Transport balance in the subpolar North Atlantic: Insights from an eddy-resolving model

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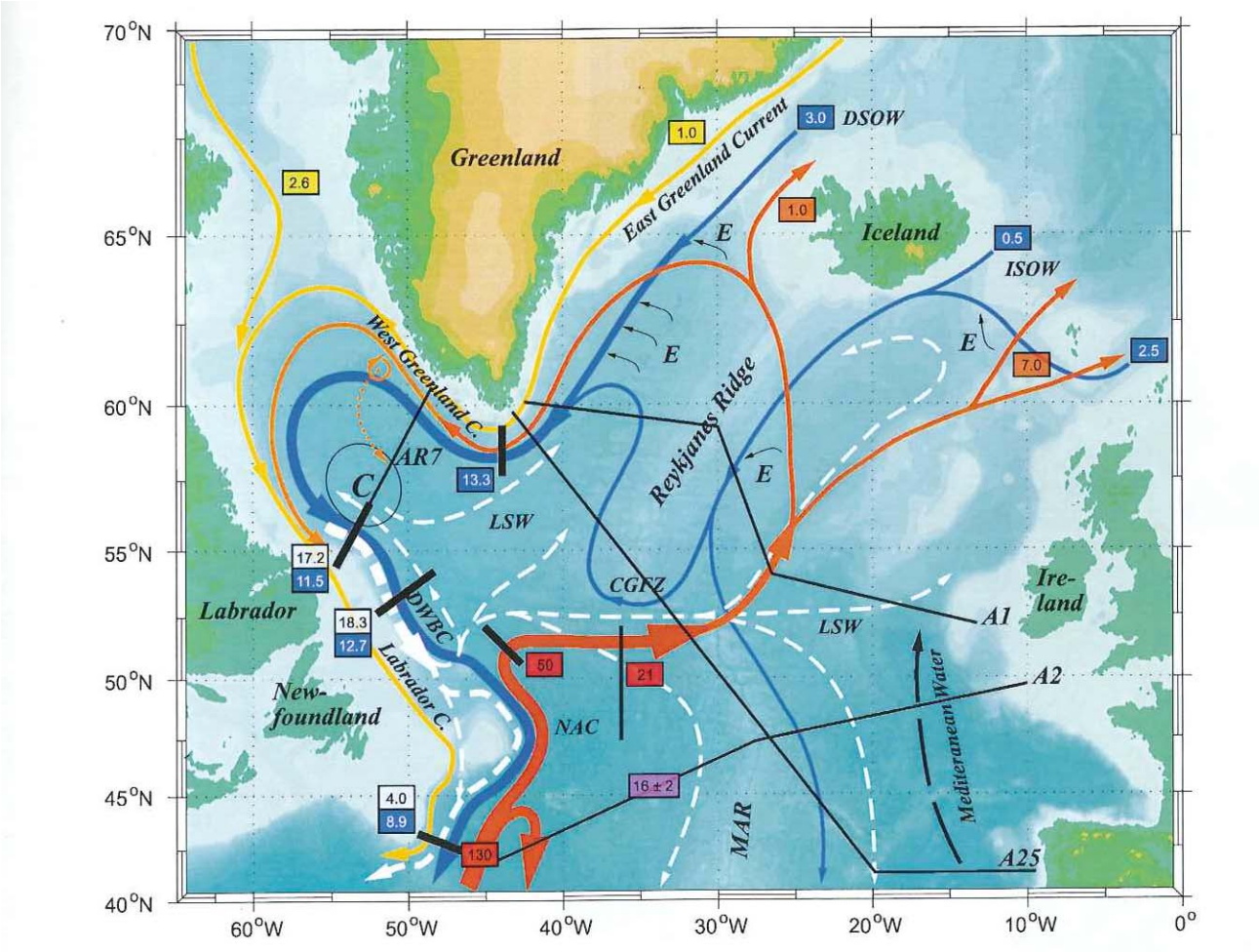
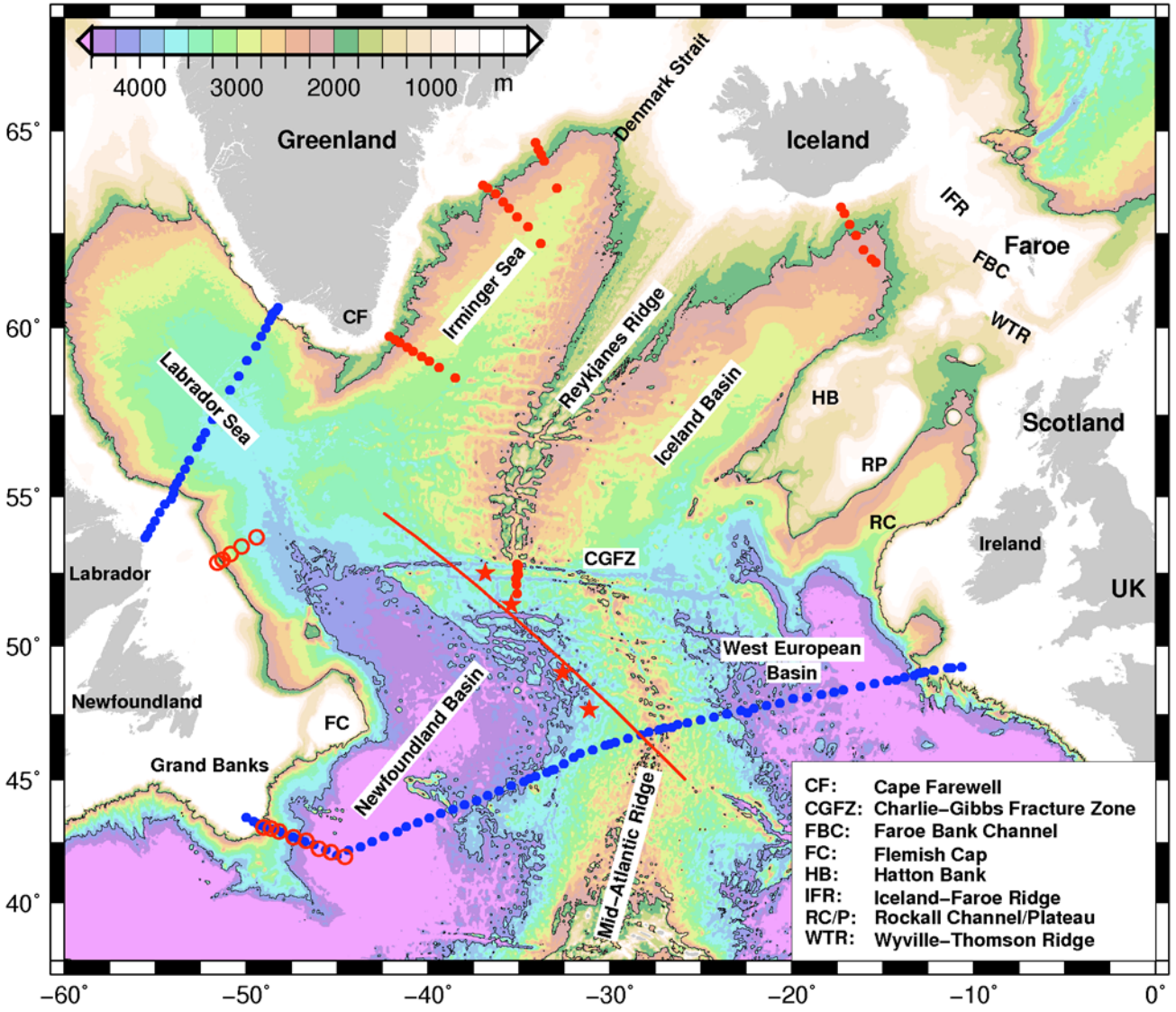
Subpolar North Atlantic



