Response to Reviewer #1

Note: In this response, the reviewers comments have been left untouched, and we added our responses in bold.

General comments
In this study, the authors analyze the overturning circulation and water mass transformation of the Arctic Ocean in a 1/12° global ocean model hindcast simulation over 1979–2015. The analysis of water mass transformation is performed both in density space and temperature– salinity space. In addition, pathways and timescales of the circulation are determined using Lagrangian virtual particle tracking. These approaches allow to quantify the contribution of surface forcing and mixing in different regions to the full water mass transformation. Results include the identification of the Barents sea as a major location of surface-forced dense water formation, and the time scales of different circulation routes in and out of the Arctic. In my opinion, this paper provides an excellent and detailed overview of the circulation and water mass budgets of the Arctic (in this particular ocean model). The analysis is extensive and thorough, and the text and figures are of high quality and clarity.

I recommend that this paper be accepted for publication after addressing the minor comments below.

We thank the reviewer for the positive and constructive comments. We respond to the comments below.

Specific comments

Literature
The results of the WMT analysis in T-S space in this paper should be compared to the following study which employed a similar approach: Pemberton, P., J. Nilsson, M. Hieronymus, and H. E. M. Meier, 2015: Arctic Ocean Water Mass Transformation in S–T Coordinates. J. Phys. Oceanogr., 45, 1025–1050, https://doi.org/10.1175/JPO-D-14-0197.1.

We thank the reviewer for pointing us to relevant literature. In the revised manuscript we have expanded the discussion on how our results compare to previous estimates of water mass transformation in the Arctic Ocean, including the paper by Pemberton et al. (2015) (L. 393-394, L.426-430, L. 407-417).

Ln. 64 How does the use of monthly mean velocities (instead of a higher time resolution) affect the applicability of the Lagrangian tracking algorithm? Did the setup include some stochastic element to account for unresolved turbulence? This should either be detailed in the Methods or commented on in the Discussion.

We have tested using 5-day time-evolving fields as input, and looping over the period 1979 - 2015 instead, but the main results did not change. We do not add any stochastic diffusion as this would break volume conservation (which is essential for our calculations of e.g., the Lagrangian streamfunctions), and instead follow water using the resolved advective pathways in the model. We now mention this in the methods in L. 137-138, L. 144-145

Section 2.2 Since the many equations in this section make it look a bit "dense", it could be useful to separate it into two subsections (e.g., 2.2.1 "Density space" and 2.2.2 "T–S space"). I leave this choice to the authors

of course.

We have followed the reviewer's suggestion and divided Section 2.2 into 2.2.1 and 2.2.2.

Ln. 80 Since you mention "previous studies", it would be good to explicitly cite them. Currently it is not clear whether these previous studies also applied the Walin framework to the Arctic ocean, or if they simply also used the Walin framework in some other way.

Good point. We have added a few studies who have used the Walin (water mass transformation) framework for the Arctic (L. 82).

Technical corrections Figure sizes In some of the figures, the text labels appear smaller than in others. In particular, the longitude labels on polar projection plots are so small as to be illegible in most cases. I recommend checking the consistency of font sizes across all figures.

We have adjusted the labels/fontsizes in Figure 6, 7, 8, 9, 11, and A3, and A4.

General In all the mathematical symbols with "sfc" and "res" superscripts, you should probably use mathrm to avoid the superscripts looking like s f c. Example: $F_{\Theta}^{\mathrm{sfc}}$ vs F_{Θ}^{sfc}

This has now been adjusted.

Ln. 11 although "northern" overturning is clearly correct, perhaps writing "Atlantic" over- turning would make the broader impact of this paper clearer (AMOC slowdown, etc.)

We have replaced 'northern' by 'Atlantic' in L.12 as suggested.

Ln. 86 Maybe explicitly state volume transport

Done.

Eq. 3 Are the units in this equation consistent? It seems that the last two terms currently have different units given their different denominator/differentiation variable.

The formula has been corrected.

Ln. 101 Use v instead of ν in the equation

Done.

Fig. 1 Consider adding a vertical line at x = 0. Also, the y-axis label σ_0 appears to be smaller than the rest of the text

The size of the y-axis label in Figure 2 has been fixed. We have not added a vertical line at x = 0 as the figure is already quite busy.

Ln. 191 The salinity range should not be in parentheses

We have removed the parentheses.

Fig. 3 In the colorbar label, the salinity units should probably be inverted

We have switched the order of the units.

Ln. 208 undergo → undergoes

Done.

Ln. 231 superfluous closing parenthesis

We have removed the parenthesis.

Fig. 8 caption Why is 50% sea ice concentration used as a threshold for sea ice extent (instead of the more common 15%)? In any case, since this is mostly for illustrative purposes in this figure, this is probably not important.

We have changed 'sea ice extent' to 'sea ice edge (defined as 50% sea-ice cover)' in the caption. This is not an uncommon definition, and is here indeed only shown for illustrative purposes.

Ln. 364 "the AMOC lower branch" → the AMOC's lower branch / the lower branch of the AMOC

We have changed the text to 'the lower branch of the AMOC' (L. 384).

Fig. 9 caption grid cell area

Done.

Ln. 372 at a rate

Done.

References

Pemberton, P., Nilsson, J., Hieronymus, M., and Meier, H. E. M. (2015). Arctic Ocean Water Mass Transformation in S–T Coordinates. *Journal of Physical Oceanography*, 45(4):1025–1050.