Bottom water oxygenation changes in the Southwester Indian Ocean as an indicator for enhanced respired carbon storage since the last glacial inception – cp-2021-29 (10.5194/cp-2021-20 RC1)

We highly appreciate the comments and suggestions provided by the two anonymous referees, and wished to thank them for the time and efforts invested in evaluating our work. We feel that their constructive comments contributed to clarify and strengthen our argumentation.
While both referees find merit in our work, they also highlight two important issues. The first issue relates to the robustness of our age model, for which we provide clarification below (as well as in the revised manuscript). The second issue relates to potential variations in the $^{238}U/^{232}Th$ ratio of the lithogenic material delivered to the core sites and the impact this potential variability may bear on our aU records. Since both referees highlighted similar issues, we took the liberty to provide one consolidated response to address their shared concerns.

We have strived to incorporate the suggested changes and recommendations into the revised manuscript as detailed below in our point-by-point response.

In order to efficiently refer to our responses to the reviewers' comments, we have opted to continuously number our replies. The original referee comments are in black and our responses in green.

We sincerely hope that our clarifications have satisfactorily addressed the reviewers' concerns. We remain at disposal would further questions arise.

This manuscript presents authigenic uranium (aU) concentrations, biogenic silica (bSi) concentrations and Mn/Ti elemental ratios in bulk sediments obtained with various analytical methods for five cores between 46ºS and 59ºS in the Southwest Indian Ocean. Mn/Ti profile was not obtained for the southernmost core. Three of the five cores provide 120 ka records, one core extends only 40 ka, and another one covers the past 180 ka.

The major conclusion is the important role of physical processes to oceanic carbon storage during cold periods due to reduced ventilation. The biological productivity is considered as a second factor. The link is proposed between Southern Ocean carbon storage and atmospheric CO2 concentration changes on glacial/interglacial timescales.

The strong points of the present study are i) the reconstruction of both oxygenation state and biological production inferred from sedimentary opal content and ii) latitudinal transect covering different frontal zones in the Indian

sector of the Southern Ocean. The authors discussed various possibility affecting the aU, bSi and Mn/Ti records. They are careful but they did not explicitly provide their specific objectives and working hypothesis. Consequently, the present manuscript gives impression "just confirming the previous studies". I will develop my major concerns below.

Reply# 14: We thank the referee for their overall positive assessment of our work as well as for their constructive comments.
We welcome the opportunity to clarify the main objectives of our work. Our goal was indeed to investigate whether the SW Indian Ocean was subject to changes in deep ocean ventilation across the last glacial cycle. Our results indeed indicate that reduced oxygenation at the sediment-water interface along a meridional transect of cores during cold intervals was primarily driven by changes in ocean circulation as opposed to enhanced organic matter export/respiration. The study is thus complementary to previous findings, which proposed similar conclusions for the South Atlantic basin. Considered together, these observations support the notion that the Southern Ocean stored a vast amount of remineralised carbon during past ice ages, thereby contributing to lower atmospheric CO_2 concentrations.

- Too general objective and poor description of original finding

The major role of ventilation changes to oceanic carbon storage on glacial/interglacial timescales has been already reported by number of studies. What is the focus of the present study? Why are the authors interested in changes since the last glacial inception? Why the transect in the Southwest Indian? If the role of the Indian sector of the Southern Ocean is the primary motivation of the present work, introduction should be focused on state-of-art of the study region.

Reply# 15: While the role of ventilation changes to oceanic carbon storage has been reported from a number of studies, only a handful of investigations focus on the Indian Ocean. In particular, it remains unclear, where enhanced remineralised carbon was stored/released from on glacial-interglacial timescales.
Our study indicates that the SW Indian sector of the Southern Ocean contributed to store remineralised carbon during the past ice age, with consequences for the atmospheric CO_2 inventory. We have thoroughly revised the introduction to clarify our research questions, and better describe why we focus on the SW Indian Ocean in particular.

The discussion is qualitative and only confirms the observation of the previous studies. The authors are careful to interpret the obtained records considering different possibilities (ex. diagenetic burn-down that could modify aU records). But it is difficult to identify robust reconstruction and new insight supported by their own results. Also, there is no figure comparing the new results with previously obtained records except dD and pCO2 to discuss the processes that the authors proposed.

Reorganization of the manuscript with addition of discussion figures will be useful to identify targeted objective and working hypothesis to emphasize original aspect of the present study.

Reply# 16: Unfortunately, as of yet, the distribution of redox-sensitive metals in bulk marine sediments only allows for reconstructing qualitative changes in deep ocean oxygenation. Our results are consistent with previously published results from the region (e.g. François et al., 1993; Dezileau et al., 2000, 2002), yet these records were arguably poorly constrained and often only covered the last glacial transition. Moreover, aU records have classically been interpreted as reflecting past changes in export production (e.g. Sachs & Anderson, 2005), yet our transect of cores spanning contrasted biogeochemical environments suggests that these changes were instead primarily modulated by changes in ocean circulation, with consequences for deep ocean carbon storage. As such, we deemed it useful to provide a direct comparison of our sedimentary records with reconstructions of past changes in atmospheric CO_2 derived from Antarctic ice. As mentioned we have revised the introduction to clarify our intentions. We have also strived to better distil the essence of our findings in the revised conclusions in an attempt to better emphasize the originality and novelty of our study.