Schematic circulation diagram of the subpolar North Atlantic Ocean (From *Schott and Brandt*, 2007)

Moored arrays, repeat surveys



Lagrangian and tracer studies

- Surface or upper-layer circulation

  Reverdin et al. (2003) and Flatau et al. (2003), Bower et al. (2002) for large scale circulation;

  Rossby (1996), Krauss (1986), and Bower and Appen (2008) focus on the NAC regime.

- Mid-depth (LSW) circulation

  Lavender et al. (2000, 2005) western basins; Bower et al. (2002) eastern basins; also Faure and Speer (2005);

  Fischer and Schott, (2002) and Bower et al, (2009) focus on the western boundary current along Labrador Coast/Grand Banks.

- LSW spreading/export

  Using PV (and Salinity, Oxygen), Talley and McCartney (1982) describe the distribution and spreading of LSW in North Atlantic. Cunningham and Haine (1995) and Paillet et al (1998) focus on the eastern subpolar regime.

  The formation rate and/or spreading pathway of LSW are also studied using CFC inventory, Smethie and Fine (2001); Rhein et al. (2002), Kieke et al. (2006, 2007)

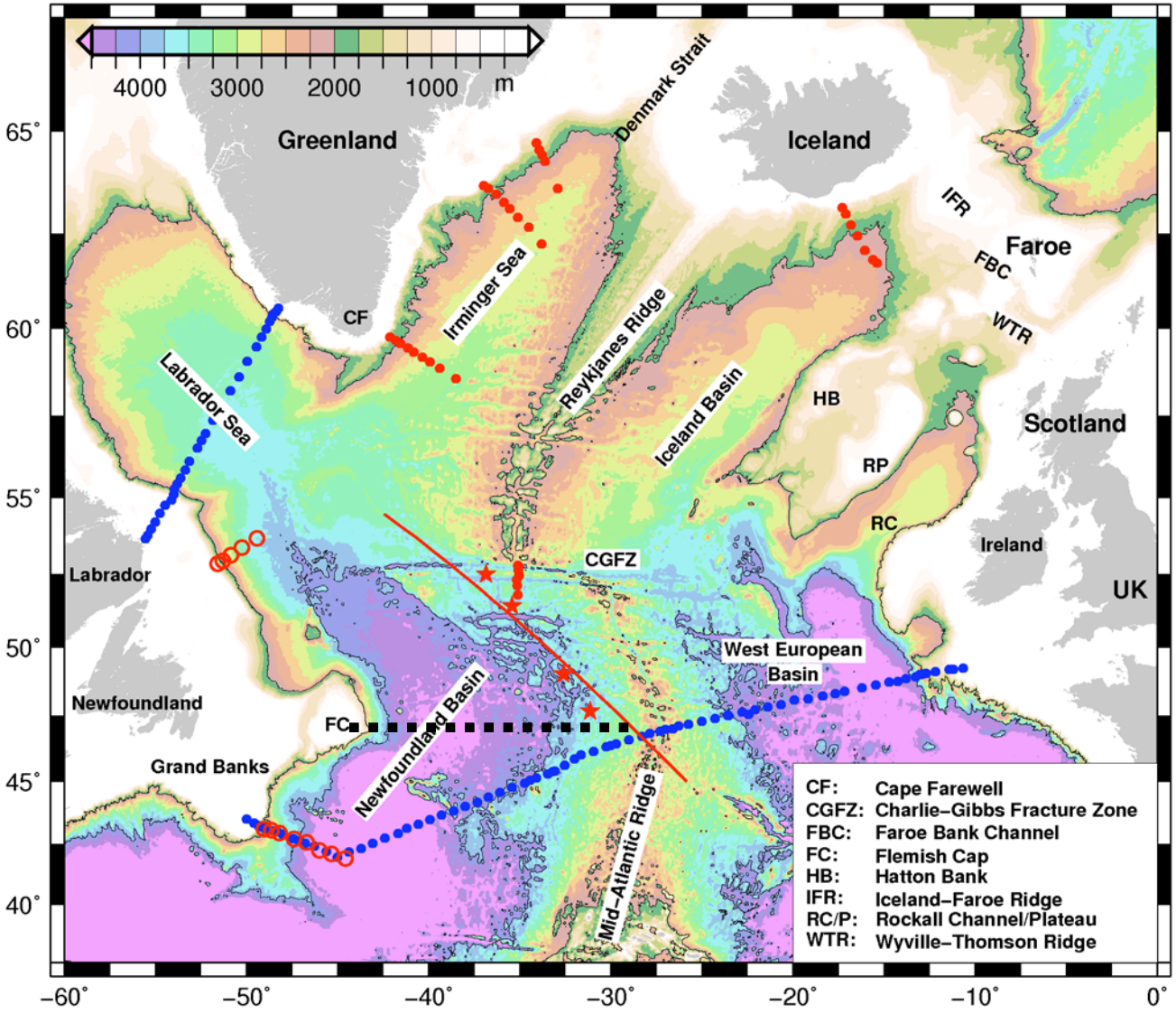
High-resolution model studies

- Böning et al. (2003), Brandt et al. (2007) on LSW formation;
- Eden and Böning (2002) and Chanut et al. (2008) on eddy variability in the Labrador Sea;
- Böning et al. (2006) on subpolar gyre variability in related to variability of AMOC;
- Käse et al. (2001) on the mid-depth recirculation in the western Labrador and Irminger Seas;
- Getzlaff et al., (2006) on a Lagrangian perspective of the southward LSW export in the Newfoundland Basin (also Bower et al., 2009);
- Treguier et al. (2005) “quantitatively” compared the subpolar circulation in four high resolution models (POP, FLAME, ATL6, MICOM) to observations (mostly those based on drifters and floats).

