**Reply to Referee #1**

General comments:

This manuscript reports high-resolution measurements of net community production in the coastal South China Sea in summer and fall, as estimated using the dissolved $O_2$/Ar technique. The authors compare measured NCP rates against physical parameters and nutrient concentrations to assess factors influencing the spatial distribution and magnitude of productivity. These new NCP data are a useful contribution in that productivity measurements in this region to date have remained relatively sparse and low-resolution, but apart from presenting this new data the manuscript offers few broader or novel conclusions and the wider scientific significance is limited.

The field, experimental, and statistical analyses appear to have been rigorously conducted largely according to current best practices. In particular the methods indicate a good experimental setup and attention to potential sources of error in field $O_2$/Ar measurements.

In some cases, however, the conclusions regarding the influence of light and nutrients upon productivity patterns that the authors draw from their data and results are not fully appropriate or justified.

The presentation of data in the manuscript and figures is generally good, but leaves some room for improvement. The text could have benefited from better description of some data and variables, while Figure 1 is difficult to interpret, in turn impacting interpretation of other figures and results throughout the paper.

The major point this reviewer would like to stress is that the authors should pay careful attention to qualifying the caveats to some conclusions, while reconsidering other conclusions if they are not fully backed by the presented analyses.

**Response:** Thank you very much for your constructive comments. We have considered all suggestions and incorporated them into the revised version. In the following we answer to your comments point by point and indicate how the manuscript is going to be revised.

1. The conclusion that NCP is subject to nitrogen limitation based on correspondences between elevated NCP rates and DIN concentrations needs further justification. Nutrient concentrations reflect the marine environment at the moment of sampling, while the $O_2$/Ar method integrates over the residence time of biological oxygen in the surface ocean. The residence time is a particularly important factor for the authors to highlight in the manuscript, as it carries important implications for how far temporally removed the measured productivity signal is relative to the cruise measurements. At a minimum, additional discussion of the residence time of the oxygen signal on both cruises and potential associated considerations is necessary. Given the availability of satellite data as presented in He et al., 2016, discussion of the history of the measured water masses should be quite feasible. The reviewer also notes that the nitrogen limitation in this region is hardly a novel finding, as the authors themselves mention in the introduction. Mixed layer depth ranges and $O_2$ surface layer residence time should be directly reported in the text of the results.

**Response:** Thanks for your suggestion. We have reported the residence time of $O_2$ in the mixed layer in both cruises together with other parameters such as mixed layer depth and euphotic depth by adding two tables (Table 1 and 2), and incorporated them into the results and discussion. We have also applied the satellite-Chl a data (https://resources.marine.copernicus.eu) to track the history of shelf water intrusion and combined it with the residence time of $O_2$ to strengthen the reliability of the relationship between NCP and nitrogen we observed. Table 3 and Figure S3 were added in the new version accordingly. Δday in Table 3 is the difference between the date of observation and the start date of shelf water intrusion at stations with surface salinity lower than 33, representing the duration of the shelf water intrusion at each station before our observation. The mixed layer $O_2$ residence time at most stations listed in Table 3 is shorter than or equivalent to Δday. This result suggests that our estimate has appropriately integrated the NCP during the period of shelf water intrusion, which can effectively reflect the influence of shelf water on productive state on the northern slope of SCS in the summer.

The nitrogen limitation in SCS has been reported before, but so far no research has focused on quantifying the NCP enhancement caused by shelf water intrusion in this region. Our research is also the first report that quantifies the contribution of shelf water intrusion to NCP on the northern slope of the SCS in the summer. We have highlighted this in the introduction and conclusion section.

