## **Response to the Reviewer**

We would like to thank the Reviewer for providing constructive and insightful comments. We incorporated the suggestions into a revised manuscript. Reviewer 1's comments have been reproduced below in black, with the authors' response in blue.

I might recommend the authors include a key at the beginning of the paper that lists all the abbreviations and their definitions. There is a lot to keep track of here.

We added a list of symbols at beginning of the Methods section:

2.1 List of symbols (unit)						
total alkalinity (µmol kg <sup>-1</sup> )						
backscatter signal (engineering units)						
amount content ( $\mu$ mol kg <sup>-1</sup> )						
amount concentration (mmol m <sup>-3</sup> )						
chlorophyll a						
dissolved inorganic carbon						
entrainment flux (mmol m <sup>-2</sup> d <sup>-1</sup> )						
diapycnal eddy diffusion flux (mmol $m^{-2} d^{-1}$ )						
fugacity of CO <sub>2</sub> (µatm)						
inventory (mmol m <sup>-2</sup> )						
diapycnal eddy diffusivity (m <sup>2</sup> s <sup>-1</sup> )						
net community production (mmol $m^{-2} d^{-1}$ )						
partial pressure of CO <sub>2</sub> (µatm)						
practical salinity (1)						
time (s)						
wind speed (m $s^{-1}$ )						
dry mole fraction (mol mol <sup>-1</sup> )						
depth of the deep chlorophyll maximum (m)						
inventory integration depth (m)						
mixed layer depth (m)						
air-sea flux (mmol $m^{-2} d^{-1}$ )						
CO <sub>2</sub> optode CalPhase (°)						
potential density (kg m <sup>-3</sup> )						
Celsius temperature (°C)						
response time (s)						

Line 375: Shouldn't the units for eddy diffusivity be m2 s-1? We corrected the units to  $m^2 s^{-1}$  here and also in the caption of Figure A2.

Figure 11: Discrete samples (red dots) plotted after 01/06 agree with SOCAT data from 14/06/14 but both these measurements are lower than the Seaglider fCO2 by ~90 uatm. Is the result of a difference in where the "discrete samples" were collected (Seaglider transect vs. SOCAT transect)? Please clarify. We changed to a new calibration method including temperature to better match the SOCAT data. In the previous manuscript, the CO<sub>2</sub> optode signal ( $p_c(CO_2)$ ) was calibrated just using a regression against the CO<sub>2</sub> concentrations of the discrete water samples ( $c_{WS}(CO_2)$ ). Plotting the regression residuals ( $c_r(CO_2)$ , calculated as  $c_{WS}(CO_2)$  minus the value predicted by the regression) revealed a quadratic correlation between the regression residuals and water temperature ( $\theta$ ) (Figure R1).



Figure R1: Residuals of the regression  $c_{WS}(CO_2)$  versus  $p_c(CO_2)$  plotted against water temperature ( $\theta$ ).

We have therefore included  $\theta$  and  $\theta^2$  in the optode calibration (revised Figure 6a below). This new calibration increased the correlation coefficient  $R^2$  from 0.77 to 0.90 and decreased the standard deviation of the regression residuals from 1.3 to 0.8 µmol kg<sup>-1</sup>. Even with this calibration, the CO<sub>2</sub> optode response remained more closely related to  $c(CO_2)$  than  $p(CO_2)$  (Figure 6b).



**Figure 6:** Regression (black lines, reg1) of the CO<sub>2</sub> optode output  $p_c(CO_2)$  against a) co-located concentration  $c_{WS}(CO_2)$  that has an uncertainty of 0.28 µmol kg<sup>-1</sup> b) and partial pressure  $p_{WS}(CO_2)$  of CO<sub>2</sub> in discrete water samples (black dots). Also shown are the values predicted by including  $\theta$  and  $\theta^2$  in the regression used for optode calibration (red dots, reg2). The regression equations are: a) reg1:  $c_{WS}(CO_2)/(\mu mol kg^{-1}) = (0.033\pm 0.003)p_c(CO_2)/\mu atm - 1.8\pm 1.6$  ( $R^2 = 0.77$ )