- Lack of demonstration about age model quality

The authors described the age model in section 2.2 and Table 1 but the provided information is insufficient. Since sedimentation rate is a factor affecting the accumulation of authigenic U (Figure 4), more extended explanation is necessary with figures. For instance, it is helpful to show 14C dating levels and tie points of each core. Which size of reservoir age was applied? Which 14C calibration equation was used? The magnetic susceptibility (MagSus) records of PS2609-1 and PS260606 were tuned to LR04-stack. What is the hypothesis to relate MagSus to the benthic d18O stack? Were XRF data (Fe, Si, Ti, Ca) used to correlate between PS2609-1 and PS260606? The authors also used alignment of XRF Ti intensity and Ca/Ti intensity ratio of PS2606-6 with the EPICA Dome C dust record. What is the size of age offset based on the tuning to LR04 and to EPICA Dome C dust record? Concerning core PS2603-3, MagSus, XRF data (which elements?) and biogenic silica were graphically aligned to the LR04 reference curve. Did the authors assume that the changes are synchronous? Why? Overall, what is the size of uncertainty of age model of each core?

Reply# 17: We certainly recognize that the strategy we followed to determine the different age models lacked clarity. Determining robust age models in Southern Ocean sediment records characterised by poor carbonate preservation is certainly a difficult task as referee #2 reckons.

We used published age models/age pointers wherever possible (DCR 1PC – Crosta et al., 2020; COR-1bPC – Oiwane et al., 2014).

Specifically for DCR-1PC, radiocarbon (14C) measurements were carried out using Accelerator Mass Spectrometry (AMS) on planktic foraminifera *Globigerina Bulloides and Neogloboquadrina pachyderma (sinistral)*. Treatment of samples

was according to the protocol used by Yokoyama et al., 2007, 2010 with graphite targets measured at the AMS facilities at the University of Tokyo. Calibration for ^{14}C was performed using CALIB7.02 software using the Marine13 calibration curve (Reimer et al., 2013) after a regionally-informed marine reservoir age correction of 890 ± 100 years (Butzin et al., 2005). MARINE13 was applied here because MARINE20 is not recommended for polar regions with variable sea-ice extent (Heaton et al., 2020).

For COR-1bPC, the age model is based on 23 calibrated ^{14}C-measurements on planktic foraminifera neogloboquadrina pachyderma (sinistral) (Oiwane et al. 2014). The samples were treated according to the protocol of Yokoyama et al., 2007, 2010) with graphite targets measured at AMS facilities at the University of Tokyo. All dates are corrected for the regional reservoir age (890 yr) (Bard, 1988) and converted to calendar years (cal yr BP) using the calibration program CALIB 6.1.0 (Stuiver and Reimer, 1993).

Regarding the PS cores, preliminary age pointers were based either on then available radiocarbon dates (Xiao et al., 2016) and/or biostratigraphic constraints. The radiocarbon measurements were carried out on the sedimentary humic acid fraction using AMS. Radiocarbon ages were converted to calendar years using CALIB4.2 (Stuiver et al., 1998) after applying a reservoir age correction of 810 years (Bard, 1988).

The preliminary age models were first refined by graphically aligning biogenic opal ($BSiO_2$) concentration measurements to the LR04 d18O benthic stack, assuming an in-phase relationship (Fig. Rev2). This approach inherently assumes that sedimentary $BSiO_2$ concentrations/export fluxes are modulated by global climate variability in the Southern Ocean (e.g. Hasenfratz et al., 2019) and more specifically in the Indian sector of the Southern Ocean (Kaiser et al., 2021). Similarly, the sedimentary MagSusc signal contains a coherent climate-related component and may thus be suitable for initial age model tuning (e.g. Weber et al., 2012; 2014) (Fig. Rev3). We certainly recognize that these assumptions remain a subject of debate.

These age solutions were then further refined by graphically aligning the XRF Ca/Ti and Ti records to the EPICA Dome C (EDC) dust record (Lambert et al., 2012) assuming an in-phase relationship between both proxies and archives (e.g. Martinez-Garcia et al., 2014; Lamy et al., 2014). Again, these assumptions may raise questions, as marine and ice core records may be transiently decoupled during climate transitions of the last glacial cycle (e.g. Thöle et al., 2019). We note however, that similar assumptions underlie the development of all three PS records and thus, all records may be affected by similar uncertainties.
Finally, we have critically tested our age models by comparing our solutions to independently defined stratigraphies. Specifically, our age model for PS2606-6 is very similar to the stratigraphic framework published by Ronge et al., 2020. The age model for core PS2603-3, which arguably contains the fewest tie-points, was critically assessed using an independent approach based on constant rate supply (CRS) (Geibert et al., 2019). Both approaches provided very similar ages, with age offsets < 1.5 kyrs for the last 20 kyrs. In summary, we recognize that our age models may certainly be perfectible, but we feel that given the constraints and

limitations, our solutions are probably realistic and permit meaningful regional comparisons on multi-millennial timescales.

- Estimation of authigenic uranium (aU) concentration

aU is estimated assuming a constant 238U/232Th that is variable with sites. Even if generally consistent aU trend is observed for the study cores on glacial/interglacial timescale, absolute aU is relatively small, often less than 3ppm except core DCR-1PC. Moreover, detrital U contribution might have changed on glacial/interglacial timescales. It will be useful to present figures comparing 238U/232Th activity ratio with aU concentration profile of each core to demonstrate potential influence of detrital 238U/232Th activity ratio on aU variability.

Reply #18: the sedimentary aU concentrations are indeed rather low, yet consistent with previously published studies from the Indian sector of the Southern Ocean (François et al., 1993; Dezileau et al., 2000, 2002) as well as from the South Atlantic (e.g. Frank et al., 2000; Jaccard et al., 2016). aU phases are precipitated primarily in response to changing bottom water oxygenation as reported in the manuscript, yet the secondary contribution from labile organic matter respiration in the uppermost layers of the sediment is essential to sufficiently decrease the sediment pore water oxygen levels. As such, aU concentrations in pelagic sediments (0-4 ppm) are typically lower than in coastal environments, as bottom water oxygen concentrations are higher, while to flux of organic matter is comparatively lower.

