Interior Pathways of the North Atlantic Meridional Overturning Circulation

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To understand how our global climate will change in response to natural and anthropogenic forcing, it is essential to determine how quickly and by what pathways climate change signals are transported throughout the World Ocean, a vast reservoir for heat and carbon dioxide. Labrador Sea Water (LSW), formed by open ocean convection in the subpolar North Atlantic, is a particularly sensitive indicator of climate change on interannual to decadal time scales[1-3] . Hydrographic observations made anywhere along the western boundary of the North Atlantic reveal a core of LSW at intermediate depths being advected southward by the Deep Western Boundary Current (DWBC)[4-9] . This has led to the widely held view of the DWBC as the dominant pathway for the export of LSW from its formation site in the northern North Atlantic toward the equator[10, 11] . Based on new subsurface float observations and simulated "e-floats" released in the subpolar DWBC, we argue that most of the LSW passing through the subtropics follows interior, not DWBC pathways. The evidence points to a few specific locations around the Grand Banks where LSW is most often injected into the interior. These results have implications for deep ocean ventilation and suggest that the interior subtropical gyre should not be ignored when considering the Atlantic Meridional Overturning Circulation (AMOC).

More than 200 profiling floats[12] were released at intermediate depths in the Labrador Sea during the 1990s to observe the formation, circulation and export of Labrador Sea Water (LSW)[13-16] . These floats showed little evidence of southward export of LSW in the Deep Western Boundary Current (DWBC), surprising in light of the widely held view of the DWBC as the dominant export pathway toward the subtropics and tropics. Instead, the profiling floats leaving the Labrador Sea in the DWBC left the western boundary and followed an eastward path along the subpolar-subtropical gyre boundary in the deep North Atlantic Current (NAC) at ~50°N (see Fig.1a for locations). Why didn't these floats follow the DWBC into the subtropics? Were they biased by upper-ocean currents when they periodically ascended to the sea surface to fix their position, as recently suggested by numerical model results[17] ? Were they released mainly in the recirculating waters of the subpolar gyre? Or is the DWBC in fact not the dominant export pathway for LSW?

To address these questions, a new float release program was undertaken with acoustically tracked RAFOS floats[18] , which do not need to surface to fix their position. Between July 2003 and November 2006, 77 RAFOS floats were sequentially released in the DWBC near 50˚N, nominally six floats every three months, at two LSW depths (700 and 1500 m) (see Fig.1a and Supplementary Information (SI) for more details). Fifty floats have completed their two-year drifting missions: high-resolution, two-year trajectories are currently available for 40. Here we describe the spreading pathways revealed by these non-profiling floats, as well as by simulated trajectories from a high-resolution numerical ocean circulation model that has been shown to capture many features of the mid-depth North Atlantic flow field[19] . We also use the model trajectories to quantify the relative importance of the spreading pathways.

All RAFOS floats initially drifted southward in the DWBC after release at 50°N (Fig. 1b). About 30% of the 700-m floats (7/24) drifted southward through Flemish Pass, the 1100-m deep channel between the Grand Banks and Flemish Cap, while the rest of the

RAFOS floats continued along the continental slope around Flemish Cap. A large fraction of the floats—about 75% (29/40)—escaped from the DWBC (defined as crossing offshore of the 4000-m isobath) before reaching the southern tip of the Grand Banks (Tail of the Grand Banks, TGB; 43°N) (Fig. 2a-b) and drifted into the interior. Many followed an eastward path along the subpolar-subtropical gyre boundary, similar to the profiling floats (Fig. 1b). Most of these floats maintained relatively cold temperatures, indicating that they were recirculating within the subpolar gyre. Of the 25% of floats that reached the TGB in the DWBC, most were 700-m floats (82%, 9/11). Only 8% of all floats (3/40) followed the DWBC continuously from launch around the TGB. This is more than the number of profiling floats from the Labrador Sea that rounded the TGB in the DWBC (zero)[14] , but still a remarkably low number in light of the expectation that the DWBC is the dominant southward pathway for LSW.

A larger percentage of the RAFOS floats—about 23% (9/40)—reached the subtropics via an interior pathway, indicated by the cluster of trajectories extending south of 42°N in the longitude band 40°-60°W. The warmer temperatures measured by these floats indicate that they crossed the Gulf Stream into the subtropical gyre. The dominance of the interior pathway is further supported by the larger ensemble of displacement vectors (Fig. 1b inset)—about 24% (12/50) surfaced south of 42°N in the interior (east of 60°W). Furthermore, the largest southward float displacements over two years were made by floats following an interior, not DWBC path (Fig. 1b inset). Interior pathways for the southward spreading of LSW into the subtropics have been suggested previously based on hydrographic, tracer and model results[20, 21, 7, 9, 17] , but these float tracks offer the first evidence of the relative dominance of this pathway compared to the DWBC.

The high-resolution RAFOS float trajectories reveal two primary locations where LSW escapes from the DWBC and enters the interior ocean—at the southeastern corner of Flemish Cap (especially for 1500-m floats) and just upstream of the TGB (Fig. 2a-b). At these locations, the northward-flowing NAC, which extends to the sea floor[15, 22] , is closest to the continental slope, supporting a previous conjecture that onshore excursions of the NAC temporarily interrupt the flow of the DWBC and divert LSW into the interior[15] .

For comparison with the float observations, simulated trajectories were generated using the eddy-resolving (~1/12º) primitive equation Family of Linked Atlantic Models Experiment (FLAME) model[19] (see SI for model specifications and details of trajectory computation). The synthetic trajectories were calculated using the full three-dimensional, time-varying model velocity fields. A previous modeling analysis of LSW pathways, using time-mean model velocity fields, suggested some differences between isopycnal (3D) and isobaric (2D) trajectories in this region[17] , but a comparison made here, using time-varying velocity fields (see SI), indicated no significant differences.

