Hydrographic Structure of Overflow Water Passing Through Denmark Strait

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INTRODUCTION

Denmark Strait Overflow Water (DSOW) constitutes the densest portion of North Atlantic Deep Water, which feeds the lower limb of the Atlantic Meridional Overturning Circulation (AMOC). Based on recent studies it is believed that DSOW approaches the sill via three pathways: the Shelfbreak East Greenland Current (EGC), the North Icelandic Jet (NIJ), and the Separated EGC (Figure 1).

Moored measurements in the strait indicate that the hydrographic structure of the overflow varies on timescales of 1-5 days [1-3]. These fluctuations have been attributed to the intermittent passage of large, cold lenses of water called boluses. Boluses were first observed in 1955 in hydrographic sections south of Denmark Strait and have since been identified in various observational datasets and numerical models [4-11]. Different mechanisms have been proposed to explain their formation including baroclinic instability and barotropic surface-intensified jets [12,13]. However, no consensus on their origin presently exists.

The goal of this study is to characterize the hydrographic structure of the different DSOW constituents at the sill, before the water descends into the Irminger Basin, and investigate their origin. We use temperature and salinity (T/S) data from 111 shipboard transects occupied in the vicinity of the sill, collected between 1990 and 2012.

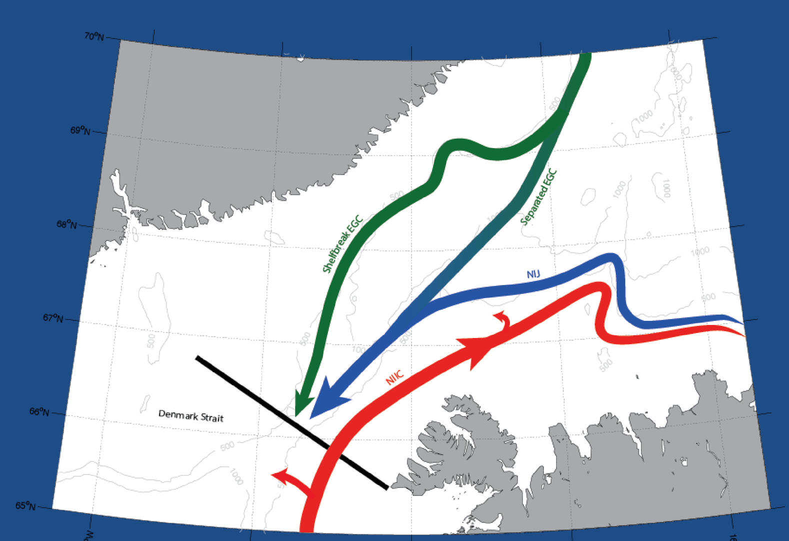

Figure 1: Schematic of the currents flowing through Denmark Strait. The T/S data used in the study are from the Látrabjarg Line (drawn in black), located near the sill in Denmark Strait.

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WHAT ARE BOLUSES?

We have developed a set of criteria to objectively identify the large, homogeneous boluses of overflow water in the synoptic sections occupied across Denmark Strait. In particular, boluses are defined as weakly stratified water with Brunt-Väisälä frequencies less than or equal to 2.0×10^{-4} s^{-1}. They must also occupy more than 65% of the trough in Denmark Strait (the region deeper than ~500 m) and extend at least 150 m above sill depth. (The results are not overly sensitive to these size constraints.)

Boluses defined as such are present in 41% of the synoptic sections across the sill in Denmark Strait (Figure 2), and they constitute the coldest and densest component of the overflow (Figure 3).

