reduce the uncertainty of marine CH4 emissions in the context the global budget of CH4 sources and sinks. Wording "Especially (…)" is not justified, all of the CH4 sources in the global budget are similarly uncertain, this is not characteristic of marine emissions.

Response: Thank you for your constructive feedback. We acknowledge that the word 'especially' is not justified in this context. We appreciate your suggestion, and we agree that the section can be revised as follows:

"Anthropogenic methane emissions (336 – 376 Tg y^{-1}) are rather well constrained and constitute ~60 % of the total atmospheric budget (Saunois et al., 2020). Individual natural sources, on the other hand are associated with comparably large uncertainties. This is particularly true for methane emissions originating from marine environments (5 to 28 Tg y^{-1}; Weber et al., 2019; Rosentreter et al., 2021)".

L 64: statement "microbial MOB filter increases with continuity in the water column" is unclear. Please rephrase and expand to make it more comprehensible to non specialists. Wording "microbial" is redundant with bacteria in the MOB abbreviation.

Response: the reviewer is right; this may be difficult to read for non-specialists. We will rephrase the statement to make it clearer: "The capacity of the microbial methane filter in the water column is typically higher during extended periods of continuity, i.e., when the water column is more stagnant (Steinle et al. 2015, James et al. 2016). This increases the contact time of MOBs with methane-rich waters so that the size of the MOB standing stock increases.

L65 : what do you mean by « water mass movement induced by temperature changes" ? Do you mean vertical thermal stratification ?

Response: correct, stratification (or destratification) is commonly induced by temperature, which can hinder or promote deep mixing. To improve the sentence, we will make the following revision: "...water mass movement induced by destratification, or seasonal winds, leads to shifting mixing regimes that disrupt continuity on a seasonal scale."

L 67 : shallow areas such as the Wadden Sea are permanently vertically mixed (thermal stratification never occurs) due to strong tidal currents.

Response: It is true that the Wadden Sea is not stratified. However, the introduction here is more general: tides entrain open North Sea Water into the Wadden Sea and likewise transport waters from e.g. surface runoff out of the Wadden Sea. As such, they disrupt water column continuity.

L 99: density is not directly measured by the CTD but computed from S and T

Response: Thank for your comment. We will change this to "conductivity, temperature and depth", the established wording for the acronym (note that the latter is also calculated from p and sal and T).

L 136: How were the samples kept at in-situ temperature?

Response: The samples were stored in a temperature-controlled incubator. We will include this into the material and methods section.

L 159 : The anemometer on the Navicula is located at 10 m height? or was wind speed measured at a lower height and recomputed and referenced at 10m height?

Response: The anemometer on the Navicula was indeed located at a height of 10 m.

L 187 : I assume it's changes at diel time scales (and not seasonal time scales).

Response: Variations in salinity at the reference station were minimal, we always encountered values of 31.3-32.3 psu irrespective of daytime or season as stated in the MS. This contrasts the Wadden Sea water column.

L333-336: It could be useful for the discussion to refer to the study of Borges et al. (2018) in the Southern Bight of the North Sea (SBNS). They show that in organic poor (sandy) sediments the CH_4 peaks in response to the phytoplankton bloom, while in organic rich (silty) sediments the CH_4 peaks with temperature. So depending on the organic matter in sediments the seasonal drivers of CH_4 seem different. I would imagine the Wadden Sea sediments to be silty and organic rich, do that it is more likely that temperature controls methanogenesis rather than organic matter availability.

Response: Good idea to add the Borges reference, this will be done.

Also note that the stated "lag of one to two months between the peak of the spring bloom and methane release from sediments was also observed in the Baltic Sea" applies because the site in the Baltic is deep, so it takes some weeks for the organic matter to sediment in the water column and reach the bottom. Such an explanation is not applicable in shallow areas such as the Wadden Sea or the SBNS because organic matter sediments faster. And indeed, in stations with the organic matter poor sediments the time lag between the phytoplankton bloom and the peak of CH_4 was shorter (Borges et al. 2018).

Response: we agree that the time lag may vary, however we disagree with the assumption that this is because of the depth of the Baltic Sea. The station studied by Bange and colleagues is about 28 m.

L348 : typo « Thes »

Response: will be corrected

L 357- 358 : Yes, all of these variables co-vary with MOx but the PCA is a crude statistical tool that does not allow to discriminate which are the most important drivers of MOx. I suggest to use more elaborate statistics. Regression Decision trees could be useful. For instance in oxygenated waters, the O2 levels are unlikely to be a major driver (will not be limiting to MOx). Similarly, if CH4 is abundant, it is unlikely that "nutrients" would limit MOx.

