Boundary Current System at 52°W in the North Atlantic

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In this work we compare two Deep Western Boundary Current (DWBC) sections in the North Atlantic to investigate the continuity of the current between the subpolar and subtropical domains.

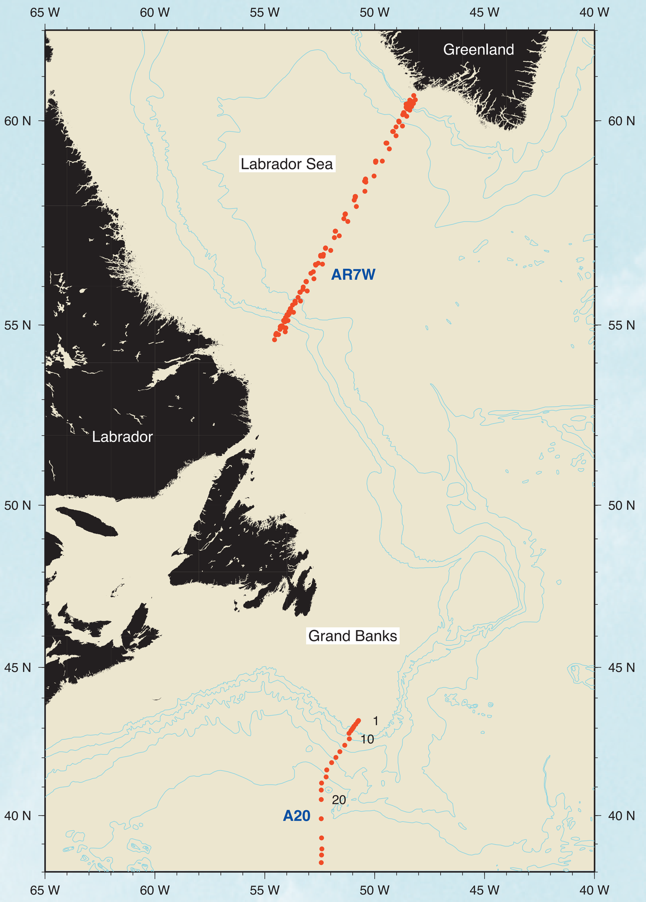

Figure 1

The upstream section is a composite of 10 springtime occupations of the WOCE AR7W hydrographic line crossing the Labrador Sea at nominally 56°N, occupied over the years 1990-7. Absolute geostrophic velocities have been computed by referencing the mean thermal wind field using PALACE float data, followed by a simple inverse calculation across the Labrador basin. The downstream section is the northern end of the WOCE A20 hydrographic/ADCP section occupied in summer, 1997, nominally along 52°W; for this section, geostrophic velocities were referenced using ADCP data, and then a mass and silicate conserving inverse was used to make additional adjustments. Both sections conserve overall mass. Their locations are shown in Figure 1, and velocity/potential density sections in Figures 2 and 3.

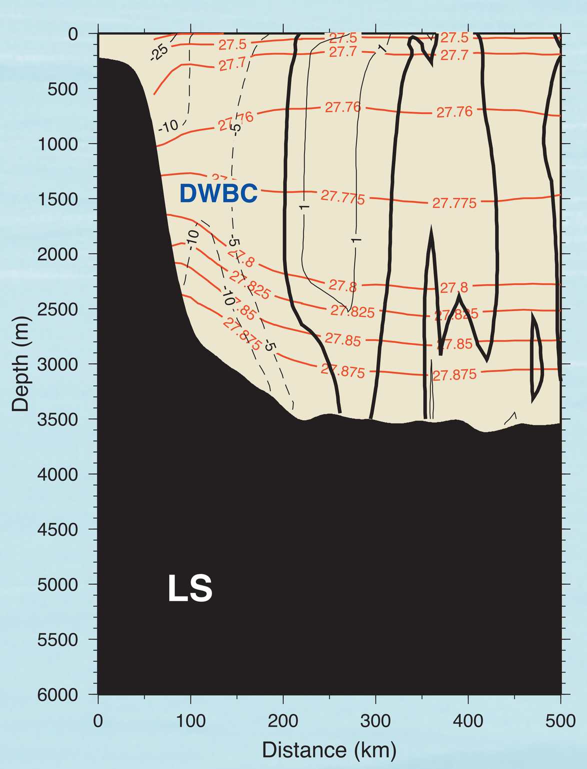

Figure 2: **Velocity and potential density contours for a composite section at 56°N. Dashed velocity contours indicate southward (equatorward) velocities.**