**Table 1.** Basic information at all CTD stations in October 2014

| Station | Date of observation[a] | MLD (m) | $Z_{eu}$[b] (m) | k[c] (m $d^{-1}$) | τ[d] (d) |
|---|---|---|---|---|---|
| O-01 | 2014/10/13 | 58 | 82 | 4.7 | 12 |
| O-02 | 2014/10/13 | 64 | 74 | 5.2 | 12 |
| O-03 | 2014/10/14 | 56 | 84 | 6.2 | 9 |
| O-04 | 2014/10/14 | 54 | 76 | 6.3 | 9 |
| O-05 | 2014/10/20 | 27 | 70 | 7.9 | 3 |
| O-06 | 2014/10/19 | 55 | 62 | 8.4 | 7 |
| O-07 | 2014/10/21 | 40 | 60 | 7.3 | 5 |
| O-08 | 2014/10/21 | 49 | 72 | 7.4 | 7 |
| O-09 | 2014/10/15 | 79 | 96 | 6.2 | 13 |
| O-10 | 2014/10/15 | 68 | 81 | 6.1 | 11 |
| O-11 | 2014/10/15 | 64 | 81 | 5.4 | 12 |
| O-12 | 2014/10/16 | 66 | 74 | 5.2 | 13 |
| O-13 | 2014/10/16 | 48 | 52 | 6.3 | 8 |
| O-14 | 2014/10/17 | 54 | 62 | 6.9 | 8 |
| O-15 | 2014/10/22 | 49 | 68 | 7.0 | 7 |
| O-16 | 2014/10/22 | 50 | 73 | 7.3 | 7 |
| O-17 | 2014/10/23 | 52 | 75 | 7.9 | 7 |
| O-19 | 2014/10/18 | 31 | 64 | 9.4 | 3 |
| O-20 | 2014/10/18 | 35 | 61 | 8.7 | 4 |
| O-21 | 2014/10/18 | 81 | 86 | 6.9 | 12 |
| O-22 | 2014/10/17 | 76 | 102 | 6.0 | 13 |

[a] All dates are in the format of year/month/day. [b] Euphotic depth, defined based on subsurface chlorophyll maximum layer. [c] Gas transfer velocity of $O_2$. [d] Residence time of $O_2$ in the mixed layer, estimated as per MLD/k.

**Table 2.** Basic information at all CTD stations in June 2015

| Station | Date of observation | MLD (m) | $Z_{eu}$ (m) | k (m $d^{-1}$) | τ (d) |
|---|---|---|---|---|---|
| J-01 | 2015/6/18 | 26 | 63 | 2.2 | 12 |
| J-02 | 2015/6/17 | 19 | 80 | 1.9 | 10 |
| J-03 | 2015/6/16 | 20 | 74 | 1.9 | 11 |
| J-04 | 2015/6/15 | 22 | 74 | 1.9 | 11 |
| J-05 | 2015/6/15 | 11 | 78 | 1.2 | 9 |
| J-06 | 2015/6/14 | 24 | 76 | 2.1 | 11 |
| J-07 | 2015/6/13 | 21 | 81 | 2.3 | 9 |
| J-08 | 2015/6/18 | 14 | 56 | 1.7 | 8 |
| J-09 | 2015/6/19 | 17 | 59 | 1.6 | 10 |
| J-10 | 2015/6/19 | 8 | 46 | 1.4 | 6 |
| J-11 | 2015/6/20 | 8 | 40 | 2.8 | 3 |
| J-12 | 2015/6/21 | 16 | 45 | 3.0 | 5 |
| J-13 | 2015/6/21 | 19 | 45 | 2.3 | 8 |
| J-14 | 2015/6/24 | 28 | 55 | 4.0 | 7 |
| J-15 | 2015/6/24 | 17 | 42 | 5.3 | 3 |
| J-16 | 2015/6/25 | 10 | 19 | 5.7 | 2 |

**Table 3.** The start date and duration (Δday) of shelf water intrusion at stations with surface salinity lower than 33 in June 2015

| Station | Date of observation | Start date of shelf water intrusion | Δday[a] | τ (d) |
|---|---|---|---|---|
| J-09 | 2015/6/19 | 2015/6/10 | 9 | 10 |
| J-10 | 2015/6/19 | 2015/6/13 | 6 | 6 |
| J-11 | 2015/6/20 | 2015/6/13 | 7 | 3 |
| J-12 | 2015/6/21 | 2015/6/13 | 8 | 5 |
| J-13 | 2015/6/21 | 2015/6/13 | 8 | 8 |
| J-16 | 2015/6/25 | before 2015/6/10 | > 15 | 2 |

[a] The difference between the date of observation and the start date of shelf water intrusion at listed stations.

