Labrador Slope Water Connects the Subarctic with the Gulf Stream

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Overview

Labrador Slope Water (LSLW) is a relatively fresh and cool water mass that originates from the Labrador Current in the subarctic and is known to occur in the Eastern Slope Sea on the US-Canadian shelf-slope north of the Gulf Stream (Fig. 1). It has potential densities of 27.4-27.65 kg m^{-3}. Using ocean observations, we show here that the LSLW penetrates as a boundary current deeply into the Western Slope Sea (west of 66°W) as a salinity minimum between 400-600 m, bringing it into close proximity with the Gulf Stream (Fig.s 2, 3). The LSLW at Line W (near 69°W) also spreads across, and brings fresher and thicker waters to, the Slope Sea north of the Gulf Stream (Fig. 4). A high-resolution ocean model simulation shows that the spreading of the LSLW occurs throughout the entire Slope Sea through the extrusion of fine-scale filaments from the boundary current following interaction with Gulf Stream meanders and eddies (Fig. 5). At Line W, the LSLW is also found to be fresher and thicker between 2003-2008, when the Atlantic Meridional Overturning Circulation (AMOC) at 26°N is higher (by 3 Sv), and the Shelf Slope Front is further south (by 0.7°), compared to AMOC low conditions in 2009-2014 (Fig. 4). The thicker LSLW causes lighter isopycnals to rise over the shelf slope, and through increasing the lateral density gradient contributes an additional 1.3 Sv to the Gulf Stream transport (Fig. 3). These changes to the LSLW and the Shelf Slope Front are likely to result from an enhanced flow of the Labrador Current into the Slope Sea, caused by changes in the wind stress in the subpolar gyre. The transport of the LSLW (as opposed to the deeper Labrador Sea Water) thereby offers a potential new mechanism for decadal variability in the Atlantic climate system, through connecting changes in the subarctic with subsequent variability in the Gulf Stream and AMOC. See published paper above for the full results and discussion.

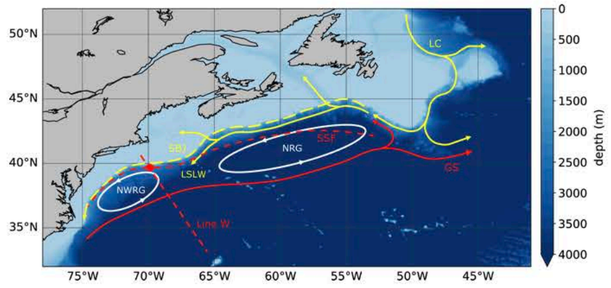

Figure 1. *Circulation schematic of the Slope Sea (the region between the Gulf Stream and the shelf slope between 52-75°W), showing the Labrador Current (LC), Labrador Slope Water (LSLW), the Shelf Break Jet (SBJ), the Gulf Stream (GS), Line W (dashed red) and Station 7 (red circle), the Northern Recirculation Gyre (NRG), the North-West Recirculation Gyre (NWRG) and the Shelf Slope Front (SSF). The ocean bathymetry is taken from the ETOPO1 dataset.*

