Answer to Referee #2

We thank Referee #2 for the time spent on reviewing our manuscript and for his/her thoughtful comments about the length of the manuscript, the timescales of the turbulent variability, the filament detection algorithm and for the many specific comments which have helped us to improve our manuscript. We include below our detailed answers to the general comment about the writing and length and to all the specific comments and describe the proposed changes to the manuscript.

General comment

Length of the manuscript and writing

"...my only real concerns with this paper is its length. This contribution is significantly long (I acknowledge it contains many interesting results but some are a bit redundant) and the writing is slightly too didactic sometimes (it could often be more "to-the-point" and more condensed). For instance, it seems weird to have both "Summary and Synthesis" and "Conclusions" sections in the same article (although I enjoy the reading of both). I agree it has a lot of content (complex analyses & interesting well-supported results) but it may be "lost-at-sea" considering that, nowadays (and unfortunately), papers are more-and-more numerous and less-and-less read by the community. Their work could gain in visibility if they opt for shorter and/or separated contributions. I would suggest the authors to try reducing the length of the article (i) by focussing their analyses and the writing and (ii) maybe by keeping aside some content for another paper (especially the regional analyses over the three subsystems -keeping here only the whole CanUS- and the seasonality of the processes, cf. A comment below)."

Proposed solution

We thank Referee #2 for his/her evaluation of the manuscript. The length of the manuscript is indeed an issue and we will thrive to streamline and shorten it, to make it more accessible to the reader. In order to move in this direction, we have decided to combine the suggestions of Referee #1 (comments MC2, MC3, P17L7) and Referee #2 (this comment and specific comment SC6) and propose here a few changes to the manuscript. We list the changes below:
1 – We will shorten the Methods section by moving the (currently rather informal) description of the new filament detection algorithm to a dedicated **supplement to the manuscript**, in which we will also provide an evaluation of the algorithm sensitivity and of its performance.
2 – We will shorten the Evaluation section by moving Figure 4 to the Appendix, as it does not provide a comparison with the observations, and by removing a few repetitions in the discussion of the Figures.
3 – We will shorten the discussion of our results. In particular, we will merge subsection 4.3 and subsection 4.4 into a single subsection titled "From turbulent anomalies to the mesoscale contribution to the organic carbon stock" which will serve as a transition between the discussion of the Reynolds decomposition and the discussion of our structure-based analysis. This will allow us to present: velocities, C_{org} anomalies and C_{org} content of the mesoscale structures. With the purpose to ease the flow of the paper, we will invert the order of Figure 9 and Figure 10 and merging the first and last paragraph of the current subsection 4.3 into a single initial paragraph, followed by the discussion of the current Figure 9. We will cut part of the current subsection 4.4, limiting the discussion to the contribution of mesoscale activity to the organic carbon stock, in line with the focus of our paper. Figure 12 (mesoscale contribution to the nutrient stock and production) will be moved to the Appendix. This is also in line with the suggestion of Referee #1 to limit speculative discussion in the Results section.
4 – We will remove from our discussion the paragraph focusing on the processes regulating production and nutrient concentrations in the eddies according to previous literature (pg.27, ll.11-23), in order to maintain the focus on the organic carbon budget and transport.

