Ocean Science Discussions

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Reply on RC1

Tillys Petit et al.

Author comment on "Role of air–sea fluxes and ocean surface density in the production of deep waters in the eastern subpolar gyre of the North Atlantic" by Tillys Petit et al., Ocean Sci. Discuss., https://doi.org/10.5194/os-2021-48-AC1, 2021

We thank Referee RC1 for his insightful reviews that have helped us improve the manuscript.

Dear editor and authors,

This well-written manuscript presents interesting and significant results highlighting the important role of ocean surface density variability in the eastern subpolar North Atlantic for driving changes in water mass transformation. I recommend publishing the manuscript subject to minor revisions.

Detailed comments:

Title: Consider changing the preposition in the title. For example, you could say "Role of air-sea fluxes and ocean surface density for the production…" or "Role of air-sea fluxes and ocean surface density in the production…" Alternatively, you can use "Impact of air-sea fluxes and ocean surface density on the production…"

We changed the preposition, and the title now reads:

"Role of air-sea fluxes and ocean surface density in the production of deep waters in the eastern subpolar gyre of the North Atlantic."

Line 69, "density": Do you mean potential density referenced to the surface? (Here and at several other instances throughout the text.)

We used potential density referenced to the surface to analyse the influence of the surface density field on the transformation of surface water. This is now clarified in the caption of Figure 1b and in section 2.2 (l.127-128):

"Temperature and salinity are used to calculate potential density referenced to the surface, s_θ (Gill, 1982)."

Line 116, "is the potential density": Do you mean the density referenced to each vertical level z? You are computing vertical stratification, so I imagine that in this particular case you are not using potential density referenced to the surface.

You are right, the equation is now clarified:

"We also use EN4.2.1 to calculate potential vorticity (..) in the Iceland Basin, where f is the Coriolis parameter, s_0 is the potential density referenced to the surface, and ds/dz is the vertical gradient of potential density at middepths."

Line 120: also cite Desbruyeres et al. (2019) https://doi.org/10.5194/os-15-809-2019

Done. The sentence now reads:

"Following past work (Desbruyères et al., 2019; Speer & Tziperman, 1992; Tziperman, 1986; Walin, 1982), the evaporation (E), precipitation (P), and net heat flux into the ocean (Q) are used to estimate the surface-forced transformation across an isopycnal, s, as follows:"

Lines 197-198, "Though a strengthening of the buoyancy forcing generally leads to an expansion of the surface area.": The correlation does not necessarily mean that this is the direction of causality. Is it possible that the direction of causality is the other way around: an expansion of the surface area can drive a buoyancy flux anomaly?

Strong buoyancy forcing is likely to increase the area of dense water at the surface since buoyancy forcing produces dense water. However, it is not clear that the introduction of dense surface water (perhaps via advection) would increase the local buoyancy forcing. We argue here that the introduction of dense surface water increases transformation but our assumption regarding the correlation between buoyancy flux anomalies and surface area change is that the former drives the latter.

Line 199: You could change "30%" to "less than 30%" if R2 is closer to 0.27 than 0.30 (R=0.52 according to line 209).

Thank you for the suggestion, the sentence now reads:

"Though a strengthening of the buoyancy forcing generally leads to an expansion of the surface area, the buoyancy flux in a given winter explains less than 30% of the surface density change in the Iceland Basin."

Figure 3: What does panel (f) represent, and what are the units in that panel?

Panel (f) of Figure 3 shows the same as panel (d), namely the spatial pattern of SPMW transformation variance, zoomed in over the Iceland Basin. The units, in Sverdrup, have been added in that panel.

Lines 235-247: Consider adding some discussion on whether the surface density variability is dominated by salinity or temperature. This could make a difference, as salinity variability does not directly drive local surface buoyancy fluxes, while temperature variability does.

New supplementary figures compare the spatial pattern of the variance in SPMW transformation when it is estimated with (1) climatological surface temperature and variable surface salinity, and (2) climatological surface salinity and variable surface temperature. These results show us the importance of understanding the mechanisms that drive temperature and salinity variability, particularly the latter for the Iceland Basin.

We now discuss this result in the manuscript (l.250-253):

"The variance in surface density has contributions from both temperature and salinity variability (Fig. A2), as expected in these high latitudes where surface waters are so cold."

Line 271, "the buoyancy anomaly": Do you mean "the buoyancy flux anomaly"?

Yes, the sentence is now clarified:

"Though the buoyancy flux anomaly is relatively strong during this winter, it is not the largest anomaly observed over the 40-year record (Fig. 6b), suggesting that additional conditions are required for large transformation."

Line 323: Consider changing "dependent" to "interdependent" (which sounds more physically intuitive) or "statistically dependent" (which is a more mathematical phrase).

Done. The sentence now reads:

"Our analysis reveals that these two variables are weakly interdependent in this region: variance in the air-sea fluxes can explain ~30% of changes in the wintertime surface density field over the Iceland Basin."

Please also note the supplement to this comment:
https://os.copernicus.org/preprints/os-2021-48/os-2021-48-AC1-supplement.pdf