Seventy-two "e-floats" were released in the DWBC near 50˚N with the same spatial and temporal pattern as the RAFOS floats. The spread of the model and RAFOS float trajectories after two years is very similar (Fig. 3a), with somewhat more e-floats penetrating northward in the subpolar gyre. There is little evidence for a continuous DWBC pathway, rather e-floats tend to recirculate within the subpolar gyre and drift southward into the subtropical gyre interior. The loss of e-floats from the DWBC is also very similar to that observed with the RAFOS floats (Fig. 2b).

This favorable comparison supports extending the integration to generate longer synthetic trajectories (Fig. 3b-c), beyond the technical capabilities of the RAFOS floats. After five years, the TGB begins to stand out as a barrier to the westward spread of e-floats in the DWBC. Only after ten years is a thin collection of a small number of trajectories evident within the DWBC west of the Grand Banks, emphasizing the importance of recirculation in the Newfoundland Basin in slowing the equatorward transport of LSW in the DWBC[7, 23].

To quantify the spreading pathways of LSW, 7280 e-floats were released and integrated for 15 years and a two-dimensional histogram of float position was mapped (Fig.3d) (see SI for details of map construction). The sharp drop in e-float concentration around the Grand Banks, and the southward penetration into the subtropical interior are clearly revealed. The e-floats are concentrated within an eddy-driven circulation that has previously been postulated to provide interior pathways from the subpolar to subtropical basin[20, 21].

A further demonstration of the lack of strong connectivity of LSW pathways around the Grand Banks is given by fifteen-year back trajectories for e-floats that arrived at "Line W" (~69˚W), where the properties and transport of the subtropical DWBC are being monitored (see http://www.whoi.edu/science/PO/LineW) (Fig. 3e). Again, a strong discontinuity appears at the TGB, complementing that for the forward trajectories (Fig. 3d). A thin ribbon of trajectories is traced from the TGB upstream to the western boundary of the Labrador Sea, but it represents only a small fraction of the total at the collection site. The model DWBC in the subtropical basin is mainly transporting waters that are recirculating north of the Gulf Stream and west of the Grand Banks in the Northern Recirculation Gyre (Fig. 1a)[24] .

To quantify the relative importance of the DWBC versus interior pathways through the subtropics in the model, we mapped the transport associated with e-floats that drifted from the float release site at 50°N to 32˚N within 15 years (Fig. 4; see SI for details of map construction). We kept track of the e-floats that (1) never crossed offshore of the 4000 m isobath into the interior (exclusively onshore), (2) were inshore of the 4000 m isobath but may have crossed that isobath at some point (all inshore) and (3) were offshore of the 4000 m isobath (all offshore). Transport values for each group as a function of distance along the boundary are tabulated in the SI.

At the release site, all transport is inshore of the 4000 m isobath. Moving southward along the path of the DWBC to the TGB, the all inshore transport drops to about 62%, and the exclusively inshore transport drops even more (43%). The transport located in the interior grows accordingly. A similar result for the all inshore transport at the TGB was obtained in a previous modeling study[17] , from which the authors concluded that the DWBC was the dominant pathway for the export of LSW. However, as seen in Fig. 4, the all inshore and especially the exclusively inshore transports drop precipitously moving around the southern tip of the Grand Banks—at 55˚W, the all inshore and exclusively inshore transports are only 11.5% and 2.6%, respectively. At Cape Hatteras (36°N), only 3.1% of the transport being tracked is located inshore and 0.1% followed the DWBC continuously from the release site.

South of 34˚N, the interior transport begins to converge back toward the western boundary, but clearly the vast majority of the LSW transport tagged at 50˚N in the DWBC that reached 32˚N did so via an interior pathway. This result is consistent with the relatively larger number of RAFOS floats entering the subtropical gyre interior south of the Grand Banks (Fig. 1b) and with the observation of relatively young tracer ages there[7] .

The *directions* of LSW spreading presented here are generally consistent with those inferred from hydrographic and tracer studies: eastward and northward within the subpolar gyre, into the subtropical interior and along the DWBC[4, 7, 9, 25] . But the new float observations and simulated float trajectories provide evidence that the southward interior pathway is *more important* for the transport of LSW through the subtropics than the DWBC, contrary to previous thinking. Though the DWBC is easier to observe—a well-defined, relatively stationary current close to shore compared to the vast, turbulent and unconstrained interior—our results suggest that further study of the interior subtropical gyre and the complex region around the Grand Banks is needed to better understand the pathways of the Atlantic Meridional Overturning Circulation.

Figure Legends

Figure 1: (a) Schematic diagram of the intermediate-depth circulation in the northwestern North Atlantic, with blue and red lines indicating cold and warm pathways, respectively. Double circle symbols show locations of sound sources used to track floats. Abbreviations: FC Flemish Cap; NAC North Atlantic Current; Newfoundland Basin Recirculation Gyre; NRG Northern Recirculation Gyre; OK Orphan Knoll; WG Worthington Gyre. (b) Two-year trajectories of 40 acoustically tracked RAFOS floats released at 700 and 1500 m in the DWBC near 50N. Positions are indicated daily with color-coded dots, where the color indicates normalized temperature anomaly, defined as $(T-T_i)/\delta T_{max}$. T_i is each float's initial temperature, and δT_{max} is the maximum temperature range observed by the floats as a group, 6.4°C at 700 dbar and 1.8°C at 1500 dbar. Dashed lines indicate missing track. The inset shows the displacement vectors for the same floats plus 10 more that were either untrackable (4) or have yet to be processed (8), color-coded by depth (red for 700 m and blue for 1500 m).