5 - We will merge the two sections “Summary and synthesis” and “Conclusions” into a single “Conclusions” section (complying with the Biogeosciences “Manuscript preparation” guidelines), as also suggested by Referee #1. To this aim, we will shorten the portion belonging to the “Summary and synthesis” as follows, while leaving the final conclusions substantially unchanged:
“Our Reynolds flux decomposition shows that the turbulent component of the zonal flux of C_{org} out of the coastal CanUS contributes, on average, from 5 % to above 30 % to the total zonal transport and 30 % to the total zonal flux divergence, extending out to 2000 km from the coast. The turbulent zonal transport is mostly confined to the first 100 m of depth, but it shows a subsurface intensification, owing to a strong turbulent vertical downwelling. The contribution of the turbulent zonal flux to the total flux and to its divergence is particularly important in the northern and southern CanUS, while in the central CanUS its contribution pales in comparison to the already intense mean offshore transport. With the use of eddy and filaments masks we separate the contribution of mesoscale eddies and filaments to the availability and transport of C_{org}. Filaments are characterized by inner flow velocities that reach up to 0.5 m s^{-1} and contain most of the total C_{org} up to 200 km from the coast, but their C_{org} share declines quickly offshore. Eddies, on the contrary, drift with speed of a few cm s^{-1} but see a sharp increase of their C_{org} content in the first 200 km from the coast and contain beyond this distance about 30 % of the total available C_{org}, two thirds of which is found in CE. Thanks to their high advective speeds, large C_{org} concentration and semi-permanent character, filaments dominate the nearshore zonal transport accounting for nearly 80 % of the total flux at 100 km offshore. The filament transport captures a large part of the mean Reynolds offshore transport near the coast, while vertically it is responsible for a strong turbulent vertical downwelling. The divergence of the filament offshore transport adds the majority of the extra C_{org} to the first few hundreds km offshore, but the divergence drops off quickly, reaching zero at 1000 km. The eddy lateral transport, on the contrary, resembles in pattern and intensity the turbulent Reynolds offshore flux and accounts for about 20 % of the total zonal flux and total flux divergence. Eddies, which move slowly but contain about 30% of the C_{org} available offshore, add C_{org} to the offshore waters up to 2000 km from the coast; in particular CE are responsible for most of the offshore transport largely because of their elevated C_{org} concentration and longer lifetimes.”
5 - We suggest to maintain the discussion of the subregional differences in the fluxes in the manuscript. These results provide essential information on the latitudinal differences in the flux contributions within the system, and can be of interest for studies that will focus on a specific portion of the CanUS. Moreover, they provide a term of comparison between our results and several previous studies which focused on a specific subregion.

Overall, the proposed changes will allow us to shorten the manuscript core (from Abstract to Conclusions) by roughly 10% of its length, i.e. from the initial 31 pages to 28 pages.

<u>Answers to specific comments</u>

SC1) *Typing/English mistakes:*
1) p 1 line 19: “anticyclonic” has been perhaps forgotten;
2) p 5 line11: delete “the”;
3) p 6 line 19: filaments;
4) p 9 line 4: delete “eddy”;
5) p 11 line 2: delete “abundant” or “found”;
6) p 11 line 25: delete “a”;
7) p 16 line 11: could it be “going deeper than 500 m within 500 km from the shore (or over 0-500 km offshore)”;
8) p 17 line 8: “which slow down the rotation...”;
9) p 18 line 14: should it refer to Fig. B7 and/or 8 instead of Fig. B6 there?;

10) p21 line 1: estimateS;
11) p 22 line 33: responsible OF a;
12) p 30 line 18: cyclonEs; etc..
Answer:
1) the sentence is actually complete as it refers to all types of eddies, and not anticyclonic eddies.
2) thank you, we will remove "the" as in: "and determined their turbulent values"
3) we will correct the sentence as in: "are upwelling filaments generated"
4) we will remove the typo and corrected as in: "the distribution of the modeled and observed large-eddy diameters"
5) we will correct this expression using: "abundantly found"
6) we will delete "a" as in: "Thin and short-lived filaments..."
7) we will use: " going deeper than 500 m within 500 km from the coast"
8) we decided to remove this sentence.
9) thank you for pointing this out, yes it should be the plot B8 of the current manuscript version, we will correct it accordingly.
10) we will correct this typo.
11) we will use: "are responsible for a strong"
12) thank you, we will correct the typo.

SC2) *Page 2 lines 9-10: there exist plenty of earlier references to support this statement, including some that are already cited, such as Rossi et al. 2008 and Gruber et al. 2011.*
Answer:
Thank you very much, we will add the references in this point.