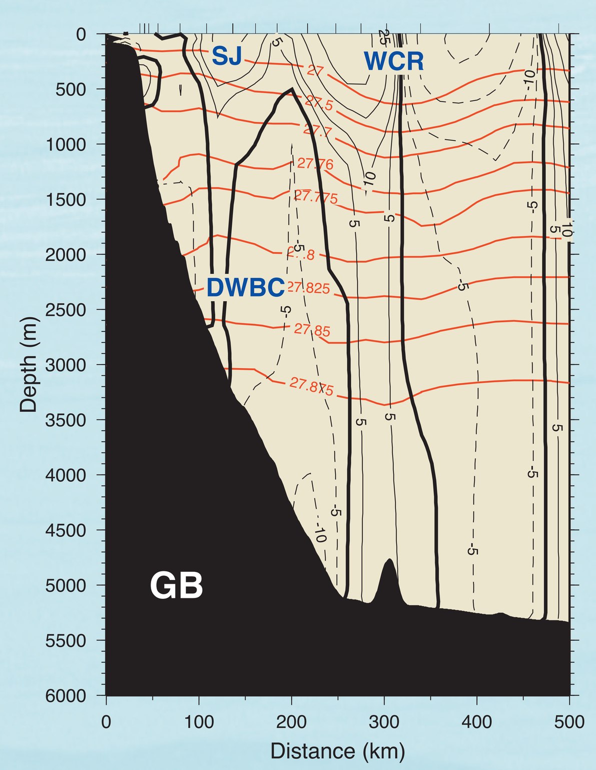

Figure 3: **Velocity and potential density contours for a section along 52°W. Dashed velocity contours indicate westward (equatorward) velocities. "WCR" refers to Warm Core Ring. "SJ" refers to Slopewater Jet.**

The comparison of these two sections was motivated by the recognition that the total equatorward transport calculated for the northern boundary current system at 52°W was nearly identical to the comparable throughput of the western boundary current system in the Labrador Sea, both being around 29 Sv. However, it has long been disputed how much of the equatorward flow in the latter is able to round the Grand Banks, where the Labrador Current, in particular, is believed to retroflect north and eastward as it encounters the North Atlantic Current. To investigate this question, we divided the water column into 10 potential density classes (Table 1), and computed transport for these classes at the two locations. For the Labrador Sea (LS), the flow was integrated from the shoreward (western) boundary to the eastern end of the weak recirculation (Figure 2) to account for the net equatorward throughflow only. For the Grand Banks section (GB) at 52°W, all westward flow between stations 1 and 18 was considered. Note that the eastward flow between Stations 11 and 14 in Figure 3 is the Slopewater Jet, a northeastward bifurcation of the Gulf Stream, and therefore not part of the DWBC system (McLellan, 1957; Fofonoff and Hall, 1983).

Table 1. Layer Transports

σ_θ	Layer #	Lab. Sea Transport (Sv)	52°W Transport (Sv)
18.0			
	1	-0.58	-1.12 /-0.72
27.0			
	2	-1.75	-1.09 /-1.00
27.5			
	3	-2.71	-1.69 /-1.20
27.7			
	4	-5.31	-2.80 /-1.88
27.76			
	5	-2.73	-1.89 /-1.21
27.775			
	6	-3.03	-3.11
27.8			
	7	-1.75	-1.68
27.825			
	8	-1.90	-1.78
27.85			
	9	-2.78	-2.84
27.875			
	10	-6.04	-10.35
29			