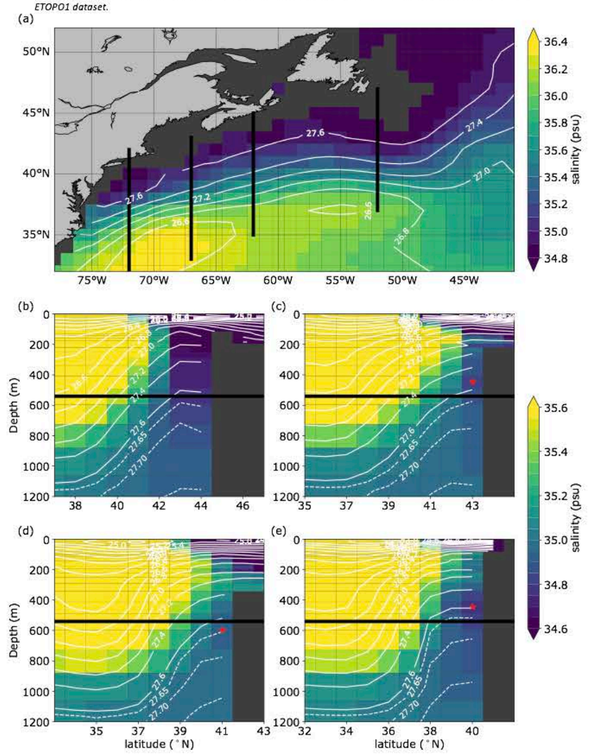

Figure 2. *Salinity (colour) and potential density (white contours) in the Slope Sea from EN4.2.1, averaged between September 2003 and August 2015. Salinity and potential density at (a) 541 m, (b) 52°W, (c) 62°W, (d) 67°W and (e) 72°W. Potential density is shown with a contour interval of 0.2 kg m^{-3} where equal to or lower than 27.6 kg m^{-3} (solid white lines) and with a contour interval of 0.05 kg m^{-3} where higher than 27.6 kg m^{-3} (dashed white lines). The red stars in (c) to (e) show the position of the LSLW low salinity core.*

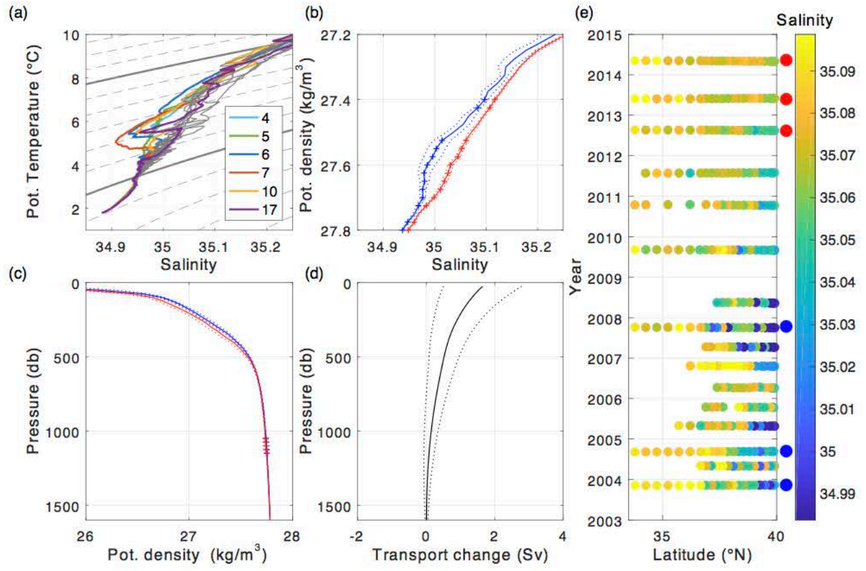

Figure 3. *Hydrographic data from Line W. (a) Potential temperature versus salinity for the May 2008 occupation, and stations 4 to 17. Individual station profiles are shown by the coloured contours as indicated in the inset. Potential density contours are also shown in increments of 0.1 kg m^{-3}, with the 27.2 and 27.8 kg m^{-3} contours shown by the thick continuous lines. (b) Potential density versus salinity at Station 7 and averaged over all occupations during the AMOC high period (blue) and the AMOC low period (red). Standard errors of the means are shown by the dotted lines and crosses indicate where the difference between the two periods is significant (95% confidence). (c) Similar to (b) but showing pressure (decibars, db, approximately equal to depth in m) versus potential density. (d) Geostrophic transport change at Station 7 (integrated upwards from 2000 m, and plotted against db) between the profiles in the two periods chosen in panel (c). (e) Salinity on the potential density surface 27.55 kg m^{-3} (showing all stations from Station 4 seawards). The blue circles show the three "fresh" (between 2003-2008), and the red circles three "salty" (between 2009-2014), occupations chosen for further analysis.*