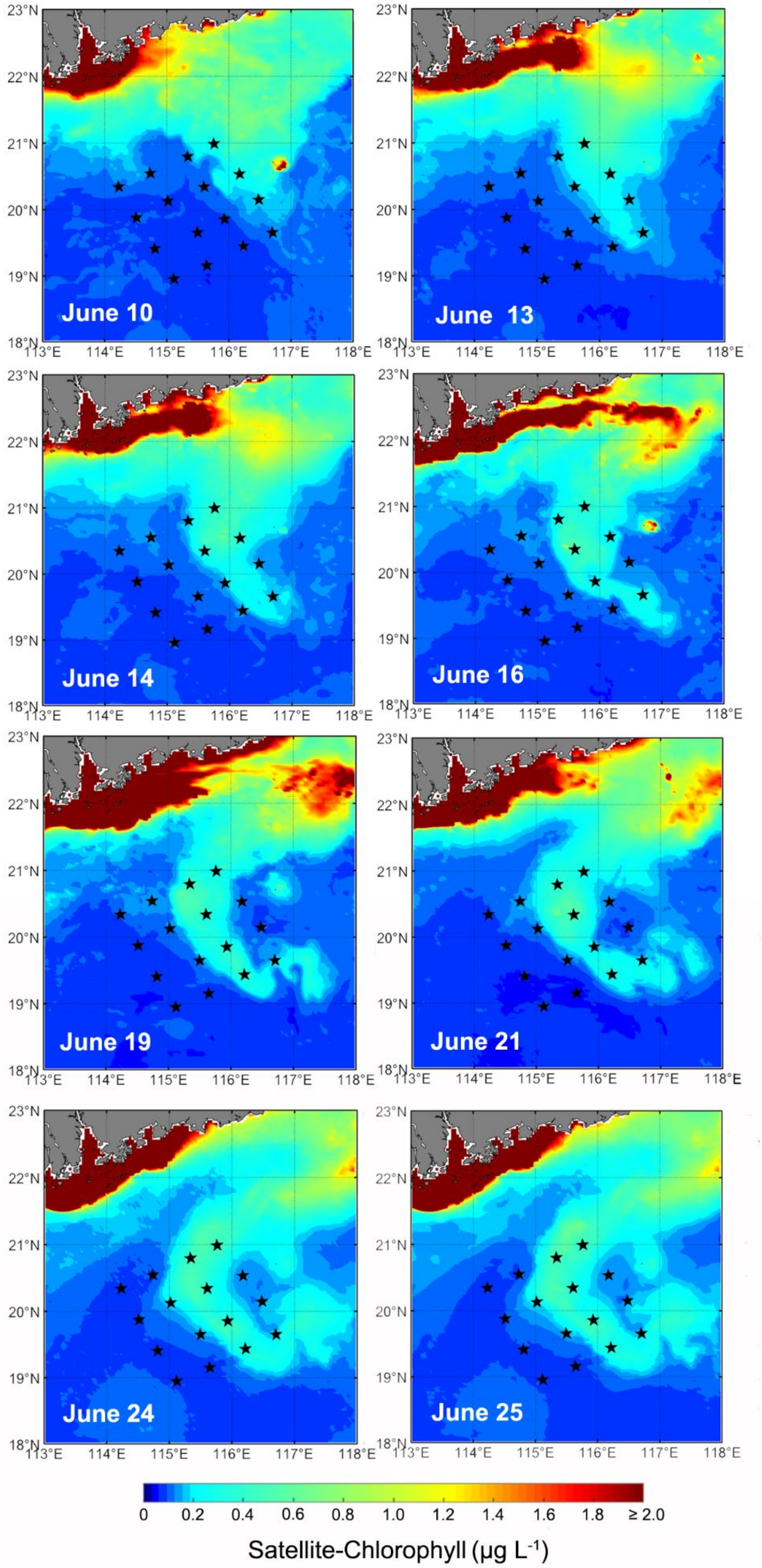


**Figure S3.** Daily satellite-chlorophyll on selected date from June 10 to 25, 2015. Stars represent CTD locations. We roughly set light blue (represents ~ 0.2 μg $L^{-1}$) in this figure as the criterion of shelf water

