Reply to reviewer #1 comments:

We thank Reviewer 1 for providing helpful comments on our manuscript, they have been carefully considered. Please find below our answers to these comments.

Review of manuscript "Changes in productivity and intermediate circulation in the northern Indian Ocean since the last deglaciation: new insights from benthic foraminiferal Cd/Ca records and benthic assemblage analyses" by Ma et al.. This manuscript presents data from sediment cores from the northern Indian Ocean (Arabian Sea and Bay of Bengal), comprising geochemical time series generated on benthic foraminifera as well as census data for planktic and benthic foraminifera. Based on these data, the authors deduce changes in monsoon driven changes in productivity mainly dominating the various records during the Holocene and changes in intermediate water chemistry during the deglaciation. In principle the authors present interesting data and some of the interpretations appear justified. There are, however, a number minor and more major issues, preventing recommending publication as is at this stage. These are some of the issues:

a) The biggest issue is related to the lack of constituency of interpreting the Cdw records. In lines 450-453 the authors claim that the Cdw values during the deglaciation are lower than during the Holocene. First, this statement is only correct if longer term averages are considered. On short time scales (which need to be considered, given that this is a chapter on millennial scale change), the youngest Cdw data in core MD77-191 (2-1.5 Ka BP) are comparable to YD and HS1 values. Up to this point a big effort has gone into establishing Cdw as reflecting productivity variations at the sea surface and the related flux of organic carbon. Now the focus shifts to bottom water ventilation changes being recorded. If general water ventilation would play are role in setting the recorded Cdw values, this has to apply to the Holocene too and would therefore need to be considered there too. Interestingly, the authors do involve water ventilation during the Holocene in relation to the carbon isotope and census data, but not very much in relation to the Cdw records. Also, if the general interpretation for the Holocene section is used, why is there no change in the Cdw record around 16-16.5 Ka BP? During this time, high *G. bulloides* concentrations (highest in the entire MD77-191 record) in the same core are shown in figure 5. High concentrations of *G. bulloides* strongly support the notion of enhanced productivity, as the authors themselves assume in case of the Holocene changes *G. bulloides* concentrations. Around 16-16.5 Ka BP the high *G. bulloides* concentrations are not reflected in the Cdw data. This would suggest that the Cdw water are not very reflective of surface productivity changes, casting doubts on parts of the Holocene storyline. This would need to be addressed in a revised version, not only in this section but in large parts of the manuscript.

Answer: The two main comments made by the first reviewer concerns i) the influence of surface productivity changes on the intermediate Cd_w records at millennial time scale during the last deglaciation (16-16.5 cal kyr BP) and the Holocene (2-1.5 cal kyr BP) and ii) the contribution of intermediate water circulation variations, especially during the Holocene. We fully agree with the reviewer that there may be some questions interpreting the Cd_w records, especially at the millennial scale. Changes in intermediate Cd_w values of benthic foraminifera can be influenced by different processes such as surface productivity, changes of the water mass sources and/or ventilation (e.g., Came et al., 2008; Bostock et al., 2010; Olsen et al., 2016; Poggemann et al., 2017; Yu et al., 2019). First, at the Arabian Sea site, we suggest that the observed significant increase of intermediate Cd_w values from the last deglaciation (~0.7 nmol/kg) to the late Holocene (~1.59 nmol/kg) could be associated with the surface productivity; indeed, this is supported by the *G. bulloides* record from the same core and another one close to the studied site (Bassinot et al., 2011; Naik et al., 2017), as well as by previous studies suggesting that increased Cd_w values (>1 nmol/kg) could correspond to elevated surface productivity (Bostock et al., 2010; Olsen et al., 2016).