SC3) *Page 2 lines 31-32 and page 30 lines 32-33 + page 31 lines 1-2: the "coherence" of eddies is still an open question to my mind; there is a bunch of papers around those questions, both from the observational and modelling point of views, and many situations (from very coherent to quite leaky) have been reported; so it seems no agreement has been reached yet. Please rewrite.*
Answer:
We agree with Referee #2 that significant progress still has to be made to understand the degree of isolation of mesoscale eddies from the surrounding environment.
We will rephrase the sentences as follows:
"Eddies trap water and tracers in their core during their formation. In stronger eddies, the degree of lateral isolation of the eddy core from the surrounding environment can be quite high, possibly resulting in the entrainment and long-range transport of trapped tracers at formation (Karstensen et al., 2015, 2017, Chelton et al.,2011)."
"Third, the relevant share of C_{org} found in the offshore region within mesoscale eddies also tells us that a fraction of the offshore biological activity is fueled at the passage or death of such a structure."

SC4) *Page 4 line 11: in addition of in-situ observations and modelling studies, there also exist purely satellite studies (e.g. Capet et al. 2014, not yet cited) as well as merged modelling & satellite study (e.g. Hernandez-Carrasco et al. 2014, already cited). Capet et al. 2014. Implications of Refined Altimetry on Estimates of Mesoscale Activity and Eddy-Driven Offshore Transport in the Eastern Boundary Upwelling Systems, Geophysical Research Letters, 41 (21), 7602–7610, doi:10.1002/2014GL061770. It could also be cited at page 6 line 27-28 (assumption of "prismatic" volume) and page 30, line 25.*
Answer:
We thank Referee #2 for the suggestion and we will add these references in the text.

SC5) *Page 5 lines 12-15: the turbulent field (e.g. mesoscale activity) exhibits temporal variability, at monthly and especially seasonal time-scales. Why did you include the monthly/seasonal variability of the fields into the mean fluxes? I presume that this choice could impact your results about the "turbulence-based" methods, as well as when comparing it against the "structure-based" approach (has it been done similarly?). These additional analyses could be kept for future work anyway.*
Answer:
We agree with Referee #2 that the turbulent field exhibits a certain level of seasonal variability. However, seasonal changes in circulation and biological activity represent the dominant mode of temporal variability in the CanUS, both on the regional and on the subregional scale (Chavez and Messié, 2009, Mittelstaedt, 1991), i.e. on spatial scales that are larger than the mesoscale. For this reason, including the seasonal cycle into the turbulent field, for example using a climatological annual mean as a reference mean, would result in the turbulent deviations including strong signals that evolve on scales longer than the ones of interest for our study. In order to clarify this point, we will rephrase the sentence at page 5 lines 14-15 as follows:
"Throughout our analysis, the reference means are climatological monthly means of velocities and concentrations as calculated from the 24 years of the run used for the analysis, and interpolated them to bi-daily fields. This choice allows us to obtain smooth mean bi-daily fields while including both the dominant seasonal variability (Chavez and Messié, 2009) and the recurrent monthly oscillations of the large scale fields into the mean fluxes. In this sense, our turbulent field represent all those signals that vary locally on timescales shorter than the month."

SC6) *Page 6 lines 18-20: Why is the reference mean SST field coarsened onto a 2x2°grid? This coarsening procedure is not applied to the snapshots, right? What could be the impact of a different coarsening? How was the threshold of -0,3°C defined? What is the sensitivity if your results to these threshold?*
Answer:
The coarsening of the reference field onto a 2x2 degree grid allows the algorithm to better recognize the upwelling filaments as connected structures in the 2-day output SST field. This procedure is not applied to the bi-daily mean field. While developing the algorithm we tested the sensitivity of our results to the coarsening and to the SST threshold.
In order to provide a comprehensive description of the algorithm and of its sensitivity to the parameters, we propose to add a **supplement to the manuscript** which includes a technical description of the algorithm and its properties, as well as an evaluation of its performance.