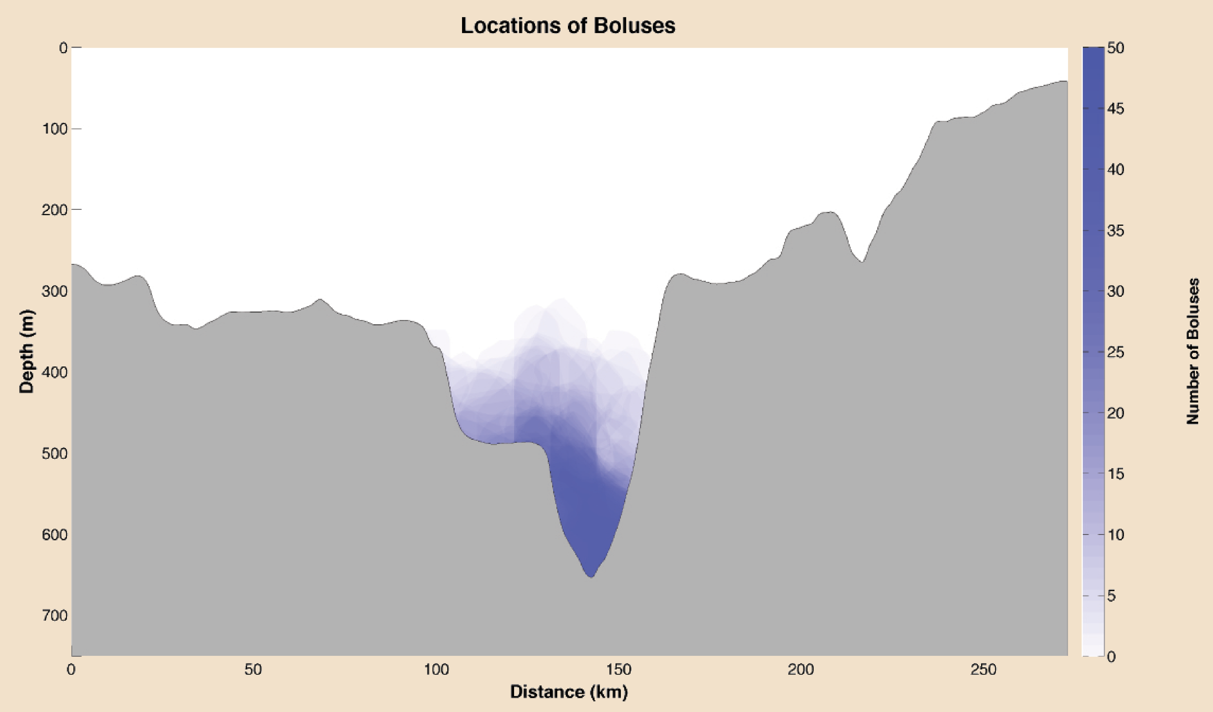

Figure 2: Realizations of all 46 boluses identified in the synoptic sections across Denmark Strait.

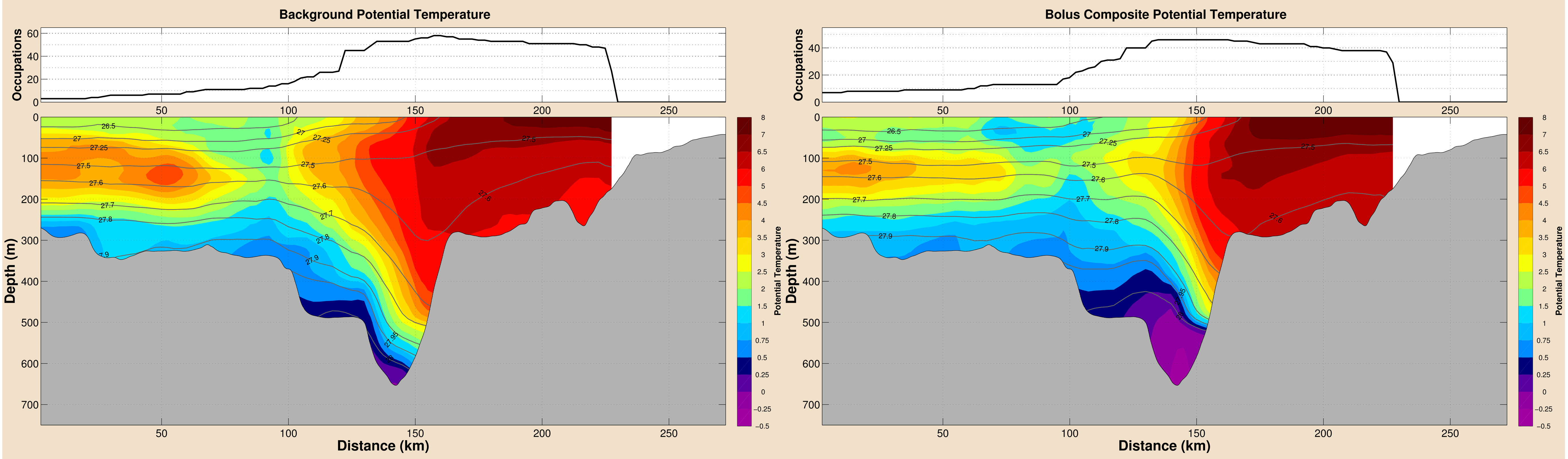

Figure 3: Mean potential temperature (°C, color) and potential density (kg/m^3, contours) of the Látrabjarg Line in the absence (left) and presence (right) of boluses. The line above the plots indicates the number of independent samples across the section.

