**Reply to comments**

Reviewer # 2

The authors detect episodic subduction of water mass in data from BGC-Argo floats in the western North Pacific and discuss their distribution and the transport of oxygen into the ocean interior. The authors used anomalies in dissolved oxygen and spicity to detect the subduction of a water mass. According to their research, subduction patches were found in 4 % of the total profiles in this area, mainly near the Kuroshio Extension region, especially between March and August. About 30-40 % of these subductions have been detected below the annual permanent pycnocline in the subpolar and subtropical regions. This indicates that the oxygen in the subducted water mass is transported to relatively deep layer of the ocean. They estimated the oxygen inventory with these subductions to be 64-152 g O2 m-2. They argue that these small-scale subductions detected in this study is one of the transport processes of oxygen as well as other material to the ocean interior.

I reviewed this manuscript last time (Reviewer #2). This revised manuscript improves on many of the points I commented. On the other hand, the argument of the paper has been reduced because the discussion on the material transport has been substantially removed. Furthermore, the added sentences need some explanation and revision. I still think this manuscript is not worthy of publication at this status. I request further revision and additional discussion.

**Reply: Thanks for your time and effort in reviewing our manuscript, and the further critical comments to help us improve the manuscript, we appreciate that! In the revision, we carefully revised the manuscript based on your comments and provided detailed answers below.**

Comments

1) In this study, the authors used anomalies of potential spicity to detect subduction patches, but can the deep mixing layer (the moment of the deep subduction) be detected during winter and spring? Especially in the southern area of the Kuroshio Extension, where the subtropical Mode Water is formed, it is known that deep mixing layers of 300 to 400 m are found between January and March. If these deep mixing processes are not considered, the estimate of oxygen inventory may be an underestimate. The authors should describe how they deals with the deep mixing during winter and spring. Also, the average values of the oxygen inventory (64.3 to 161.5 g O2 m-2) is described in the manuscript, but it would be better to carefully explain that these are average values of the amount of oxygen into the ocean interior by an episodic subduction event.

**Reply: We understand your concern on the deep mixing in winter and spring, and it may influence our ability to detect subduction events. But recognize that deep mixing acts to bring oxygen and warmed surface waters to depth, where strong mixing leads to isothermal and uniform oxygen concentrations to the base of the mixed layer. The subduction patches identified here are anomalies within this background during winter and spring (i.e., distinct water mass with elevated oxygen but lower oxygen than saturation level-AOU, below the mixed layer).**

**Generally, subduction patches were identified below the deep mixing layer in winter**

**and spring. Specifically, we showed the monthly mixed layer depth (MLD) dynamics in both the subtropical (i.e., south of 35° N) and subpolar (i.e., north of 35° N) regions in Fig. S3, and correspondingly, we demonstrated the number of subduction patches identified in each month in Fig. S4, and the subduction detection chance (%) in each month in Fig. S5. Indeed, the mixing layers are deep in winter and spring, deeper than 150 m between December and April, and reach maximum (> 300m) in February and March. In these months with deep mixing, we did have subduction patches identified (see Fig. S4a), and in fact, we found the largest number of detected subduction patches and the highest detection chance in March. In addition, as the reviewer noted, in the southern area of the Kuroshio Extension where the subtropical Mode water is formed and mixing layers are deep between January and March (see Fig. S3), subduction patches were also found at depth below the base of winter mixing layer. In Fig. 5c, we showed the spatial locations of the subduction patches identified in each season including spring (i.e., red dots, from March to May) and winter (i.e., yellow dots, from December to February). In the revision, we added more description on deep mixing in winter and spring, and clarified that subduction patches were detected below the deep mixing layer (see Lines 27-28, Lines 385-395, and Lines 438-442, in the revised manuscript with track changes).**

**As suggested, in the revision, we clarified that, the average values of the oxygen inventory are the average values of the amount of oxygen into the ocean interior by one episodic subduction event (see Line 554-555, as well as the caption of Table 1).**

2) It is an unfortunate that episodic subduction detected in this study cannot be quantitatively estimate how it affects the stock of oxygen in the ocean interior. For example, is it possible to compare the annual oxygen inventory between years with more and less subduction? I think that by carefully observing the detected subductions, they may be able to assess the impact of these events on the material transport into the ocean interior.

**Reply: We agree that it would be ideal if we could quantify the overall amount of oxygen (and carbon) transported by subduction patches and compare it with the stock of oxygen in the ocean interior. Indeed it was a point of conversation during the early data interpretations. However, unfortunately, it is not possible to develop reliable estimates based on the 1-dimensional BGC-Argo profiling data alone, particularly considering the BGC-Argo data only provide "snapshots" of the subduction events. The biggest problem we face is that we do not know subduction rates, and thus oxygen transport rates. Our "back-of-the-envelope" estimates in an early version of the study were considered by others to be too "non-quantitative" to be useful. We therefore have curtailed the finding to quantitatively present the spatial and temporal distributions of the subduction occurrence and the fact that it brings excess DO into the ocean interior. More quantitative estimates will depend on both more intensive sampling and modeling effort. Our results suggest that the unexpected effective small-scale subduction processes need to be better constrained in global climate and biogeochemical models. We foresee the likelihood to quantify how these events affect the stock of oxygen and other materials (e.g., carbon) in the ocean interior as such**