a) reg2:  $c_{WS}(CO_2)/(\mu mol \text{ kg}^{-1}) = (0.12\pm0.14)\theta/^{\circ}C - (0.071\pm0.011)(\theta/^{\circ}C)^2 + (0.0094\pm0.0048)p_c(CO_2)/\mu atm + 16\pm4 (R^2 = 0.90).$ 

b) reg1:  $p_{WS}(CO_2)/\mu atm = (0.05\pm0.05)p_c(CO_2)/\mu atm + 344\pm33 \ (R^2 = 0.02)$ 

b) reg2:  $p_{WS}(CO_2)/\mu atm] = (21\pm3)\theta/^{\circ}C - (1.9\pm0.2)(\theta/^{\circ}C)^2 + (0.2\pm0.1)p_{c}(CO_2)/\mu atm + 209\pm76 \ (R^2 = 0.60)."$ 

With the new calibration, our estimate of CO<sub>2</sub> optode-derived fugacity  $f_t(CO_2)$  follows SOCAT  $f_{SOCAT}(CO_2)$  much better, including the decrease of  $f(CO_2)$  in the middle of June from 380 to 300 µatm (Figure 11).



**Figure 11:** Comparison between surface  $f(CO_2)$  from 2014 SOCAT and  $CO_2$  optode on the glider. Top panel: The black lines are the median glider  $f(CO_2)$  in the top 10 meters, with  $f_c(CO_2)$  (dotted line) corresponding to regression 1 (Figure 6a) and  $f_i(CO_2)$  (continuous line) to regression 2 (Figure 6b). Discrete samples collected during the deployment are shown as red dots, with the other coloured dots representing cruises in the SOCAT database (Bakker et al., 2016). Bottom panel: Glider and SOCAT data positions (same colours as in the top panel).

In the new version of the manuscript we changed section 2.5, line 253-256: "Plotting the regression residuals  $(c_r(CO_2), \text{ calculated as the difference between } c_{WS}(CO_2)$  and the value predicted by the regression) revealed a quadratic relation between the regression residuals and water temperature ( $\theta$ ). We have therefore included  $\theta$  and  $\theta^2$  in the optode calibration (Figure 6a). This second calibration increased the correlation coefficient  $R^2$  from 0.77 to 0.90 and decreased the standard deviation of the regression residuals from 1.3 to 0.8 µmol kg<sup>-1</sup>. Even with the explicit inclusion of temperature in the calibration, the CO<sub>2</sub> optode response remained more closely related to  $c(CO_2)$  than  $p(CO_2)$  (Figure 6b)."

We also recalculated  $\Phi(CO_2)$  and N(DIC). This resulted in changes to section 2.5, 3.1, 3.2. 3.4, 4.1 and 4.2 and figures 10, 11, 12 and 14.

Lines 610-614: The position, years, and seasons/months information for the comparative studies might be better summarized in Table 3 rather than written out in the text. (just my opinion). We have moved all this information to the Table 3 caption.

Lines 620-627: The N(CT) and N(O2) estimates do not change appreciably for integration depths of 30 and 45 m, but the N(CT) values drops considerably when the integration depth is increased to 100 m whereas N(O2) changes very little. The authors state that the lack of change in O2 resulted from the fact that the air-

sea flux dominated the oxygen budget. I'm not sure I fully understand. The authors indicate that the decrease in N(CT) was likely the result of remineralization of organic matter below the euphotic zone; such remineralization must also decrease N(O2). If I am not mistaken, the impact of the air-sea flux of O2 "extends" to the integration depth of 100m because of the deep mixing that occurs until June. For the latter period when the water column in more stable, does the deepening of the integration depth decrease N(O2) appreciably?