Figure 2: Loss of RAFOS floats from the DWBC. (a) Trajectories of 40 RAFOS floats (blue, 1500 m; red, 700 m) between launch position and the position where they first cross the 4000 m isobath (colored dots) illustrate where floats were most likely to leave the DWBC and drift into the interior. The mean path of the Gulf Stream and NAC is shown with the mean absolute dynamic topography from AVISO for the float sampling time period. Arrows indicate direction of geostrophic surface flow, and the gradient is proportional to flow speed. The path of the NAC is similar to that derived from subsurface floats[26] and hydrographic data[27] . The 700-m isobath is shaded gray. (b) Retention of RAFOS floats (solid lines) and e-floats (dashed lines) in the DWBC as a function of along-boundary distance from 50°N.

Figure 3: Synthetic or e-trajectories for 2 (a), 5 (b) and 10 (c) years from 72 e-floats at 700 m (red) and 1500 m (blue), selected from an ensemble of 7280 15-year trajectories initiated at the RAFOS float release sites near 50˚N. Note that “700 m” and “1500 m” refer to the approximate depth at release: the model trajectories were computed using the 3D model velocity fields, so the virtual particles change their depth accordingly. The RAFOS trajectories (light gray) are shown in (a) for comparison. The endpoint of each e-float trajectory is marked with a black dot. Isobaths are shown in darker gray for 0, 700, 1500, and 3000 m; (d) 7280 forward e-trajectories launched at Orphan Knoll and (e) 7280 backward trajectories launched at Line W in the core of the DWBC, condensed into float location 2-d histogram maps. The float launch locations are shown in black. The insets to each map show the float launch locations at each site superposed on the mean velocity cross-section from the FLAME model. The RAFOS and e-float launch points are shown with red and black dots, respectively. The inset color bar has units of cm/sec.

Figure 4: Transport map for 1338 e-floats released in the layer 703-1548 m at 50˚N that crossed the latitude 32˚N within 15 years. Colored circles indicate transport associated with “all inshore” (red) and “exclusively inshore” (yellow) e-floats, where circle radius is proportional to transport. Blue lines indicate transport associated with “all offshore” e-floats as a function of longitude for selected latitudes. Cyan lines show the zero reference for each blue line. Details on map construction as well as tabulated transport values are given in the SI.

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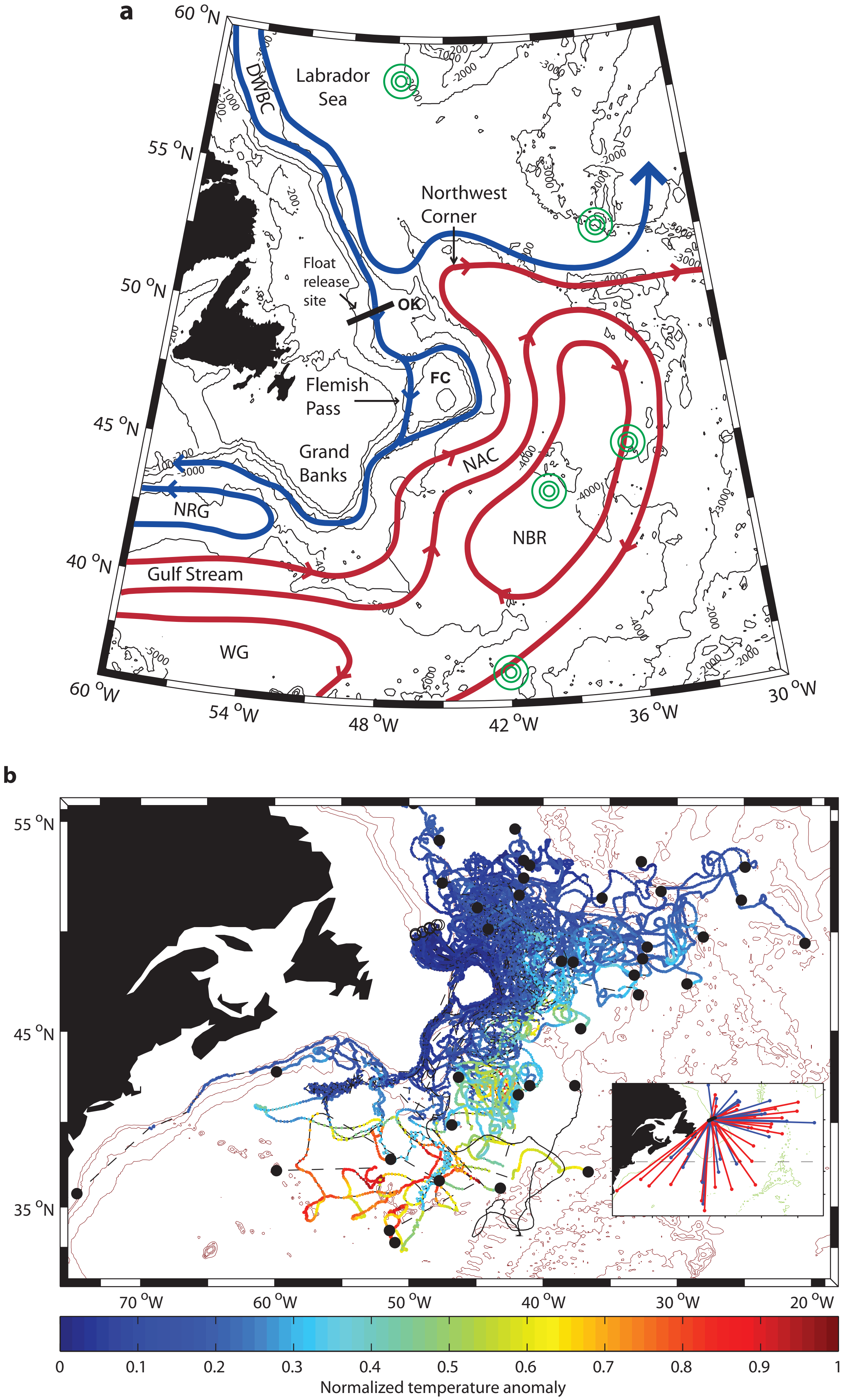
Figure 1



