Response to the referees

First and foremost, we would like to take this opportunity to express our gratitude to the referees for their time in reviewing our manuscript and the constructive nature of their comments. Both referees praise the quality of the data set and the modelling work and the potential of this study to further our understanding of CBE in oxygen deficient regions. Main criticisms centre on the following points:

1. The uncertainties and errors of the bottom-up approach to calculate rain rates and CBE are inadequately addressed.
2. The paper does not arrive at definitive or new conclusions about the mechanisms leading to the relatively low CBE on the shelf and relatively high CBE below the OMZ.

Referee #2 also suggests a fundamental re-organisation and focusing of the discussion. We have re-structured the discussion to address these concerns and, consequently, the manuscript is much improved.

Both referees would like us to provide a more explicit explanation for the low CBE on the shelf and the high CBE below the OMZ. The first referee mentions the role of sediment resuspension, lateral distribution and the particle residence time in the water column as factors modulating the reactivity of organic matter before it finally enters the sediment compartment. The second referee suggests ways to more concretely identify the controls on organic matter preservation using OET and OC/SA ratios. In the new version, the trends in CBE are dealt with as before, but the arguments are more focussed. Speculative diatribe regarding macrofauna and DOC in sediments that is not relevant to the CBE story has been either reformulated or removed.

To start with, grain surface area was not measured, although we do have gain size from 11^{o}S (Mosch et al., 2012) and surface porosities have been added to Table 1 (porosity profiles were given in the Supplement). The data from Mosch et al. (2012) show that the dry sediment clay plus silt fraction is highest on the shelf (>80 %) and decreases to ca. 60 % below the OMZ due to increasing fractions of coarser particles. Our data further show that POC content is relatively low on the shelf and highest in the OMZ. We can thus infer that the OC/SA ratio is lower on the shelf compared to the OMZ stations, implying more complete mineralization (Hedges et al., 1999). We conclude that the low CBE on the shelf (despite anoxic bottom waters) is caused by episodic ventilation of bottom waters; a characteristic feature of Peruvian margin. We now extend this finding to both the middle and outer shelf stations since these sites are subject to variable O_2 concentrations (Levin et al., 2002). Low CBE on the shelf is consistent with the existing CBE database if the shelf can be geochemically classified as a 'normal' setting despite fluctuating bottom water O_2 levels. Previous biochemical analyses suggest that this is the case.

Below the OMZ, CBEs are higher than expected compared to the existing CBE database. In line with the prior definitions of normal oxic (≥20 μM O_2) versus oxygen-deficient settings (<20 μM O_2) in the database, only the two deepest stations can be characterized as normal oxic. For these stations, we calculated the OET according to Cai and Sayles (1996) and then, using the relation between OET and CBE (Hartnett et al., 1998) were able to show that our calculated CBEs of >60 % were much higher than ~20 % predicted by the Hartnett et al. (1998) relationship. Hence, factors other than the OET of carbon in the sediment must influence the CBE at the deep sites. We then go on to discuss the likelihood that deposition of reworked, degraded material originating from sites higher up on the slope is responsible for the elevated CBEs at the deep sites below the OMZ. Consequently, although these sites fall into the normal oxic category, they are not representative of oxygenated sediments. This mechanism could also explain the increase in Al accumulation (now shown in new Fig. 3) and mass accumulation rates below the OMZ. These findings have been more clearly stated in the text, abstract and conclusions.

We now address in more detail the uncertainties in our CBE estimates, as requested by Referee #2. We discuss comprehensively the potential artifacts and errors arising from (i) DIC measurements and flux estimates, (ii) POC content and (iii) sedimentations rates. Regards (i), we find that correcting DIC flux for seasonal effects linked to variability in rain rate would increase our CBE estimates by around 4 to 5 % on the shelf and 5 to 7 % in deeper waters. This error, as well as that potentially caused by chamber artifacts, is likely to be much smaller than the difference in DIC flux measured in the two chambers during each lander deployment (i.e. seafloor heterogeneity). Regards (ii), our overall approach remains unchanged. Regards (iii), we now re-emphasise that whilst our empirical reaction-transport model is a robust tool to estimate the sedimentation rate, $^{210}Pb_{xs}$ distributions at the deeper stations may indicate higher rates of sediment bioturbation mixing and lower sedimentation rates. In fact, bioturbation coefficients of ca. 100 cm^2 yr^{-1} were derived from ^{234}Th distributions below the OMZ (Levin et al., 2002). Although these high coefficients are likely to be artifacts caused by the use of short-lived radioisotopes to infer mixing rates in weakly mixed sediments (Lecroart et al., 2010), we now make more use of our ^{241}Am data to confirm the lead-derived mixing and burial rates. These data show an activity peak due to 1950s bomb tests at four stations along 12^{o}S, including one of the deep sites below the OMZ (now shown in Fig. 2, reproduced below). Sedimentation rates determined using ^{241}Am agree with the $^{210}Pb_{xs}$ rates to within 10 to 50 %, confirming the order-of-magnitude values determined by the $^{210}Pb_{xs}$ model. We have now included Volker Liebetrau as co-author for his input regarding these data. Furthermore, bioturbation coefficients derived using the ^{234}Th data clearly overestimate the rate of sediment mixing that the $^{210}Pb_{xs}$ data suggest, an example of which is now also shown in Fig. 2. This section is long, and whilst informative and worthwhile including, we prefer to place it in the appendix. Including it at the start of the discussion (as suggested by the referee), distracts too much from the main flow of the paper.