2. Similarly, assertions regarding the influence of light availability on NCP are questionable. Are MLDs around the time of these cruises really deep enough for light to influence mixed-layer productivity? In June of 2015 the data indicate that the maximum MLD value was just 30m. Water column PAR and Chl profiles are undoubtedly available from the CTD casts and should be presented and discussed in the context of such claims. A June 2015 Chl-a maxima of 0.6 ug/L certainly suggests that biomass-induced light attenuation in the mixed layer wouldn't be an issue, etc: : : Furthermore, residence time should once again be discussed, as light limitation is a factor influencing the time integrated productivity signal over the relevant wind speed history at the measurement sites. Figure 10 also seems to suggest that the strength of MLD relationships with NCP are dependent on a relatively low number of data points.

**Response:** Thanks for your suggestion. Because of your comment and the comments of reviewer 2, we have noticed the limitation of our analysis of MLD and $NCP_{vol}$. The negative correlation between $NCP_{vol}$ and MLD we obtained may partly result from that $NCP_{vol}$ is calculated by NCP/MLD. Thus we calculate an average surface PAR by integrating the daily satellite-PAR data obtained from NASA's ocean color website (https://oceancolor.gsfc.nasa.gov/l3) over the residence time of $O_2$ at each selected station in October 2014. 8-day PAR data were used to estimate the missing daily data. Then we use light attenuation coefficient ($K_d$) to calculate an average PAR in the mixed layer to make a correlation analysis with NCP. This new analysis gives a result that light availability is not a limitation on NCP in the SCS (Table 4), much more convincing than the former analysis just based on MLD.

The calculation of $K_d$ basically based on Lambert-Beer law (Kirk 1994; Jerlov 1976):

$$K_d = -\frac{1}{z}\ln\frac{E_d(z)}{E_d(0)} = \frac{4.605}{Z_{eu}}$$

Where $K_d$ ($m^{-1}$) is the light attenuation coefficient in the euphotic layer; $E_d(0)$ is the PAR at the surface, integrating an average over the residence time of $O_2$ before our observation, in the unit of mol $m^{-2}$ $d^{-1}$; z represents a depth (m) and $E_d(z)$ is the PAR at this depth; $Z_{eu}$ is the euphotic depth (m).

**References:** Kirk, J. T.: Light and photosynthesis in aquatic ecosystems, Cambridge university press, UK, 1994.

Jerlov, N. G.: Marine optics, Elsevier, Netherlands, 1976.

**Table 4.** Satellite-PAR data and NCP at selected stations in October 2014

| Station | Date of observation | MLD (m) | $Z_{eu}$ (m) | Surface PAR[a] (mol $m^{-2}$ $d^{-1}$) | $K_d$ ($m^{-1}$) | ML PAR[b] (mol $m^{-2}$ $d^{-1}$) | NCP (mmol C $m^{-2}$ $d^{-1}$) |
|---|---|---|---|---|---|---|---|
| O-01 | 2014/10/13 | 58 | 82 | 42.0 | $5.6 * 10^{-2}$ | 12.0 | 3.0 |
| O-02 | 2014/10/13 | 64 | 74 | 42.0 | $6.2 * 10^{-2}$ | 10.0 | 15.1 |
| O-03 | 2014/10/14 | 56 | 84 | 41.1 | $5.5 * 10^{-2}$ | 12.4 | 10.1 |
| O-08 | 2014/10/21 | 49 | 72 | 38.7 | $6.4 * 10^{-2}$ | 11.4 | 15.7 |
| O-10 | 2014/10/15 | 68 | 81 | 40.0 | $5.7 * 10^{-2}$ | 9.8 | 4.4 |
| O-13 | 2014/10/16 | 48 | 52 | 39.2 | $8.9 * 10^{-2}$ | 8.7 | 15.3 |
| O-15 | 2014/10/22 | 49 | 68 | 38.6 | $6.8 * 10^{-2}$ | 10.8 | 16.3 |
| O-20 | 2014/10/18 | 35 | 61 | 39.2 | $7.5 * 10^{-2}$ | 13.3 | 16.4 |
| O-22 | 2014/10/17 | 76 | 102 | 42.2 | $4.5 * 10^{-2}$ | 11.6 | 15.7 |

