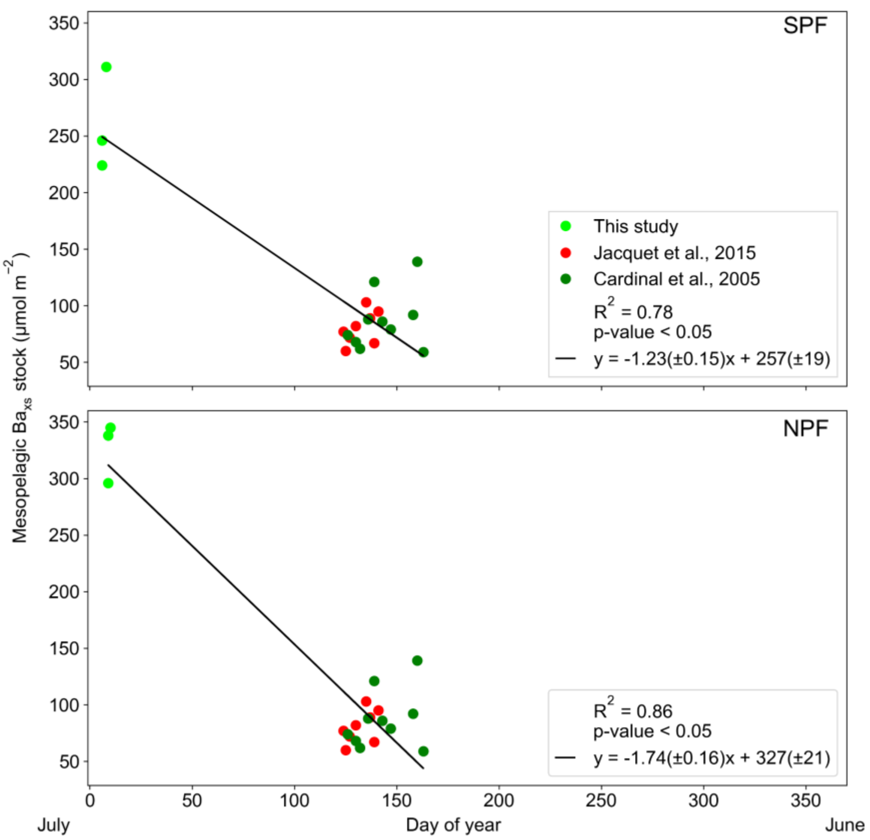
Referee #1: Frank Dehairs, fdehairs@vub.be

The authors have done a considerable effort addressing the comments of the reviewers and the manuscript has been considerably strengthened, especially regarding the discussion about the time scale of the Baxs signal.

Response: We thank Prof. Frank Dehairs for this very positive comment

The calculation of mesopelagic Baxs accumulation rates is an interesting outcome, but which is not really exploited further. Could authors say more about this, maybe in terms of the oceanic Ba cycle (ins, outs)?

Response: The Ba_{xs} accumulation rate indeed reflects the balance between "ins" (remineralisation of organic material and advection) and "outs" (dissolution, advection and settling). If we assume minimal surface export remineralisation in the mesopelagic zone, during winter, we can have a rough approximation of the loss rate between winter and early spring (Figure 4b & c: going back to the "baseline" ~ 180 pmol L^{-1}). An extrapolation from measurements conducted during winter down to early spring observations results in an estimated loss rate of ~ 1 µmol m^{-2} d^{-1} and ~ 2 µmol m^{-2} d^{-1}, south and north of the PF, respectively (see Figure below). That would give an estimated net Ba_{xs} accumulation rate (i.e. gross accumulation rate + loss rate) of ~ 1.9 µmol m^{-2} d^{-1} and ~ 2.9 µmol m^{-2} d^{-1} during the productive season, south and north of the PF, respectively. However, these estimates remain very crude and we believe that these preliminary results should be further investigated, e.g. in a physico-biogeochemical model (which is beyond the scope of our paper). The figure showing the decline of mesopelagic Ba_{xs} stock from winter down to early spring can be included as a supplementary figure if Prof. Dehairs wishes so, however, we do not feel that the regression is robust enough with the current available data spanning this timeframe.



In the supplementary material the heading of Table S4 has the sentence: "Where no POCrem fluxes are reported negative values were estimated ..." I guess this is an error? Please correct.

Response: We were initially not aware of the publication by Dehairs and Goeyens (1996). We thus calculated the mesopelagic POC remineralisation fluxes for the INDIGO 3 and EPOS 2 datasets (which were kindly provided by Prof. Dehairs) using the depth range (100 - 1000 m depth) and $Ba_{residual}$ value (180 pmol L^{-1}) as was used for our data and data from previous publications, where mesopelagic POC remineralisation fluxes were not published. This resulted in negative values for some stations where pBa concentrations was very low, due to the high $Ba_{residual}$ value used. Since we made use of published values for the compilation dataset, where available, we have now included the values as calculated by Dehairs and Goeyens (1996), where POC remineralisation fluxes were calculated using a 200 - 400 m depth range and 50 pmol L^{-1} as the $Ba_{residual}$ value. This recalculation does not affect the results of our study, as these data were not included in the regressions due to the samples not being digested with HF and the observations being conducted prior to the availability of remotely sensed PP (Figure 4).

