**Interactive comment on 'Tracing water masses with $^{129}I$ and $^{236}U$ in the subpolar North Atlantic along the GEOTRACES GA01 section' by Castrillejo et al.**

Maxi Castrillejo et al., on behalf of all co-authors.
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Dear Reviewer 1,

We are grateful for the thorough review and the constructive comments from the reviewer.

We will gladly make most of the changes suggested. Special emphasis will be put on providing a more detailed introduction to provide a better background about the tracer sources/levels, their transport and distribution; the ocean circulation of the study area and also, highlight the pursued objectives. The 'results and discussion' will include a first, new section with the complete description of the water mass structure. The overall discussion shall be revised to make clear what is the novel information obtained from these tracers and the GEOVIDE cruise and what are confirmations of earlier tracer/physical studies. The specific comments will also be addressed, as shown in the point by point answer (in bold) to the comments made by the reviewer (in italic).

On behalf of all coauthors,

Maxi Castrillejo

**Detailed point by point answers to reviewer 1.**

*This manuscript focus on the distribution of $^{129}I$ and $^{236}U$ along the GEOVIDE section (transect GEOTRACES GA01) in spring 2014. GEOVIDE cruise covered the subpolar North Atlantic Ocean and the Labrador Sea. This manuscript represents an important updated dataset and the authors successfully use $^{129}I$ and $^{236/238}U$ and $^{236}U/^{129}I$ atom ratios to describe water masses. The authors confirm with this study the major potential of the combination of $^{129}I$ and $^{236}U$ as circulation tracers, especially in the area of study and the Arctic Seas and I really enjoyed reading it. However, I think that given that the combined use of $^{129}I$ and $^{236}U$ provide such rich information, some of the results provided could be discussed in more depth. My impression is that the description and overall use of some the data still require a bit of discussion.*

*If I am not mistaken, the paper have three main objectives that should be emphasized and clarified in the abstract and the introduction.*

*1. Update and improve the database of $^{129}I$ and $^{236}$, to be used for future studies and/or modelisation of the ocean circulation in the North Atlantic*

*2. Present new evidences of the advantages of using both radionuclides as dual tracers in the ocean. In this case, what I miss in the text is a more detailed explanation/introduction of why and how $^{236}U$, $^{129}I$ and $^{236/129}I$ combined provide different and complementary information. The authors reference previous works but should provide the reader with a bit of context and additional information about how these tracers/methodology work.*

*3. Use the tracers to understand ocean circulation in the area. This seems to be the main objective of the paper, however the conclusions from this part are mixed with the other two objectives, together with what is already known and what is novel in this paper. e.g. the final conclusion in the Abstract "Data of $^{129}I$ and $^{236}U$ from 2014 and the $^{129}I$ time series in the Labrador Sea agrees with the hypothesis that Atlantic Waters follow at least two circulation loops from their source region […] recirculation in the Arctic Eurasian Basin" is not new was already stated by Orre et al. (2010) with $^{129}I$ and partially by Povinec et al., (2003) using other radioactive tracers such as $^{137}Cs$. But there is missing information in the abstract to emphasize that the other conclusions are indeed novel, i.e contribution of ISOW to eastern SPNA is quite recent.*

*A general comment on the paper is that it presents an impressive dataset and it would be desirable to make more clear which of the conclusions are confirmations of previous hypotheses/results. In the* *text it is indeed explained, however I think that the novel results, found mainly from the dual use of these radiotracers, are mixed with results that are confirmation of known facts and its relevance it is not explicitly enhanced, which is a shame. Section 3.4 is basically where the novel features of these tracers are presented, in contrast with previous sections that basically use previous data and hypotheses and verify that the new $^{129}$I and $^{236}$U data are in agreement. However, this distinction is, in my opinion, not totally clear especially when presenting section 3.3. Novel and/or on discussion hypotheses reinforced by these dataset should be highlighted. I would also emphasize conclusions obtained by the use of $^{236}$U and $^{129}$I/$^{236}$U, since they are novel tracers and the first time that they are measured simultaneously in the area. However, in this sense I find the Conclusion section very well structured.*

**The discussion will be modified in order to make clear which are the results that confirm hypotheses/results reported in the literature and we shall highlight the novel results. Special care will be taken in section 3.3.**

*Finally, it is assumed in the text that the reader knows well about the ocean circulation in the North Atlantic and Arctic Oceans and about $^{129}$I and $^{236}$U, if this is the case, the paper is quite straightforward to read. But in my opinion one can get easily lost if that is not the case, I have add a few examples of this in the specific comments below.*

**A more complete background will be provided on the introduction section about the circulation in the North Atlantic, and about the origin and transport of these tracers.**

*To provide a general background to better understand the discussion of the results I suggest something like:*