a
Labrador Sea
DWBC
Northwest Corner
Float release site
OK
FC
Flemish Pass
Grand Banks
NAC
NRG
NBR
Gulf Stream
WG
60 °N
55 °N
50 °N
45 °N
40 °N
60 °W
54 °W
48 °W
42 °W
36 °W
30 °W
b
55 °N
45 °N
35 °N
70 °W
60 °W
50 °W
40 °W
30 °W
20 °W
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Normalized temperature anomaly

Figure 2

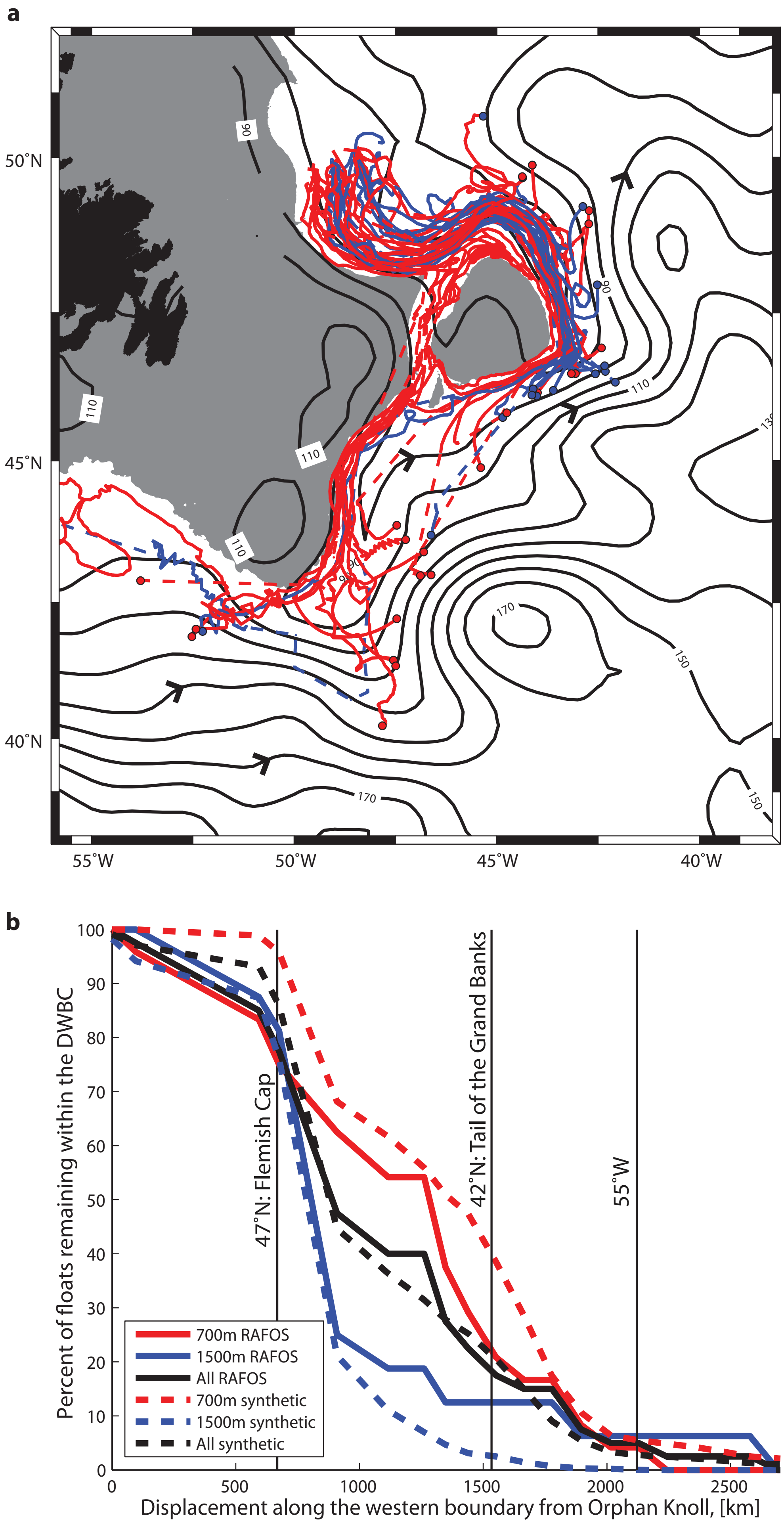

a
50°N
45°N
40°N
55°W
50°W
45°W
40°W
90
110
110
110
110
90
110
130
170
150
170
150
b
Percent of floats remaining within the DWBC
Displacement along the western boundary from Orphan Knoll, [km]
47°N: Flemish Cap
42°N: Tail of the Grand Banks
55°W
700m RAFOS
1500m RAFOS
All RAFOS
700m synthetic
1500m synthetic
All synthetic
0
10
20
30
40
50
60
70
80
90
100
0
500
1000
1500
2000
2500