The rationale underlying us selecting a temporally invariant $^{238}U/^{232}Th$ ratio for the lithogenic material (i.e. 0.5, Henderson and Anderson, 2003) relates to the possibility to compare our records to those published previously for the region (e.g. François et al., 1993; Dezileau et al., 2000, 2002). This value reflects the average composition of upper continental crust material (Wedepohl, 1995; Rudnick and Gao, 2003) and the lithogenic $^{238}U/^{232}Th$ ratio has been shown to vary little (10-15%) throughout pelagic regions of the Southern Ocean, away from Antarctica (François et al., 1993; Anderson et al., 1998). Applying this specific value to the southernmost core (PS2603-3) generated negative aU concentrations, suggesting that lithogenic material originating from Antarctica (possibly supplied to the core sites via IRDs), warranted using a different value for the lithogenic background.

Although the detrital $^{238}U/^{232}Th$ ratio may have varied in response to changing detrital sources, for example during glacial intervals, the authigenic component is typically > 60% of the total U, so this correction remains small (Fig. Rev4 and Fig. Rev5). As such, a decrease in the $^{238}U/^{232}Th$ value would indeed affect the absolute aU concentrations, but not the general downcore patterns.

What's more, our interpretations are supported by the Mn/Ti records (where available). The anti-phased pattern of both proxies downcore provides further, independent support corroborating the robustness of the aU records, in spite of potentially changing supply of detritic material through time.

As such, we remain convinced that the temporal variability in aU for all cores are primarily driven by changes in bottom water oxygenation.

At last, this study used different analytical procedures to obtain the same parameter (aU, Mn/Ti and bSi) for the different cores. The consistency of the results is mentioned but it is not shown how the comparison was realized: some selected common samples were analyzed or common standards were regularly measured? Some more detail will strengthen the manuscript.

Reply# 19: Good point. We used an internal standard for each batch of samples selected for the determination of biogenic opal (BioSi) concentrations to assess precision and reproductivity. Replicate measurements indicate a reproducibility of ± 5%, consistent with other methods.

The comparison between the BioSi measurements generated at UniBe using Fourier Transform Infrared Spectroscopy (FTIRS (Vogel et al., 2016) - red) and AWI using alkaline extraction of silica (Müller & Schneider, 1993 - green) is illustrated below for core PS2609-1 (Fig. Rev6).

For U/Th isotope measurements, we used an internal standard (UREM-11) to assess precision and reproductivity. The relative standard deviation for U and Th is less than 3.8 % and 3.5 % for ^{238}U and ^{234}U, and less than 5.7 % and 4.9 % for ^{230}Th and ^{232}Th, respectively (as mentioned l. 132-133 in the original version of the manuscript)

Furthermore, a series samples from core PS2609-1 were measured at UniBe using a MC-ICP-MS (Thermo Fisher Neptune Plus - red) and at AWI using a single collector ICP-MS (Thermo Fisher Element - blue) to assess the consistency our U isotope measurements (Fig. Rev7). A similar comparison was unfortunately not conducted for Th isotope measurements.

XRF core scanning "only" provides semiquantitative measurements. A comparative study between the records and methods is thus not possible.

I recommend to accept this manuscript after major revision.

Minor / specific comments

Abstract last sentence (lines 23-24), "These records highlight… insufficiently documented role the southern Indian Ocean played in the air-sea partitioning of CO2 on glacialinterglacial timescales". It is unclear how this statement is extracted from the results obtained in this study.

Reply# 20: The introduction and conclusions of the manuscript have been thoroughly rewritten, as stated above. The abstract, and particularly the sentence highlighted above now more faithfully convey the main conclusions of your study.

Line 25, "exogenic carbon cycle". Please define this term.

Reply# 21: we removed the term “exogenic carbon cycle” and replaced it with “global carbon cycle”

Lines 26 and 41, “Sigman and Boyle, 2000”. The reference is missing in the reference list.

Reply# 22: Sigman, D. M. and Boyle, E. A.: Glacial/interglacial variations in atmospheric carbon dioxide, Nature, 407, 859–869, doi:10.1038/35038000, 2000 was added to the reference list.

Line 67, “underrepresented Indian sector of the Southern Ocean”. It will be helpful to add the state of art about bottom water oxygenation state in the Indian sector to clarify unsolved issues. Such description will better define the objective of the present study.

Reply# 23: The introduction has been thoroughly revised to better convey novelty of our research, in the context of existing, arguably scarce, records from the literature.

Lines 71-84, “2.1 Core locations and material”. Add the description of the present-day water masses occupying the core locations.

Reply# 24: Figure 1 was revised and the location of present-day water masses included in the figure (Fig. Rev8).

Line 88, “neogloboquadrina ” should be “Neogloboquadrina ”.

Reply# 25: Amended.

Line 135, about Mn and Ti measurements. To avoid any confusion, indicate from the beginning, XRF scanning or ICP-MS measurement realized for different cores. Also, it is necessary to mention that Mn/Ti record was not obtained for core PS2603-3.

Reply# 26: We modified the text as follows:

“To analyse Mn and Ti in the sediments, either ICP-MS measurements or XRF-scanning were carried out in different cores. For Mn and Ti analyses in cores PS2609-1 and PS2606-6, the samples were fully digested, evaporated and redissolved in 20 ml 1M HNO_3. An aliquot was then diluted 1:100 and rhodium as internal standard was added. The Mn and Ti concentrations were measured on the single-collector ICP-MS (Thermo Fisher Scientific Element 2) at AWI in Bremerhaven. Reference material NIST 2702 was digested with each batch and measured with the samples.
For cores COR-1bPC and DCR-1PC, the Mn and Ti measurements were acquired by XRF-core logging with a Tatscan-F2 at the Kochi Core Center, Japan (Sakamoto et al., 2006). For core PS2603-3 neither Mn nor Ti data have been obtained.”