Referee #3: J.K.B. Bishop, jkbishop@berkeley.edu

Review. van Horsten et al. "Early winter barium excess in the Southern Indian Ocean as an annual remineralisation proxy".

The authors have made significant improvements to their manuscript and have addressed virtually all comments from reviewers.

Response: We thank Prof. Jim Bishop for this positive comment.

Here are 4 (Qx) important questions that I'd like the authors to address.

The concentration of micron sized barite particles in the water column reflects the balance between the rate of addition from fragmenting large aggregate particles and the rate of their loss due to combined effects of three processes: single particle sinking, dissolution, and finally, reaggregation and sinking due to actions of filter feeders living in the mesopelagic.

Question 1: If source and sink processes are variable with depth and season, and food web, why would the authors expect a constant "background" Baxs?

Response: The hypothesis of a "background signal" arises from measurements showing values close to 180 pmol L^{-1} in deep water masses, previously reported multiple times in the Southern Ocean (Dehairs and Goeyens, 1996; Dehairs et al., 1997; Jacquet et al, 2008a; 2008b; 2011; 2015; Planchon et al., 2013).

That being said, the consistency of this value is still up for debate. It can be hypothesized that background Ba_{xs} is mainly constituted of barite crystals. Indeed, considering the residence time of barite crystals of ~ 6 yrs in the mesopelagic layer (as estimated in the previous review), and considering a mean current speed varying from ~20 cm.s^{-1} (500 m depth) to 14 cm.s^{-1} (1975 m depth) in the ACC region (Vigo et al, 3D Geostrophy and Volume Transport in the Southern Ocean, Remote sensing, 2018), barite crystals can be transported over 26 000 to 38 000 km before settling out of the mesopelagic zone. With the circumference of the Southern Ocean being ~ 20 000 km, these small particles may have enough time to be mixed throughout the deep waters of the Southern Ocean, homogenizing the background signal that would not reflect the variability in surface PP, food web, etc.

A better characterization of the Ba particles along the water column, and physical speciation, together with more accurate estimates of the sinking speed of these particles, would be necessary to confirm this hypothesis. That being said, measurements so far do indicate a "background" value for Ba_{xs} that is close to 180 pmol L^{-1} for studies conducted throughout the year (Dehairs and Goeyens, 1996; Dehairs et al., 1997; Jacquet et al, 2008a; 2008b; 2011; 2015; Planchon et al., 2013).

In Dehairs et al. (1997; DH1997) the regression of Baxs(averaged 200-400 m) vs estimated O2 consumption rate yields the equation: Baxs = 218 * 10(20.01*O2consumption), where 218 pM Ba is the intercept, or "Background" value. DH1997 justifies the O2 vs Ba relationship with data shown in their Fig 5 where there is a similarity of profiles of O2 consumption rate and Baxs.

In this paper, The authors have recast the same 7 points used in DH1997 to a linear relationship: $JO2 = (Mesopelagic\ Baxs - Ba\text{residual})/17200$ in equation (3); Where

*Mesopelagic Ba*xs is depth-weighted Baxs from the base of the euphotic layer to 1000m. Furthermore, they have assigned Babackground = 180 pM. In this paper, Equation (2) scales Jo2 by the thickness of the mesopelagic zone (~900m), the Redfield C:O2 ratio and by 12.01, the atomic weight of carbon to yield mesopelagic POC remineralization.

Question 2: How do the authors justify applying the DH1997 transfer function with results calculated in a fundamentally different fashion?

Response: Through personal communication with Prof. Dehairs, who has also reviewed this manuscript, it was confirmed that there were two transfer functions, one linear (Dehairs and Goeyens, 1996) and one exponential (Dehairs et al., 1997). It was confirmed that both functions gave very similar results, and it was therefore decided to use the simpler, linear version (Dehairs, per. comm.), which is what has been used in all publications since, with POC remineralisation fluxes corresponding well to estimates using the ^{234}Th method in the Southern Ocean and the North Atlantic (Lemaitre et al., 2018; Planchon et al., 2013). The linear function was reassessed in the North Atlantic by Lemaitre et al. (Figure 8: 2018, below), as well as more recently in the Mediterranean Sea by Jacquet et al. (2021).

