Dear Editor and Reviewers,

Thank you for taking the time to once again review our manuscript. Please find our responses to each of your comments below. As previously, our responses are written in italic blue font. We have included a pdf showing the tracked changes in the following document:

revised_manuscript_tracked_changes.pdf

This indicates where text has been added, deleted or replaced. The line numbers indicated below refer to the tracked changes document.

Reviewer #1

I am still not fully convinced about the water mass transformation that appears to take place on the Greenland shelf in Figure 8a and the authors' response to this concern. The figure shows that densification by air-sea fluxes in the two lowest density bands (27.40-27.60 kgm^{-3} and 27.60-27.77 kgm^{-3}) occurs on the Greenland shelf, which is typically still ice-covered in winter. The authors suggest that this could be summertime water mass transformation or that it is a consequence of remapping from temperature/salinity space to geographical space. I don't think that either of these suggestions can fully account for the water mass transformation shown in Figure 8. Firstly, in summer, I am unsure which process the authors refer to that would cause densification on the Greenland shelf. The air-sea interaction taking place would in general add buoyancy to the water column, particularly by solar insolation, not densify the water column. Mixing processes might, upwelling-favorable winds could for example bring dense water onto the shelf, but summertime air-sea interaction would in the mean reduce rather than increase density. Secondly, the Greenland shelf is primarily filled with Polar water masses. Within the domain considered in the manuscript, these water masses are found on the Greenland, Baffin, and Labrador shelves. It is not clear to me in which other regions densification by air-sea interaction in these temperature-salinity classes would occur, and then be remapped onto the Greenland shelf. I think it would be great if the authors could clarify this in the final version of the paper.

We apologise for the confusion caused by our explanation of the surface forced water mass transformation over the Greenland Shelf. It's first worth re-iterating that the values shown in figure 8 are remapped from density space to geographical space. For the surface forced water mass transformation, we do this by assigning the transformation from a given density bin to each geographical point where the sea surface density falls within the range of the given density bin. This process is performed at each time-step, so that the fields shown in the manuscript represent the time-mean of the re-mapped fields. This implies that at each time-step the transformation for a given density bin is assigned equally to any location within density range of that bin, regardless of whether any surface fluxes acted at that location (see for example Figure 1 and 2 in this response for the EN4/ERA5 dataset combination). This is a caveat of the remapping process that is more detrimental for transformations in density space compared to temperature and salinity space.

An alternative approach for the surface forced water mass transformation is to average the water mass transformation before binning into density space (see for example Petit et al., 2020). In Figures 3 and 4, we show the seasonal average of this unbinned surface forced water mass transformation for the two lighter density ranges shown in Figure 8 of the manuscript using ERA5 and EN4. This highlights that while some water within these density ranges may exist where sea-ice is present, the surface buoyancy forcing in these regions of sea-ice cover is zero. That water within these density ranges exists where sea-ice is present, explains why the remapped transformations, given the caveat discussed above, incorrectly imply that surface fluxes act in these regions of sea-ice cover (Figure 1 and 2). Critically, as air-sea buoyancy fluxes do not act in these region of sea-ice cover, we therefore do not derive a surface forced water mass transformation where sea-ice is present. Further, our remapped transformations act only to aid visualisation of the transformation shown in tracer space.

We have chosen to continue to use the remapped the surface forced water mass transformations so that they remain consistent with the remapped residual water mass transformations also shown in the manuscript. To provide more clarity within the manuscript we have added some discussion on the caveat discussed above at lines 379-383 as follows:

"This also implies that the water mass transformation for a given tracer bin may be remapped to a region in which that transformation did not occur. For example, the water mass transformation by air--sea fluxes in a given tracer bin may be remapped into a region typically covered by sea ice where water within the range of the given tracer bin could exist. This caveat is more detrimental for the remapped diapycnal transformation due to the large isopycnal gradients of Θ/S in the subpolar North Atlantic and Nordic Seas."

Line 27: Labrador Sea Water should be capitalized.