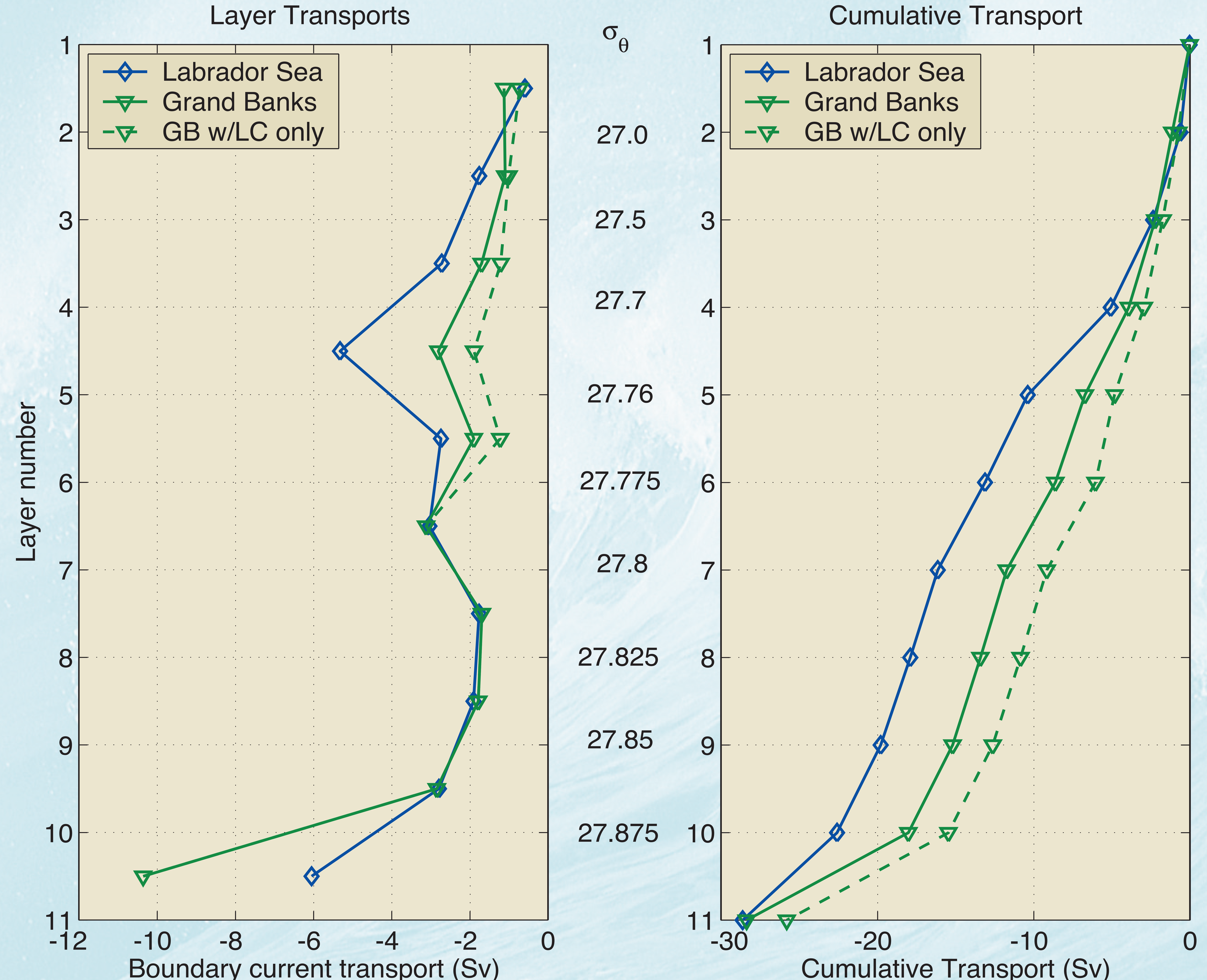

Figure 4

Transport by density class for the two locations is shown in Table 1 and Figure 4. The results are striking: excluding the lightest density layer (which barely exists in the LS section), transport in the other 4 lightest density classes (which lie above ~1500 m) decreases by about half from the Labrador Sea to the other side of the Grand Banks; transport in the denser classes, lying between 1500m and 3000m (LS) / 3500m (GB), is virtually conserved; and in the deepest class, the transport downstream is about 60% greater than upstream (note that the bottom topography is deeper at 52°W, as well). Thus, the overall conservation of throughput (29 Sv total) appears to be fortuitous, with the loss of transport in the Labrador Current being compensated by the gain in transport at depth.

We next examined whether these conclusions are borne out by the water properties in the various density layers. In particular, we would expect water at the GB section to be warmer and saltier than that at the LS section for a given density class, since the water must travel 1000 km between the sections and is entraining saltier, warmer water en route. Theta-S plots are shown for the various density layers in Figures 5 (layers 2 through 5) and 6 (layers 6 through 9). In the less dense layers, theta-S properties of the GB westward flow inshore of the Slopewater Jet (stations 9 and 10 over the 1500-2000 m isobath) are more closely matched to those for the LS section. The dashed lines in Figure 4 represent the westward transport for stations 1 to 11 only (vs. 1 to 18) in the upper 5 layers. We propose that only this water represents a continuation of the Labrador Current, with a downstream decrease in equatorward transport from 13.1 Sv at 56°N to 6.0 Sv at 52°W. For layers 6 to 9 (Figure 6), it is certainly plausible that theta-S properties at 52°W have evolved from those in the LS; perhaps not surprisingly, smaller changes in properties occur for denser classes of water. Unfortunately, at this point, we cannot compare other properties (such as oxygen or CFCs), as we do not yet have those data for the LS section.

