

Review on "Major sources of North Atlantic Deep Water in the subpolar North Atlantic from Lagrangian analyses in a high-resolution ocean model" by Fröhle et al.

General Comments

The paper from Fröhle and colleagues investigates the relative contributions of the different sources of the North Atlantic Deep Water (NADW) that exits the Labrador Sea at 53°N. The manuscript outlines an analysis of Lagrangian particles in a high-resolution model to determine the NADW sources and its pathways and associated timescales from each source to the 53°N. The authors detail the interesting finding that within the subpolar North Atlantic the water mass transformation towards the density range of the NADW mainly happens through the process of diapycnal mixing (non-convective and convective).

These are interesting results that further our understanding of the high latitude ocean circulation, given all the present discussions of the Labrador Sea and its potential role, at different timescales, in the Atlantic Meridional Overturning Circulation (AMOC). Overall, the paper is generally well organized and clear, however some of the writing could be improved. I am pretty sure that this can be easily addressed by the authors and that might help to improve this already good paper. Thus, I recommend this paper for publication after major revision.

Specific Comments

1. Diapycnal mixing vs deep convection: Although the separation of the two processes might be trivial for most of the readers, I would suggest that the authors clarify a bit better the differences in the manuscript. I believe that the authors aim in distinguishing the diapycnal water mass transformations which are associated with deep convection, thus unstably stratified water masses, from water mass transformations, which are caused by internal diapycnal mixing across stratified density layers. Although in section 2.2 the authors clearly separate the two processes for the particles' categories, I would recommend a better explanation

of the two processes in the rest of the manuscript.

2. **Guidance to the reader:** I found myself wondering too many times at which figure/table should I look for many statements in the manuscript and in particular in section 3. I pointed out a few such examples below, but it is not an exhaustive list. Also, the terminology used in this manuscript regarding the source and the point of origin for each particle category is somehow mixed within the text.
3. **Discussion (section 4):** I feel that this section needs a better structure. It might be helpful to add some subsections to organize the discussion of your results. Many paragraphs are rather large with mixed information and difficult to follow. Furthermore, in many statements a reference to the relevant figure/table is missing. I would also suggest that the discussion begins with a short summary of the goal/methodology of this manuscript.

Technical Comments

1. **Title:** This study is based on the results of one experiment, right? Therefore, I suggest that you change ".. Lagrangian analyses.." to ".. Lagrangian analysis.." in the title.
2. **Line 1:** The North Atlantic Deep Water (NADW) ..
3. **Line 3:** ... components of NADW (namely..)
4. **Line 4 and elsewhere:** experiments -> experiment
5. **Line 5:** "according to the strength of the velocity field", this could be removed
6. **Line 5:** change "computed" to "traced"
7. **Line 6-7:** "Water masses were defined ... hydrography field", I don't see the importance of this sentence in the abstract. Consider removing this.
8. **Line 13:** Please consider rephrasing "... is hence dominated by the processes of diapycnal mixing and deep convection in the Labrador Sea."

9. **Line 15:** I believe that a short description of the AMOC would be beneficial.
10. **Line 16-18** Please rephrase this sentence in line with the general comment #1. Also, references of Straneo and Katsman are odd here. You could refer to Johnson et al. (2019)¹.
11. **Line 22:** .. of the North Atlantic Deep Water ..
12. **Line 26-28 & 31-32 & 33:** References are missing.
13. **Line 45:** further → farther
14. **Line 46:** east Greenland → East Greenland
15. **Line 53:** ".. is not finally understood.." → still remains unclear
16. **Line 54:** Consider adding more recent references than Lozier (2012) and Rhein et al. (2013).
17. **Line 60-62:** Please revise this sentence and add references of relevant studies.
18. **Line 68-69:** "Additionally, the observed .." → Additionally, the deep convection in the Irminger Sea is more frequently evident in recent observational studies ... or similar.
19. **Line 75:** ".. and pathways of the single.." → ".. and pathways of each of the deep water sources..
20. **Line 77:** section 5 is omitted here.
21. **Line 96:** .. along a section → at a section
22. **Line 99-100:** Are the particles released over the whole water column in the vertical?
23. **Line 115:** How are the particles traced backward in time? Do you use the velocity/hydrography field averaged over a certain period and re-

¹Johnson, H. L., Cessi, P., Marshall, D. P., Schloesser, F., & Spall, M. A. (2019). Recent contributions of theory to our understanding of the Atlantic Meridional Overturning Circulation. *Journal of Geophysical Research: Oceans*, 124, 5376– 5399

peat this as input for Parcels or do you use the daily snapshots from the release day of each particle and backwards?