[a] Average surface PAR over the residence time of $O_2$ in the mixed layer. [b] Average PAR in the mixed layer.

3. The claim at lines 426-428 that "there was no significant productivity below the mixed layer that was missed by underway sampling" also seems unjustified and contradicts earlier results and text. Earlier for instance, the authors note that a subsurface oxygen maximum is a characteristic feature in the South China Sea, and significant subsurface productivity is observed in many oligotrophic regions globally such as the Sargasso Sea. Vertical Chl profiles would again be important evidence to present in support of the claim that underway measurements did not miss significant subsurface production.

**Response:** Sorry for this arbitrary conclusion. We have deleted it. Subsurface chlorophyll maximum layer (SCML) existed at all stations in both cruises, while the obvious subsurface $O_2$ maximum just existed in Transect 1 and 2 in June 2015. We have reported these results in section 3.2. Both SCML and subsurface $O_2$ maximum were below the MLD, indicating that they might not influence the NCP in the mixed layer a lot.

4. In general, since Delta $O_2$/Ar is directly used to calculate NCP, reporting and discussing relationships between Delta $O_2$/Ar and other parameters provides little value. This reviewer would recommend removing discussions of Delta $O_2$/Ar versus Chl, MLD, and so on from the manuscript.

**Response:** Thanks for your suggestion. We have done that and also removed related figures from Figure 8 and 9.

5. The authors should also consider whether alternative hypotheses (nutrient co-limitation, limitation by a non-measured variable such as Fe, etc: : :) could potentially present alternative explanations for observed patterns/relationships.

**Response:** Thanks for your suggestion. We had tried to analyze the relationships between NCP and Fe, N:P ratio, but we didn't find any valuable result to report. Zhang et al. (2019) reported that Fe may not be a limitation to phytoplankton growth on the northern slope of SCS. In addition, we didn't find significant correlation between Fe (data provided by Ruifeng Zhang) and NCP in the mixed layer in Oct. 2014, thus we didn't report this result. N is acknowledged as the major limitation of primary production in the SCS, and P deficiency usually occurs when excessive river runoff results in a high N:P ratio nutritive state (Lee Chen and Chen 2006). N:P ratio is an important basis for judging whether the main influencing factor on NCP is N or P in the SCS. But most of our nutrients data in the mixed layer are too low to support a convincing analysis of N:P ratio. We have added some background information of these alternative hypotheses in the introduction section.

**References:** Zhang, R., Zhu, X., Yang, C., Ye, L., Zhang, G., Ren, J., Wu, Y., Liu, S., Zhang, J. and Zhou, M.: Distribution of dissolved iron in the Pearl River (Zhujiang) Estuary and the northern continental slope of the South China Sea, Deep. Res. Part II Top. Stud. Oceanogr., 167, 14–24, doi:10.1016/j.dsr2.2018.12.006, 2019.

Lee Chen, Y. and Chen, H.: Seasonal dynamics of primary and new production in the northern South China Sea: The significance of river discharge and nutrient advection, Deep Sea Res. Part I Oceanogr. Res. Pap., 53(6), 971–986, doi:10.1016/j.dsr.2006.02.005, 2006.)

**Specific comments:**

Lines 13-14: it should be clarified at the very start of the abstract that the $O_2$/Ar ratio refers to dissolved gases in surface seawater.

**Response:** Following your suggestion, we started the abstract with *"Dissolved oxygen-to-argon ratios ($O_2$/Ar) in the oceanic mixed layer has been widely used to estimate net community production (NCP), which is the difference between gross primary production and community respiration and is a proxy of carbon export from the surface ocean."*.

