Response to reviewer 1

May 7, 2018

The authors thank the reviewer for their careful reading of our discussion paper, and for their helpful and constructive comments regarding its content and improvement. The text of the review is reproduced below in black type; our comments are in blue; and changes to the original discussion paper are presented in italics.

This manuscript looks at the exchange of fresh shelf water into the Labrador Sea using a high resolution numerical model and Lagrangian trajectories. The authors find that much of the freshwater that reaches the interior of the Labrador Sea comes from the West Greenland Current (which isn't a new result). But they expand on this work, by showing two seasonal pulses, associated with different geographical positions (southeast, northwest) and different salinity waters. Where this work truly expands upon previous studies is showing the key role of wind-driven Ekman transport compared to the typical view of eddy driven exchange. Given this is an important topic (fate of enhanced high latitude freshwater on water formation in the Labrador Sea), this work is appropriate for the journal. It is a well written paper, easy to follow and understand. Thus it is definitely will be eventually suitable for publishing in Ocean Science. However, there are a few places where the manuscript could be improved upon. Thus I recommend minor revisions. Details of my comments are given below.

Introduction General: Although the introduction provides a good summary, it feels a bit short. More discussion of previous work related to offshore exchange in the Labrador Sea can be added. Both with respect to observational studies, but especially with respect to previous modelling works. Since the authors are going to dispute the commonly held paradigm that eddies are the main exchange mechanism from the WGC, they need to discuss the previous modelling works that have highlighted that mechanism (and then in the discussion try to bring out why the present results are different). Beyond papers listed such as Chanut et al, there are newer studies such as McGeehan and Maslowski, Gelderoos et al., Kawaski and Hasumi, Saenko et al., Dukhovskoy et al to name a few.

Thank you for the suggested papers. We have highlighted previous model (in addition to Chanut et al.) that suggest that eddies are the main exchange mechanism from the WGC. Additional discussion was added.

Page 2, Line 11: ? in the references needs to be filled in

This has been fixed

Page 2, Line 28: But doesn't the Cooke paper use a very coarse resolution model, making it easy for freshwater to leave the Labrador Current. If so, this point could be clarified

Yes, Cooke's paper uses a ¼ degree model. We now also noted this in the manuscript.

> ***P3. L80.*** *Using a 1/4^o model, Cooke et al. (2014) argue that the instabilities could indicate a direct connection between the Labrador Current and central basin salinities. Such a connection would further support the idea of a Labrador Current source to the fall freshening in the central Labrador Sea, but the dynamics are not further discussed and the coarse model allows freshwater to leave the Labrador Current more easily than might be the case in the real ocean.*

General: At some places in the manuscript the authors report salinities as dimensionless, and in others places use psu as a unit. At the very least the authors must be consistent.
Thank you for noting this. We made sure that this is consistent throughout the manuscript opting for the more modern dimensionless salinity.

Page 4, Line 19: More detail on the lateral boundary conditions in the region, and the impact of that choice would be useful.
We limit the information here to the sentence:

> ***P6. L.178.*** *" No-slip conditions are implemented at the lateral boundaries - except in the Labrador Sea where a region of partial slip is applied. This is done to favor the break up of the West Greenland Current into eddies (as observations have suggested)."*

Page 4, Line 31 – is used…
This has been changed as suggested.

Page 5, 1st paragraph: Changes implemented in the model are listed as 1), 2) and 4). Where is number 3?
This was a typo and has been fixed. We also re-worded this paragraph slightly

> ***P7. L.194.*** *To improve the NEMO 1/4^o run, changes were incorporated in the 1/12^o run used here to better represent boundary currents, interannual variability and depth of mixed layers. These changes were: 1) more consistent wind forcing reaching back to 1958 (more information at www.drakkar-ocean.eu/forcing-the-ocean/the-making-of-the-drakkar-forcing-set-dfs5), 2) steeper topography along the Greenland Coast and 3) use of a partial slip along western Greenland. Together with the changes in topography, the partial slip condition promotes the formation of eddies in this region which results in improved salinity and velocities fields (Figure 1). The simulation used in this study was previously used in other studies of the North Atlantic, one of which found that the model represents the variability of heat transport at 26.5^o N.*

Page 5 – in terms of evaluation, given the importance of the West Greenland Current to the paper, it might be good to see further evaluation of the model representation of this feature. I.e. Don't just focus on the EKE in terms of observational comparisons.
Evaluating the West Greenland Current in the model would be useful to understand if the transport and freshwater content of the WGC in the model agrees with observations. Here we decided to concentrate on the EKE since this is regarded as a measure of the West Greenland Currents stability and the region from which eddies are most commonly shed.

