Dear Stefano Ciavatta and anonymous Reviewer #2,

We thank the reviewer for the detailed and insightful comments, which will help to improve the manuscript. In the following, we would like to comment on the major concerns of Reviewer #2. Further minor or individual comments will be addressed during the revision stage of the manuscript.

1) We do not agree with the statement that our paper/study is mainly of a regional interest. As described in our manuscript, to our knowledge, there is no study available so far that has performed a detailed assessment of the factors that control the burial/preservation of organic matter (OM) in fine-grained sediments of the North Sea. We have therefore used the Helgoland Mud Area, which is characterized by a broad range of natural depositional conditions (water depth, sedimentation rates, origin/reactivity of organic matter, etc.) - as a test field or natural laboratory, respectively, to determine the key factors that control OM burial in the North Sea. Only in this way we were able to determine the key factors in the required – and at the same time unprecedented - high spatial resolution – including the extremely time-consuming radiometric analyses (^{210}Pb, ^{226}Ra, ^{137}Cs). In this respect the results obtained in the framework of this study present key findings for the whole North Sea as well as for shelf seas in general/globally– as these represent the most important seafloor areas for the longterm burial of organic carbon and thus key natural sinks for CO_2. Moreover, the North Sea is a crucial area in Europe due to its important role in economy (e.g. offshore energy, fishing activities, navigation) and ecology. Our results are not only important for better understanding carbon fluxes and burial in the North Sea, with important implications for estimations of European blue carbon wealth, but also provides key process-understanding that can be applied to all mud belts on continental shelves worldwide.

We thank the reviewer for the suggestion to extend the comparison with similar environments, in order to discuss and complement the global comparison. We will include and discuss more studies in similar environments in addition to the global comparison and Figure 12.

2) Question on the reproducibility of TOC measurements

The presented high-quality TOC measurements were performed in the group of Prof Elda Miramontes at the University of Bremen Faculty of Geosciences and MARUM, a laboratory with a multi-year expertise in C measurements. Based on replicate analyses of two different standards, the precision (relative standard deviation in percentage) was 1.23 % for the standard of 0.99 wt% (n=15), and 1.34 % for the standard 5.00 wt% (n=7). We will add those details to the material and method section.

Further we revisited two sites from the cruise in 2021 (HE575) in 2022 (HE595) and the TOC profiles from both years match (as described in Fig. 7 in the manuscript), highlighting the precision of the analysis and consistency of the sampled sites.

3) Concern regarding the calculations/intervals used for the determination of total organic carbon (TOC) contents and TOC accumulation rates.

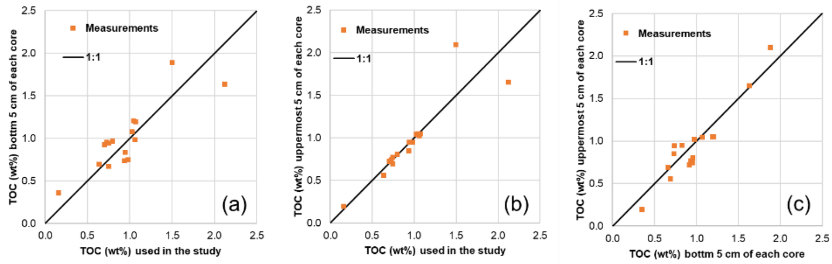

Figure 1: TOC contents (orange squares) of (a) the interval used in the study and the bottom 5 cm of the core, (b) the interval used in the study and the uppermost 5 cm of the core and (c) the bottom 5 cm of the core and the uppermost 5 cm of the core. The black line is the 1:1 relation.

We can demonstrate that the TOC contents show no or only little variation over depth and remain almost constant (Fig. 1a-c). Within the natural variability we see no clear/systematic deviation from the 1:1 line. Therefore, we consider the values presented in the manuscript and the following calculations using these values to be sound.

4) Comment regarding the organic carbon burial efficiencies (OC BE).

As outlined in the Materials and Methods chapter we calculated the organic carbon burial efficiency as described by Burdige (2007) and van de Velde et al. (2023): we assume aerobic respiration to contribute most of the total organic carbon remineralisation since no further decrease in TOC over depth can be found in our data (see Fig. 1), similar to the work by Mouret et al. (2010), Sobek et al. (2011) and Oguri et al. (2022). It is correct, that we did not consider the contribution of anaerobic remineralisation to the total organic carbon remineralisation in this paper. Previous studies have demonstrated that in depositional settings characterised by oxic bottom-water conditions, aerobic respiration is the dominant pathway of organic matter degradation. Moreover, diffusive oxygen uptake was shown to indirectly also include anaerobic degradation pathways because part of the oxygen is consumed by oxidation of reduced reaction products liberated into pore water as a consequence of anaerobic mineralization pathways (e.g., Wenzhöfer and Glud, 2004; Glud, 2008 and references therein). We have quantified the possible offset by the fraction of anaerobic remineralisation and found it justified to use just our present data for comparison within the HMA and with the literature, especially as there is no standard approach (for various approaches see Henrichs and Reeburgh, 1987; Aller, 1998; Ogrinc et al., 2003; Sobek et al., 2011; Sampere et al., 2011; Baloza et al., 2022). In our opinion, the application of a full diagenetic model to address anaerobic remineralisation processes exceeds the scope of this paper and is subject of a follow-up manuscript currently in preparation.

5) Comment on the preservation of TOC in an area which is fuelled with particles of different origins

It is correct that (1) we compare the TOC contents and therefore the preservation of OC in the study area and (2) that different sources deliver OC to different areas within the HMA. However, this is exactly what we discuss, that a difference in origin and hence reactivity is - besides the oxygen exposure time/sedimentation rate - a key factor for the preservation and burial (efficiency) of OC on shelf sediments.

6) Question regarding the influence of bottom trawling on organic carbon preservation

Thank you for this comment. It is true that the grain sizes differ between the sites (coarser at the frequently trawled site, finer at the other two). However, we think this is no reason not to evaluate the impact of bottom trawling on the preservation of OC at these sites. Bottom trawling not only enhances the oxygen exposure time and hence aerobic remineralisation but also causes resuspension of the sediments, preferentially affecting fine particles as shown by e.g. O'Neill and Summerbell (2011). Thus, bottom trawling reduces the resilience of the sediment to resuspension (Bruns et al., 2023). Recurrent bottom trawling at the same site and natural events will then lead to increased sediment remobilization (Bruns et al., 2023) and result in coarser residual sediments (Mengual et al., 2016). We will add this aspect and discuss this in this section accordingly, to make this point clear.

Kind regards

Daniel Müller, on behalf of all co-authors

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