SC7) *Figures 3 and 4: for ease of understanding, please report in the caption that the unit of some panels is "number of eddies per 1 degree bin per day" (if I understood correctly).*
Answer:
Thank you for your suggestion, we will add it in the caption.

SC8) *According to their specific behaviours showed in Fig 7 inserts, it would be interesting to see the equivalent of Fig. 8 but for the different subsystems (to be kept for future work I suppose).*
Answer:
Thank you for your suggestion, we include below the subregional plots of the zonal flux of organic carbon as a term of comparison with Figure 7 and Figure 8 of the manuscript.

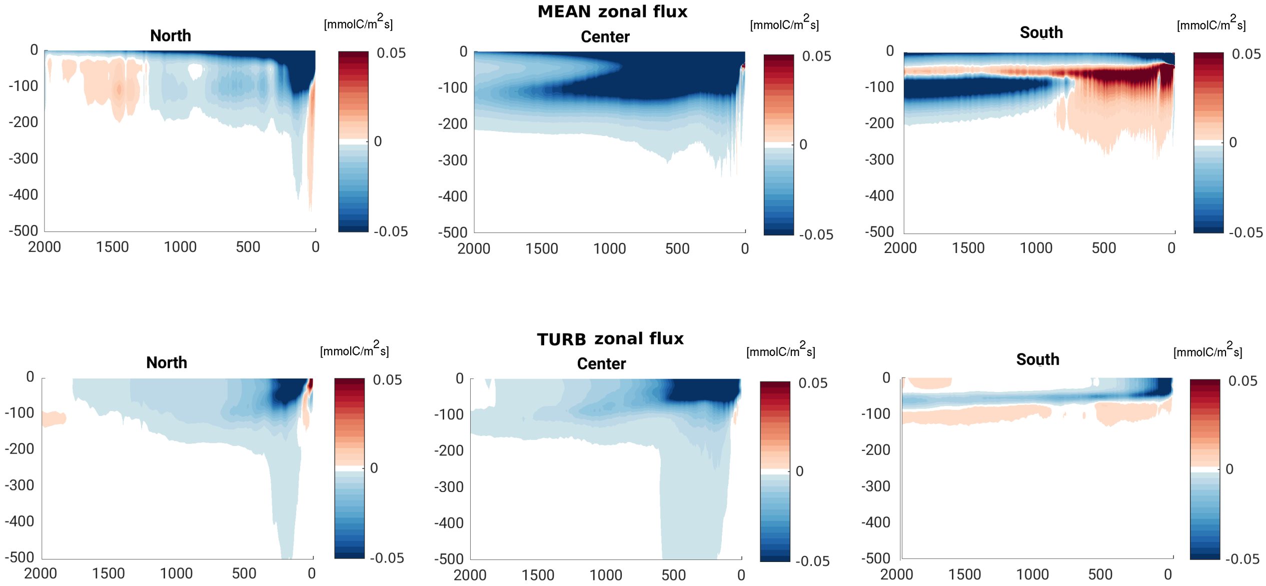

Figure re SC8: *Reynolds mean and turbulent components of the zonal flux of C_{org} averaged along lines of equal distance from the coast in the three CanUS subregions, as defined in the manuscript.*

SC9) *Page 18 line 5-7: Were these velocities estimates taken from the Hovmöller plots of Fig. 10 or from a direct check of exemplary velocities modelled at the boundaries of those structures? If these propagation speeds (for each structure type) were derived from the Hovmöller of Fig. 10, are they in accord with those derived from Fig. B6?*
Answer:
These velocities were calculated explicitly from the 2-day mean output. We plan to state this in the manuscript.

