Dear Reviewer,

First of all we would like to thank you for the time and effort you spent on reviewing our manuscript. We very much appreciate your comments that clearly have identified parts of the paper that needed more attention. We tried to address all the questions and comments you raised and are convinced that the manuscript will be improved significantly.

In the following we sorted all comments/questions (**RC:**) by numbering these (according to your numbering) and providing for each an answer (**AC:**).

Best regards,
B. Fiedler & Coauthors

1. Reviewer #2:

Review of Fiedler et al., Oxygen Utilization and Downward Carbon Flux in an Oxygen-Depleted Eddy inb the Eastern Tropical North Atlantic.
bg-2016-23

General comments:

Reviewer Comment (RC)1_: *Reference Data Set: an assumption that needs to be strengthened*

The three Reference Data Sets used by the authors for the bgc fluxes calculations are from cruises that were conducted on the Mauritanian shelf around the second-half of July 2006, beginning of June 2010, and beginning of June 2014. The surveyed eddy is supposed to have formed on the Mauritanian shelf around June/July 2013. This can be inferred from the paper, but it's not explicitly stated. At page 8 lines 17-21 the authors explain how they reconstructed the region of origin of the eddy on the shelf on the base of statistical analysis of historical SLA, and how this region coincides with the location of the 3 Reference Data surveys. However, the eddy trajectory from SLA in "Figure 1" starts about two months later (Sept. 2013) at least 100km in the off-shore direction. The fact that the trajectory of this specific eddy was not retrieved on the shelf that may imply, for example, that the eddy boundaries of this eddy were not already well formed, therefore the eddy may have continued to trap water while leaving the shelf area of the Reference Data Sets, or may have been spun by a lateral filament. At page 11 lines 4-5 the authors underline the matching between the Temperature and Salinity of the eddy core when it was surveyed and the reference station measurements on the shelf. This supports the assumption of isolation of the eddy core from the shelf to the offshore waters. However, biogeochemical properties can be more variable than physical properties on both spatial and time scales, especially in active shelf regions. The authors write about the Reference Data Sets [page 8 lines 23-27] "in order to account for small scale variability [: : :] an average profile for each investigated parameter was created [: : :]. These mean profiles were assumed to represent typical initial conditions of ACMEs [: : :]". Given the complex dynamics of the flow around the shelf edge, the time and spatial variability of biogeochemical processes, the timescale of sporadic upwelling events; given the fact that the eddy trajectory from SLA was not retrieved in the shelf region, and the complexity of the eddy formation process:

1. *Can the choice of these Reference Data Sets be better justified? Are there no available data for the region in which the trajectory was actually retrieved in Sept.2013?*
2. *How do mean profiles account for small scale variability?*
3. *Is it possible to exclude strong discontinuities (input of external water, sediment resuspension, interaction with other forming eddies, etc.) in the eddy evolution between the shelf region of the Reference Data Sets and beginning of the track in "Figure 1"?*
4. *Several times in the article the authors refer to sporadic upwelling events fueling the high surface productivity in the eddy. How is the hypothesis of "production being boosted in the surface of the eddy by upwelling events" compatible with the hypothesis of "complete isolation of the eddy core" along the whole eddy lifetime? What is the spatial distribution of these upwelling events in the eddy?*

Author Comment (AC)1_:

We appreciate this comment and related thoughts about proper reconstruction of initial conditions of the surveyed ACME. We also see the need to constrain initial conditions of the eddy as good as possible as this directly affects derived rates for biogeochemical parameters. According to RC17 we decided to slightly reorganize the presentation and discussion of SLA results. We will introduce the SLA-derived trajectory already under 2.2 (reference data sets) and will add some discussion on this under a more general eddy description section under 3 (results & discussion), as also proposed in RC2_.