Response: Thank you for your detailed feedback. We used a PCA as an additional tool to explore potential correlations and seasonality in the data. We recognize its limitations in determining the most important drivers of MOx. Therefore, we exercised caution in interpreting the results. However, it is worth noting that salinity appears to have no substantial effect on MOx, which diverges from other findings (as discussed). Additionally, we have discussed the interrelation of other parameters, such as the correlation between high CH4 levels and temperature (T), in the subsequent paragraph. Furthermore, we have explicitly stated that O2 and nutrients are highly unlikely to modulate MOx in the Wadden Sea.

This is even more critical because due to the experimental design, all of these variables co-vary with the tidal phase. So at low tide the salinity will be low and MOx, CH4 and nutrients high, because at low tide there is less (saline) water from the North Sea. This does not necessary mean that higher nutrients explain higher MOx. It only means that MOx depends on CH4 concentration, and that high CH4 concentration coincides with high nutrients.

Response: yes it is true that there is a lot of covariation (as mentioned in the original MS already). However, we never argued that nutrient levels influence either CH4 or MOx. What is striking is that in winter and autumn, the salinity levels in the Wadden Sea can drop to around 20 psu due to elevated freshwater influx. When the incoming water from the North Sea with a salinity of 34 psu mixes with the lower salinity water in the Wadden Sea, there is a rapid increase in salinity. Microbes present in the surface sediments and the water column at lower salinity need to quickly adapt to this change in salinity as the newly introduced water mixes with the existing water mass. The effect on k/MOx is however not as dramatic as has been recorded elsewhere which argues that the MOBs in the Wadden Sea are euryhaline.

L 368: "This begs the question if waters, with rapidly changing salinity levels such as the Wadden Sea, are environments that are rather not conducive for MOx, in particular in colder months where salinity levels may drop to ~ 20 psu because of elevate freshwater influx (see above)." Again, this "question" is rather strange because the water mass is displaced with the tide and the microbial communites in the water column are also transported with the tide (and all of the dissolved constituents). So the microbial communities in this patch of water (that is moving around with the tide) are always experiencing the same salinity.

Response: This is not really correct. North Sea waters with probably a low standing stock of MOBs (as indicated by the low *k* at the ref station) enters the Wadden Sea at incoming tide. On its way through the Wadden Sea, it picks up methane (and likely microbes from sediments that are irrigated), mixes with terrestrial water (so is completely overprinted) and then flows out into the North Sea. Hence, the microbes coming in with the North Sea water will not always be at the same sal/T conditions. We will clarify that in the revised MS.

A case could be me made for the benthic communities, although I do not think that the salinity in the porewaters changes at such short-time scales with the tide. I guess it depends on the sediment granulometry.

Response: Currents flowing over sediment structures quickly entrain into the sedimentary matrix

L 408 : this is probably because a different water mass is transported by the tide with a different microbial community.

Response: See above, you are correct that a different water mass is transported by the tide, and this water mass may have a different microbial community composition. But this does not stay constant, the water mass itself becomes overprinted.

L 411 : Indeed, but a different water mass was transported with a higher abundance of organisms.

Response: see above.

L 435 : It might be relevant to compare to the nearby SBNS in addition to the Arctic.

Response: We appreciate the idea of comparing our findings to the nearby SBNS in addition to the Arctic. We will explore the study by Borges et al. in the SBNS and incorporate relevant comparisons and discussions in our manuscript.

General comment reviewer: The authors should consider to discuss their results by comparing with the study of Santos et al. (2015) that looked into dynamics of CH_4 in the German Wadden Sea.

REFERENCES

Borges AV, G Speeckaert, W Champenois, M.I. Scranton & N Gypens (2018) Productivity and temperature as drivers of seasonal and spatial variations of dissolved methane in the Southern Bight of the North Sea, Ecosystems, 21, 583–599, https://doi.org/10.1007/s10021-017-0171-7

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222Rn and pCO2 observations in the German Wadden Sea, Marine Chemistry, 171, 10-20, https://doi.org/10.1016/j.marchem.2015.02.005

Response general comment: Thank you for providing the reference to the study by Santos et al. (2015) on the dynamics of CH_4 in the German Wadden Sea. We appreciate your suggestion to consider discussing our results in relation to their findings. We will carefully review the study by Santos et al. and evaluate how their work can be incorporated into our manuscript.

Additionally, we would like to express our gratitude for sharing the references by Borges et al. (2018) and Rosentreter et al. (2021). We will examine these papers as well to determine their relevance to our study and consider their inclusion in our discussion.