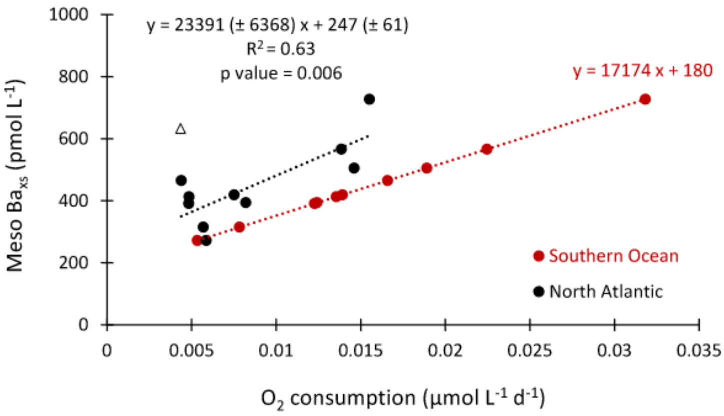


Figure 8. Regression of DWA mesopelagic Ba_{xs} (pmol L^{-1}) versus O_2 consumption rate (μmol L^{-1} d^{-1}) using the Southern Ocean transfer function from Dehairs et al. (1997; red circles) and the transfer function obtained here for the North Atlantic (black circles). Station 44 (triangle) was excluded from the regression. If station 44 is included, $R^2 = 0.33$ and the p value $= 0.07$.

We have amended the citation in the manuscript to refer to Dehairs and Goeyens (1996) as well as the Dehairs et al. (1997) publication. All data used in our manuscript made use of the linear function. The depth range over which the Ba_{xs} is integrated varies between studies due to where the Ba_{xs} peak is detected in the water column. We integrated Ba_{xs} over varying depth ranges from the base of the mixed layer covering the specific peak depth range, down to 1000m, 1500m and down to deep waters, with no significant differences between the mesopelagic POC remineralisation fluxes obtained, using the different depth ranges. We therefore decided to use the operationally defined mesopelagic depth range (100 - 1000m: Robinson et al., 2010) for our calculations.

As previously stated, we made use of the standard $Ba_{residual}$ concentration used in previous Southern Ocean studies included in the compilation dataset (Jacquet et al, 2008a; 2008b; 2011; 2015; Planchon et al., 2013).

Indeed, later calculations by Jacquet et al. (2008; DSR) refined the background value using the saturation state of the water with respect to barite (Monnin et al., 1999, Monnin and Cividini, 2006). This has been found to be in agreement with other Southern Ocean studies (Jacquet et al, 2008a; 2008b; 2011; 2015; Planchon et al., 2013), including our study (see Results : "when averaging all concentrations below 2000 m along the transect, the $Ba_{residual}$ concentration was 161 ± 43 pmol L^{-1} (mean ± SD, n = 15).")

P. 10 lines 255 – 260: The mean $Ba_{residual}$ concentration south of PF was 183 ± 29 pmol L^{-1} (mean ± SD, n = 7), whereas it was 142 ± 45 pmol L^{-1} (mean ± SD, n = 8) between the PF and the STF. The two regions were however not significantly different to each other when conducting a Welch's t-test (t-statistic = 2.10; p-value = 0.06) and when averaging all concentrations below 2000 m along the transect, the $Ba_{residual}$ concentration was 161 ± 43 pmol L^{-1} (mean ± SD, n = 15). This concentration is not statistically different from the literature value of 180 pmol L^{-1} (Jacquet et al, 2008a; 2008b; 2011; 2015; Planchon et al., 2013), which is widely used for estimates of POC remineralisation fluxes.

P. 12 lines 311 – 314: In deeper waters along the transect, south of the STF, (below 2000 m) where remineralisation is minimal compared to the mesopelagic zone, our Ba_{xs} concentration of 161 ± 43 pmol L^{-1} (mean ± SD, n = 15) is not significantly different from the widely used $Ba_{residual}$ concentration of 180 pmol L^{-1}, measured during early Spring to late Summer (e.g., Jacquet et al., 2008a; 2008b; 2011; 2015; Planchon et al., 2013).

Question 3: Can the authors demonstrate that their data or other datasets fall on the same trend as in Fig. 5 in DH1997? It is fundamentally important to the paper to make this important logical transition.

Response: The correction has been made to the citation, to refer to the linear transfer function published by Dehairs and Goeyens (1996). The linear function has been used in all Southern Ocean publications since. We are currently not capable of replicating this function as we do not have access to the required oxygen utilization rate data. It was, however, done by Lemaitre et al. (2018), in the North Atlantic, and no significant difference was found for their data.

Question 4: Why would the authors expect the DH1997 transfer function to apply across the entire southern ocean domain?

Response: The linear transfer function was obtained using data from across various environments, characterized by different regimes of plankton community composition and productivity (Dehairs and Goeyens, 1996).

The linear transfer function has also been used successfully and validated across biogeochemical zones and basins of the Southern Ocean (Cardinal et al., 2005; Planchon et al., 2013), as well as in the North Atlantic (Lemaitre et al., 2018) and recently in the Mediterranean Sea (Jacquet et al., 2021).

In summary, I thank the authors for their efforts so far. The expanded data analysis/inclusion of other data sets greatly improves the paper. That said, please address the above questions prior to publication.