We explicitly neglected SLA trajectory data closer to the shelf for two reasons: ACMEs only show a very minor sea level elevation of the eddy surface. This makes it very difficult to track these eddies. Furthermore, the high density of (short-lived) eddies and filaments close to the shore drastically impairs the reliability of the eddy tracking. Background noise impedes clear identification of individual eddies, in particular those with only minor signals (ACMEs). Schütte et al. (2016) performed an elaborate analysis of eddy statistics which clearly indicated this region as a release hotspot and states that this is related to a seasonal weakening of the coastal undercurrent along with coastal topographic features. Further, Thomsen et al. (2016) observed the initial formation of an ACME off Peru, which exactly took place at the shelf edge and thereby capturing hydrographic and biogeochemical conditions at this place. We cannot derive information about how intermittent/sporadic the upwelling is and we will rephrase that to a more general statement on "upwelling processes". The analysis of an oxygen float showed that the respiration derived from 5 day oxygen profiles over a period of several months showed a surprisingly constant decrease which in turn suggests that particle sinking is also constant and thus upwelling. However, the duration of the blooms apply a running mean to any intermittence of the upwelling.

Answers to the 4 specific issues:

1. We only have a very few surveys near the Mauritanian shelf edge available which fall into boreal summer months and which also conducted biogeochemical samplings in that region. Data are also available for regions further offshore from the same expeditions. However, as we are confident that the origin of the eddy is located closer to the shelf edge, we would significantly bias our calculations if you choose the more offshore area as the starting conditions.
2. This sentence was not phrased correctly in the discussion paper. We will rephrase is as follows: "In order to neglect small-scale variability of water column properties within this area, an average profile for each investigated parameter was created by averaging on isopycnals but mapped back to depth via the mean depth/density profile."
3. Even though we were not able to have in situ observations of this particular eddy close to its origin we are confident that once the eddy has been created no further exchange of waters masses between the inner and outer part took place. Usually, such eddies begin their lifetime with very stable conditions and slowly decay over their lifetime. Since we observed very stable conditions still after 6-7 months we don't think that major fluxes occurred in the early days of this eddy.
4. . Indeed the apparent contrariety between isolation on the one side and upwelling on the other side is a very interesting observation. We do not have a final answer to it but in Karstensen et al. (2016, "Upwelling and isolation in oxygen-depleted anticyclonic mode water eddies and implications for nitrate cycling") we discuss a concept for the processes that interact on the submesoscale. In brief, the upwelling occurs at the rim of the eddy where the vertical shear in velocity is largest (enhanced by vertical propagating Near Inertial Internal Waves). The upwelling is thus expected to originate from shallow depth, say the upper 100m or so and should be rather constant. One part of the upwelled waters is "trapped" by eddy retention and as is accessible for productivity across the eddy. While we speculated in the past that the isolation is related to the eddy coherence further analysis reveals that the buoyancy frequency/stability maximum encompassing/defining the core is very efficient in isolating the core for mixing (e.g. shown in Sheen et al. (2015). Details are described in Karstensen et al. (2016). We will add a sentence in section 3.2 (2nd paragraph) in order to provide a link to that paper: "As such, this finding is interpreted as being a signature of a vertical flux event related to submesoscale processes and stratification which on the one side isolate the core and prevent oxygen supply while in parallel support vertical nutrient flux at the eddy rim (see Karstensen et al., 2016, this special issue, for further details)."

RC2_: *Description of the surveyed eddy*

The authors do not provide a clear general description of the characteristics of the surveyed eddy, among which some basic details: date (month/year) and coordinates of the eddy when forming on the shelf; date and coordinates of the beginning of the track; date, coordinates, radius, shape and age of the eddy when surveyed. Some of these characteristics can be retrieved in different parts of the article explicitly or implicitly, but it is the work of the reader to collect them. I suggest presenting these characteristics in a dedicated paragraph where the eddy is introduced and described. As regard to "Figure 1": it may be helpful to add a timescale of the eddy trajectory and to draw the eddy contours in the region of the cruises, to understand where the measurements were located with respect to the eddy center and boundaries. Most of the observations described in the chapter "3 Results Discussion" would be much easier to understand if a nice description of the vertical physical structure of the surveyed eddy was given.

AC2_: We appreciate this comment and will provide a dedicated section that describes the eddy characteristics. In this section we will provide the requested information and we will incorporate section 3.1 (Hydrography) as well. The new section will be entitled as "Eddy Characteristics" and will replace the current section 3.1 (Hydrography).