Page 6, Line 22: Badly worded sentence with place/placed used an extra time
This sentence has been fixed

> ***P.10 l.286****. To determine the impact of wind vs. eddies on surface freshwater fluxes into the Labrador Sea, we release particles at three different depths (0 m, 15 m, and 30 m).*

Section 2.6 – The calculation of Ekman transport is discussed here, but the sections for which it is computed are not shown until the white line in figure 7. Be good to show that earlier.

Additionally, how close is that line to the actual isobaths in the model? Does the line follow a model grid line?
We added the sections (shown in Figure 7) to Figure 2.
The sections do not follow a model grid line. Instead it they smooth the isobaths to create a straight line. However, this was tried with multiple lengths of sections (not shown) and we conclude that changing the angle and/or length of the sections does not change the overall results.

Page 10, line 12 – looks like there is weak EKE in late summer too.
We have re-worded this to be more quantitative rather than to refer to the EKE as "strong/weak"

> ***p.15 l.449*** *Three-monthly composites of EKE and wind speeds show that the northeast portion of the Labrador Sea experiences EKE of up to 500 cm^2/s^2 in the spring and winter, up to 400 cm2/s2 in the summer and up to 200 cm^2/s^2 in the fall.*

Section 4.2.1 – Does the 3 month averaging remove eddies and thus the damp the potential importance of this term?
This is a very interesting point. Averaging SSH in time would remove some eddy effects. However, here we have calculated EKE prior to averaging, meaning that periods of strong eddy activity will still have a large value in the 3 month averaging used. In addition, EKE does not only dictate eddy transport, but also indicate variability of the boundary current. When it is large/eddying, it is expected to result in the formation of eddies. For both these reasons, we believe that averaging in this case will not dampen the potential importance of this term.

Page 12, Line 20: The statement "in the NEMO model…" is not correct. The authors mean in their configuration of the NEMO model, with the given forcing, they find…
Changed as recommended.

Page 12, Line 32: With respect to the statement about higher resolution being needed, doesn't Chanut et al argue that at least 1/15 degree is needed?
Chanut et al use a 1/15 degree model and argue that it performs better than the 1/3 degree model. They do not compare their result to lower (i.e. 1/12 degree) or higher resolution models.

Page 13, line 21: Do any of the years mentioned stand out in terms of freshwater transport, melt from the Greenland ice sheet, very positive NAO, etc.?
We looked into this and nothing really stands out in terms of freshwater, runoff and NAO. The only relationship that might be important is the deep convection that was observed in 2007 – 2008. As for the other years, we are not sure what caused the presence of fresher water. It would be interesting to look at this closer in the model. Maybe a composite of these years, or an analysis targeted to these years versus the other years would help understand this question better.

> **p.20 l.592** *Our results show that water entering the Labrador Sea basin was freshest in in the mid-1990s, with other maxima in 1999, the early 2000s and mid-2000. The freshening in the mid-1990s is likely to be related to the freshening observed by Häkkinen (1999), with the freshest waters located on the shelves. Several other years stand out as well, such as 1999, 2003 -- 2004 and 2007 -- 2008. The water responsible for these freshening periods originates in the inshore part of the EGC. A surface freshening signal in 2007 -- 2008 was found in observations, as well as the model. This is also the year during which deep convection was observed again after a long period of absence (Våge et al.*

2008). It is not clear what exactly caused the freshening periods since the NAO is neither strongly positive nor strongly negative and there is no obvious increase in Greenland runoff at these times.

Table 1: within is one word; Additionally I don't like the phrasing "Crossing Later" – the authors can be more precise and quantitative.
We have made the term "Crossing Later" more precise, changing it to "Crossing after 7 mth" and the typo has been corrected.

Figure 1: Why are the observations and model field plotted for different time periods (1990-2009 vs 2002-2012)? Can't the results be subsampled to plot everything over the same time period to allow a fairer comparison? Also for the model mixed layer depth, is it based on the default NEMO threshold method? If so, Courtois et al, 2017 show this approach significantly overestimates the actual model mixed layer in deep convection regions.
Comparing observations and model fields for the same time period is a great suggestion and has been done. The mean of the model fields and ARGO data are now calculated for the timeperiod of 2002 – 2009.
Yes, the mixed layers are based on the default NEMO threshold method. Thank you for pointing out the Courtois et al. 2017 paper. We now reference it in the revised manuscript (p.7 l.210).

Figure 4 – Why does it say 'Salt' in the middle of Greenland?
'Salt' was removed from the figure