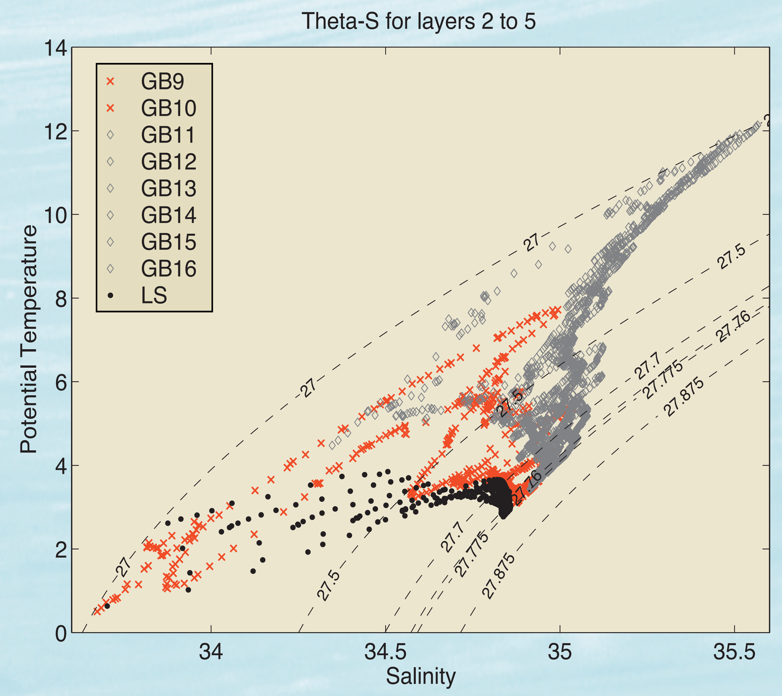

Figure 5

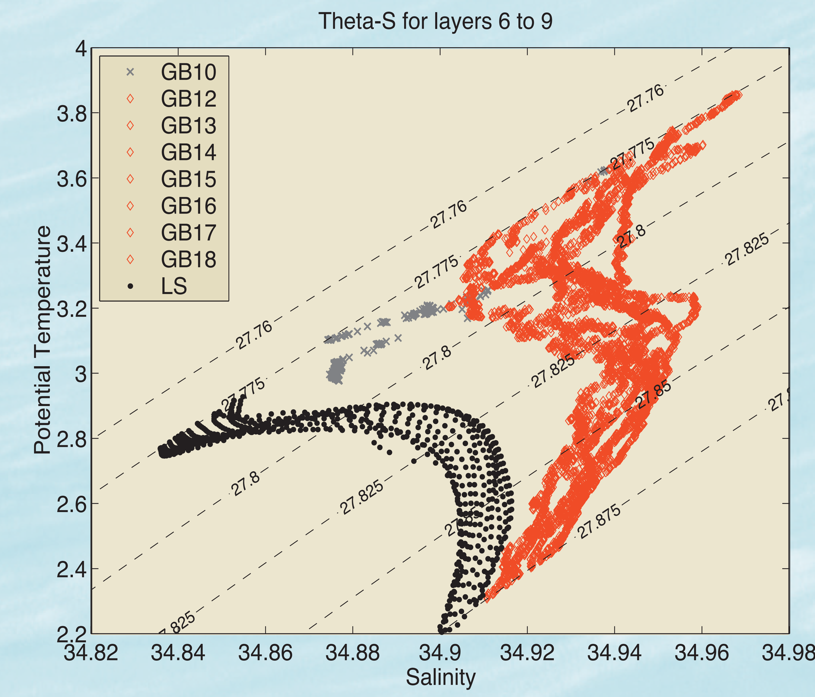

Figure 6

Finally, we compare the properties for the abyssal layer 10 (Figure 7). Although the bottom depth is greater at the GB section, denser water exists in the LS. Note that the deepest water in the GB section is colder and fresher than water of similar density in the LS. This is opposite from the expected trend, suggesting that the abyssal GB water did not originate in the DWBC upstream. This is consistent with the transport results: the GB equatorward transport below 1.9°C (where the GB and LS theta-S curves diverge) is 5.0 Sv, similar to the difference between the net transports for layer 10 at the two locations (4.3 Sv). Pickart and Huang (1995) used potential vorticity arguments to demonstrate that, indeed, the deepest part of the DWBC should be blocked by the Southeast Newfoundland Rise. Thus, the additional deep transport at 52°W must come from one of two sources: 1) either it is due to the presence of the Northern Recirculation Gyre centered west of the GB (Hogg et al., 1986); or 2) it is water that derives from remnant Antarctic Bottom Water. The latter would be consistent with the low salinities, as suggested by McCartney (1992). Strongly enhanced silicate values below 2C (Figure 8) suggest that the latter is, indeed, the source of the additional transport.