Line 32: Rather than oceanic $CO_2$ uptake, which is strongly dominated by physical factors, it might be more appropriate to say that oceanic carbon sequestration is regulated by primary production and export.

**Response:** Thanks for your suggestion. We have changed the oceanic $CO_2$ uptake to oceanic carbon sequestration.

Line 38: No longer recent: : : quite an established technique at this point.

**Response:** We agree with the reviewer that using the $O_2$/Ar ratio to estimate NCP is an established technique, hence the word 'Recently' was deleted.

Line 41: No longer clear that coastal $O_2$/Ar-derived estimates of NCP are sparse.

**Response:** Thanks for your suggestion. We have revised this paragraph and it now reads as *"During recent years, several high-resolution measurements of $O_2$/Ar and NCP in coastal waters have been reported (Tortell et al., 2012; Tortell et al., 2014; Eveleth et al., 2017; Izett et al., 2018). Despite the coastal waters such as shelves and estuaries only account for 7 % of the global ocean surface area, they are known to contribute to 15–30 % of the total oceanic primary production (Bi et al., 2013; Cai et al., 2011) and play an important role in marine carbon cycle and production. However, these regions still suffer from low resolution measurements and are poorly represented in global NCP data sets."*

Line 97: This is minor, but the original publication describing the MIMS technique (Tortell, L&O: Methods, 2005) should be cited here.

**Response:** Thanks for your suggestion. We have cited this paper here.

Line 158: Clarify units.

**Response:** The unit here is $\mu g\ L^{-1}$.

Lines 170-175: For this section, units for density should be in kg/mˆ3 to arrive at the correct units for NCP, or the appropriate conversion factor

**Response:** We have revised it as suggested.

Line 181: remove "excellent"

**Response:** We have deleted it.

Lines 213-220: Encourage authors to also display the ranges for SSS and Chl-a for the June 2015 cruise using the same format employed in the paragraph above for the October 2014 cruise, for consistency and clarity.

**Response:** Thanks for your suggestion. We have done that as suggested.

Lines 225-227: Elaborating on the assertion that high $O_2$/Ar and low $pCO_2$ signify a strong biological $CO_2$ sink may be useful. The $pCO_2$ values are indeed considerably low and I would be curious about the associated residence time of $O_2$/Ar on Transect 3.

**Response:** Thanks for your suggestion. We have applied an atmospheric $pCO_2$ obtained in July 2015 in the SCS to calculate a $\triangle pCO_2$, directly showing the difference of $pCO_2$ between surface water and atmosphere. We have also cited related paper to clarify that the negative $\triangle pCO_2$ in Transect 3 represented a strong $CO_2$ sink (Li et al., 2020). It's arbitrary to say "biological $CO_2$ sink", because this strong sink might not be totally caused by biological process. Thus we delete "biological". Residence time of $O_2$ at all CTD stations has been shown in Table 1 and 2.

**References:** Li, Q., Guo, X., Zhai, W., Xu, Y. and Dai, M.: Partial pressure of $CO_2$ and air-sea $CO_2$ fluxes in the South China Sea: Synthesis of an 18-year dataset, Prog. Oceanogr., 182, doi:10.1016/j.pocean.2020.102272, 2020.

Line 236 and elsewhere: Here and throughout the paper, you are reporting averages as ##.## +/- ##.##. You should specify that these represent avg +/- std dev: : : etc: : :

**Response:** Thanks for your suggestion. We have clarified this in the first paragraph of Results and Discussion： *"In addition, please note that all averages we have published in this paper are reported in the format of mean ± standard deviation"*.

Lines 299-301: Keep it clear in this sentence that upwelling does not necessarily produce an underestimation of NCP. It is more accurate to say that subsurface waters may have different (either more positive or more negative) $O_2$/Ar signatures that could produce either an underestimation or an underestimation of NCP, as you explain a few sentences later in the context of subsurface $O_2$ maxima in oligotrophic regions.