Corrected

Lines 499: It should be "complementing" rather than "complimenting"

Corrected

Editors corrections:

L.176 "and we expect the we expect"

Corrected

L.565 "the in the"

Corrected

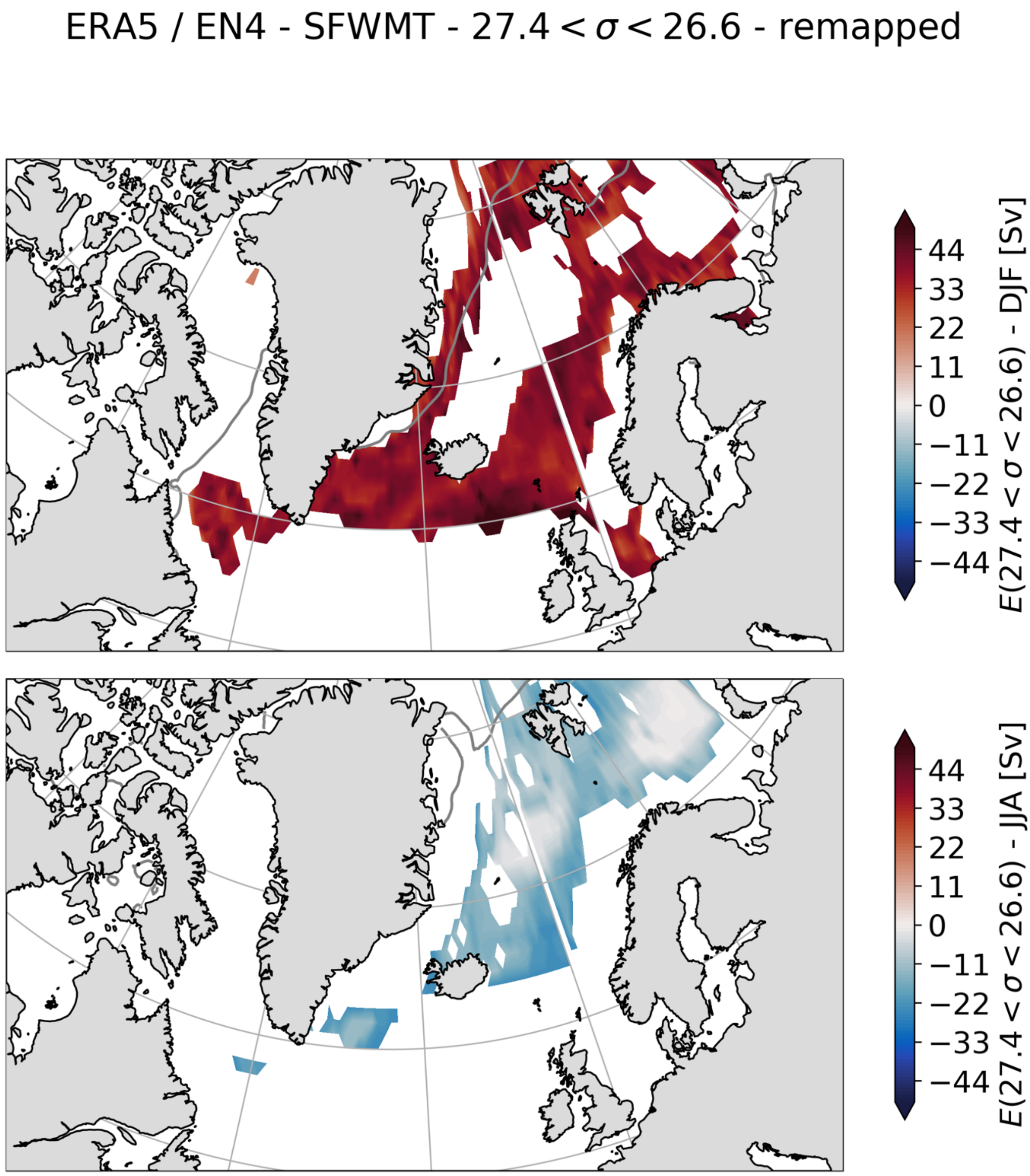

Figure 1. The remapped surface forced water mass transformation (SFWMT) for the density range between 27.4 and 27.6 kg/m^3 using surface buoyancy fluxes from ERA5 and surface temperature and salinity from EN4. The top panel shows the mean for December, January and February. The bottom panel shows the mean for June, July and August. The grey contour shows the 50% sea ice concentration contour from ERA5.