Figure 3

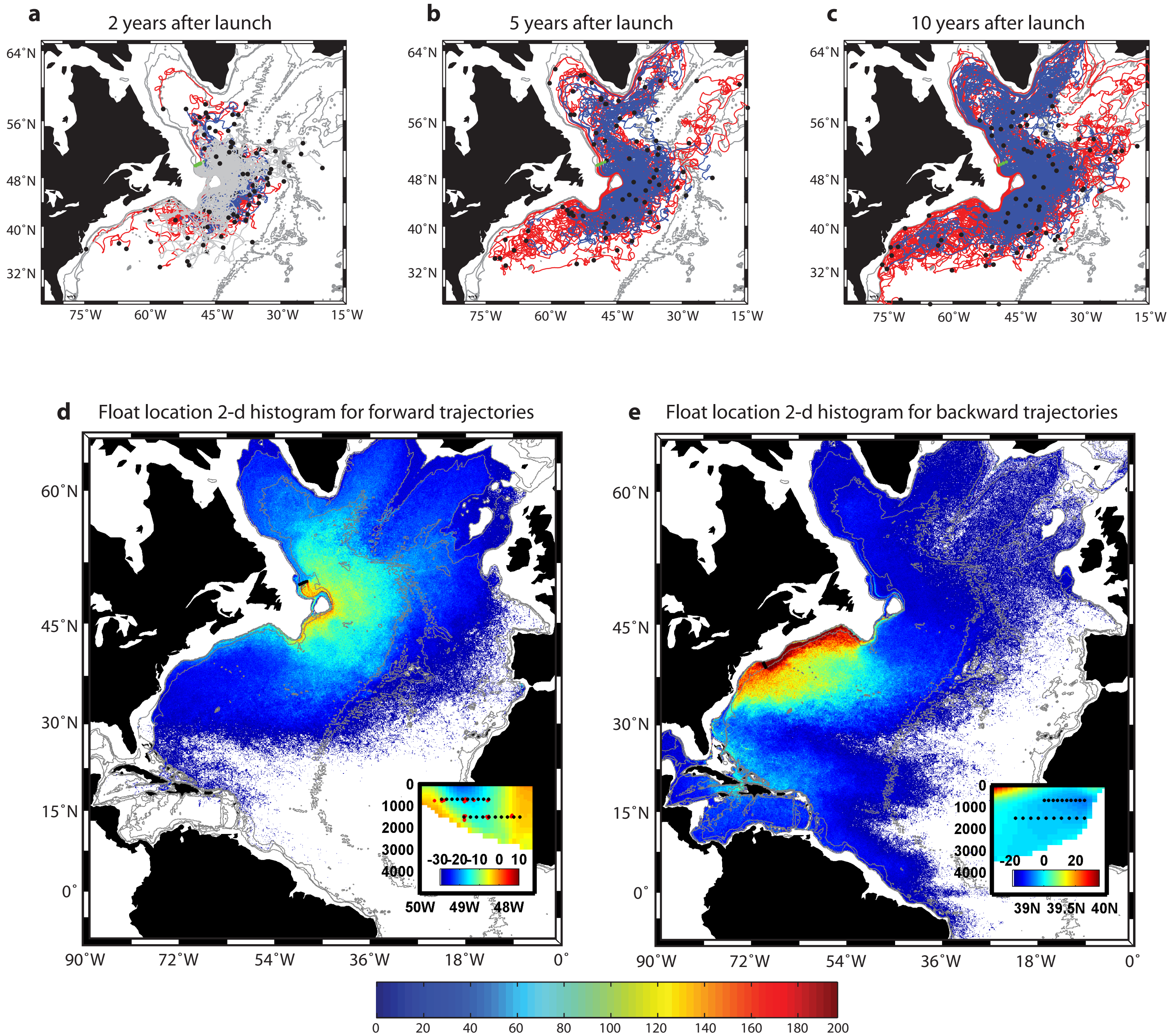
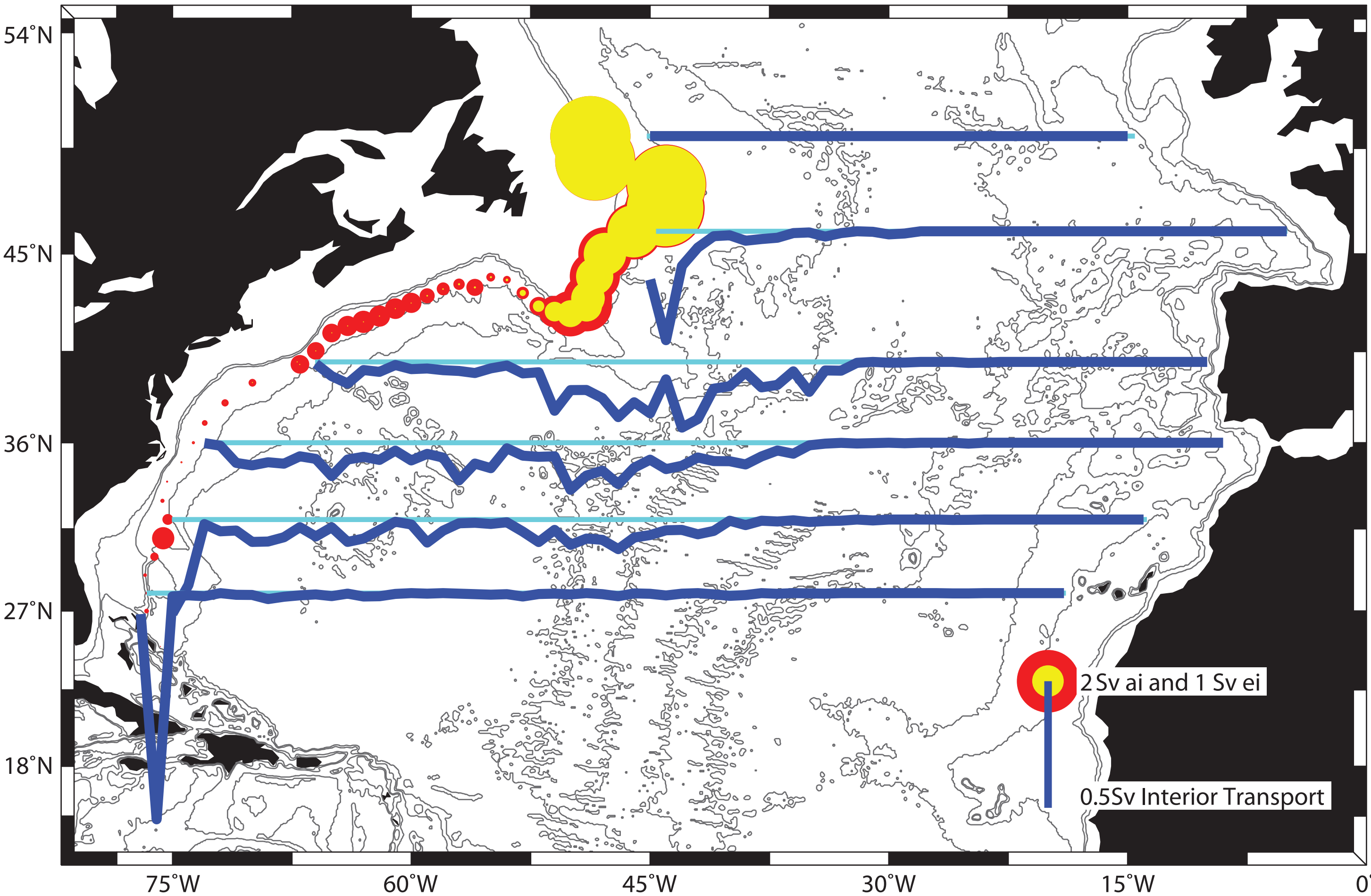