**Response:** Thanks for your suggestion. We have revised the sentences as "*Vertical mixing is considered the largest source of error in $O_2$/Ar-based NCP estimates because the upwelled subsurface water with different $O_2$/Ar signatures can produce either an overestimation or an underestimation of NCP in the mixed layer (Cassar et al., 2014; Izett et al., 2018). Former researches usually ignored the underestimated negative NCP that caused by vertical mixing (Giesbrecht et al., 2012; Reuer et al., 2007; Stanley et al., 2010).*"

Lines 313-315: The cutoff for salinity to account for waters influenced by shelf water injection is justified, but the cutoff intended to exclude regions with upwelling seems somewhat arbitrary.

**Response:** Sorry for that. We have specified the criteria of upwelling as "*the regions with negative NCP and the regions with salinity higher than 33.5 and temperature lower than 30 °C in Transect 4*". There are lots of overlap of these two criteria, effectively removing the upwelling regions.

Line 330: Consideration of other explanations is needed in this section as described in the general comments.

**Response:** Thanks for your suggestion. We have reported the residence time of $O_2$ and related it to the history of shelf water intrusion based on daily satellite-chl a data in the revised manuscript. Please see our reply to comments 1 for more detail.

Lines 412-418: As mentioned in the general comments, is it even meaningful to analyze the influence of light limitation on NCP when the euphotic zone is 2-7 times the depth of the mixed layer in this region? Much more discussion is needed to back this light limitation idea. Cassar et al 2011 makes the point for instance that MLD is not the only factor affecting light availability.

**Response:** Thanks for your suggestion. Because of your comment and the comments of reviewer 2, we have noticed the limitation of our analysis between MLD and $NCP_{vol}$. Cassar et al. (2011) pointed out that the correlation analysis between MLD and NCP actually reflected an iron-light co-limitation. Thus we decide not to use MLD as an indicator of light availability. In the revised manuscript, we calculate an average surface PAR by integrating the daily satellite-PAR data over the residence time of $O_2$ at each selected station in October 2014. Then we use light attenuation coefficient to calculate an average PAR in the mixed layer to make correlation analysis with NCP. Table 4 was added accordingly to show the results.

Lines 426-428: “This result implied that there was no significant productivity below the mixed layer that was missed by underway sampling.” As mentioned in the general comments, you need to address the contradiction between this and subsurface $O_2$ maxima and potential deep chlorophyll maxima.

**Response:** Sorry for this arbitrary conclusion. We have deleted it. Subsurface chlorophyll maximum layer (SCML) existed at all stations in both cruises, while the obvious subsurface $O_2$ maxima just existed at Transect 1 and 2 in June 2015. We have reported these results in section 3.2. Both SCML and subsurface $O_2$ maxima were below the MLD, indicating that they might not influence the mixed layer NCP a lot in the region without vertical mixing.

Figure 1, lines 681 - 683: please describe what the point and star symbols represent.
Are these the locations of CTD casts? The fact that the color scale in (a) and (b) represents bathymetry should also be stated as well. The cruise path in (a) is also difficult to interpret based on the arrows. This figure is critical for the interpretation of subsequent figures. Perhaps numbering of points on the cruise plan would convey the path of travel better.

**Response:** Thanks for your suggestion. Following your suggestion, we redraw this figure and added an explanation of the symbols and color scales to the caption. Two insets have been added in Figure 1a and 1b to show the station numbers better.