However, we also agree with the reviewer that there is some mismatch between the increased *G. bulloides* abundances and the decreased Cd_w values obtained from the same core MD77-191 during the last deglaciation, especially at around 16-16.5 cal kyr BP. As the resolution of both records from core MD77-191 is relatively low during YD and HS1, it seems more reasonable to use the high resolution *G. bulloides* abundances records from the near core site SK237 GC04 (1245m, southeastern Arabian Sea, Naik et al., 2017), reflecting the surface productivity changes in this area. Therefore, we observe that although the *G. bulloides* abundances from the Arabian Sea display an increasing trend during HS1 and YD events, these modest increases in surface productivity are synchronous with low Cd_w values (~0.6 nmol/kg) during HS1 and YD, much lower compared to the Cd_w results during the late Holocene (~1.59 nmol/kg). Thus, we suggest that the variations of surface productivity could not be the main control at this studied site during the last deglaciation, and thus we proposed that changes in the circulation can explain the observed results. Indeed, the influence of intermediate water masses variations has also been demonstrated by many proxies (ε_{Nd}, benthic $\delta^{13}C$, B-P age offsets and CO_3^{2-}) in the northern Indian Ocean (Bryan et al., 2010; Yu et al., 2018; Ma et al., 2019; 2020). These previous studies have been summarized and detailed discussed in the manuscript (lines 465-507). Consequently, the conclusion that the influence of changes in water masses and/or ventilation on Cd_w records from the northern Indian Ocean during the HS1 and YD may be still reasonable. In order to take this comment into account, we modified the discussion in section 5.4 as below:

Significant decreases in *G. bulloides* relative abundance of cores SK237 GC04 (Naik et al., 2017) and MD77-191 records were observed from the HS1 to B-A (Bassinot et al., 2011), and thereafter slight increases occurred in the YD (Fig. 5). These high values at both core sites during the HS1 and YD may indicate an enhanced surface productivity during these intervals (Fig. 5). This should have led to increased intermediate Cd_w and organic matter preservation under low oxygen concentration conditions during the HS1 and YD. However, despite a low resolution for the MD77-191 Cd_w record during the last deglaciation, we do not observe high values of intermediate Cd_w during the HS1 and YD (~0.6 nmol/kg) compared with the late Holocene (~1.59 nmol/kg), especially at 16.5-16 cal kyr BP. Although we cannot fully discard the influence of surface productivity on the intermediate Cd_w in these time intervals, this apparent discrepancy seem to provide another evidence for the influence of changes in water masses and/or ventilation during the HS1 and YD, as already demonstrated by previous studies and proxies in the northern Indian Ocean (Bryan et al., 2010; Yu et al., 2018; Ma et al., 2019; 2020).

We also would like to thank the reviewer to point out that the influence of water mass ventilation on the intermediate Cd_w during the Holocene should be discussed. In order to clarify this point, we added some new parts in Section 5.2 about the possible contribution of past water masses changes to the Cd_w records obtained from northern Indian Ocean during the Holocene.

Briefly, increased benthic $\delta^{13}C$ values and B-P age offsets, as well as depleted ε_{Nd}, $\delta^{18}O_{ivc}$ and Mg/Li results obtained from MD77-176 and MD77-191, suggest the increased influence of NADW (Yu et al., 2018; Ma et al., 2019; 2020); indeed, deep-water masses can contribute to intermediate water masses in the Northern Indian Ocean by upwelling when flowing northward (Talley et al., 2011; Naqvi et al., 1994). NADW is characterized by the fresh, well-ventilated and depleted nutrient (modern Cd_w, ~0.2 nmol/kg; Poggemann et al., 2017), which is also in good agreement with the benthic assemblage analyses from the same cores. Therefore, although it may be difficult to exclude the influence of NADW during the Holocene, the significant high intermediate Cd_w during the late Holocene does not correspond to the increased contribution of NADW, suggesting that our initial interpretation could be also maintained during the Holocene.