Following our improved CO<sub>2</sub> optode calibration, we have recalculated net community production  $N(O_2)$  and N(DIC) and updated Table 3 (see revised version below). This has led to a marked change in the magnitude and depth-variation of the N(DIC) estimates. For a 30 m integration depth, the new estimates are 4.1 and 3.1 mol m<sup>-2</sup> a<sup>-1</sup>, respectively (for the period March to July covered by glider measurements of both O<sub>2</sub> and DIC concentrations). For a 45 m integration depth, the corresponding estimates are similar at 4.2 mol m<sup>-2</sup> a<sup>-1</sup> for  $N(O_2)$  and 3.3 mol m<sup>-2</sup> a<sup>-1</sup> for N(DIC). For a 100 m integration depth,  $N(O_2)$  decreased to 3.7 mol m<sup>-2</sup> a<sup>-1</sup> (about 12 % lower than the 45 m-estimate), whereas N(DIC) remained at 3.3 mol m<sup>-2</sup> a<sup>-1</sup>. The lower  $N(O_2)$  value for 100 m is due to the inclusion of remineralisation below the euphotic zone. This is not captured by our N(DIC) estimate, likely due to uncertainties in the c(DIC) calibration. Extending the integration period until the end of the deployment (30 October 2014) increased  $N(O_2; 30 \text{ m})$  to 5.0 mol m<sup>-2</sup> a<sup>-1</sup>,  $N(O_2; 45 \text{ m})$  to 4.9 mol m<sup>-2</sup> a<sup>-1</sup> and decreased  $N(O_2; 100 \text{ m})$  slightly to 3.6 mol m<sup>-2</sup> a<sup>-1</sup>.

**Table 3.** Net community production (*N*) estimates in the Norwegian Sea (with integration depth  $z_{\text{lim}}$ ). Falck and Anderson (2005) used year-round data from 1960 to 2000 between 62 and 70° N and from 1991 to 1994 at OWSM. Skjelvan et al. (2001) used year-round data from 1957 to 1970 and from 1991 to 1998 between 67.5° N 9° E and 71.5° N 1° E and along 74.5° N from 7 to 15° E. Kivimäe (2007) used year-round data from 1955 to 2005 and Falck and Gade (1999) used year-round data from 1955 to 1988 in all of the Norwegian Sea. While the previous studies report annual *N* estimates, the present study derives *N*(O<sub>2</sub>) between March and October and *N*(DIC) between March and July.

Study	N(DIC) / mol m <sup>-2</sup> a <sup>-1</sup>	$\frac{N(O_2)}{\operatorname{mol} \operatorname{m}^{-2} \operatorname{a}^{-1}}$	N(O <sub>2</sub> ) / N(DIC)	z <sub>lim</sub> / m	Variables used to derive N
(Falck and Anderson, 2005), annual	3.4	—		100	$c(\mathrm{NO}_3^-), c(\mathrm{PO}_4^{3-}), c(\mathrm{DIC})$
(Skjelvan et al., 2001), annual		2.6		300	$c(O_2), c(PO_4^{3-})$
(Kivimäe, 2007), annual	_	11 (4.7 to 18.3)		z <sub>mix</sub> until 100 m	<i>c</i> (O <sub>2</sub> )
(Falck and Gade, 1999), annual		3.9		30	$c(O_2)$
This study, March to July	3.1	4.1	1.3	30	$c(O_2), c(DIC)$
This study, March to July	3.3	4.2	1.3	45	$c(O_2), c(DIC)$
This study, March to July	3.3	3.7	1.1	100	$c(O_2), c(DIC)$
This study, March to October		5.0			
This study, March to October		4.9			
This study, March to October		3.6			

Lines 628-637: The implied PQ values of 4, instead of 1.3-1.6, are quite surprising and I would have appreciated a bit more explanation from the authors. They briefly discuss wider variations in carbon:nutrient ratios, with examples in deeper waters during remineralization which does not necessarily apply here. Can the authors provide other examples of such a high C:O2 ratio from other studies? The potential implications of such a large, apparent deviation of C:O2 from traditional PQ values is important and deserve a bit more attention. Otherwise, readers are left to question the accuracy of N(CT) and/or N(O2) estimates. Using the revised calibration we find a PQ value of 1.3 for integration depths of 30 and 45 m and 1.1 for an integration depth of 100 m, but – as discussed above – we suspect that the lower value at 100 m may be due to c(DIC) calibration uncertainties. These PQ values are in agreement with the original Redfield ratio of 1.3 (Redfield, 1963) and other studies which found PQ values of  $1.45\pm0.15$  for new production and  $1.1\pm0.1$  for recycled production (Anderson, 1995; Anderson and Sarmiento, 1994; Laws, 1991).