Line 184, “millennial-scale oscillations’. What is the temporal resolution of aU record? Considering the possibility of aU remobilization, is it appropriate to treat millennial-scale variability, in particular for the interval of low sedimentation rate such as MIS 5 (Figure 4a)?

Reply# 27: Fair point. It may indeed not be appropriate to discuss millennial-scale oscillations in aU considering the age model constraints discussed above and the potentially delayed emplacement of aU as suggested by referee # 2. The sentence was accordingly revised as follows -

“The sedimentary aU concentrations are characterized by transient, shorter-scale oscillations during MIS 5 (106–100 ka, 88–85 ka)…”

Lines 189-191, “detritic values”. Mn/Ti variability of core DCR-1PC is estimated by XRF intensity ratios that are not converted to concentration. How did the authors know the background level corresponds to detrital values?

Reply# 28: Good point. We inherently assume that most glacial intervals are devoid of authigenic Mn enrichments, as conditions were probably too reducing to preserve Mn oxides. As such, the Mn/Ti during cold intervals may primarily reflect “detritic background” values. However, as referee # 2 correctly infers, in the absence of quantitative Mn measurements, this cannot be ascertained. We have thus modified the sentence as follows -

“Mn is typically enriched during the two major warm climate intervals of MIS 5 and the Holocene, during which values are higher and show increased variability, while Mn/Ti peak intensity count ratios hover around lower values during cold climate intervals, including a period between 115–100 ka.”

Lines 194-197, about glacial-interglacial trend of bSi for core DCR-1PC. Caution should be paid because the expected glacial high bSi value is not observed for MIS 2.

Reply# 29: Referee # 1 highlighted the presence of a possible hiatus covering most of MIS 2 in core DCR-1PC (see reply# 2), possibly accounting for the “early” decrease in both BSiO2 and aU signals. We are now accounting for this possibility in the revised version of the MS.

We have slightly modified the sentence as follows -

“Opal flux reconstructions show generally a glacial-interglacial pattern, with typically higher opal fluxes during cold periods and lower fluxes during warmer climate intervals.”

The early decrease of the bSi values in MIS2 is discussed in § 4.1.

Line 207. Add “aU” between “Sedimentary” and “concentrations”.

Reply# 30: Amended.

Line 209, “a pronounced increase in sedimentary aU concentration during MIS 4”. This sentence should be revised because the description is true for PS2609-1 but not for PS2606-6 that shows a modest increase (Figure 3b).

Reply# 31: Fair point. We have amended the sentence as follows -

“For both PS2609-1 and PS2606-6, sedimentary aU concentrations increase during MIS 4, with a more pronounced increase in the PS2609-1 record.”

Lines 213-214, “The highest aU…a gradual increase from about 30 ka, peaking during the LGM”. Core PS2603-3 does not show the described trend because no clear peak is identified (Figure 3d). Please revise the text.

Reply# 32: Good observation. The revised sentence reads as follows -

“The highest aU concentrations in cores PS2609-1, PS2606-6 and COR-1bPC occur during MIS 2 with a gradual increase from about 30 ka, peaking during the LGM. Thereafter, aU levels decline sharply to values well below 1 ppm within 2–4 ka, concomitant with the onset of the last glacial termination. After TERM I, a small increase around 11–8 ka is apparent. Throughout the Holocene, aU levels remain below 1 ppm. In PS2603-3 the aU highest values are also observed within MIS 2, but the downcore variability is much more subdued.”

Line 228. Delete “which seems to higher CO2 levels during MIS 5”. This is result section, thus premature to compare with pCO2 record.

Reply# 33: We removed the comparison with the pCO2 record at this stage:

“During MIS 5 there is a small increase in opal fluxes around 85–75 ka.”

We also modified the text, line 295:

“Also, the small increase in opal fluxes around 85–75 ka seems to reflect the slightly higher CO_2 levels during MIS 5.”

Line 233. Add “inside of the sediments” after “at the sediment-water interface”.

Reply# 34: Amended.

Line 237, “the proxies broadly agree”. What does this sentence mean? The proxies follow an expected trend? If so, what is the hypothesis to expect some trend?

Reply# 35: We indeed try to imply that both proxies were following a similar trend.

We modified the sentence as follows –

“When comparing both redox-sensitive metal records to opal fluxes, the proxies broadly allude to similar oxygenation conditions, in particular during glacial inceptions.”

Line 240. Add “of core DCR-1PC” after “values”. It is unclear why the observed Mn/Ti trend can be treated as “a regional increase in carbon export and sequestration”.

Reply# 36: Added “of core DCR-1PC”. As suggested by referee # 2, we removed the last part of the sentence. The revised sentence now reads -

“The first drop in atmospheric pCO_2 at around 115 ka marking the glacial inception, coincides with a reduction in Mn/Ti values, which could be attributed to a transition towards more reducing conditions ~~associated with a regional increase in carbon export and sequestration~~ (Figure 2).”

Lines 292-293, “broadly similar to the SAZ record”. I don’t see the similarity because the SAZ core (DCR-1PC) is characterized by aU maximum during MIS 3 that is totally absent for the SAZ cores.

Reply# 37: Fair enough. While all records show consistent downcore patterns, we agree that DCR-1PC shows more variability during MIS3.

Line 293, “noisy Mn/Ti signal”. In general, the authors did not provide temporal resolution of different parameters for different cores. The mentioned “noisy signal” of COR-1bPC was possibly related to high-resolution XRF scanning.

Reply# 38: Correct. The substantially higher resolved XRF scanning data may inherently include more high-frequency variability.