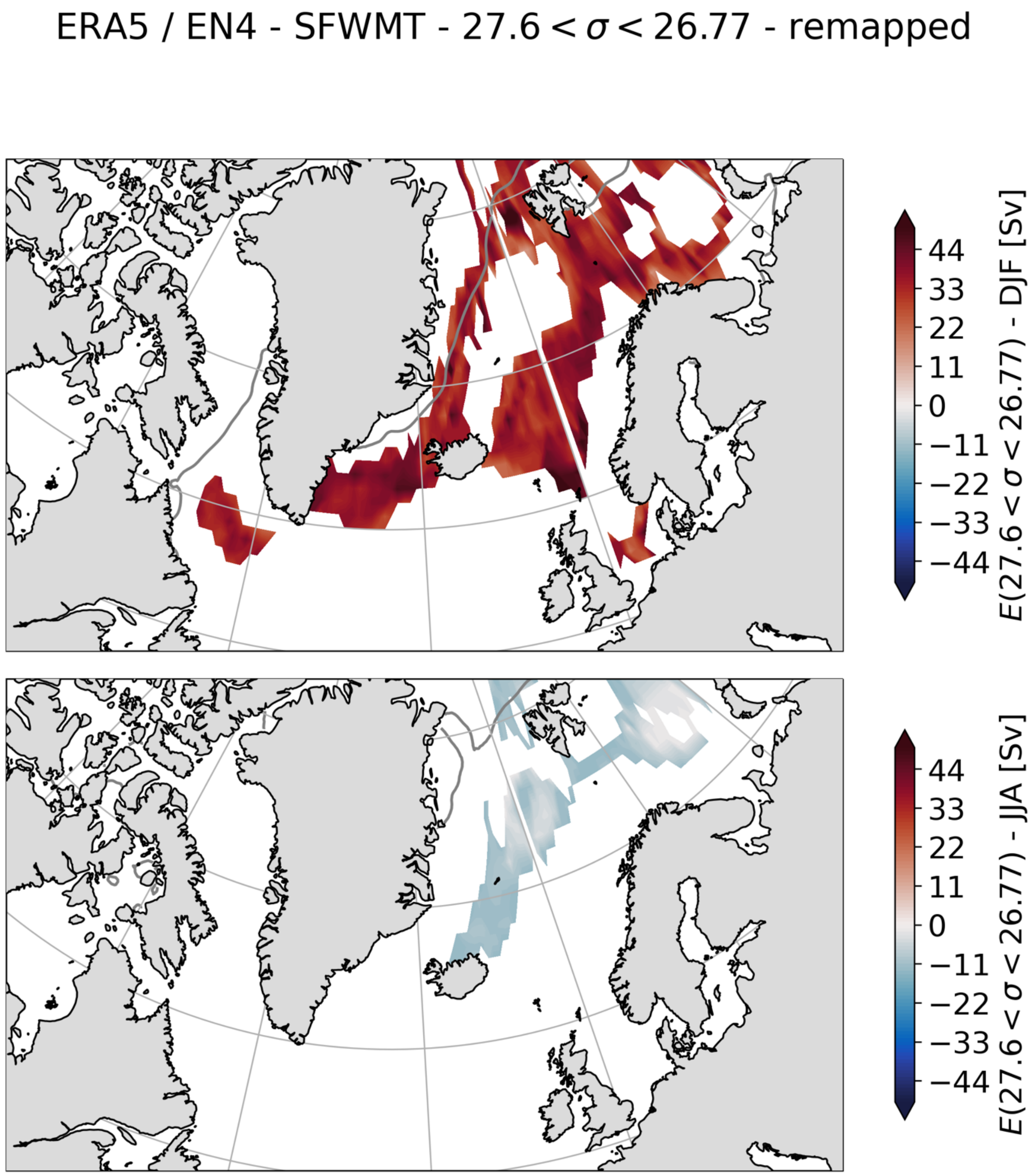

Figure 2. The remapped surface forced water mass transformation (SFWMT) for the density range between 27.6 and 27.77 kg/m^3 using surface buoyancy fluxes from ERA5 and surface temperature and salinity from EN4. The top panel shows the mean for December, January and February. The bottom panel shows the mean for June, July and August. The grey contour shows the 50% sea ice concentration contour from ERA5.