## **Response to the Editor**

We would like to thank the Editor for providing constructive and insightful comments. We incorporated his suggestions into a revised manuscript. The Editor's comments have been reproduced below in black, with the authors' response in blue.

There is a bit of a more important comment, which was mentioned by the referee and which I encourage you to give attention. This is in regard of the very high PQ value (O2:CO2 ratio) of the NCP. This is much higher than the usual ratio which is close to 1. It is very important to discuss this in much detail and where you show that this is realistic. The short discussion in the revised manuscript is not sufficient for this purpose. Possibly a better explanation for this high ratio is some error in the calculations or assumptions for calculating NCP. I encourage you to check all calculations carefully.

This comment inspired a new calibration of the  $CO_2$  optode that includes temperature (see response to Reviewer 1). This resulted in PQ values much closer to the "canonical" range of  $1.45\pm0.15$  for new production and  $1.1\pm0.1$  for recycled production (Anderson, 1995; Anderson and Sarmiento, 1994; Laws, 1991).

I suggest you use the more common abbreviations which makes reading much easier: NCP Net Community Production; GPP Gross Primary Production; CR Community Respiration

In the new version of the manuscript, we use NCP, GPP and CR as abbreviations of net community production, gross primary production and community respiration. We continue to use a single letter N as symbol of the quantity net community production (as per international conventions, which recommend the use of a single Greek or Latin letter in italics as a physical quantity symbol [with the only exceptions being pH and certain characteristic transport numbers of dimension 1, e.g. Schmidt number *Sc*, Rayleigh number *Ra*, etc.]).

Some data sets, taken or downloaded from other institutes, are mentioned in the manuscript. Please acknowledge its use and check if there is a specific request of the data originators in a fair data use statement for acknowledging.

We acknowledge the scientists, engineers, and crew that contributed to the glider mission and data collection along the glider transect and at Ocean Weather Station M (OWSM). Also, we thank Kristin Jackson-Misje, who performed all the carbon analyses.

The Acknowledgements section is the following (line 701-708): "Luca Possenti's PhD project is part of the Next Generation Unmanned Systems Science (NEXUSS) Centre for Doctoral Training which is funded by the Natural Environment Research Council (NERC) and the Engineering and Physical Science Research Council (EPSRC) [grant number NE/N012070/1]. We would like to thank the scientists, engineers, and crew that contributed to the glider mission and data collection along the glider transect and at Ocean Weather Station M (OWSM). We also would like to thank Kristin Jackson-Misje, who performed all the carbon analyses, as well as Michael Hemming and Bastien Queste for their initial contributions to the data analysis."

L15-16 ... in the Norwegian Sea from March to October 2014. We changed the sentence as suggested.

L21 ... in situ CT measurements. Instead of direct? We replaced "direct" with "in situ".

L46 "to observe CO2 variability" Not only the variability is important, but generally CO2, its trends and variability.

We mentioned trends and now the sentence is: "For that reason, it is important to develop precise, accurate and cost-effective tools to observe CO<sub>2</sub> trends, variability and related processes in the ocean."

L67 c(O2) has not been explained before. Please do that here as this is not the usual notation for a concentration.

We explain that  $c(O_2)$  represents the oxygen (amount) content (in µmol kg<sup>-1</sup>), in contrast to the O<sub>2</sub> (amount) concentration  $C(O_2)$ . See also the new list of symbols in Section 2.1 in our response to Reviewer 1 and the paper of Cvitaš (1996) on "Quantities describing compositions of mixtures".

L85 The sentence is not logical. I suggest something like: ... varies during the year and 5 different periods can be discerned. Thanks for the suggestion, we changed the sentence as suggested.

L102-106 The info given here is exactly the info which appears in Table 1. It should be deleted or strongly shortened.

We removed all 4 lines.

L115, 117 Caption of Figure 1: What is shown are not the water masses, but the currents. Please change to make consistent.

We replaced water masses with currents.

L116 Define OWSM We define OWSM as Ocean Weather Station M.