Lines 302-303, “COR-1bPC was closest to the most vigorous upwelling location”. Is this statement enough robust? The bSi concentration of COR-1bPC is high but comparable with bSi at PS2606-6 considering different temporal resolution.

Reply# 39: Good point. We removed the sentence to avoid confusion.

Line 306, “alterative” should be “alternative”.

Reply# 40: Amended

Lines 327-333, about the deep or bottom water masses. This part should be placed in section 2.1. The present-day water masses (AABW, upper CDW and lower CDW) should be shown in Figure 1b. How did the author distinguish the water masses? Using a T-S plot?

Reply# 41: The water masses were distinguished using oxygen levels (in Figure 1, revised Fig Rev8).

Line 340. Add “and in pore water” after “interface”.

Reply# 42: Amended as recommended

Line 372. Delete “XRF peak” since some Mn/Ti data were obtained using ICP-MS.

Reply# 43: Amended; “XRF peak” was removed.

Numbering of the figures and the table should be corrected since the number always contains “2”.

Reply# 44: Amended.

Figure 1. (a) right panel. “AAZ” should be replaced by “AZ”. Show the position of transect indicated Figure 1b. (b) Indicate the present-day water masses.

Reply# 45: Figure 1 (revised Fig Rev8) was modified as suggested.

Figures 2 and 3. Combine the two figures like Figure 4 to facilitate comparison between all study cores and avoid presenting atmospheric CO2 and dD twice. Indicate the latitude and water depth of each core.

Reply# 46: We indeed considered this option, but we feel the figure would be too elongated and narrow, respectively too small to read properly. We have thus opted for separating the results into two distinct figures.

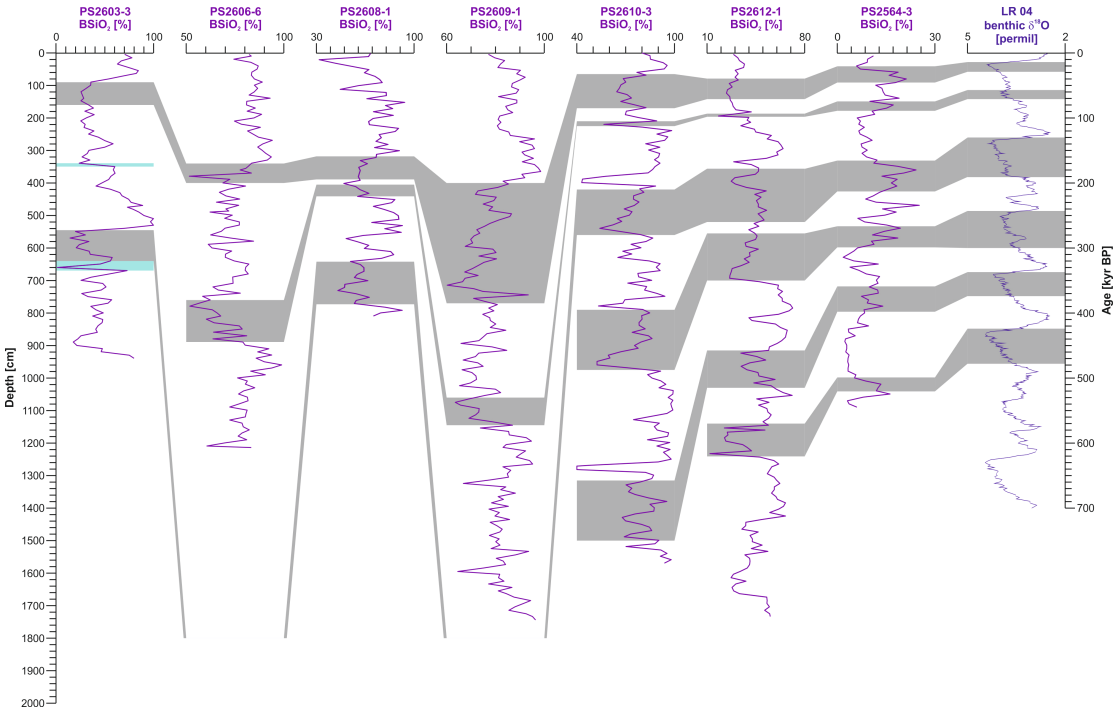


Fig. Rev2 Preliminary stratigraphic correlation between the dowcore BSiO2 data for the PS cores and the LR04 benthic d18O stack (Lisiecki and Raymo, 2005).