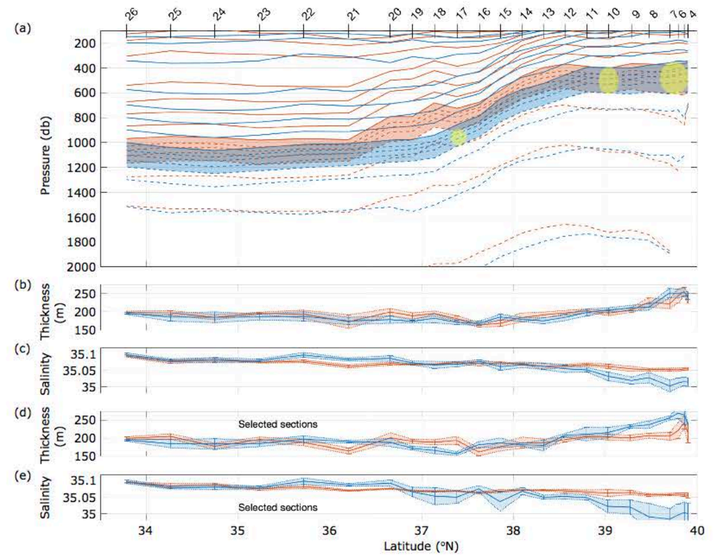

Figure 4. *(a) Density sections (plotted against depth in db) on Line W in the AMOC high (blue) and low (red) periods between stations 4 and 26, with the LSLW layer (between densities 27.4-27.65 kg m^{-3}) shown shaded. Contours are shown every 0.2 kg m^{-3} from and lower than 27.4 kg m^{-3} (solid lines), and every 0.05 kg m^{-3} from and higher than 27.5 kg m^{-3} (dashed lines). Station positions are indicated at the top of the panel and yellow ovals show the occurrence of the freshest LSLW in the May 2008 occupation, overlaid on the density structure in the AMOC high period. (b) Thickness (m) of the LSLW layer in the AMOC high (blue) and low (red) periods, showing the mean and standard error of the mean. (c) Salinity on the 27.55 kg m^{-3} isopycnal in the AMOC high (blue) and low (red) periods. Panels (d) and (e) are similar to (b) and (c) respectively, but use averages over the selected full-length "fresh" (in blue) and "salty" (in red) sections as indicated in figure 3(e).*

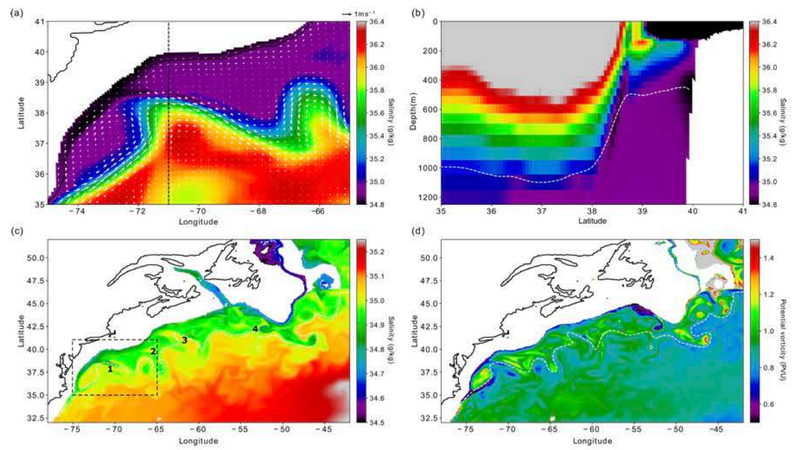

Figure 5. *NEMO ocean model 5-day means centred on January 23 in year 2 of the integration ((a) to (d)). (a) Salinity (colour) and currents (arrows, shown every third gridpoint, 1 m s^{-1} scale arrow at top right) at 565 m northeast of Cape Hatteras. (b) Salinity at 71°W, also showing the 27.55 kg m^{-3} density contour (white dashed line). (c) Salinity averaged over the 27.5-27.6 kg m^{-3} layer, also showing the position at which the average layer depth is at 700 m (white dashed line), and multiple ejection events 1 to 4. The black dashed box is the area shown in (a). (d) Similar to (c) but showing full potential vorticity in PV Units (PVU) where 1 PVU = 10^{-7} kg m^{-4} s^{-1}.*