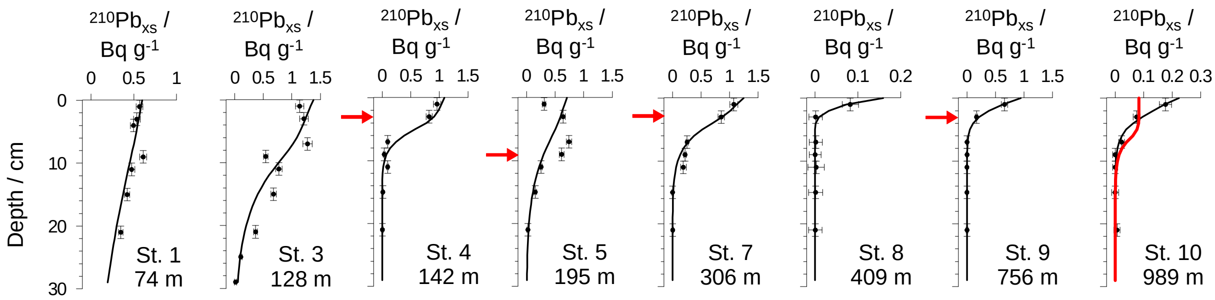

Figure 2. Measured (symbols) and modelled (curves) $^{210}Pb_{xs}$ at 12^{o}S (see Bohlen et al. (2011) for $^{210}Pb_{xs}$ at 11^{o}S). Vertical error bars span the depth interval from where the sample was taken, whereas horizontal error bars correspond to the analytical uncertainty. Derived upper boundary fluxes and bioturbation coefficients are listed in Table S2. The red arrows indicate the profile steps reflecting the detection of ^{241}Am and indicating the depth-position of the peak with activities as follows: St. 4 = 3.7 ± 1.0 Bq kg^{-1}, St. 5 = 5.8 ± 0.99 Bq kg^{-1}, St. 7 = 6.6 ± 0.95 Bq kg^{-1}, St. 9 = 2.2 ± 0.68 Bq kg^{-1}. The accuracy of the peak depth is defined by the sampling resolution. The red curve at St. 10 shows the results of a model simulation using the ^{234}Th-derived bioturbation coefficient of 100 cm^2 yr^{-1} (see Appendix A).

The section dealing with organic carbon mineralization in the water column is as before but tighter. Our message in the original paper was that the derived *b* value (0.8) using sediment data is unusually high for an anoxic water column, whereas other studies in oxygen-deficient regions calculated *b* values of around 0.4 or less. We now correct *b* for the offshore decrease in primary production (according to the ROMS model) since our original *b* may have been artificially increased by assuming no offshore gradient in primary production. Yet, our new *b* value is still relatively high (0.54±0.14) and overlaps with the open-ocean composite estimate of 0.7±0.08 by Primeau (2006). Hence, our findings regarding pelagic mineralization are essentially unchanged. We now propose that the high *b* for Peru can be explained by the same mechanisms leading to the high CBE below the OMZ, i.e. a prolonged particle residence time in the water column due to the multiple resuspension/deposition events and down-slope transport.

In summary, changes to the manuscript include:

1) Re-structuring of the Discussion.
2) New Fig. 3 showing mass accumulation rates and Al accumulation ('proxy' for terrestrial inorganic material)
3) ^{241}Am peak depths added to Fig. 2 as a cross-reference on $^{210}Pb_{xs}$-derived sedimentation rates.
4) H_2S concentrations removed from concentration-depth profiles Fig. 3 (no added value in the current context).
5) Fig. 8 shows the new *b* value of 0.54 ± 0.14 (was 0.8) after the rain rates were corrected for the offshore decrease in primary production (according to the ROMS model). The Primeau (2006) curve has also been added alongside the Martin curve.
6) The CBE in Fig. 8 for the middle and outer shelf are now grouped together because the outer shelf sites down to 200 m also experience periodic O_2 intrusions, despite being anoxic at the time of sampling (Levin et al., 2002; Gutiérrez et al., 2008).
7) Primary production estimates added to Table 3.
8) Fig. 5 (DIC fluxes) has been moved to the supplement.

All specific/technical comments have been addressed, including (see also above):

1) English grammar mistakes corrected.
2) Stirring rate etc of chambers added.
3) Precisions and detection limits for all methods have been included.
4) For the shelf stations where sulfide was released from the sediment, corrections were made for the contribution of HS- to TA using the relevant equilibrium constants (Zeebe and Wolf-Gladrow, 2001). Now clarified in manuscript.
5) Low non-local transport rates by burrowing organisms were established via model sensitivity analysis. Now clarified in manuscript.
6) The use of the word "discretized". The verb "discretize" is commonly used in mathematical and engineering sciences.
7) The linkage between faunal abundance of periodic intrusion of oxygenated bottom water has been clarified. Although we can only speculate on the evolution of macrozoobenthos species richness and bioturbation potential, we feel that this is intrinsic to understand the potential mechanism for the low CBE on the shelf. We now hope that the new text links these two aspects in a more coherent manner.
8) Sediment reworking and winnowing was established at St. 8 by (i) the low mass accumulation rates and (ii) the characteristic presence of foraminiferal sands and phosphorites granules that form under high-energy conditions (Glenn and Arthur, 1988; Reimers and Suess, 1983b; Arthur et al., 1998; Mosch et al., 2012). The role of hydrodynamics in the distribution and reworking of sediments is now discussed more explicitly in the new version of the manuscript.
9) Font size on several figures has been increased.