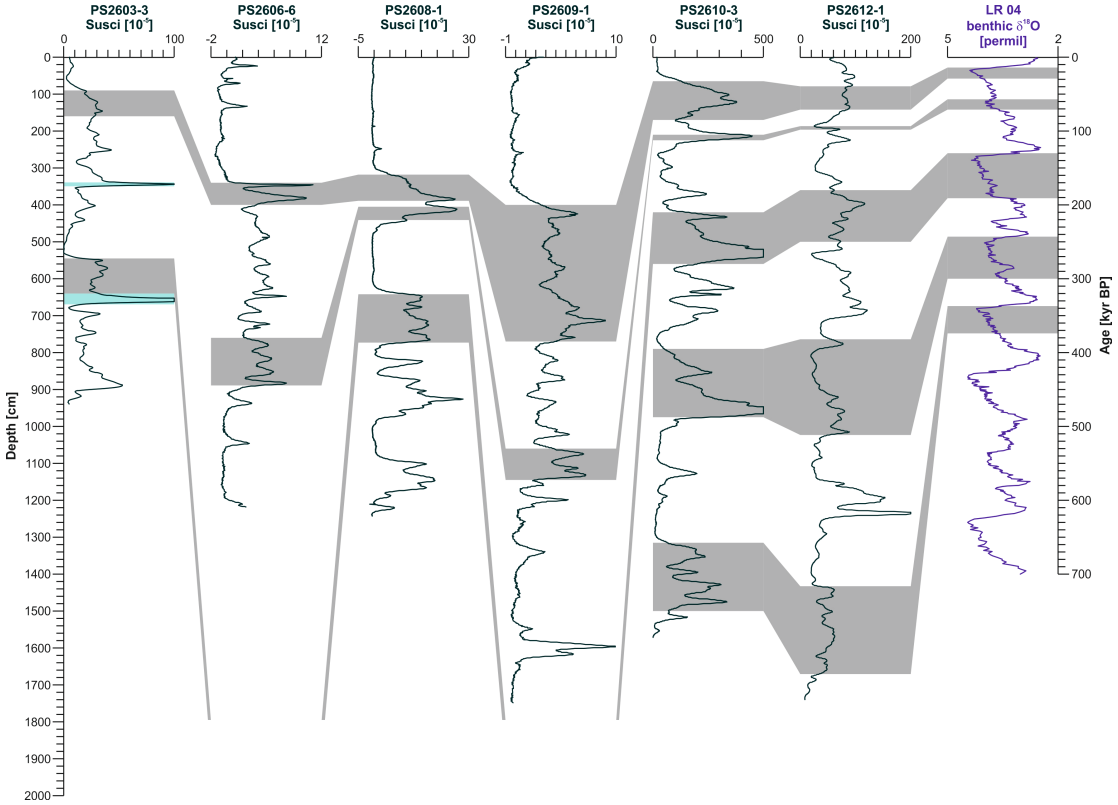


Fig. Rev3 Preliminary stratigraphic correlation between the dowcore MagSusc data for the PS cores and the LR04 benthic d18O stack (Lisiecki and Raymo, 2005).

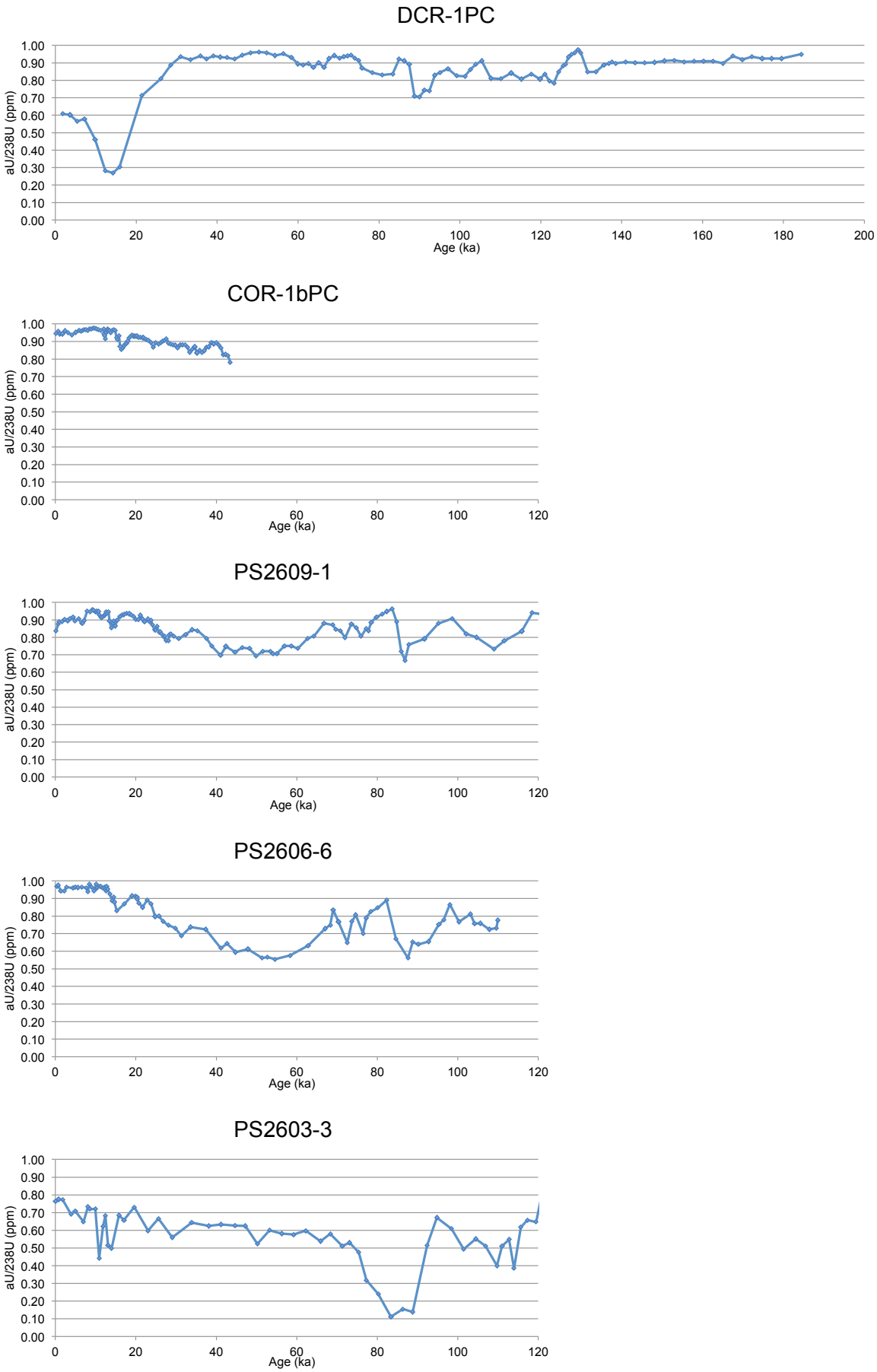
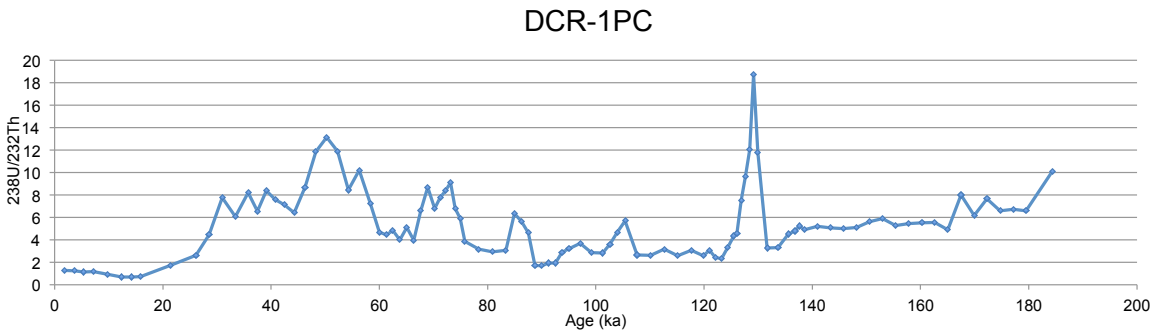
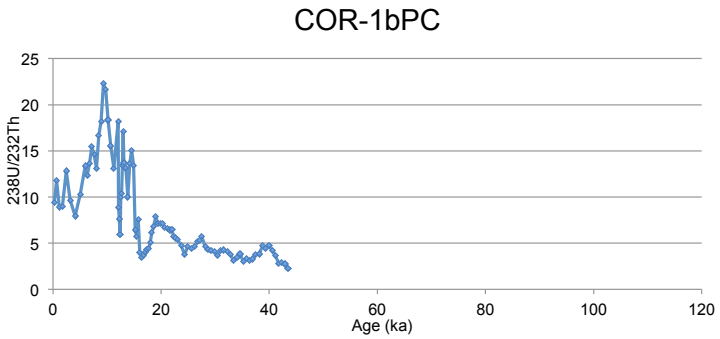
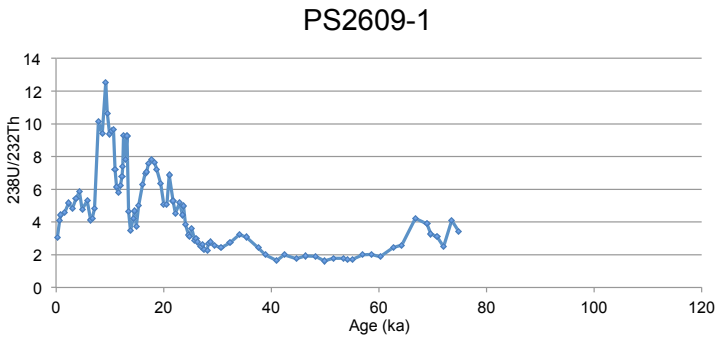
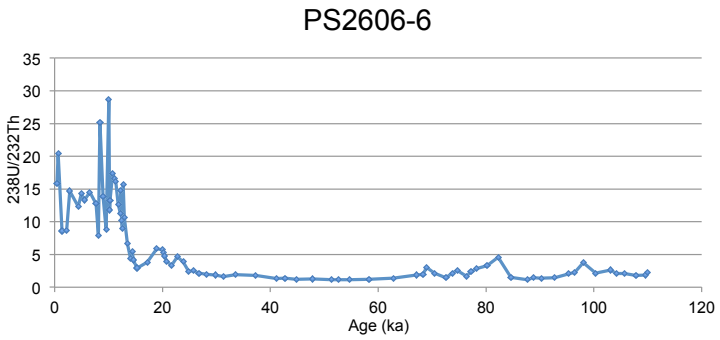