**models being developed and matured.**

3) As I have pointed out the previous review, the continuous anomaly seen in Fig.4 is not evidence of widespread subduction. This is because the float may be moving with the water mass. In addition to Fig.4, it is necessary to verify using each profile and the sea level height at the observation period.
On the other hand, I am interested in this case study. The fact that three subductions were detected for a few months and in a limited area may indicate that this area is easy to observe subduction events. It is important to know where subductions are most often occurred. I suggest adding some descriptions of the observation area and condition where this case study was conducted.
**Reply: Yes, that's a good point. We agree, because the 1-dimensional BGC-Argo profiles only capture "snapshots" of subduction events, thus it is hard to say whether subduction patches identified from adjacent profiles come from the same subduction event or not, i.e., widespread subduction. In box 3 of Fig. 4, we show four consecutive subduction patches at similar depth identified on August 12$^{th}$, 13$^{th}$, 14$^{th}$, and 15$^{th}$ 2014, all with similar water properties (i.e., temperature, salinity, density, spicity, DO, AOU); thus, we speculate that the subduction patches observed during these four consecutive samplings were most likely from the same relatively larger subduction patch produced through a larger spatial subduction event took place at an early time and a different location. As the reviewer pointed that the float may be moving with the water mass. This large subduction patch may be trapped and carried by the mesoscale eddy and moved around in the ocean interior. Here in the revision, we examined the sea level anomaly (SLA) over the study period to support our argument. Fig. R1 shows the positive SLA associated with the warm core eddy during the observation period. It seems a warm-core eddy dominated the SLA dynamics over the observation period. The four subduction patches were consecutively observed when the float followed the anticyclonic trajectory typical for the warm-core eddy and approached its center, as indicated by the graduate increase of depth of the anomalous patch (Fig. 4 in the main text).**