SIGNIFICANCE OF BOLUSES

When boluses pass through Denmark Strait the deep isopycnals are raised upwards as much as 150 m (Figure 4). Assuming a constant advective speed of 0.2 m/s (representative of the overflow [14]), the transport of DSOW increases by more than a Sverdrup (Table 1). The overflow water is also significantly colder and denser in the presence of boluses.

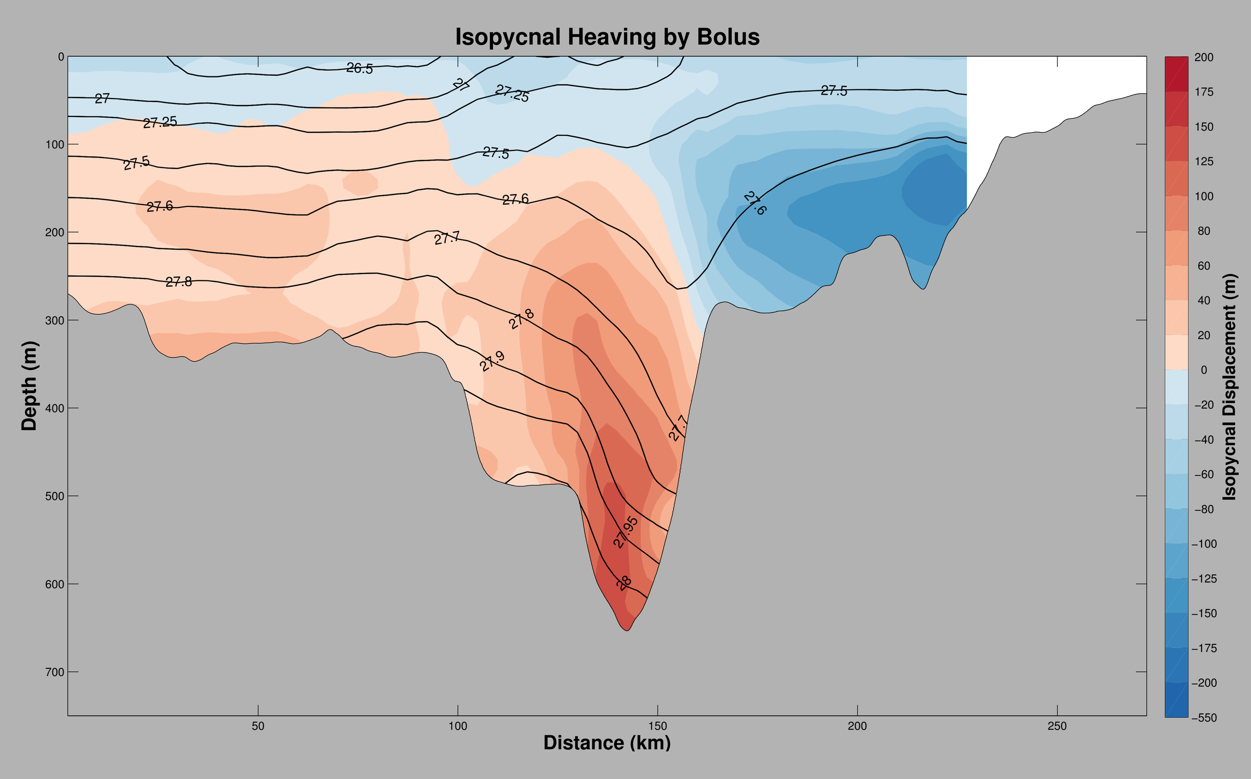

Figure 4: Mean vertical displacement of the isopycnals in Denmark Strait due to the passage of boluses (color). Overlaid on this is the potential density (contours) of the background state (in the absence of boluses).

Table 1: Mean and standard errors of the potential temperature and density of the overflow water (denser than 27.8) with and without boluses. The transport was estimated using a constant velocity of 0.2 m/s, a value characteristic of the overflow [14].

	θ (°C)	σ_θ (kg/m^3)	Est. Transport (Sv)
Bolus Overflow	0.517 ± 0.039	27.960 ± 0.003	4.445 ± 0.002
Background Overflow	0.802 ± 0.063	27.935 ± 0.004	3.348± 0.001
Difference	-0.285 ± 0.102	0.025 ± 0.007	1.097 ± 0.003

ORIGIN OF BOLUS WATER

The densest water in Denmark Strait occupies a narrow range of temperature and salinity (Figure 5a). The location of this mode in T/S space generally coincides with the boluses: nearly 72% of the mode water is contained within these features. Water with the same T/S properties of the mode in Figure 5a is found upstream of the Denmark Strait in the NIJ and central Iceland Sea (Figure 5b). This is consistent with a previous modeling study [14] suggesting that the Iceland Sea Gyre is the primary source of the NIJ water that feeds Denmark Strait.