Fig Rev4: Authigenic component of the total U in all cores.









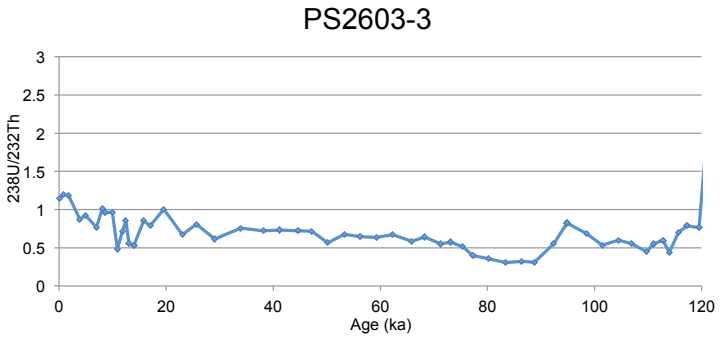


Fig Rev5: Changes in $^{238}U/^{232}Th$ over time in all cores.

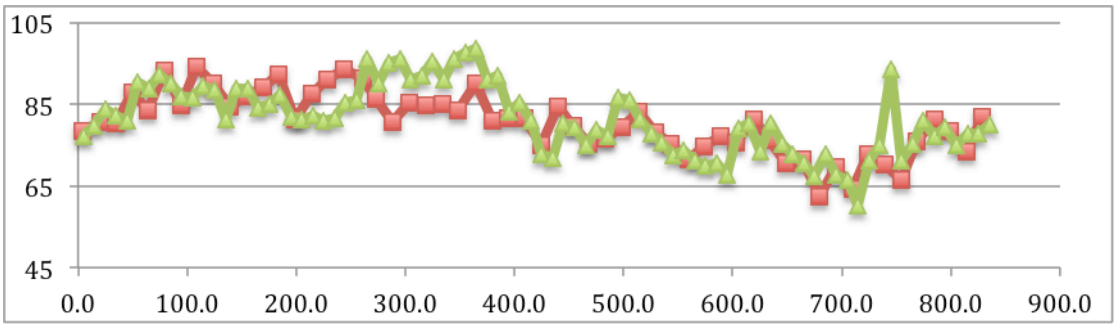


Fig. Rev6 – Comparison of the sedimentary BSiO2 concentrations measured by FTIRS (red) and alkaline extraction of silica (green) in core PS2609-1.