L123-124 Mentioned are 4 cruises, but there are 5 dates for those. Please correct the inconsistency. Thanks for spotting this error; there are indeed 5 cruises and we updated the manuscript.

L144 It is contended here that the uncertainty in the nutrient concentration is negligible to the calculated c(CO2). However, it is not mentioned what the uncertainty in c(CO2) is, which is vital info here. We added the uncertainty of  $c(CO_2)$  calculated using as input the precision of  $A_T$  and c(DIC). The derived  $c(CO_2)$  uncertainty is 0.28 µmol kg<sup>-1</sup>.

We changed section 2.2, line 166-167: "The precision of  $A_T$  and c(DIC) led to an uncertainty in the calculated  $c(CO_2)$  of 0.28 µmol kg<sup>-1</sup>."

Section 2.2. Give precision and accuracy of all measurements. Were CRMs used during the CT and AT analyses? How long have the samples been stored before analysis after the cruises? The samples were analysed within 14 days after the collection. During the analyses were used the batches 118 and 138 of Certified Reference Material (CRM) provided by professor A. Dickson, Scripps Institution of Oceanography, San Diego, USA (Dickson et al., 2003).

We changed section 2.2, line 151-152: "The c(DIC) and  $A_T$  samples were preserved with saturated HgCl<sub>2</sub> solution (final HgCl<sub>2</sub> concentration: 15 mg dm<sup>-3</sup>) and analysed within 14 days after the collection." Line 155-157: "The precision of the samples' c(DIC) and  $A_T$  values was 1 µmol kg<sup>-1</sup> for both, based on duplicate samples and running Certified Reference Material (CRM) batch numbers 118 and 138 provided by professor A. Dickson, Scripps Institution of Oceanography, San Diego, USA (Dickson et al., 2003)."

L148 do you mean: ... which is even worse for the ...

Yes, we updated the sentence to: "which is even worse for the fast-response foils in the 4330F optode for glider deployments."

L149 I think it is more correct to state: It has been suggested that it is necessary to calibrate We changed the sentence as recommended: "It has been suggested that it is necessary to calibrate and drift correct the optode using discrete samples or in-air measurements (Nicholson and Feen, 2017)."

L178 16 March (format) We changed the date format to 16 March.

L224 "... was rLOWESS-smoothed to remove ... " Is this correct? It is hard to understand when a reader is not familiar with this. Please rewrite so that the function or routine becomes clearer. In the new manuscript, we explain that rLOWESS is a built-in Matlab function.

We changed section 2.5, line 250-251: "Before the lag correction,  $\varphi_{cal,d}$  was smoothed to remove any outliers and "kinks" in the profile using the Matlab function rLOWESS."

L250 Figure 6 What is not included in this plot are the uncertainties in the calculated Cws(CO2). I think these are not negligible.

In the new figure caption (see response to Reviewer 1 above), we mention the uncertainty of the calculated

 $c_{WS}(CO_2)$ , which is 0.28 µmol kg<sup>-1</sup>. Even with the improved calibration including temperature, this uncertainty is small compared with the regression residual of 0.8 µmol kg<sup>-1</sup>.

## L330-333 This sentence is too long and therefore not well understandable. Please rephrase.

We changed the sentence to: "This value was calculated using the varying daily-mean wind speed U in the time interval between  $t_n$  and  $t_{n+1}$  ( $\Delta t$ ) (50 days) using a 5 point-median  $z_{mix}$  (section 3.2) (Reuer et al., 2007). The time interval is the same as used to calculate  $\frac{\Delta I(0_2)}{\Lambda t}$ ."

L410 "The uncorrected c(O2) continually decreased (Figure 8c)." This is not clear. Decreased from what to what?

We changed the sentence including the size of the drift that caused a decrease of the deep  $c(O_2)$  (for  $\sigma_0 > 1028$  kg m<sup>-3</sup>) from 289.9 to 282.3 µmol kg<sup>-1</sup>.

