1. Introduction

Profiles from studies in the 1990s showed virtually no evidence of Labrador Sea Water (LSW) being exported from the subpolar North Atlantic by the Deep Western Boundary Current (DWBC). To determine if these results were biased by the periodic outflow of the drifts, a Lagrangian experiment was conducted using acoustically tracked R A F O S floats. During 2003–2004, 380 R A F O S floats were sequentially released in groups of six every three months in the DWBC at 50° N and tracked for two years (Fig. 1). The floats were released at several positions across the continental slope at 750 and 1500 m, spanning the width of the tracer- and velocity-based indicators of the DWBC at the latitude (Fig. 2).

2. LSW Export Pathways: R A F O S and FL A M E

Most (>75%) of the R A F O S floats left the slope and drifted eastward out of the Grand Banks, the same pathway taken by nearly all the profiling floats (Fig. 3a, b). The relatively cold temperatures measured by these floats indicate that they were mainly recirculating within the subpolar gyre (Fig. 3a). Unlike the profiling floats, a few R A F O S (<15%) followed an interior pathway from the southern tip of the Grand Banks into the subpolar interior (Fig. 3b), as reported by Bower et al. (2008) based on a subset of the R A F O S float data set. This suggests that the interior pathway may be at least as important now as previously, and substantially more important than the DWBC pathway for the export of LSW to the subpolar region. The R A F O S export statistics are summarized in Fig. 4.

The R A F O S float trajectories were compared to 100 ensembles of simulated floats computed using the high-resolution general circulation model FLAME (Family of Linked Atlantic Modeling Experiments). Each ensemble had the same number of floats as the R A F O S group and the same distribution in depth and release site. The trajectories and displacement vectors (Figs. 3c–d) are qualitatively similar in most respects. The export results in all 100 ensembles (with standard deviations; Fig. 4g) show slightly less export to the subtropics via any pathway (22±5% for FLAME versus 29% for R A F O S) and substantially less export to the subpolar interior (7±3% for FLAME versus 17% for R A F O S). The FLAME simulations do not change significantly with differing temperature and salinity boundary conditions. Rather, the differences may result from the eddy kinetic energy distribution in the model (not shown).

3. Does it Matter that the R A F O S Floats were Isobaric: FL A M E

A previous modeling study (Gottschal et al., 2001) suggested that isobaric floats were less likely to remain trapped in the DWBC around the southern tip of the Grand Banks compared to isopycnal floats. This study used a mean velocity field from the time-mean hydrography of the Labrador Sea, which is steady-state and is less likely to represent the time-dependent model velocity fields (Fig. 3c and Table 1) shown from FLAME exported around the Grand Banks, emphasizing the importance of the eddy field in LSW spreading pathways. There is a large difference between 3D and 2D (Table 1). This is likely because LSW spreads into the interior mainly by eddies that affect most of the intermediate water column, in which case isobaric and isopycnal floats will behave similarly (see next panel).

4. Does it Matter that the R A F O S were Isobaric: R A F O S

Comparison of the R A F O S float trajectories with maps of absolute dynamic topography from R A F O S (Fig. 4) illustrates the potential importance of eddy pathways near the southern tip of the Grand Banks in the export of LSW into the interior. Float #522 and two others were entrained into a coherent anticyclonic eddy that appeared to form at the TGB. The eddy had a rotation period of 4.5 days and the floats looped at a radius of about 25 km. The eddy's DWBC entrance in the Spin Out was about 30 days before it was absorbed into the Gulf Stream. Float #522 eventually crossed the Stream and ended up in the subpolar interior. Importantly, the float's temperature was nearly constant during the eddy formation and propagation, indicating little vertical motion (Shaw and Rosly, 1994) and that isopycnal and isobaric drifters would have behaved similarly.

Conclusions:

- Only 30% of the LSW in the DWBC at 50° N is exported to the subpolar region in two years, and <10% follows the DWBC continuously around the Grand Banks.
- More LSW reaches the subpolar region in two years via an interior pathway from the southern tip of the Grand Banks.
- Comparison with the Lagrangian behavior in FLAME shows similar trends, although the model underestimated the export to the subpolar interior, possibly due to an underestimate of eddy kinetic energy south of the Grand Banks.
- The interior pathway does not appear to be an artifact of the isobaric nature of the R A F O S floats, but rather a real phenomenon related to the high eddy kinetic energy near the southern tip of the Grand Banks.