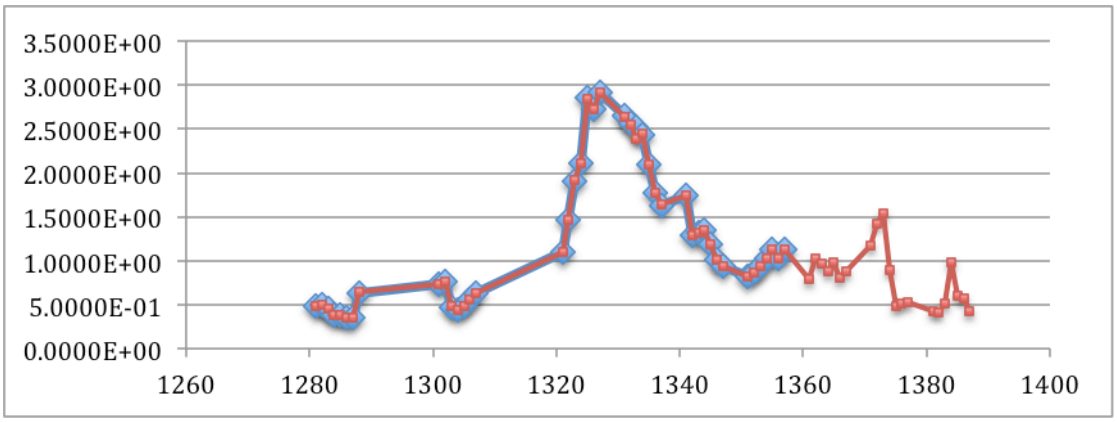


Fig. Rev7: – comparison of the sedimentary 238U concentrations measured using a MC-ICP-MS at UniBe (blue) and single collector ICP-MS at AWI.

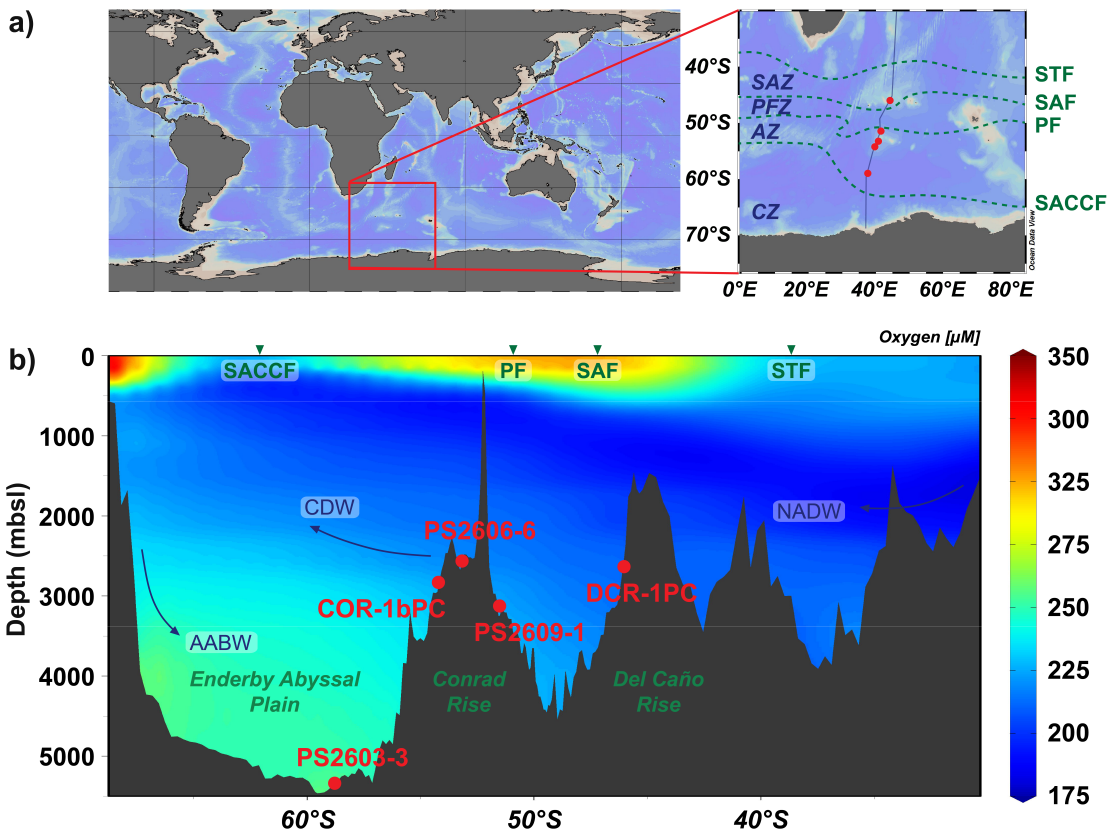


Figure Rev8: a) Core locations in the SW Indian Ocean across the Southern Ocean frontal system with line indicating location of cross section shown below. The fronts from north to south are the Subtropical Front (STF), Subantarctic Front (SAF), Polar Front (PF), and the Southern ACC Front (SACCF); the zones between them are defined as the Subantarctic Zone (SAZ), Polar Frontal Zone (PFZ), Antarctic Zone (AZ), and Continental Zone (CZ) (Orsi et al., 1995). b) Cross section of core locations with modern oxygen concentrations; the indicated water masses are North Atlantic Deep Water (NADW), Circumpolar Deep Water (CDW), Antarctic Bottom Water (AABW) (plotted with the ODV-software, Schlitzer, 2018).