Eddy-resolving Atlantic Simulation

- Configuration similar to GLBa0.08 experiment 018, but with northern and southern boundary relaxation, different sss restoring, and without heat offset
- Integrated for 20 years, time average of the final 5 years used as model-based “long-term” mean state
- Viscosities: C_{smag} = 0.05; A = 20m^2/s; veldf4 = 1cm/s (or 1.0x10^{10} m^4/s for Δx = 10km); thkdf4 = 1cm/s;
- Bottom Drag = 2.5e^{-3}(|U|+0.05)U
- Transport of Nordic Seas overflow water from the GIS Ridge to Cape Farewell discussed in detail in *Xu et al., (2010) JGR-Ocean*.

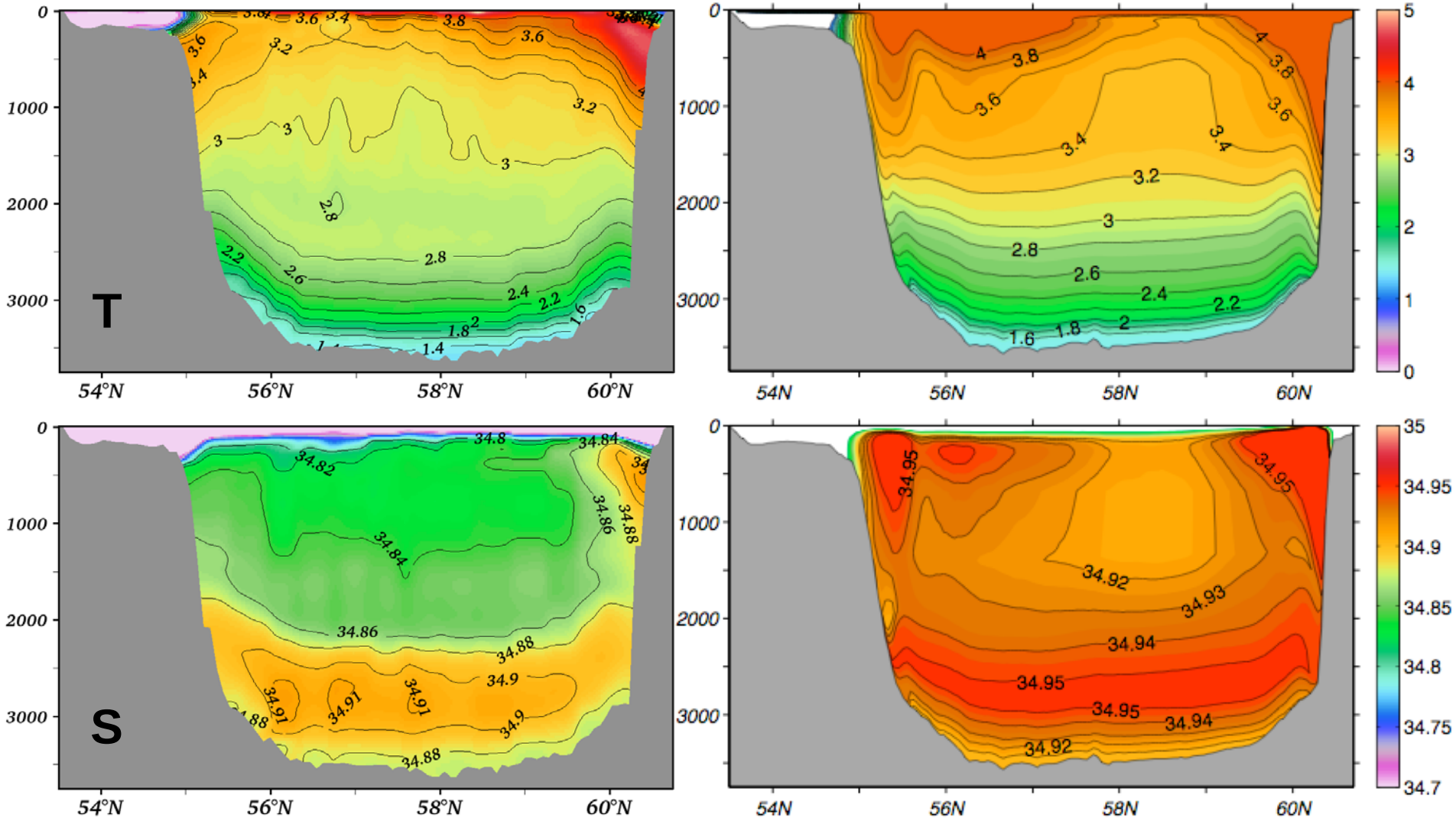
Model results evaluation



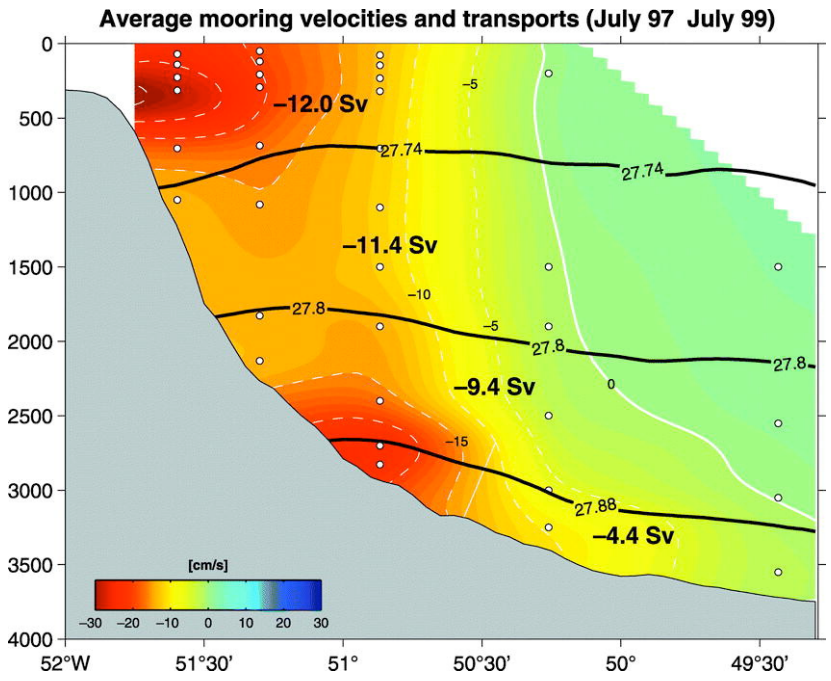
T/S along AR7W

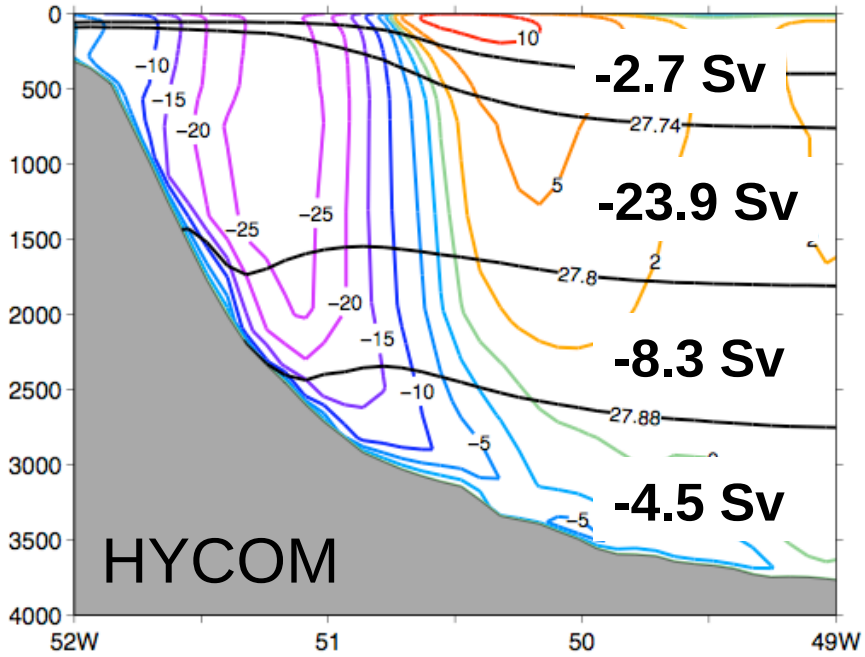
Obs. (1993-2003)