a
2 years after launch
b
5 years after launch
c
10 years after launch
64°N
56°N
48°N
40°N
32°N
75°W
60°W
45°W
30°W
15°W
d
Float location 2-d histogram for forward trajectories
e
Float location 2-d histogram for backward trajectories
60°N
45°N
30°N
15°N
0°
90°W
72°W
54°W
36°W
18°W
0°
0
1000
2000
3000
4000
-30-20-10 0 10
50W 49W 48W
-20 0 20
39N 39.5N 40N
0 20 40 60 80 100 120 140 160 180 200

Figure 4


54˚N
45˚N
36˚N
27˚N
18˚N
75˚W
60˚W
45˚W
30˚W
15˚W
0˚
2 Sv ai and 1 Sv ei
0.5Sv Interior Transport

Supplementary Information

Methods

RAFOS Floats

The RAFOS floats used in this study were isobaric and ballasted to drift at two levels corresponding to the tracer cores of Upper Labrador Sea Water (700 dbar) and Classical Labrador Sea Water (1500 dbar). Float position was determined daily relative to moored sound sources. Four sources were initially deployed in July 2003. A failure of one source in March 2004 resulted in some loss of tracking over the continental slope between Flemish Cap and the Tail of the Grand Banks. Where possible, some tracks have been reconstructed from one sound source time-of-arrival assuming (based on the temperature record) that the float remained over the continental slope. The sound source array was returned to full operation in August 2005. Sound sources associated with other programs in the western and eastern North Atlantic were also used for tracking.

The floats internally recorded travel times from the sound sources, as well as temperature and pressure measurements once daily for two years, before returning to the surface and transmitting all the collected data via Service ARGOS. The floats were released sequentially, nominally six floats every three months, at the same positions on each setting, along a section extending from Cape Bonavista, Newfoundland to Orphan Knoll, in water depths between 1400 and 2800 m (Table S1). The first float setting was made from the R/V Oceanus during the sound source mooring deployment cruise in July 2003. All subsequent float releases were made from various Canadian fisheries research vessels by E. Colbourne and colleagues at the Northwest Atlantic

Fisheries Centre in St. John’s, Newfoundland during spring, summer and fall Atlantic Zone Monitoring Program cruises.

To release RAFOS floats during winter, six dual-release floats were deployed during each fall cruise in addition to the six regular floats. The dual-release floats each had a heavy length of chain attached that initially anchored them to the sea floor, creating a ‘float park’[1]. These floats were programmed to release the anchor chain on the following February 15th, and then drift to their ballast depth to begin their two-year mission. Due to increased risk of damage during the rapid descent to the sea floor and during the three-month stay on the bottom in a known fishing area, return of the dual-release floats was not as high as for the single-release floats.

Table S1. Positions of float release sites along Bonavista hydrographic section

Station Number	Latitude	Longitude	Water depth (m)	Float levels (dbar)
BV12	49.90N	49.51W	1397	700
BV13	50.00N	49.00W	1919	700, 1500
BV14	50.19N	48.45W	2508	700,1500
BV15	50.33N	47.94W	2789	1500

Satellite Altimetry

In Fig. 2, we determined the path of the Gulf Stream and North Atlantic Current using maps of absolute dynamic topography (MADT) produced by Ssalto/Duacs at Collecte Localization Satellites (CLS), a subsidiary of the French Space Agency (CNES) and the French Research Institute for Exploration of the Sea (IFREMER). This product is generated using satellite altimetry data obtained by the TOPEX/Poseidon (1992-2002), Jason-1 (2002-2006), ERS-1

(1992-1993, 1995), ERS-2 (1996-2003), and ENVISAT (2003-2006) satellite missions. With support from CNES it is distributed online by Aviso (http://www.jason.oceanobs.com/html/donnees/produits/hauteurs/global/madt_uk.html).