Regarding Figure 1 we will add a few dates for illustrating the timescale of the eddy propagation. However, we decided to not draw assumed eddy contours into the figure for the following reasons: 1) In reality the form factor of such an eddy is quite dynamic and a representing ellipse or circle would be a bit misleading, 2) the figure may become too busy and 3) this kind of illustration is already presented in two more papers as part of this special issue (Hauss et al., 2016; Löscher et al., 2015) and we want to avoid too many replicates. Finally, as our analysis mainly focuses on the comparison between the inner station, the CVOO reference station (far out of the eddy) and the shelf station (even further away) we don't see an urgent need to include the potential size and shape of the eddy to this figure.

RC3_: *Description of the dedicated eddy surveys*

In paragraph "2.1 Eddy surveys" the number of samples that were collected during each cruise is not clear and some of the descriptions are confusing. As the 2 cruises are described as "first dedicated biogeochemical surveys" of the eddy the reader may expect to see some 2D biogeochemical sections and wonder what the spatial resolution of the samples is. However, it becomes clear later that the biogeochemical data analyzed in the article consist in only 2 bottle measurements per cruise, 1 per cruise referring to the eddy center. I suggest stating this clearly in the text. The CTD/UVP-only (no bgc) section M105 is introduced but never plotted or clearly discussed. At page 5 lines 19-24 the authors write that some stations supposed to be at a certain distance from the center of the eddy on the base of SLA "turned out probably more at the rim of the eddy than in the surrounding water representing typical background conditions". What is the reason for this conclusion? Can this be elaborated more in depth to justify this sentence?

AC3_: We agree that we haven't clearly pointed out that the biogeochemical component of these surveys only comprises hydrocast stations in- and outside this eddy. Since we mostly focus on the eddy center stations (one during M105 and another one during ISL_00314) we will emphasize this in the text as follows: "During both cruises hydrographic and biogeochemical data were sampled in the same eddy (Figure 1) although extensive biogeochemical samplings were performed only during single hydrocast stations at the eddy center."

Since we don't show any data from the hydrographic section across the eddy (M105, see Hauss et al. 2016 or Löscher et al., 2015) we removed the short paragraph about this section and also removed the section from Fig1 in order to avoid confusion about this.

We will also add some evidence for the location of the outside station in relation to the eddy center and rim as follows: "Based on the SLA data the "outside stations" during ISL and M105 were located 43 and 54 kilometers away from the supposed eddy center, respectively. However,

ship-borne Acoustic Doppler Current Profiler data (ADCP; see Hauss et al., 2016) as well as SLA data (Löscher et al., 2015) suggest a radius of this eddy of approx. 50 - 55 km. This points out that these stations where more at the rim of the eddy than in the surrounding water representing typical background conditions."

RC4_: *Quantitative results*

Some of the results presented in the sections from 3.1 to 3.4 are not well quantified. Data collected in the eddy center and data on the shelf or in the open Atlantic are often compared with not-well-defined or confusing terms. I strongly suggest giving to the descriptions a more quantitative flavor.

AC4_: We will go through these sections carefully and remove these terms wherever possible (see also AC35).

RC5_: *Style: English, typos*

The paper, apart for a few sections, is scattered with typos, misspellings and incorrect formulation of the English sentences. Sentences are often very convoluted and difficult to follow. The frequent use of bracketed subordinates makes the reading process even more complicated. I highly suggest a proof-reading of the paper for typos, grammar and syntax, as well as a simplification of the structure of the sentences and the limitation of the use of brackets to the very essential. Some errors are listed in the "Detailed comments" section.

AC5_: We will follow the reviewer's recommendation by having the paper proofread by a second native speaker. We will remove bracketed subordinates wherever possible.

Specific comments:

RC1: Introduction: The section "Introduction" of the paper ends with a paragraph (from page 3 line 29, to page 4 line 10) that introduces the content of the article. However, it forgets to anticipate any section about consequences and conclusions of the present study. I suggest to strengthen this paragraph in this sense, anticipating to the reader the presence of relevant conclusions connected to the results.