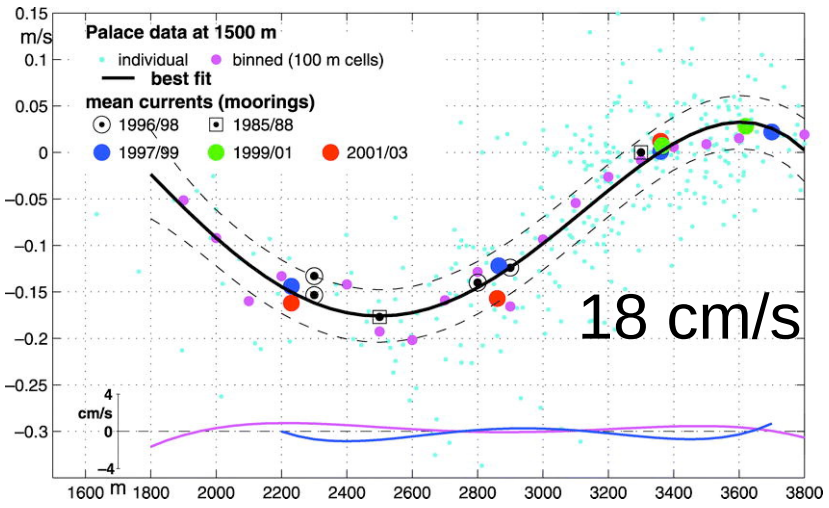
Model (0016-0020)