*1. Presenting first a brief introduction to ocean circulation and water masses involved with the data.*

**The tracer transport will be explained in more detail considering the currents and water masses involved.**

*2. Explain in more detail the role of $^{129}$I, $^{236}$U and $^{236}$U/$^{129}$I as ocean tracers of the SPNA, making clear what we have learn so far using them i.e. provide context.*

**More detail will be provided on the use of these tracers and about the knowledge obtained from them.**

*It would be also good to better explain how to read and understand Figure 3. Which is extremely useful and provides a lot of information.*

**A better explanation will be provided in the main text and the caption of Figure 3 to facilitate the interpretation of the data.**

*ABSTRACT*
*I think that these lines "Results show that part of the effluents discharged from Sellafield and La Hague apparently enter the eastern SPNA directly through the Iceland-Scotland passage or the English Channel/Irish Sea, as it is shown by elevated $^{129}$I concentrations and $^{129}$I/$^{238}$U ratios in shallow central waters flowing in the West European Basin (WEB)" are saying the same than these ones "The Iceland-Scotland Overflow Water spreading pathways into the eastern SPNA have been confirmed by the unequivocal transport of reprocessing $^{129}$I into the deep WEB".*

**The first sentence refers to the shallow tracer transport while the second refers to the deep transport of ISOW. This will be clarified.**

*When it is said "The Iceland-Scotland Overflow Water spreading pathways into the eastern SPNA have been confirmed by the unequivocal transport of reprocessing $^{129}$I into the deep WEB", it should be briefly explained why we find this transport unequivocal.*

**The increase in $^{129}I$ concentrations at those depths but not in overlying waters can only be explained by the intrusion of dense waters carrying the signal from the European nuclear reprocessing plants. This will be explained accordingly referring to tracer data.**

*INTRODUCTION*
*When one reads from lines 15 (Page 3) to line 23 (Page 4) gets a very general idea about how $^{129}I$ and $^{236}U$ are distributed in the North Atlantic, but do not get a precise picture of what are the paths followed by the radionuclides when released by the RP. That information is given later in the text, the problem is that it is scattered in different sections of the manuscript.*

**A complete and precise description of tracer transport pathways will be provided in the introduction instead of scattering the information in different sections.**

*Furthermore, lines 15 to 20 (Page 4) provides some information about previous results of $^{236}U/^{129}I$ however it does not explain what these numbers represent or why and how they change geographically or in time. For example, it is not explained why "Yet, LSW and DSOW were clearly identified by $^{236}U/^{238}U$ >1000 x $10^{-12}$"; or why the atom ratio varies from "$^{129}I/^{238}U$ < 1 for GF to about 1 - 350 for European NRPs".*

**The sources and geographical distribution of the tracers will be better explained so that the reader understands what their potential is for tracing water masses.**

*Lines 10-15 (Page 4). Why reference data are given here and not for $^{129}I$?*

**The referencing will be provided for both tracers.**

*Line 18 (Page 5). No mention to deep water formation at the Greenland Sea? And ISOW formation? ISOW is later described (Line 7, Page 8), but it would be easier to follow the manuscript having the whole picture since the beginning.*

**The deep-water formation and transport of DSOW and ISOW will be included in the aforementioned description of tracer transport pathways.**

*SECTION 3.1.*
*Line 5 (Page 7). A brief introduction to $^{129}I/^{236}U$ ratios is missing to understand their values and the further discussions.*

**A more detailed description on the sources of $^{129}I$ and $^{236}U$, and on the range of values for $^{129}I/^{236}U$ will be provided in the introduction making the discussion more straightforward.**

*Line 10-30 (Page 7). I also miss a complete introduction to water mass structure. It will be easier to follow the discussion if first we understand water mass structure and then 129I and 236U/238U are given.*

**The discussion will begin with a new section to present the water mass structure in 2014.**

*This way, ISOW description (Lines 7 -11, Page 8) should be move to that introduction, and merge with description in Page 5.*

**The change will be made as recommended by the reviewer.**

*Line 26 (Page 7). "SAIW probably incorporates $^{129}I$ from precursor water masses (e.g., waters carried by LC and/or LSW) while forming in the western SPNA". Why is that? Some of the statements, like this one, are properly given but not explained in terms of $^{129}I$ (or $^{236}U/^{238}U$) values.*

**This sentence (and similar ones) will be clarified providing information on the water mass origin/transformation and how that can be observed by higher $^{129}I$ and $^{129}I/^{236}U$. Also, the overall comprehension of the discussion will be improved with a more complete background about the tracer sources and transport in the introduction section.**

*Line 5 (Page 8). "Thus, 2014 data probably reflects the dilution with old LSW and SPMW carrying less $^{129}I$ and $^{236}U$ than MW". How is it that waters from LSW and SPMW, both affected by NFRP, carry less $^{129}I$ and $^{236}U/^{238}U$ than MW, also mainly affected by GF? Is it the influence of Marcule?*