AC1: We will edit this paragraph as follows: "Here, we present the first biogeochemical insights into low-oxygen ACMEs in the ETNA based on direct in situ sampling during two coordinated ship-based surveys. The main objective of this study is to reveal and quantify biogeochemical processes occurring inside a low-oxygen ACME in the ETNA. This publication is part of a series that describes biological, chemical and physical oceanographic processes and their interaction inside these eddies. In this publication we first present the vertical hydrographic structure of a surveyed ACME and discuss nutrients concentrations and the marine carbonate system. All data are put into regional context by comparing ACME conditions with 1) ambient background conditions represented by CVOO and 2) the biogeochemical setting in the proximal EBUS off the West African coast, where the eddy originated from. Derived estimates for transformation rates of various key parameters and for carbon export rates within the surveyed ACME highly exceed known values for the ETNA and also other open-ocean regions."

RC2: page 2 line 25: Eastern Tropical should be capitalized when defining acronym

AC2: We will change this as suggested.

RC3: page 3 lines 18-20: incorrect syntax, "that" should follow the name that it refers to (ACME)

AC3: Sentence will be corrected: "They found that about 2 to 3 ACMEs are generated each year at distinct regions in the EBUS and then propagate into the open ETNA waters."

RC4: page 3 line 27: commas out of place

AC4: Sentence will be corrected: "Consequences for carbon cycling such as production and export as well as the impact on the ETNA OMZ also remain unclear."

RC5: page 3 line 29: word "process" is redundant
AC5: The word "process" will be removed.

RC6: page 4 line 2: misspelling "describes"
AC6: Will be corrected.

RC7: page 4 lines 16-19: sentence beginning with brackets; confusing sentence, "in the ETNA" better after "in situ-data", maybe the sentence should be divided in two parts
AC7: We will correct and rephrase the sentence as follows: "Schütte et al. (2016) analyzed satellite and corresponding in-situ data in the ETNA and found that on average about 20% of all anticyclones (10% of all eddies) are ACMEs that exhibit a pronounced low oxygen core."

RC8: page 4 line 28: unnecessary brackets
AC8: Brackets will be removed.

RC9: page 5 line 8-10: data is a plural word, "were", "do"
AC9: Will be corrected as suggested.

RC10: page 5 lines 11-12: if the quality of the measurements is lower then it's half the accuracy (not double), the error doubles, the accuracy halves; numbers should go before the "for"
AC10: Will be corrected as suggested.

RC11: page 5 line 21: misspelling "turned"
AC11: Section will be rephrased according to AC3_.

RC12: page 6 line 10: sentence in brackets should actually be better illustrated and high-lightened since it's an important piece of information for the whole paper
AC12: We will remove this sentence and place this information at the beginning of this section: "Analysis of SLA data of the surveyed eddy revealed that it was generated in August/September 2013 close to the Mauritanian shelf (Figure 1)."

RC13: page 6 line 22: unnecessary brackets
AC13: Sentence will be split and rephrased as follows: "The observatory includes a ship-based sampling and a mooring program (Fischer et al., 2015; Karstensen et al., 2015). At the time of the ISL sampling CVOO was located about 167 kilometers south of the eddy survey location in an open-ocean setting."

RC14: page 8 line 9: "by" not "from"
AC14: Will be corrected as suggested.

RC15: page 8 lines 9-12: unnecessary brackets; the vertical structure of the eddy is unclear: What is the depth of the euphotic zone and how does it compare with the depth of the eddy core? What is the depth of the mixed layer? Is primary production only taking place in the shallow mixed layer as it may be hypothesized from the chlorophyll plot, or is primary production also happening in the core? Is the core still in the euphotic zone? These points should be very well clarified also in the "Results" sections
AC15: Brackets will be removed.

Regarding the vertical structure of the eddy we will provide this information in the "Eddy description" section following your suggestion made in RC2_. We also edited two sentences in section 3.1 (which will be incorporated into the new section) in order to explicitly mention the mixed layer depth in and outside the eddy.

"The upper bound of the eddy core is the mixed layer base at a depth of 70 m which has the same magnitude as the mixed layer outside the eddy (Karstensen et al., 2016, this special issue). A very sharp gradient exists between 70 – 77 m depth which amounts to 0.73 in salinity, 3.98°C in temperature and 165.8 µmol kg^{-1} in dissolved oxygen."