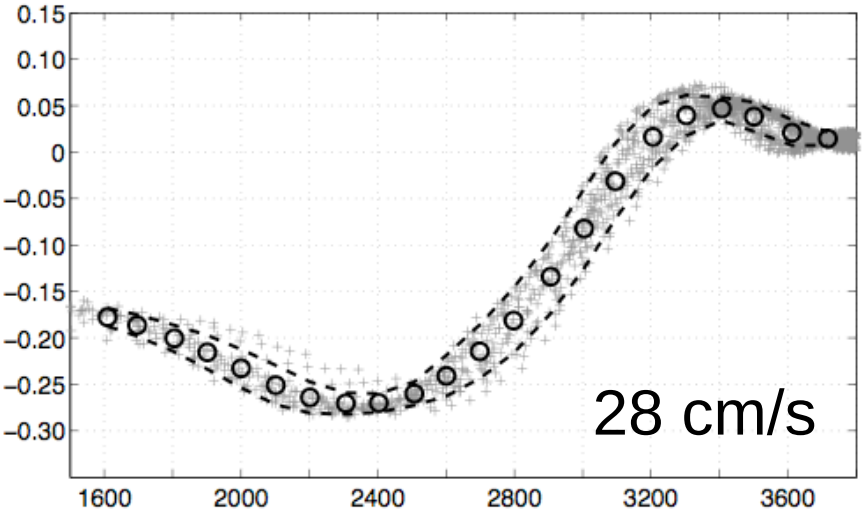


Boundary Current @53ºN



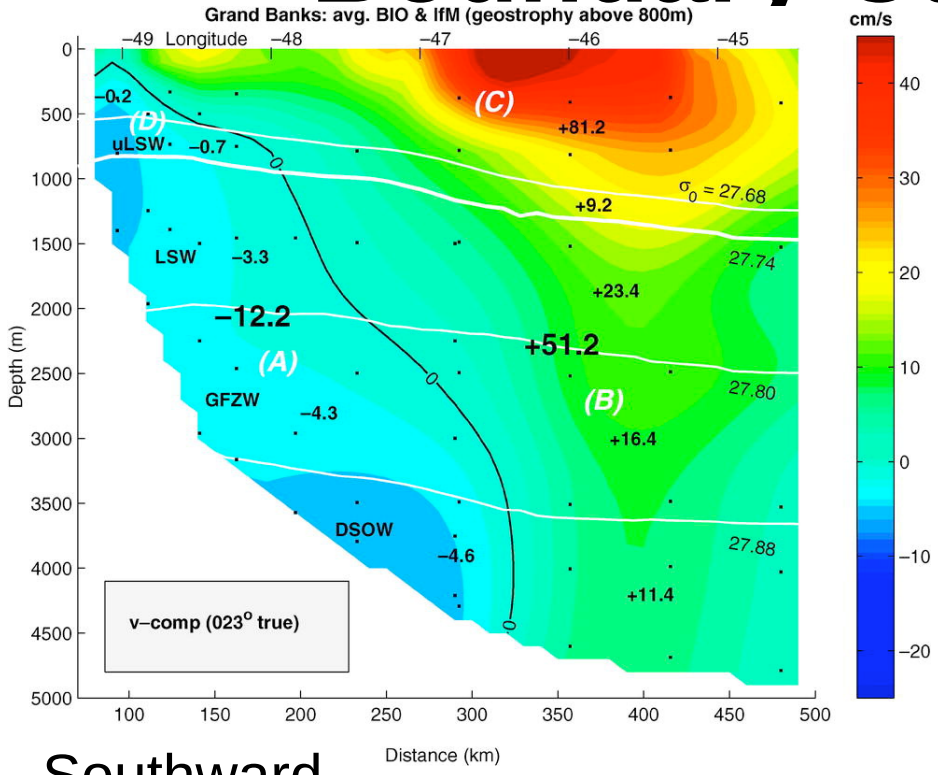


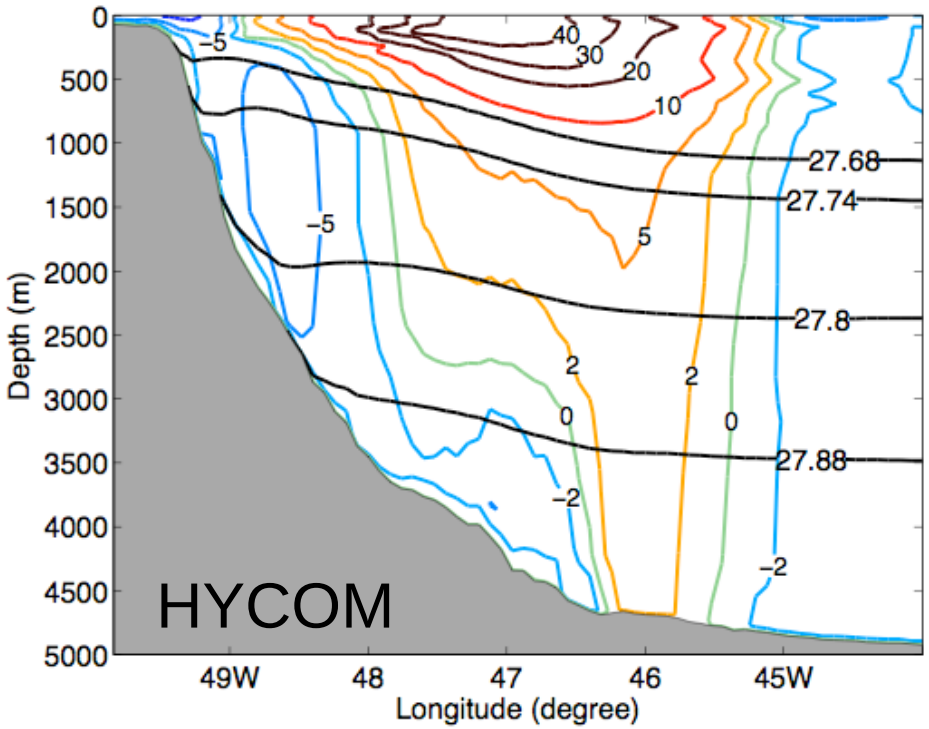




Fischer and Schott (2004)