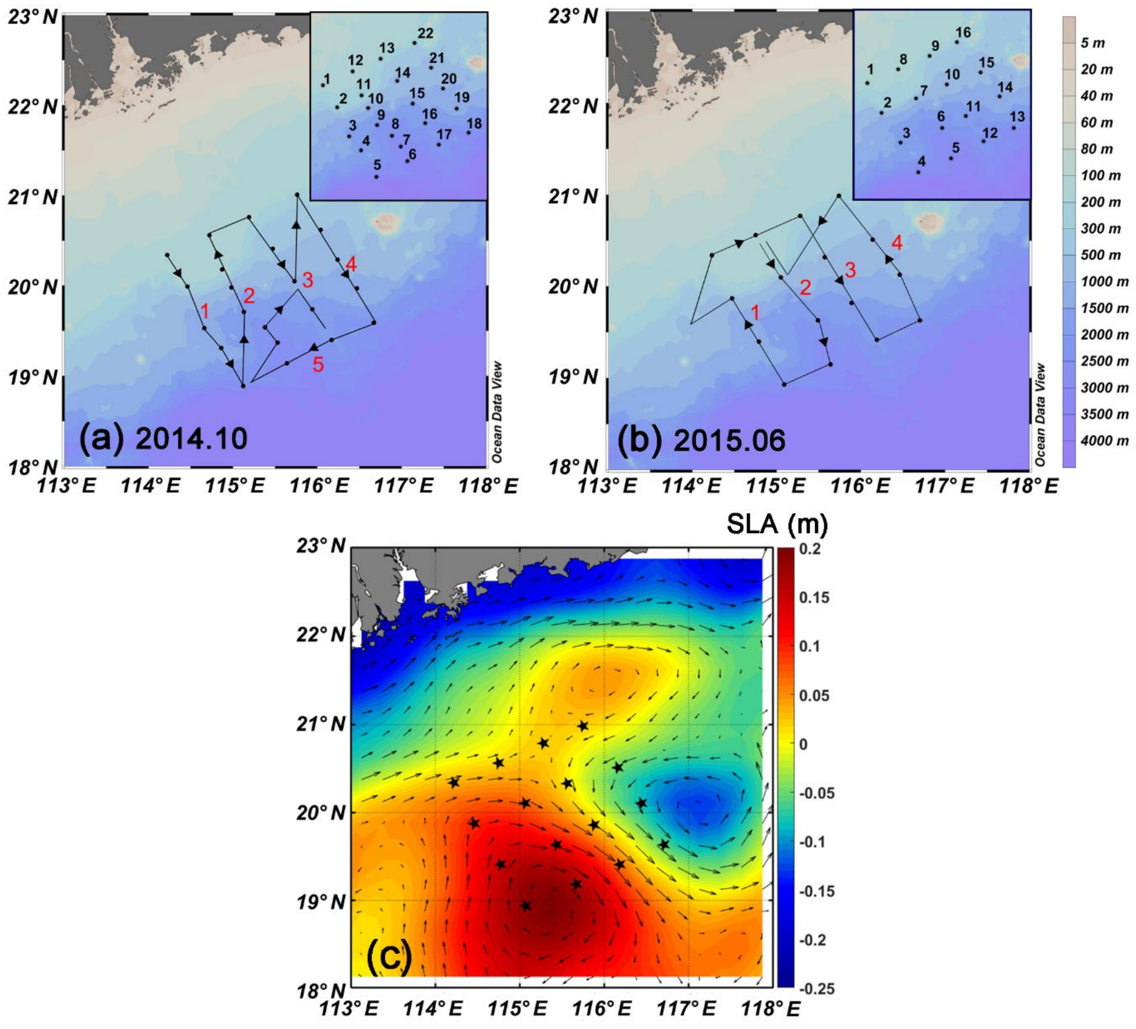

**Figure 1.** Cruise tracks of two cruises in the slope region of the Northern South China Sea in **(a)** October 2014, **(b)** June 2015. The sea level height anomaly (SLA) and geostrophic current during observations in June 2015 (Chen et al., 2016) are shown in **(c)**. The black dots/stars represent the locations of the CTD casts. Red numbers indicate transects, while black numbers indicate the serial number of CTD stations based on the cruise plan. The color scale in **(a)** and **(b)** represents bathymetry.

**Technical corrections:**

Lines 310-318: Here and elsewhere throughout the manuscript, you use sentence structures that rely too heavily on parentheses, which can cause confusion for readers.These sentences in particular are very difficult to interpret.

General: There are some grammatical errors in the conclusion

**Response:** We have reduced the number of parentheses in the text and revised the grammatical errors in the conclusion.