24. **Line 142-144:** Is the inspection of the location of the particle's density change (within or outside the mixed layer) based on a time-mean value of the mixed layer depth?
25. **Line 155:** Why did you select the 3000 m isobath for the separation between the boundary current and the interior? Please also consider mentioning the reasoning behind this separation.
26. **Line 177 and elsewhere:** In my understanding, the point of origin is relevant only for the DIA_p and ML_p particles. If so, please mention this here and keep a consistency between the terms "source" and "point of origin" in the remaining of the manuscript.
27. **Line 78-79:** ".. based on their respective starting points." What do you mean here?
28. **Line 180:** "To determine .. respective basin." → Rephrase to something like: "To determine the transport contribution of the different basins within the subpolar North Atlantic, we define ...". You could omit the limits of each area that you define and just refer to figure 2 for the definition of the different areas.
29. **Line 185-186:** You define the travel time of each particle based on the point of origin (point where the particle changes its density). However, in Figure 5 you include the transit time of DS_p and ISR_p . Please revise this sentence.
30. **Figure 2:** Why did you choose to average the mixed layer depth over the 2000-2019 period and not over 1958-2019 or 2010-2019, which are periods that are discussed earlier in the manuscript? Also, this figure is mainly discussed after Figure 3. Consider changing the order of these figures. If you do so, you could remove the blue dashed lines that you use to define the areas in Figure 2 and add these lines in Figure 1.
31. **Table 1:** Please check the values. The transports/contributions associated with each particle category do not sum up to the total transport (i.e., for NADW: 101% instead of 100%, for LSW: $12.8+7.0+3.4+1.7+1.7 =$

26.6 Sv instead of 27.7 Sv). There is also an extra parenthesis at 3 column, 4 row.

32. **Line 200:** I am missing a short introductory paragraph/sentences here. It is a rather rough beginning for the reader. It is not clear in which figure the reader should look.
33. **Line 283:** "The upper transport.." → The lighter transport peak ..?
34. **Line 249:** "... is dominated by diapycnal mass flux and the particle residuum." → "... is dominated by the DIA_p and RES_p particles.
35. **Line 207:** (ML_p , 7.0 Sv or 26%, Table 1)
36. **Line 214:** I don't feel this has been fully demonstrated. Perhaps adding the region of high EKE in one of the figures would help.
37. **Line 219:** "... within the boundary current in the Labrador Sea (5.5 Sv, **Table 2**) and Irminger Sea (4.6 Sv, **Table 2**) at depths between ..."
38. **Line 222-224:** I guess that this statement refers to Figure 4 a. However, I don't see the 1000 m isobath.
39. **Line 225-229:** References to the associated figure/table are missing. Also, consider adding the values of INADW in Tabel 2.
40. **Line 231:** "... single regions in the interior..". What do you mean?
41. **Line 240:** "Boundary Current" → boundary current
42. **Line 248:** add a reference to Figure 5b.
43. **Line 253:** "Transport" → transport
44. **Figure 5:** Consider making a new figure for the panels (e-f). You only mention these panels shortly in section 4 (Discussion).
45. **Line 259 and Figure 5:** The definition of the transit/travel time here differs from DIA_p and ML_p , right?
46. **Line 267-268:** Please be more concrete here. What do you mean by "due to the importance of interior pathways"?

47. **Line 275-284:** Why not including a figure showing the major pathways of RES_p ?
48. **Line 286-289:** Please revise; refer to earlier figure/table to support your statement and guide the reader of what is following in this section.
49. **300-301:** Do you mean the region south of $53^\circ N$? Is this still considered the interior of the SPNA?
50. **Line 312-319:** Here, many elements of discussion have already been discussed in section 3.1.2. Consider revising the text.
51. **Line 335:** ".. is followed by a continuous decrease in salinity until $53^\circ N$." Is this statement verified by a figure?
52. **Figure A2:** There are some extra parenthesis in the caption.
53. **Figure A3 and Figure A4:** Consider adding a title in each panel. Also, mention in the caption of figure A3 that this figure is for the DIA particles.
54. **Line 345-346:** Please revise this sentence.
55. **Line 357-358:** If the water masses are laterally advected within an isopycnal, how a change in density is then possible?
56. **Line 378-380:** Figure 5(e-f) is only shortly discussed here. I don't see the relevance here. Is the signal of downwelling only related to the particles that originate at the GSR? What about the other particle categories?
57. **Line 394-396:** Please revise.
58. **Line 405-406:** I guess that here you are referring only to the contribution of ML_p . If so, why? What about DIA_p ?
59. **Line 412-420:** Please add references to the associated figures.
60. **Line 420-421:** Please revise.
61. **Line 422:** Volume transports of what?
62. **Line 438 and elsewhere:** stemming \rightarrow originating or similar.