b) Also, in line 329 (and thereafter), the authors, for the first time, mention NADW, claiming that this water mass would dominate during the early Holocene at site MD77-191. How does this claim compare to the modern water mass distribution in the area? Is it not true that most of the deep waters in the Indian Ocean are mixes of various end members, of which NADW is just one? The only place original (largely unmixed) NADW occurs is off the southeast coast of Africa, with the northward propagation blocked by the Davie Ridge (although there is some discussion in relation to a potential northward spillover occurring). In order to substantiate their argument, a) the hydrography section needs improvement and b) there needs to be a more in-depth explanation how (even contributions) of a deep water mass, currently occurring below ~2km in in the Mozambique channel, affect sediment cores at true intermediate water depth. The latter changes affect the discussion of the entire Holocene record.
Answer: We fully agree with the reviewer that the discussion about the NADW has to be improved. In the modern northern Indian Ocean, the Indian Deep Water (IDW) lies between 1500 and 3800 m. The IDW forms from the mixing between NADW and Circumpolar Deep Water (Talley et al., 2011). As already detailed in the answer to the upper comment, multiple geochemical proxies obtained from core MD77-191 (Arabian Sea) and MD77-176 (northern BoB) as well as previous studies (Yu et al., 2018; Ma et al., 2019; 2020) have provided strong evidence for the increased contribution of well-ventilated NADW during the Holocene. Thus, although the influence of NADW on the intermediate Cd_w cannot be fully discarded during the Holocene, our records suggest the dominated role of surface productivity in controlling Cd_w records during the Holocene, and thus, our conclusion will not change but will be better discussed (the modifications of NADW discussion are explained in Reply a)); indeed, in order to take into account these comments, we developed the discussion about NADW during the modern and Holocene periods (revised Section 2).

c) There is some inconsistency regarding the description (interpretation?) of the habitat of the various benthic foraminifera species used in the study. In lines 141 and 142, the authors state that *C. pachyderma* is an epifaunal species. In contrast, in 289 and 290 they state that it is a shallow infaunal species. This needs to be clarifified and consistently used throughout the manuscript.
Answer: We have corrected this mistake in the revised manuscript to be:

C. pachyderma is a shallow infaunal species.

d) At times the description of results/findings is too generic. As an example in lines 364 and following, a number of comparisons are made regarding the similarity of records. Generally, on longer time scales, yes there is some similarity. It should be pointed out though that there are also substantial differences at the millennial scale. This is particularly relevant for the comparison between Corg and *H. elegans* Cdw records. This needs a better wording.

Answer: We agree that these sentences are not well-written because we only focused on the long time scale variations, so we used this comment to improve the following discussion of the comparison.

Despite a lower resolution for MD77-191 *H. elegans* Cd_w records, when compared to the C_{org} and the *G. bulloides* percentage from core SK237 GC04, all of them seem to exhibit similar trends at the long time scale from the last deglaciation to Holocene; however, some little discrepancies can be observed at millennial time scales, especially during the late Holocene (Fig. 5).

e) (minor point) Figure 6 needs a better embedding/explanation in the manuscript. Some of the records are neither explained in the main text nor in the figure caption.

Answer: Thanks for this reminding. We have detailed these records explanation in the main text as the following paragraph, especially for figures 6 d-f records.

These changes are consistent with the weakened the summer monsoon intensity, with less rainfall during the late Holocene, as observed in the BoB using core MD77-176 seawater $\delta^{18}O$ and core SO188-342KL δD_{Alk-ic} records (Marzin et al., 2013; Contreras-Rosales et al., 2014; Figs. 6 e-f). In addition, this is also strongly supported by the $\delta^{13}C_{wax}$ records from the Lonar Lake over the Indian continent (Sarkar et al., 2015; Fig. 6d) and a progressive increase in monsoon summer winds to the South of India (Bassinot et al., 2011).

Besides, in the figure and caption, we also made the brief description.

Overall, there are some useful data in this manuscript. The discussion of the data and subsequent interpretation lacks maturity at this stage and requires improvement. A moderate to major revision is required.