Boundary Current @43ºN





Southward

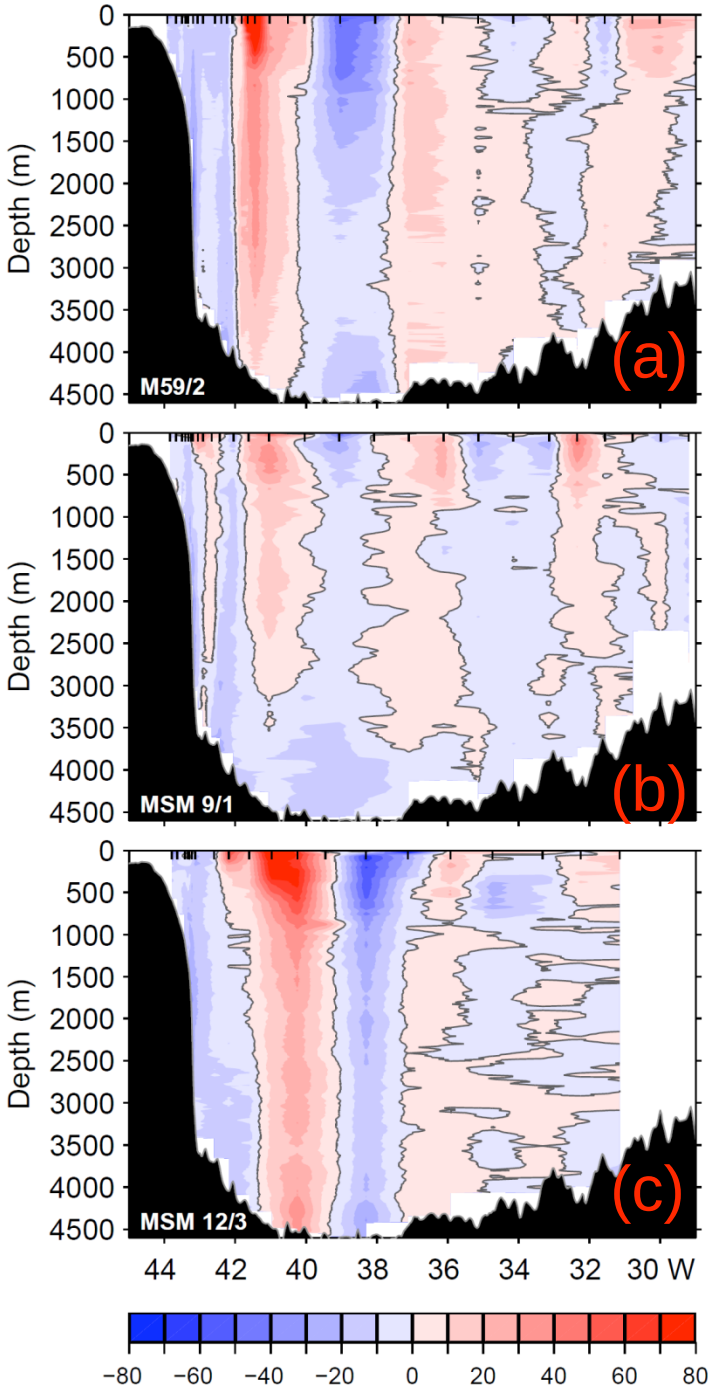
Mooring[1]/LADCP[2]/HYCOM			
			27.68
0.7	2.5	1.7	27.74
3.3	4.5	6.2	27.80
4.3	6.9	2.9	27.88
4.6	3.6	3.8	