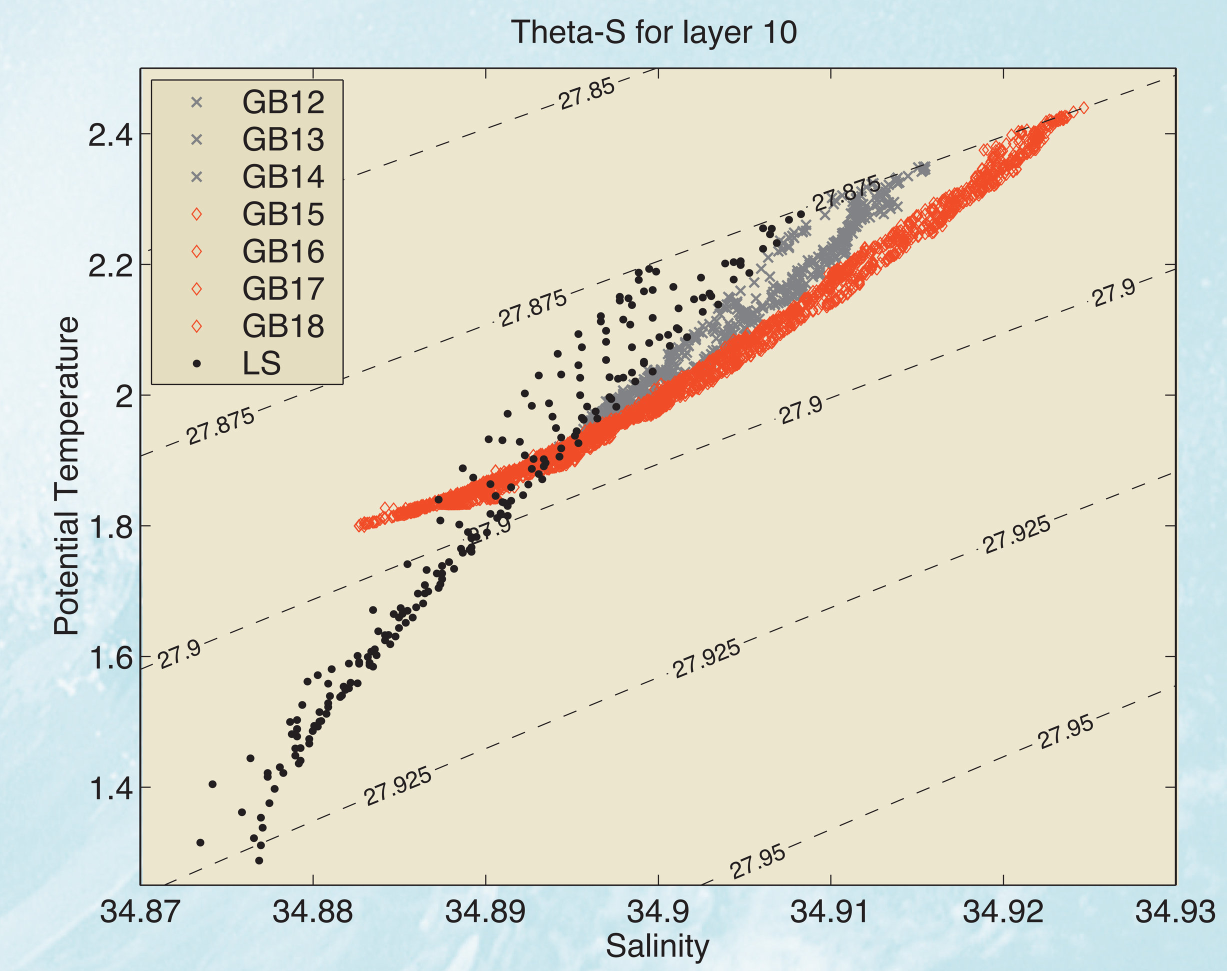

Figure 7

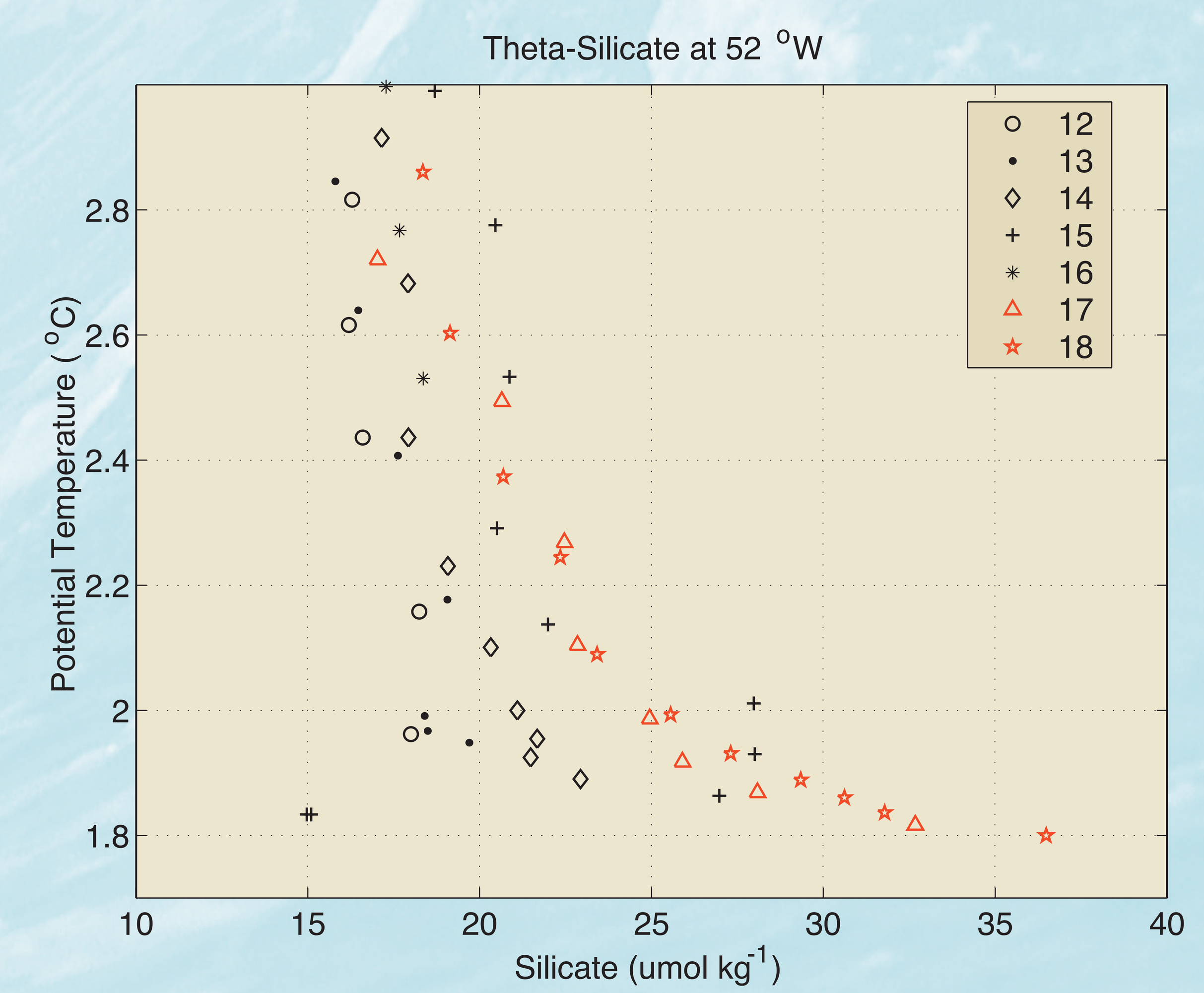

Figure 8

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McLellan, H. J., 1957: On the distinctness and origin of the slope water off the Scotian Shelf and its easterly flow south of the Grand Banks. *Fish. Res. Bd.* Canada, 14, 213-239.
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