Sea level anomalies (SLAs) have been interpolated onto a grid with a 1/3°x1/3° spatial and a 7-day temporal resolution starting in October 1992. In order to compute the MADT, CLS Space Oceanography Division combines the SLA measured by the satellites in real-time with its Combined Mean Dynamic Topography (Rio05)[2].

Model Specifications

The ocean circulation model of the North Atlantic used in this study, the Family of Linked Atlantic Models Experiment (FLAME) model, was based on the GFDL's MOM2.1 code[3] and modified as part of the FLAME project[4]. The model domain spans 18ºS to 70ºN and 100ºW to 16ºE. Following a spin-up from rest, this model was run for nine years with climatological forcing fields and then with interannually varying wind stresses and heat fluxes for the period 1987-2004. Model output consists of three-dimensional snapshots of horizontal velocity, temperature and salinity fields over the domain on a 1/12º resolution Mercator grid. In the vertical, the domain was split into 45 z-coordinate levels. The vertical velocity was computed from the horizontal velocity by requiring that the local divergence of the three-dimensional velocity field be zero throughout the model domain.

Synthetic Float Trajectory Computation

A synthetic trajectory is composed of successive displacements of a particle determined from a linear interpolation of the velocity field surrounding that particle. The synthetic trajectories presented in this paper were computed using 3-day average 3-dimensional velocity fields from the FLAME model. Temporally successive velocity fields were interpolated to produce displacement information at a finer temporal scale. Note that throughout the study, “700 m” and “1500 m” e-floats refer to the approximate depth of float initialization. Subsequent e-float positions are estimated from the 3D model velocity fields, so the virtual floats are displaced both horizontally and vertically in accordance with the velocity fields to simulate water parcel movement as accurately as possible. Below it is argued however that the major results of this work are not sensitive to the use of 3D or 2D model velocity fields.

Velocity fields from FLAME model years 1994, 1996, and 1998, repeated sequentially, were used for the 15-year trajectories. These years represent a variety of forcing states: 1994, 1996 and 1998 had high (+3.03), low (-3.78), and comparatively neutral (+0.72) North Atlantic Oscillation (NAO) indices, respectively. Floats were released sequentially over the course of the first three years and every trajectory was computed for 15 years.

In a previous model study of LSW pathways in the western North Atlantic[5], synthetic trajectories were computed using both the three-dimensional and two-dimensional (horizontal only) time-mean model velocity fields to uncover any differences in LSW pathways around the southern tip of the Grand Banks. It was found that the 3D e-floats were somewhat more likely to be retained in the DWBC compared to 2D e-floats (59% versus 42%). Based on this difference, these authors concluded that isobaric drifters such as the RAFOS floats, which only follow the horizontal component of velocity, would underestimate retention of LSW in the DWBC around the Grand Banks, especially at the Upper Labrador Sea Water level.

Their calculations were essentially repeated here, but using the time-varying model velocity fields rather than the time-mean. To quantitatively compare these two sets of trajectories in the context of the present study, we reproduced the Fig. 2b, showing the loss of e-floats from the DWBC as a function of downstream distance, for both the 3D and 2D trajectories at 700 and 1500 m (Fig. S1). Differences are insignificant compared to differences between the model and RAFOS floats. We conclude that the stirring effect of the eddy field present in the time-varying model output overwhelms any differences in the 3D and 2D e-float trajectories. This lends support to the use of the isobaric RAFOS floats for identifying LSW pathways around the Grand Banks. Even after the RAFOS floats enter the subtropical gyre, their trajectories are likely good approximation of the (now somewhat deeper LSW) because the circulation in this region has been shown to be only weakly depth-dependent[6].

Computation of E-Float Position Histograms

To efficiently present the pathway information from the thousands of synthetic trajectories used in this study, a two-dimensional histogram of float positions, essentially a map of "float concentration", was used (Fig. 3d-e). A count was made of the number of floats that passed through each 1/12 º horizontal bin; repetitions of the same float were counted. The units on the two-dimensional histogram are the number of floats passing through each bin. Histograms of the 700m and 1500m subsets of the float population are qualitatively similar to the whole population histograms presented here.

Computation of Float Loss from the Deep Western Boundary Current

Because the DWBC generally flows inshore of the 4000 m isobath in the study region, a RAFOS or e-float was considered out of the boundary current if it crossed this isobath into deeper water.

To determine the number of floats that remain within the DWBC at different points along the coast, 10 boxes, each spanning the width of the continental slope, were defined along the boundary. The number of floats that passed through each box was counted. In this analysis, floats that left the DWBC at any point along the boundary were never counted again, even if they happened to reenter one of the boxes. Thus, the number of floats remaining within the DWBC includes only those floats that have remained in the DWBC continuously since launch (also called "exclusively inshore" floats).

Construction of Transport Map

E-floats were initialized at the RAFOS float release site (near 50˚N) in the layer spanning 703m to 1540m. The e-floats were launched on a 7-level grid with nodes at: 744, 828, 920, 1022, 1140, 1280, and 1448m. Each e-float was assigned a transport computed from the velocity, layer thickness and cell width at the e-float's release location. The layer thicknesses used to compute the transport tag for each float range from 78-184 m, increasing with increasing layer depth. The three-dimensional trajectories were computed using the repeating cycle of 1994, 1996, and 1998 3-day updated velocity fields for 15-year integrations. At release, the total transport was 12 Sv in the layer (for each of the 36 launch dates) divided between a grand total of 6539 floats. Floats were launched every 30 days for the first three years (and since the velocity field repeated itself after the first three years, no new initializations were made after that point). Only those e-floats that crossed 32˚N within 15 years were retained, which accounts for the movement of 2 Sv (average transport per launch initialization) among a total of 1338 e-floats. Longer integrations gave very similar results.