We changed section 3.1, line 448-449: "The O<sub>2</sub> optode drift caused a continuous and unexpected decrease of the uncorrected  $c_G(O_2)$  from 290 to 282 µmol kg<sup>-1</sup> for  $\sigma_0 > 1028$  kg m<sup>-3</sup> (Figure 8c)."

L484-486 (Caption Fig 12) I suggest: Air-sea flux of oxygen and CO2 during spring and summer, a) csat(O2) in blue and c(O2) in red, b) csat(CO2) in blue and c(CO2) in red, ...

We changed the figure caption as suggested. The new figure caption is: "**Figure 12**: Air-sea flux of O<sub>2</sub> and CO<sub>2</sub> during spring and summer for CO<sub>2</sub> and during spring, summer and autumn for O<sub>2</sub>, a)  $c_{sat}(O_2)$  in blue and  $c(O_2)$  in red, b)  $c_{sat}(CO_2)$  in blue and  $c(CO_2)$  in red, c)  $\Delta c(O_2) = c(O_2) - c_{sat}(O_2)$ , d)  $\Delta c(CO_2) = c(CO_2) - c_{sat}(CO_2)$ , e) sea surface temperature, f)  $k_w(O_2)$  in blue and  $k_w(CO_2)$  in red normalised back to 50 days (Reuer et al., 2007), g) oxygen air-sea flux  $\Phi(O_2)$  and h) CO<sub>2</sub> air-sea flux  $\Phi(CO_2)$ . The flux from sea to air is positive while that from air to sea is negative."

L496 ... decreased the variability to 68±75 m. We changed the sentence as suggested.

L498-499 "This method was used in order to have similar time interval between repeat occupations of the same transect position to calculate the inventory changes and entrainment." This is duplicated info from the methods section and not needed here.

In the new version of the manuscript, we removed the sentence.

L607-608 The references are not needed here. They appear in Table 3. We removed the references in this section (4.2).

L633-637 This info is not relevant for the case of NCP in the surface layer and should thus be deleted. In the new version of the manuscript, this information has been removed.

L639 Do you not mean inter-annual variability between 1955 and 2005? Yes, in this section we mention the study of Kivimäe (2007) that found a strong inter-annual variability in oxygen net community production.

L638-644 I think this reasoning is not convincing. The explanation mentions the variability, but N(O2) and N(CO2) should, despite this variability, move in similar directions. A reasonable ratio of CO2:O2 should be the result. Is there any literature value of this ration that is that low as in the present study? The improved calibration of the CO<sub>2</sub> optode changed  $N(O_2)/N(DIC)$  ratio to 1.3 for integration depths of 30

and 45 m and 1.1 for an integration depth of 100 m that is in agreement with what was found in previous studies (Redfield, 1963)(Laws, 1991; Anderson and Sarmiento, 1994; Anderson, 1995). – see also our response to Reviewer 1 (p. 4).

We changed section 4.2, line 636-650: "The ratio of  $N(O_2)$  and N(DIC) for an integration depth of 45 m gave a photosynthetic quotient (PQ) of 1.3, in agreement with the Redfield ratio of 1.45±0.15 (Redfield, 1963; Anderson, 1995; Anderson and Sarmiento, 1994; Laws, 1991). The  $N(O_2)$  estimate is influenced primarily by the air-sea exchange flux  $\Phi(O_2)$  (median: 34 mmol m<sup>-2</sup> d<sup>-1</sup>), followed by the inventory change (15 mmol m<sup>-2</sup> d<sup>-1</sup>). In contrast, N(DIC) is dominated by the inventory change (-29 mmol m<sup>-2</sup> d<sup>-1</sup>), followed by  $\Phi(CO_2)$  (-7.0 mmol m<sup>-2</sup> d<sup>-1</sup>). This reflects the slower gas-exchange time constant of CO<sub>2</sub> compared with O<sub>2</sub>, due to DIC buffering. To compare our results with previous studies we also used  $z_{lim} = 30$  m (Falck and Gade, 1999) and 100 m (Falck and Anderson, 2005; Kivimäe, 2007). The calculated N(DIC; 30 m) was 3.1 mol m<sup>-2</sup> a<sup>-1</sup>, N(DIC; 100 m) was 3.4 mol m<sup>-2</sup> a<sup>-1</sup>,  $N(\text{O}_2; 30 \text{ m})$  was 4.1 mol m<sup>-2</sup> a<sup>-1</sup> and  $N(\text{O}_2; 100 \text{ m})$  was 3.7 mol m<sup>-2</sup> a<sup>-1</sup>. The N(DIC; 100 m) value is in agreement with the value of 3.4 mol m<sup>-2</sup> a<sup>-1</sup> given by Falck and Anderson (2005). However, the latter estimate was for the entire year, whereas our estimate only covers the months from March to July.  $N(\text{O}_2)$  was similar for  $z_{\text{lim}} = 30 \text{ m}$  and 45 m, but lower for  $z_{\text{lim}} = 100 \text{ m}$  because of  $\text{O}_2$  consumption during organic matter remineralisation below the euphotic zone. The PQ value at 30 was 1.3 and at 100 m decreased to 1.1."