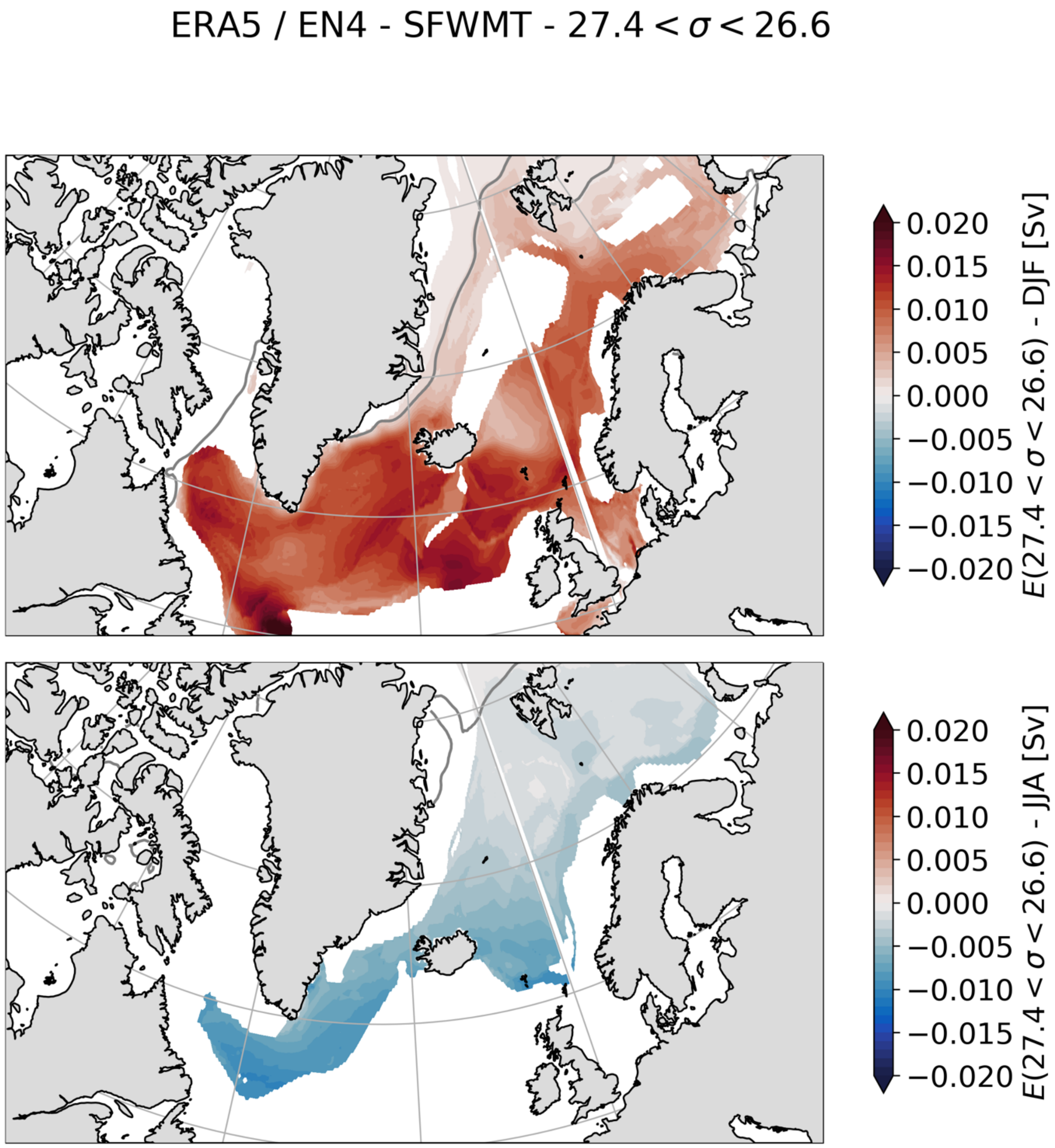

Figure 3. The surface forced water mass transformation (SFWMT) for the density range between 27.4 and 27.6 kg/m^3 using surface buoyancy fluxes from ERA5 and surface temperature and salinity from EN4. The top panel shows the mean for December, January and February. The bottom panel shows the mean for June, July and August. The grey contour shows the 50% sea ice concentration contour from ERA5.