SC10) *Fig. 12: inconsistency between the caption and the plots displayed. I am also wondering if the explanations described lines 1-14 p 20 were obtained after having analysed the simulated fields of a few typical structures (if so, please show some figures in Appendix)? If not, I presume those lines of text are rather "discussion", so that they should have more references and they could be transferred somewhere else.*
Answer:
Thank you for pointing out this inconsistency, we will remove the reference to the subregions in this caption. Following this suggestion and the need to shorten the manuscript, we decided to shorten section 4.4, limiting the discussion to the contribution of mesoscale activity to the organic carbon stock, while moving Figure 12 to the Appendix. See our answer to the first comment (General comment) in this document for further details.

SC11) *Page 21 line 10: I found that the expression "coastally confined" is a bit misleading to describe a process prominent over a region extending from the shores to more than 500 km offshore; maybe "shelf-confined"? (although the shelf might be even narrower than this...), else?*
Answer:
Thank you for your suggestion, we will replace "shelf-confined" by "nearshore-confined".

SC12) *Page 25 lines 7-11 and page 26 line 4: to further support those arguments, you could refer also to Rossi et al. 2013 (already cited) who documented (from in-situ observations in the Iberian Peninsula Upwelling) a filament of 50-60 m depth which experienced subduction when moving offshore (see their sect. 3.2.2 and 3.6).*
Answer:

Thank you very much for this suggestion, we will add the reference in these points.

SC13) *These "intermittent hotspots of downwelling" are puzzling; I wonder what mechanisms are involved and why are they so transitory?*
Answer:
Animations of our model output show small scale and highly variable hotspots of downwelling in the filaments, mostly concentrated to the first 100 km of offshore range. These hotpots evolve quickly and often drift laterally following the filament flow. This corresponds to the previous findings of Nagai et al. 2015, and suggests us that these small scale fluxes are associated to the formation and degradation of frontal regions at the edges of the filaments, which are associated by high strain in the horizontal flow. The formation of such small scale downwelling is also favored by the relatively high resolution of our grid in the nearshore, ranging between 8 and 5 km of grid spacing. We will rephrase the mentioned passage as follows:
"Animations of the vertical velocities at 100 m depth in the filaments show transitory and irregular hotspots of strong downwelling, which evolve quickly and often drift laterally following the filament flow.The vertical transport inside filaments is therefore highly variable both due to horizontal movements of the downwelling cells and due to the intermittency of the process.
With a numerical study, (Nagai et al. 2015) showed that this subduction happens primarily at the periphery of the filament due to the formation and degradation of frontal and high-strain regions at the filament edges, and it moves offshore during the filament formation, oscillating laterally with the structure."

SC14) *Page 26 line 10: compilations of offshore transport due to upwelling filaments were also reported in Sanchez et al. 2008.Physical description of an upwelling filament west of Cape StVincent in late October 2004. Journal of Geophysical Research—Oceans, vol.113, C07044, http://dx.doi.org/10.1029/2007JC004430.*
Answer:
Thank you very much for your suggestion, we will add this reference in the passage.

SC15) P*age 29 lines 3-9: why maps of chlorophyll are mentioned here? I thought that your structure*
detection algorithms were indeed applied to modelled SST
Answer:
The filament detection algorithm was indeed developed only on the basis of SST, which is the only field used by the algorithm. To evaluate the performance of the the algorithm, the masks were also compared to images of modeled surface chlorophyll. Surface chlorophyll constitutes a good tracer for the identification of the streams of upwelled water and the choice was made also in analogy to the traditional methods of single filament identification (by hand) from satellite images, often based on surface chlorophyll signatures. However, in order to avoid confusion we will remove this detail from the discussion section:
"Our newly-developed SST-based filament detection algorithm was tested on our grid with satisfactory results, with the large majority of the filaments being detected and very limited over-detection in the southern CanUS."
We will instead add the following sentence in the caption of Figure B1:
"The comparison of the detected mask with the S-CHL field, a good tracer for the identification of the streams of upwelled water, allows us to evaluate the filament-identification algorithm in analogy to the visual methods of single filament identification from satellite images."

Furthermore, we will include a dedicated **supplement to the manuscript** with the aim of providing a better description of the algorithm evaluation and of its performance.