We changed Figure 9 with  $c(O_2)$  and the saturation ratio,  $s(O_2) = c(O_2)/c_{sat}(O_2)$ , for the whole deployment. We calculated the O<sub>2</sub> air-sea flux for the whole deployment and calculated the CO<sub>2</sub> air-sea flux using the calibrated CO<sub>2</sub> optode output.

We calculated  $N(O_2)$  until 30 October and updated section 3.3 and figure 13..

We also updated section 3.4 and figure 14 with the new estimates of the carbon net community production calculated after the new calibration of the  $CO_2$  optode.

We improved the calibration of the  $c(CO_2)$  optode, which resulted in changes to the DIC-based net community production estimates and brought the  $N(O_2)$ :N(DIC) ratios closer to expected values between 1.1 and 1.6 (see also comment above). We also extended the period the  $N(O_2)$  estimate covers until the end of the deployment (30 October).

We changed section 4.2, line 650-651: "The ratio of  $N(O_2)$  and N(DIC) gives a Redfield ratio of 1.5 that is larger than the original Redfield ratio of 1.3 (Redfield, 1963) but it is in agreement with previous studies (Laws, 1991; Anderson and Sarmiento, 1994; Anderson, 1995)."

L646-667 The Conclusions section: I think this is not how a typical Conclusion section should look like. As it is now, the large first and second paragraphs are just a summary, with no real conclusions in it. Only the final short paragraph complies with the conditions of a Conclusion section.

We changed the entire conclusion section with an explanation of why this study is important and the applications of the  $CO_2$  optode in the future. Also, we suggest similar deployments to fill the spatial gap around the globe of the annual net community production.

We changed section 5, line 673-694: "To the best of our knowledge, this study represents the first glider deployment of a  $CO_2$  optode. The  $CO_2$  optode together with a  $O_2$  optode shows the potential of using these sensors on autonomous observing platforms like Seagliders to quantify the interactions between biogeochemical processes and the marine carbonate system at high spatiotemporal resolution. The deployment helped to uncover NCP and air-sea flux variability over a period of 8 months.

Despite all the problems (drift, lag and poor calibration), the CO<sub>2</sub> optode data could be used to quantify dissolved inorganic carbon concentration variations. The temporal resolution sampling resolution was 106 s in the top 100 m (increasing to 381 s from 500 to 1000 m). This could be improved to less than 10 s, but this would reduce the length of the deployment due to the limited glider battery capacity. With better calibration and stability improvements, the CO<sub>2</sub> optode could be routinely used to measure the carbonate system on gliders, floats and surface vehicles. Glider deployments up to 8 months are possible thanks to the sensor's low power consumption of 8 mW at 5 s sampling intervals and 7 mW at 60 s sampling intervals (Atamanchuk et al., 2014). Combined with other novel sensors that measure another DIC-related quantity such as  $A_{\rm T}$  or c(DIC), CO<sub>2</sub> optodes on gliders could help provide estimates of NCP, air-sea flux, respiration and remineralisation and aragonite saturation.