Unfortunately, light/PAR measurements failed during the surveys due to sensor problems. Thus, we can't give reliable information about the euphotic zone for this particular eddy. We removed speculative connections between the eddy core and the euphotic zone from the abstract and the conclusions.

Results for primary production rates are presented in Löscher et al., 2015 (Figure 7). Rates were found to be in accordance with discrete samples for chl-a. Unfortunately, no rates were determined for the depth of the eddy core.

RC16: page 8 line 13: misspelling "resembles"; I find it not so proper to say that this sporadic upwelling resembles coastal upwelling, it's probably Ekman pumping, which does not require a coastal boundary to happen

AC16: It is true that coastal upwelling is maybe mostly an Ekman pumping problem, while for the eddies different upwelling models have been proposed. However, the effect of eddy-induced upwelling on the biogeochemistry is comparable to coastal upwelling regions (upward nutrient flux, enhanced surface productivity, etc.).

RC17: page 8, lines 17-31: this description should in part be moved to an eddy description section and in part be included in the 2.2 Reference Data Sets section

AC17: We appreciate this comment and will move most of this paragraph into section 2.2

RC18: page 8 lines 23-25: sentence is hardly understandable, "but" is incorrectly used

AC18: We will split and rephrase this sentence as follows: "In order to neglect small-scale variability of water column properties within this area, an average profile for each investigated parameter was created. This was done by averaging parameters along isopycnal surfaces and then mapping back these values to the mean depth of each isopycnal surface."

RC19: page 8 line 29: "en route"?

AC19: Sentence will be reworded as follows: "This reference data from the shelf was then used to determine the changes in biogeochemical parameters that occurred on the way from the formation to the survey area northwest of Cape Verde."

RC20: page 9 lines 4-6: "remineralization", not "mineralization"; words before acronyms should be capitalized; "age" doesn't need quotation marks; very convoluted sentence, could be split in two parts

AC20: Sentence will be split and corrected as suggested: "Changes of oxygen and carbon due to remineralization of organic matter are being expressed as the Apparent Oxygen Utilization Rate (aOUR) and the Carbon Remineralization Rate (CRR). In order to determine these rates not only the anomaly but also the age of the eddy, the time between formation on the shelf and the time the eddy surveys took place, needs to be known."

RC21: page 10 line 9: there should be a comma (not a dot) before "as"

AC21: Sentence will be changed as suggested.

RC22: page 10 line 24: misspelling “resemble”
AC22: Correction will be done.

RC23: page 10 line 25: “predominating” not the right word, maybe “dominant”
AC23: Word will be changed to “dominant”.

RC24: page 10 lines 26-27: not sure if this sentence is needed. Either the paper includes a full description of the basin and relative water masses (eg, in the introduction) or it seems out of place; also: what is the typical TS signature of SACW that is also found in the core of the eddy? A reader my not be familiar with this water mass
AC24: We decided to mention NACW at this part of the paper as it directly emphasizes the observed anomaly. We will incorporate this sentence into the sentence prior to it: “They resemble South Atlantic Central Water (SACW), the dominating upper layer water mass in the Mauritanian Upwelling region, whereas the region around CVOO is actually dominated by high salinity North Atlantic Central Waters (NACW; Pastor et al., 2008).”

RC25: page 11 line 8: I don’t understand “vertical contrast”, does it mean “gradient”?
AC25: Term will be replaced by “gradient”.

RC26: page 11 line 11: “underway”?
AC26: “underway” will be replaced by “Shipborne Sea Surface Temperature (SST)”

RC27: page 11 line 22: “minimal” not an adverb
AC27: Sentence will be changed as follows: “We expect the oxygen decrease from continuous respiration of the organic material that sinks out of the euphotic zone into an environment that is at most only slightly affected by lateral ventilation of the eddy waters.”

RC28: page 11 lines 25-26: “inside the ACME” seems to refer to the whole eddy, are these lines referring to remineralization that happens in the low-oxygen core?
AC28: We will now write “ACME core” in order to avoid confusion.