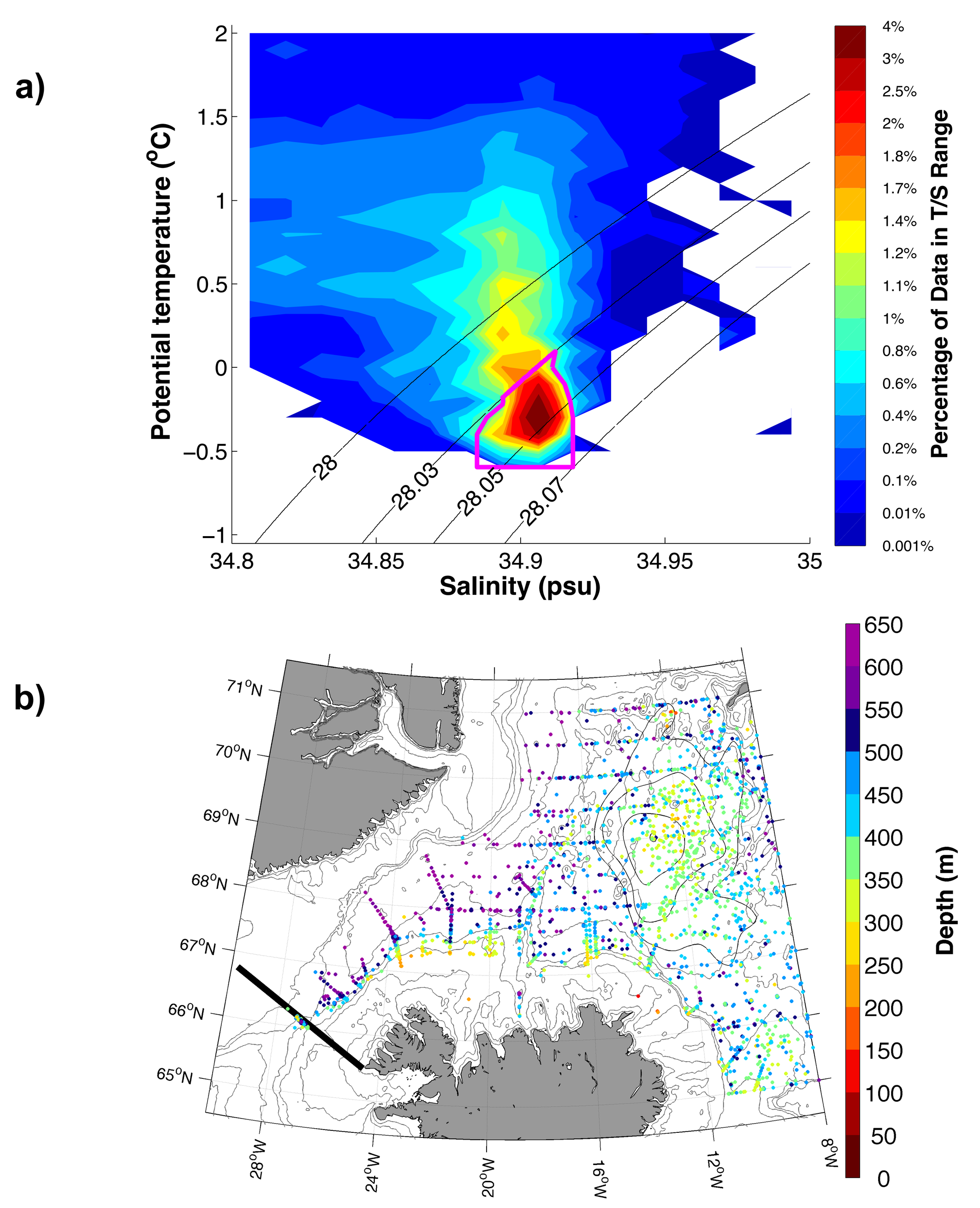

Figure 5: (a) Volumetric T/S plot of the densest portion of the measurements from the Látrabjarg Line. The T/S mode is outlined in pink. (b) Proximity of the mode water to the surface in the region north of Iceland. Only water above sill depth (650 m) is considered. The black contours denote the dynamic height of the Iceland Sea gyre.

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