During our deployment we calculated  $O_2$  and DIC-based NCP over the spring and summer period. In the future, extended deployments could be used to estimate annual (full year) NCP. To have an accurate estimate of annual NCP, at least one additional glider deployment is needed to have continuous coverage (Binetti et al., 2020). Similar deployments can be used in other areas of the globe to fill gaps in N(DIC) and  $N(O_2)$ . In particular, glider deployments have potential in under-sampled areas of the globe such as the Southern Ocean and the Arctic. Also, it can be used in well-studied areas such as North and Mediterranean Sea to reduce monitoring costs and compare NCP estimates with previous studies that used other sampling strategies."

L670 Does this hold for all authors?

Yes, this holds for the authors.

L680 What kind of publication is this? Please add info accordingly.

We removed this citation of a PhD thesis. The papers by Atamanchuk et al. cover the relevant information.

L690-692 There are many more authors on this paper. We updated the citation.

L698-699 There is no journal and volume We updated the citation.

L700 Reference is not correct We updated the citation.

L708 Chu et al: Info missing We updated the citation.

L714 pCO2 (do not use 0) We updated the citation.

There are a large number of incorrect or incomplete references. Please go through all of them for correction. We went through all the references and updated the list.

## References

- Anderson, L. A. (1995) 'On the hydrogen and oxygen content of marine phytoplankton', *Deep sea research part I: Oceanographic research papers*. Elsevier, 42(9), pp. 1675–1680.
- Anderson, L. A. and Sarmiento, J. L. (1994) 'Redfield ratios of remineralization determined by nutrient data analysis', *Global biogeochemical cycles*. Wiley Online Library, 8(1), pp. 65–80.
- Atamanchuk, D. *et al.* (2014) 'Performance of a lifetime-based optode for measuring partial pressure of carbon dioxide in natural waters', *Limnology and Oceanography: Methods*, 12(2), pp. 63–73. doi: 10.4319/lom.2014.12.63.
- Bakker, D. C. E. *et al.* (2016) 'A multi-decade record of high-quality f CO 2 data in version 3 of the Surface Ocean CO 2 Atlas (SOCAT)', pp. 383–413. doi: 10.5194/essd-8-383-2016.
- Cvitaš, T.: Quantities describing compositions of mixtures, Metrologia, 35, 10.1088/0026-1394/33/1/5, 1996.
- Dickson, A. G., Afghan, J. D. and Anderson, G. C. (2003) 'Reference materials for oceanic CO 2 analysis : a method for the certification of total alkalinity', 80, pp. 185–197.
- Foltz, G. R. *et al.* (2003) 'Seasonal mixed layer heat budget of the tropical Atlantic Ocean', *Journal of Geophysical Research: Oceans*. Wiley Online Library, 108(C5).
- Kivimäe, C. (2007) 'Carbon and oxygen fluxes in the Barents and Norwegian Seas: production, air-sea exchange and budget calculations'. The University of Bergen.
- Laws, E. A. (1991) 'Photosynthetic quotients, new production and net community production in the open ocean', *Deep Sea Research Part A. Oceanographic Research Papers*. Elsevier, 38(1), pp. 143–167.
- Nicholson, D. P. and Feen, M. L. (2017) 'Air calibration of an oxygen optode on an underwater glider', *Limnology and Oceanography: Methods*, 15(5), pp. 495–502. doi: 10.1002/lom3.10177.
- Obata, A., Ishizaka, J. and Endoh, M. (1996) 'Global verification of critical depth theory for phytoplankton bloom with climatological in situ temperature and satellite ocean color data', *Journal of Geophysical Research: Oceans.* Wiley Online Library, 101(C9), pp. 20657–20667.
- Redfield, A. C. (1963) 'The influence of organisms on the composition of seawater', *The sea*. Wiley-Interscience, 2, pp. 26–77.
- Reuer, M. K. *et al.* (2007) 'New estimates of Southern Ocean biological production rates from O2/Ar ratios and the triple isotope composition of O2', *Deep Sea Research Part I: Oceanographic Research Papers.* Elsevier, 54(6), pp. 951–974.
- United States. National Environmental Satellite and Information Service, D., Monterey, G. I. and Levitus, S. (1997) *Seasonal variability of mixed layer depth for the world ocean*. US Department of Commerce, National Oceanic and Atmospheric Administration ....