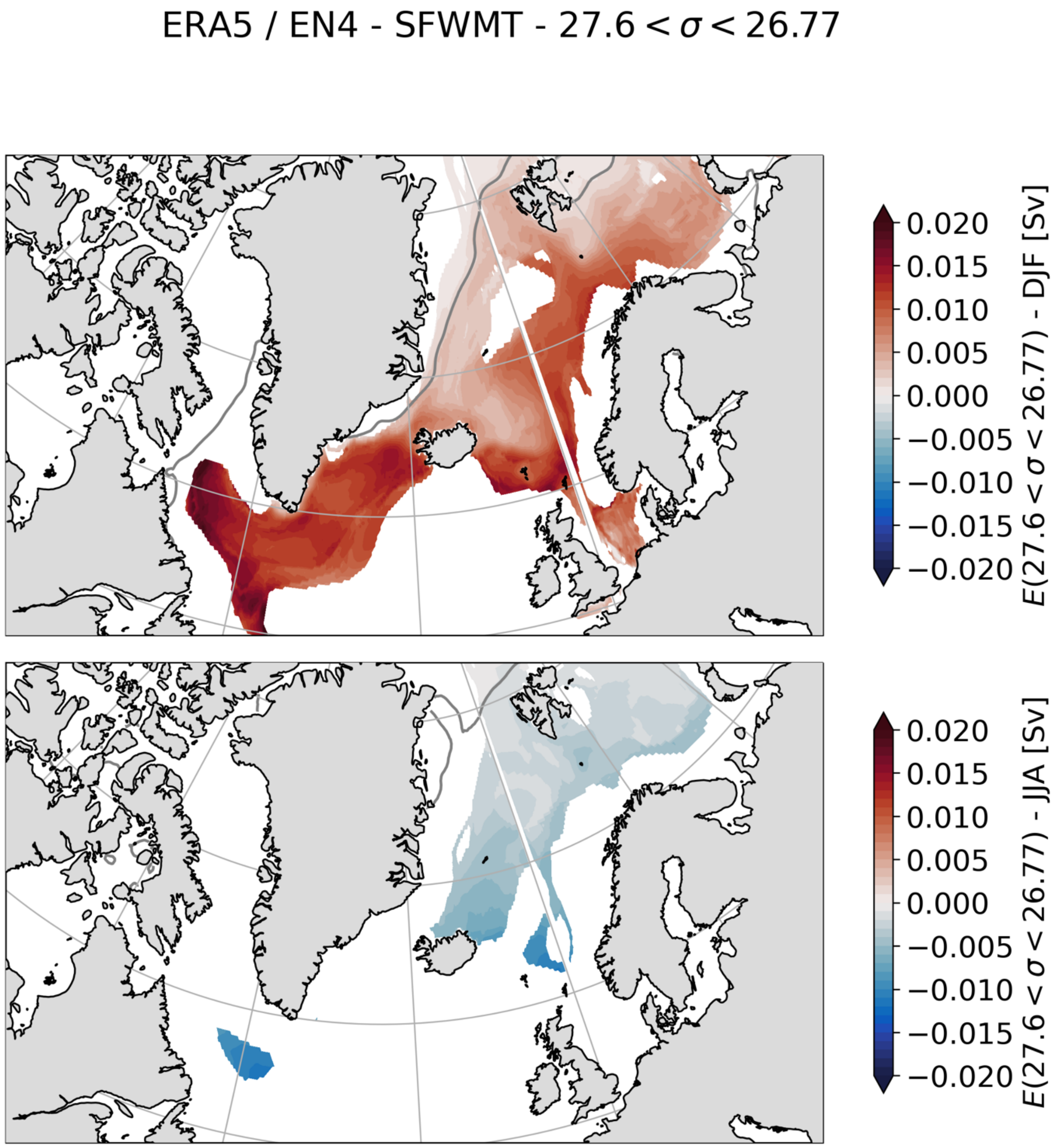

Figure 4. The surface forced water mass transformation (SFWMT) for the density range between 27.6 and 27.77 kg/m^3 using surface buoyancy fluxes from ERA5 and surface temperature and salinity from EN4. The top panel shows the mean for December, January and February. The bottom panel shows the mean for June, July and August. The grey contour shows the 50% sea ice concentration contour from ERA5.