**Yes. The $^{129}I$ concentrations and $^{236}U/^{238}U$ atom ratios are larger than expected in the Mediterranean Sea. Recent work showed that this is very likely due to the discharge of $^{129}I$ and $^{236}U$ from the Marcoule Facility (see Castrillejo et al 2017, Science of the Total Environment).**

**The sentence will be completed and clarified including information about Marcoule.**

*Lines 1-13 (Page 8). This is clearly explained, but it will be even easier to follow if the name of stations and references to Table 2 are given.*

**The station numbers will be provided, as well as the reference for Table 2.**

*Lines 14 -18. As already said, previous brief introduction to the use of $^{129}I/^{236}U$ as tracer should be included to make this lines easier to follow. This way it said "The highest $^{129}I/^{236}U$ ratios (> 100) are present in waters transported by the shallow EGC and LC. Overflow waters are also distinguishable by their relatively high $^{129}I/^{236}U$ ratios (60 to 110 for DSOW, 15 to 40 for ISOW)" Why is that?*

**That is because they have a larger contribution from the European nuclear fuel reprocessing plants than other waters which are affected only by global fallout. This will be clearly stated. Also, the tracer source(s), geographical distribution and transport will be better explained in the introduction to facilitate the discussion.**

*SECTION 3.2.*
*Line 25- 30 (Page 8). I really like Figure 3. I contains lots of information, may be it could be further explained in the mentioned intro introducing the $^{129}I/^{236}U$ tracer?*

**The range of values for $^{129}I/^{236}U$ and its potential to provide information on the source and origin of the water mass will be more clearly explained in the introduction. Also, the text and the caption associated with Figure 3 will be completed. This will clarify the overall use of the dual tracer to constrain the radionuclide sources and the ocean circulation.**

*SECTION 3.3.*
*Line 14 (Page 9). "$^{129}I$ discharge rate from European NRPs was observed in the whole water column, being more pronounced (about 10 times increase) in overflow waters". This actually an previously observed fact but an explanation should be given here.*

**The explanation shall be provided and the previously reported observation will be acknowledged.**

*Figure 4A. Indicate in the caption that Smith 2016 corresponds to 2012 and 2013 profiles. "The depth distribution of $^{129}I$ concentrations in the Labrador Sea in 2014 (station 69), displays $^{129}I$ concentrations in DSOW about 15 % lower than in 2012 – 2013 (Smith et al., 2016)". Is this because samples from 2012-2013 are measuring the peak in the NFRP releases? If this is the case, please mention that the explanation for that decrease will be given in Section 3.5.*

**We think that it is the most likely explanation. The change will be made as recommended by the reviewer.**

*As I said, it is a well-known fact DSOW present an increase in $^{129}I$ concentrations for all years. This is already approached by previous works, but a brief discussion could be also given here.*

**The manuscript will be modified to make clear which are confirmations of previous studies and to provide a brief discussion related to the cited literature.**

*Line 18 (Page 9). "The main difference between the $^{129}I$ depth profiles in the Irminger Sea (station 44) and central Labrador Sea (station 69) in 2014 is the surface $^{129}I$ peak in the latter one (Figure 4A).*

*Which is probably caused by waters that split off from the boundary currents, either the West Greenland Current or the LC". I don't quite understand this. Splitting won't change $^{129}$I concentrations.*

**The EGC and the LC carry particularly high $^{129}$I and $^{236}$U, respectively. We propose that the surface in the C. Labrador Sea might have been influenced by waters that separated from the mainstream of the EGC, which are characterized by specially high $^{129}$I. The sentence shall be changed to clarify the interpretation.**

*Line 26 (Page 9). "This similarity suggests little time variation and similar water mass composition for that region, although PAP might present slightly larger $^{129}$I concentrations because of its proximity to Sellafield and La Hague". And will support the later mentioned hypothesis of direct contribution of NFRP to SPNA without previous recirculation (Line 10, Page 10).*

**Indeed, it could be the case. We shall add the reviewers point to reinforce the hypothesis on the direct contribution from Sellafield and La Hague.**

*SECTION 3.4.*
*Line 17 (Page 10). "twice" instead of "two times"*

**The change will be made as pointed by the reviewer.**

*Line 16 -17 (Page 10). "near-surface transport of $^{129}$I from European NRPs also across Iceland-Scotland into the eastern SPNA" is also clearly seen in Table 2. That shows that profiles 1, 13 and 21 strongly contrast from profiles 26 and 32. Not only due to ISOW (IcSPMW) contribution in intermediate depths but also at shallower depths.*