RC29: page 12 line 25: clearly missing reference (!)
AC29: We will add Schulz et al. (2013) who describe the range of pH values used for their mesocosm study.

RC30: page 13 line 5: paragraph on DIC should probably end here, not at line 3
AC30: Will be changed as suggested.

RC31: page 13 line 6-7: not quantitative, not clear, terms as “minor change” and “small but significant” should be defined
AC31: We will add the maximum value of change in TA beneath the eddy core as follows: “Here, only a minor small change of up to 17 µmol kg-1 in TA inside the eddy core is found.” We will further rephrase the following sentence as well: “This was expected as respiration processes may have a positive or negative effect on TA depending on the form of reactive nitrogen being released (Wolf-Gladrow et al., 2007).”

RC32: page 13 lines 17-18: “data not shown” used for drawing conclusion does not strengthen the paper, given the limited number of plots and their simplicity maybe some of the data could also be shown; same for the next “data not shown” in the paper
AC32: We decided to rather remove this sentence as the differences in correlations are very weak due to the very limited number of TA samples. Correlations pointing towards this direction but

are clearly not robust. Regarding the following “data not shown” we decided to keep this statement as it is. It relates to POC samples collected during the remaining part of the M105 expedition south of Cape Verde. If we would include all this POC data into the subpanel it would make this plot too busy.

RC33: page 13 lines 20-32: all the detected small particles are assumed to be POM; this assumption is not explicitly stated even though it is at the base of the conclusions, I suggest to state and justify the assumption for this region. Are dust-deposition-derived particles irrelevant in this region/season?

AC33: The UVP is an optical instrument, thus we do not know the composition of the respective size classes of particles. However, although dust deposition is certainly an important factor in this region (also for ballasting of particles containing organic compounds), it seems unlikely that the marked increase in particles observed within the eddy is linked to a local dust event rather than the eddy itself. Particles larger than approximately 500 µm equivalent spherical diameter (for which the UVP stores the image information) mostly resemble "marine snow"-type aggregates (compare section across eddy and example images in Hauss et al. 2016, Fig 4a). While they may contain lithogenic material to some extent, it seems reasonable that they contribute to the POM (which was also measured independently by elemental analysis in discrete bottle samples) and provide the basis for water column respiration and carbon export flux (see also Fischer et al. 2015). We will edit the first sentence of this section as follows: “We used data from the UVP to illustrate vertical distribution of small particles (60 – 530 µm) in the water column which we assume to primarily consist of POM but may also contain lithogenic material (Fischer et al., 2015).”

RC34: page 13 line 23: convoluted sentence

AC34: We suppose that actually the sentence in lines 21-23 was meant. Thus, we rephrased this sentence as follows: “During both surveys, particle abundances show a peak within the shallow OMZ slightly below the oxygen minimum (Figure 6).”

RC35: page 13 line 24 and 27: “significantly exceeds” and “much higher” not very quantitative

AC35: We will change this as follows: “This points at accumulated particles fueling microbial respiration in the core of the eddy. Furthermore, surface concentrations of particles exceed open-ocean conditions as found at CVOO by a factor of 2 to 3. This is in line with Löscher et al. (2015) who described a threefold higher primary production for surface waters inside the eddy as compared to the outside. In the Mauritanian shelf area particle concentrations are high throughout the water column (Figure 6).”

RC36: page 13 lines 30-31: “according to Hauss et al (2015)”, is this the same eddy?

AC36: Yes, it is.

RC37: page 17, lines 22-32: In the first paragraph of the conclusions the authors are very generic about their findings regarding the eddy bgc composition discussed in the sections from 3.1 to 3.4. Some of the results are not recalled (eg, particle, POM and DOM distribution). Since many interesting findings are discussed in the paper, I strongly suggest strengthening this part of the conclusion.

AC37: We agree and also see the need to improve this section. We will extend this section and ensure to cover all relevant findings of this paper.

RC38: Figure 2: colorbar and legend seem to contradict each other: if orange points refer to ACME (M105), what do the blue points refer to? This choice of colormap is unhelpful, the color is mostly constant.

AC38: We agree that the legend is misleading due to the color. We will change this in a revised version of this figure and may also consider adjusting the non-linearity of the colorbar.

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