Numerical values for the transports (listed as percent of total transport that passes from 50˚N to 32˚N) are given in Table S2 to assist with interpretation of Fig. 4.

Table S2: Percent of total transport tagged at 50˚N that reaches 32˚N for all inshore, exclusively inshore and all offshore e-floats as a function of latitude from Fig. 4.

Latitude (Longitude)	All Inshore (%)	Exclusively Inshore (%)	All Offshore (%)
50N	100.0	99.8	0.0
48N	99.5	95.0	0.5
46N	69.9	63.1	30.1
44N	63.0	47.0	37.0
43N	61.5	42.7	38.5
(50W)	57.5	34.0	37.2
(55W)	11.5	2.6	76.7
(60W)	24.8	1.2	55.9
(65W)	23.7	0.9	50.7
40N	8.5	0.7	91.5
38N	9.1	0.4	90.9
36N	3.1	0.1	96.9
34N	2.2	0.0	97.8
32N	13.7	0.0	86.3

Notes

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Figure Legend

Fig. S1: Percentage of 3D (blue) and 2D (black) e-floats and RAFOS floats (red) retained in the DWBC as a function of along-boundary distance starting from 50˚N. Upper panel is for 700-m floats, and lower panel for 1500-m floats.

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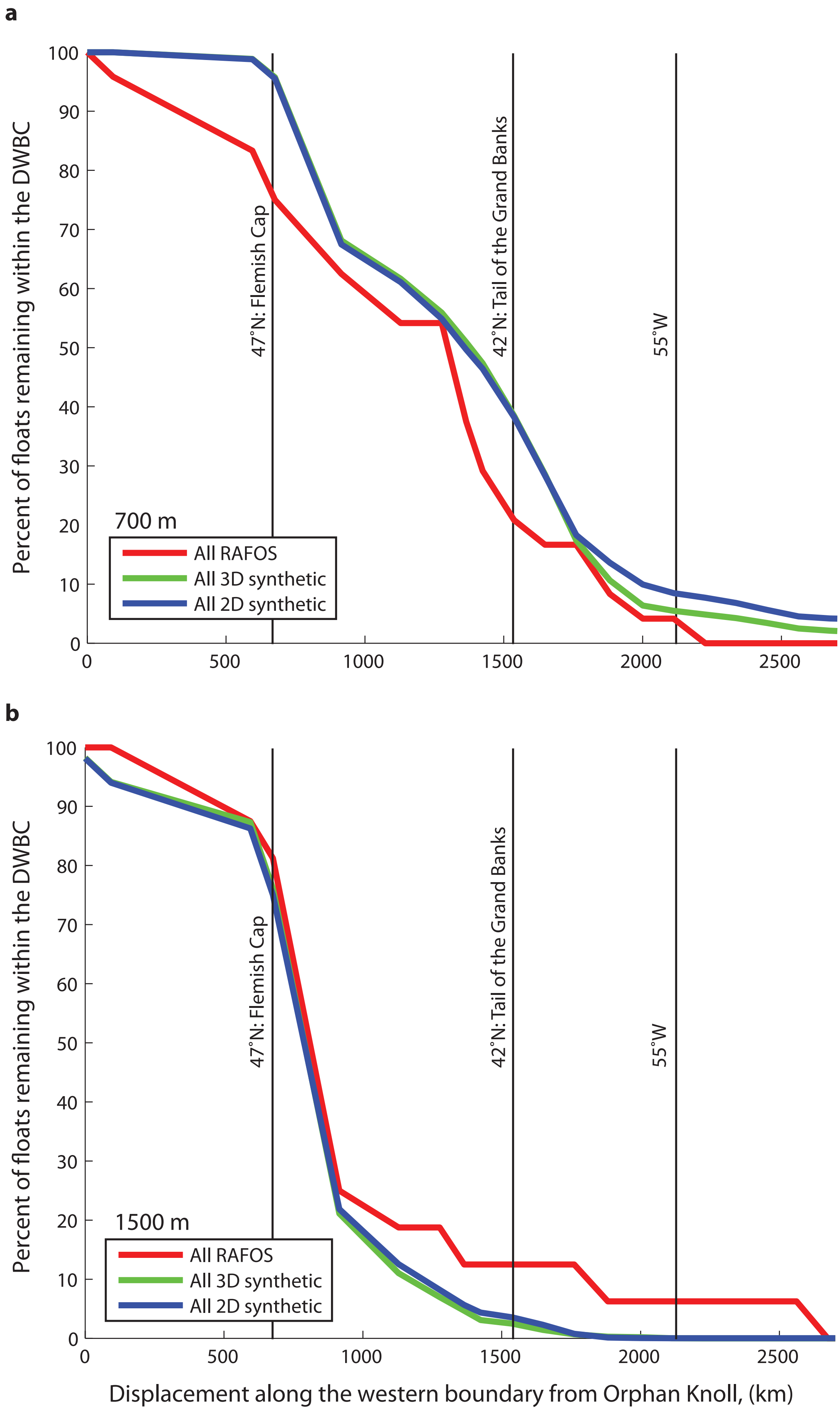
Figure S1



a
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
Percent of floats remaining within the DWBC
47°N: Flemish Cap
42°N: Tail of the Grand Banks
55°W
700 m
All RAFOS
All 3D synthetic
All 2D synthetic
b
1500 m
All RAFOS
All 3D synthetic
All 2D synthetic
Displacement along the western boundary from Orphan Knoll, (km)