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Two superimposed cold and fresh anomalies enhanced Irminger Sea deep convection in 2016 - 2018

by Patricia Zunino, Herlé Mercier, and Virginie Thierry

In this manuscript persistence of deep convection in the Irminger Sea is investigated. One winter of particularly severe atmospheric forcing and deep convection was followed by three winters of climatological strength which also had deep mixed layers. The authors quantified the buoyancy loss required for deep convection to commence each winter and concluded that the preconditioning arising from the previous winter's homogenization of the water column was a main reason for the persistence of deep convection.

I think this manuscript has the potential to be an important and valuable contribution to better understand deep water formation in the Irminger Sea /subpolar North Atlantic. However, as made clear also by the other reviewers, I have concerns about the determination of mixed-layer depths. As such, I recommend that the paper be revised before publication.

Major comments:

I am not convinced that automated routines, such as the threshold or split and merge methods, are particularly suitable for determining the vertical extent of the mixed layer. These routines generally perform well when applied to summer and fall profiles, when the upper ocean is stratified and there is a pronounced density difference between the mixed layer and the lower part of the profile. However, they are less accurate during periods of active convection when stratification is eroded. Furthermore, such routines cannot identify mixed layers that are isolated from the surface, either in the form of vertically stacked mixed layers or by early stages of surface restratification. Such isolated mixed layers are prevalent in the Labrador and Irminger Seas during winter (e.g. Pickart *et al.*, 2002). As pointed out by the other referees, if the density profile is considered in isolation, changes in temperature and salinity may be density-compensated such that the water column can appear to be homogenized while in reality it is not. Examples of that can be seen in Figure 2a-c (in particular 4901809 - 35). To avoid erroneous mixed-layer depths, I strongly recommend employing the semi-objective method developed by Pickart *et al.* (2002) instead of relying on automated routines.

Deep convection evidently took place in winter 2015 as documented by the many deep mixed layers shown in Figure 1. For winters 2016-2018, on the other hand, the vast majority of the Irminger Sea profiles do not have particularly deep mixed layers. If widespread deep convection occurred also during these winters, there should be many more profiles with deep mixed layers. Is it possible that the mixed-layer depths determined by the automated routines are remnants of deep convection from a previous winter or from the Labrador Sea where mixed layers are generally deeper? To get a more robust estimate of convection in the subpolar North Atlantic these winters, I suggest dispensing with the 700 m "deep convection" criterion and showing if not every mixed layer at least the 50-80% deepest mixed layers encountered by each float every winter. That would remove shallow mixed layers arising from early phases of the seasonal evolution of the mixed layer and profiles obtained within stratified eddies, while the remaining mixed layers would allow for more robust quantification of the general depth of convection.

Profiles that do not extend beneath the base of the mixed layer (there may be some examples in Figure 2d-f) would result in a shallow bias of the mixed-layer depth estimate and should be excluded from the analysis.

Specific comments:

Line 95:
It should be: "...Argo and **mooring** data..."

Lines 106 and 361:
Mixed layers exceeding 1400 m depth were determined also from shipboard measurements in the Irminger Sea in April 2015 (Fröb *et al.*, 2016).

Line 122:
If the TEOS-10 convention is used, conservative temperature and absolute salinity should be used instead of potential temperature and salinity.

Line 123:
Please explain why a salinity of 35 was chosen as a reference value.

Line 124:
Please provide more information about the gridded products. Are different time periods and resolutions the only difference between the products? What are the errors, in particular for the EN4 product which extends back to 1900 and covers some very data-sparse periods?

Line 130:
Does the net air-sea heat flux include radiative fluxes or only turbulent fluxes?

Line 149:
I do not think that 48°W is commonly used as a border between the Labrador and the Irminger Seas. Many of the deep mixed layers were recorded directly south of Greenland, in a region that is not really part of either the Labrador or the Irminger Seas.

Line 156 and elsewhere:
Please insure that all papers cited in the text are included in the References section. For example is Gill (1982) missing.

Line 174:
How was the depth of the Ekman layer estimated?

Line 179:
For consistency, it might be better to use SST also from the EN4 product.

Line 185:
It should be: "...most of **the** Argo profiles..."

Line 197:
It should be: "...to be removed (B(zi)) **from** the late summer density profile..."

Line 234:
Salted, in this context, is not appropriate. "Became saltier" would be a better expression.

Line 284:
If B remained nearly constant, does that imply that restratification and advection are unimportant?

Line 297:
Units (m) are missing after 800-1000.

Line 321:
What was the basis for choosing the point 59°N, 40°W?

Line 377:
If convection exceeded 1400 m in winter 2014-15 (e.g. Fröb *et al.*, 2016), why is it unlikely that this layer was locally formed?

Line 382:
The papers by Lavender *et al.* (2000) and Straneo *et al.* (2003) could also be cited here.

Line 383:
Corroborated is misspelled.

Line 388:
If deep convection occurs every year, perhaps the definition of deep convection should be revised.

Line 403:
It should be: "...the deep halocline was **successively** deepening..."

Line 410:
I am sceptical of the claim that the deepest convection-depth ever observed in the Labrador Sea occurred in winters 2016-2018. Very likely convection in the successive high-NAO winters of the early 1990s substantially exceeded convection in winters 2016-2018. At that time mixed-layer depths were at least 2300 m (e.g. Avsic *et al.*, 2006).

Lines 419 and 421:
Density units are not capitalized consistently.

Line 425:
It should be: "...observed in both **basins**..."

Line 430:
There were no wintertime measurements in the Irminger Sea in the early 1990s, but there is strong indirect evidence that deep convection occurred in the Irminger Sea at that time (see for example publications from the group of R. Pickart).

Line 481:
Acknowledgement is misspelled.

Lines 519 and 522:
The name de Jong is inconsistently capitalized.

Figure 5:
Please indicate, for example using tick marks along the top axis, when Argo float profiles were available in the Irminger Sea.

References

Avsic T, Karstensen J, Send U, Fischer J. 2006. Interannual variability of newly formed Labrador Sea Water from 1994 to 2005. *Geophysical Research Letters* **33**: L21S02, doi:10.1029/2006GL026 913.

Fröb F, Olsen A, Våge K, Moore G, Yashayaev I, Jeansson E, Rajasakaren B. 2016. Irminger Sea deep convection injects oxygen and anthropogenic carbon to the ocean interior. *Nature Communications* **7**: doi:10.1038/ncomms13 244.

Lavender KL, Davis RE, Owens WB. 2000. Mid-depth recirculation observed in the interior Labrador and Irminger Seas by direct velocity measurements. *Nature* **407**: 66–69.

Pickart RS, Torres DJ, Clarke RA. 2002. Hydrography of the Labrador Sea during active convection. *Journal of Physical Oceanography* **32**: 428–457.

Straneo F, Pickart RS, Lavender KL. 2003. Spreading of Labrador Sea Water: An advective-diffusive study based on Lagrangian data. *Deep Sea Research I* **50**: 701–719.