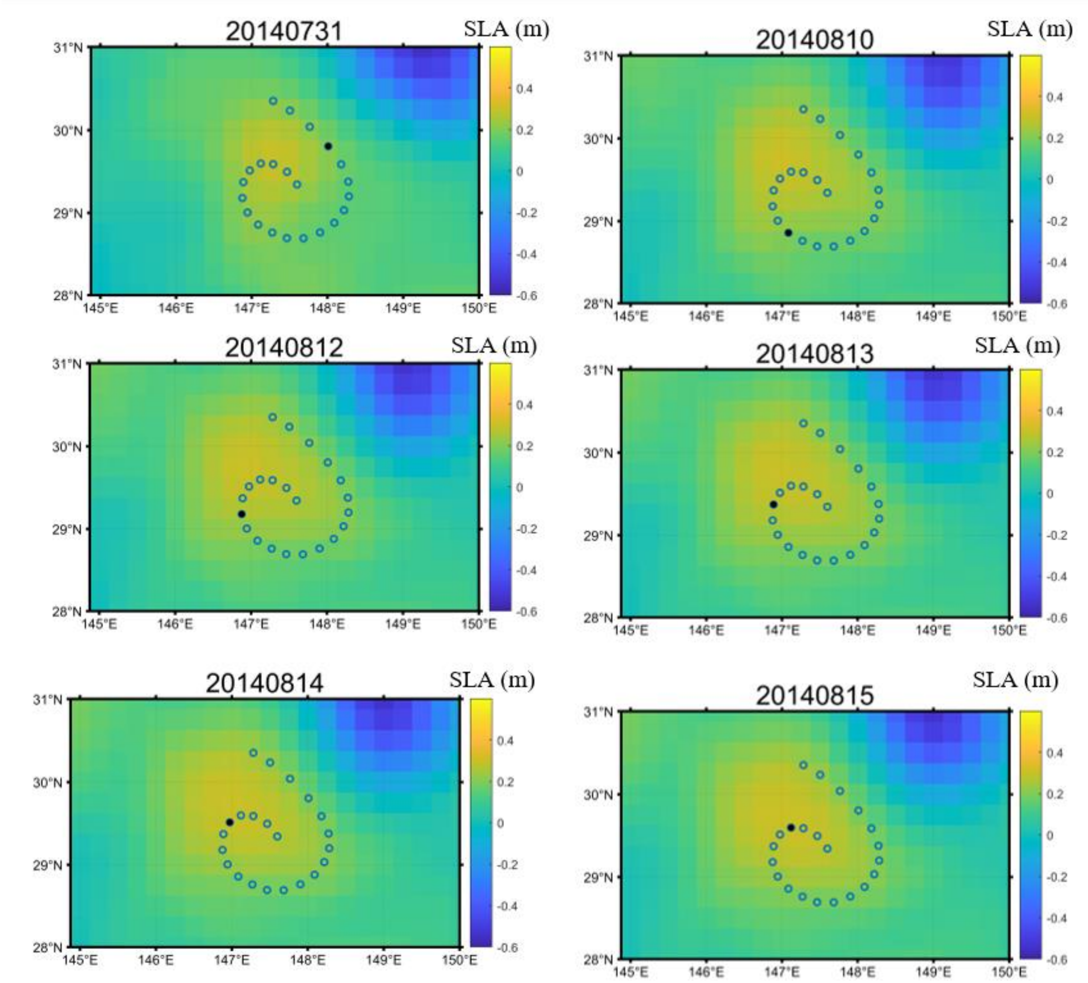


**Fig. R1 The daily SLA dynamics at the observation period when episodic subduction patches were detected from float MR2901556 on July 31st, Aug 10th, and August 12th to 15th, 2014. The circled data points represent the trajectory of the float over the period, with filled circle to show the corresponding location of the float on each day.**

**In addition, we clarify that the subduction patches from this float were detected within 21 days (between July 28th and August 18th 2014), instead of a few months. The trajectory of the float during this period is shown in Fig. 2a (at ~ 29°N, the white line in Fig. 2a, and open circles in Fig. R1). Nevertheless, the case study does not indicate it is easy to observe subduction events in this area. In fact, we examined where subductions most often occurred. Fig. 2b shows the data density (i.e., number of available profiles) over the study domain, and Fig. 5 shows the distribution of the BGC-Argo data profiles associated with subduction patches. We found 83% of the subduction patches being concentrated in the Kuroshio-Oyashio extension region, and far fewer subduction patches in the less energetic region to the south of 29°N despite a higher BGC Argo sampling density (Fig. 2b). Please see Section 3.2 for more details.**

**In the revised manuscript, we added descriptions of the observation area and ocean conditions of this case study, by analyzing the SLA for each profile at the observation period (Fig. R1 was added in the supplemental file as Fig. S2) (see Lines 277-285). We**

**also clarified the high detection chance of subduction by this float within this limited area does not indicate the area is easy to observe subduction (see Lines 333-336).**

4) I think the lines for MLD and isopycnals in Fig.4 should be drawn more prominently.
**Reply: Fig. 4 is a color figure, and it is quite difficult to adjust the color stretching and different lines for annotation. We think we have tried our best to draw the lines of MLD and isopycnals, which are very clearly shown in Fig. 4 at its originally full resolution. The issue the reviewer pointed could be caused by the reduced resolution in PDF file, and we will make sure the original figure with full resolution to be used in production phase if the manuscript is accepted for publication.**

I think the authors have captured a very interesting phenomenon in this study. I recommend that they carefully analyze the detected events.
**Reply: Thanks for the constructive comments. We added more analyses in the revision. Most of the published studies demonstrate that subduction can be identified using BGC-Argo profiles. In this study, for the first time, we presented the spatial and temporal distributions of the subduction occurrence in the western North Pacific, and quantified the excess DO supply into the ocean interior. We did analyses from different perspectives, including the detection method, the spatial (both horizontal and vertical, below or above the permanent pycnocline) and temporal distributions of the subduction patches, the properties of the subduction patches in terms of AOU anomalies, DO anomalies, and spicity anomalies, the oxygen injections into the twilight zone, and the surface forcing of subduction. We believe that we have taken our interpretations as far as can reasonably be done at this stage. We intend to use the findings to justify more focused BGC-Argo deployments to address some of the points the reviewer brings up here.**

Reviewer #3
The authors took our comments seriously and revised the paper. The second version of the paper is a great improvement and the authors are to be commended. I believe that this manuscript will be acceptable after a few corrections.
**Reply: Thanks for the valuable comments to help us improve the manuscript. Accordingly, we addressed all the minor comments below.**

Minor specific comments:

L352: Replace "S2" with "S3"
**Reply: Corrected.**

L370: ... until August (Fig. S2).
**Reply: Modified as suggested.**

L383-384 (caption for Fig. 6): Please make the meaning of "integrated" a little clearer.
**Reply: Clarified. The integrated anomalies indicate the significance and prevalence of**

**the episodic subduction events over time.**

L419: I cannot find AOU anomaly data point with 81 umol/kg in Fig. 7a.

**Reply: We mean the maximum of AOU anomaly of the detected subduction patches reached 81 μmol/kg. In Fig. 7a, to well present the data distribution, we set the color scale in the range of [-10, -50].**

L423: Replace "Figs. 5b" with "Fig. 5b"

**Reply: Corrected.**

L490: The average DO anomaly (34.5 umol/kg) and the maximum value in March (88 umol/kg) were described here. Are these statistics for each detected subduction patch? On the other hand, the caption for Fig. 6d (from which these values were likely derived) noted that it shows "integrated" values. This part confused me a bit, so please make it more clear. And there is no need to refer to Fig. 7 here as it shows the spatial distribution of the AOU anomaly, not the DO anomaly.

**Reply: Clarified in the revision. Yes, different from Fig. 6d which shows the variation of integrated DO anomalies, these are the statistics for each of the detected subduction patch on average. We removed the citation of Fig. 7 here.**