**The station numbers and Table 2 will be referenced within the sentence.**

*Line 27 (Page 10). allowing to identify key circulation features such as the EGC/LC and the DWBC in the Labrador and Irminger Seas. Explain in terms of radioactive tracers.*

**The discussion will be modified here and whenever necessary to explain the circulation features in terms of tracer observations.**

*Line 30 -30. Differences of $^{129}$I and $^{236}$U in boundary currents are mentioned but not explained. It should be further discussed in terms of radioactive tracers.*

**As pointed above, the discussion will be modified whenever necessary to explain the circulation features in terms of tracer observations.**

*Line 1-2 (Page 11). "EGC shows particularly high $^{129}$I concentrations and $^{129}$I/$^{236}$U ratios because it is carrying Arctic water of Atlantic origin (PIW-Atlantic) and RAW that have been largely influenced by NRP effluents". I assume the authors do not explain this further because this is well known from previous works. Nevertheless, a brief description should be given, may be in the previously mentioned introduction?*

**The transport of Atlantic and Pacific waters from the Arctic will be better explained in the introduction or in this part of the section, taking care of acknowledging earlier findings.**

*Line 5-6 (Page 11). "while its $^{236}$U/$^{238}$U ratios are likely > 2000 $10^{-12}$ due to GF and unconstrained Arctic rivers inputs". Influencing how? In $^{236}$U, $^{129}$I or both?*

**Earlier studies showed that Pacific-Arctic water arriving to the Labrador Sea carry little $^{129}$I (Ellis and Smith 1999), while the $^{236}$U/$^{238}$U atom ratios are unexpectedly high in the realm of Pacific waters (Casacuberta et al., 2014). Although that source is not well constrained yet, it would appear that rivers might be a source, especially for $^{236}$U.**

*Line 12 (Page 11). "rise of $^{129}$I concentrations at certain depths on the Greenland slope (e.g., station 60; Figure 2 and Figure S1), and particularly in bottom waters of the Irminger Sea (station 44), which* *are probably related to the cascading of $^{129}$I-rich waters from the Greenland Shelf". And why not an increase in $^{236}$U?*

**Our interpretation is that waters carried by the EGC may cascade from the shelf (station 53 and 61) over the slopes in the eastern (station 60) and western (station 64) sides of the southern tip of Greenland. The EGC carries about 10 times more $^{129}$I (the core presents about 250 $10^7$ at/kg, station 53 and 61, Table 2) than in surrounding off-shore waters (about 20-25 x$10^7$ at/kg, e.g. station 60 and 64). In contrast, the $^{236}$U concentration in the EGC (about 15 x$10^6$ at/kg) is only ½ times higher than in the mentioned off-shore waters. Thus, while the spike of $^{129}$I is easily observed in near bottom depths on the western and eastern slopes of Greenland (stations 60 and 64, Figure 2 and vertical profiles in the supplemental material), such spike is not distinguishable for $^{236}$U.**

*Line 22-23 (Page 11). "The ISOW is best distinguished by its relative $^{129}$I concentration maxima". Explain origin of this maximum.*

**The origin of the maximum will be explained and better understood thanks to a more elaborate background on tracer source and distribution provided in the introduction. $^{236}$U**

*Line 24 (Page 11). The differences can be more clearly seen in Table 2.*

**Table 2 will be referenced.**

*Line 24-25(Page 11). "Further, in the next years one can expect a stronger $^{129}$I signal associated with ISOW in the SPNA due to the releases from the NRPs". Explain this further.*

**A better explanation on the input function of $^{129}$I and its expected temporal evolution will be provided in the manuscript.**

*Line 3 (Page 12). "The evolution of $^{129}$I (and $^{236}$U) in the SPNA is closely related to the effluents discharged from the two European NRPs". It sounds weird to mention this at the end of the paper.*

**This shall be mentioned in the introduction also.**

*Line 18 (Page 12). "Data reported in this study (2014) supports this 'Arctic loop' and suggests that the second 129I front probably peaked before the GEOVIDE cruise". Could Vivo et al. values be also used to support this "Arctic loop"?*

**It is difficult to say given the different location and sampling time of the two studies. Our point of view is that the comparison should be kept to nearby stations measured repeatedly over time to avoid uncertainties related to transit times and water mass mixing. DSOW dilutes 1-2 times during the 0.3-2 years of transport from the Denmark Strait to the Central Labrador Sea (Smith et al., 2005). This makes difficult usingVivo-Vilches et al., (2018) data to confirm the Arctic loop in the context of the Labrador Sea. Vivo-Vilches et al., (2018) present $^{129}$I concentration of about 102 x$10^7$ at/kg in bottom depths at their station 9 in the Denmark Strait, typically occupied by the DSOW core, for samples collected in 2012.**

***All references provided in the above answers can be found in the original manuscript.**