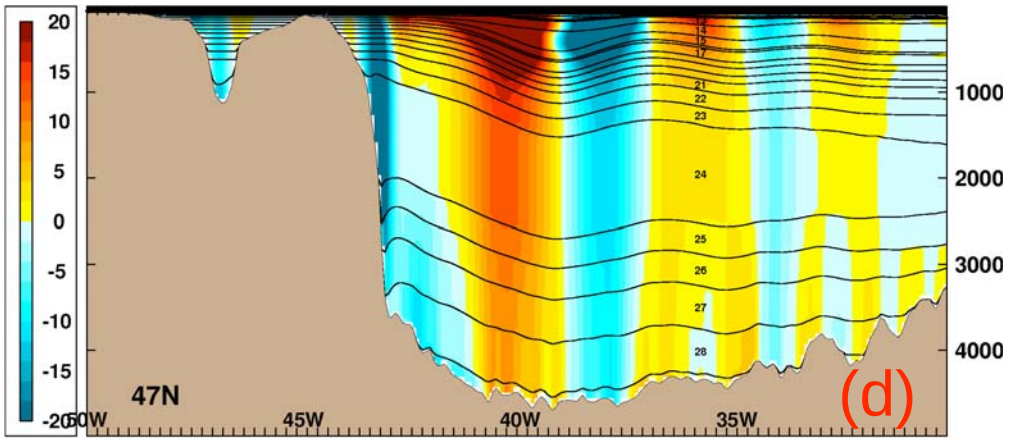
Northward

Mooring[1]	HYCOM	POP0.1[3]
81.2	41.5	23.8-37.3
9.2	3.7	1.7- 2.6
23.4	6.8	8.5-10.6
16.4	3.9	7.5-12.5
11.4	2.4	5.3- 8.4

[1]Schott et al. (2004) ; [2]Schott et al. (2006); [3]Table 2 of Bryan et al (2007)

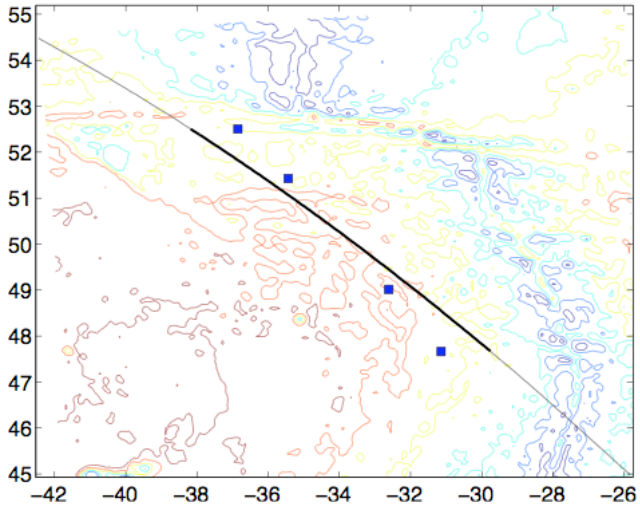
Current across 47ºN



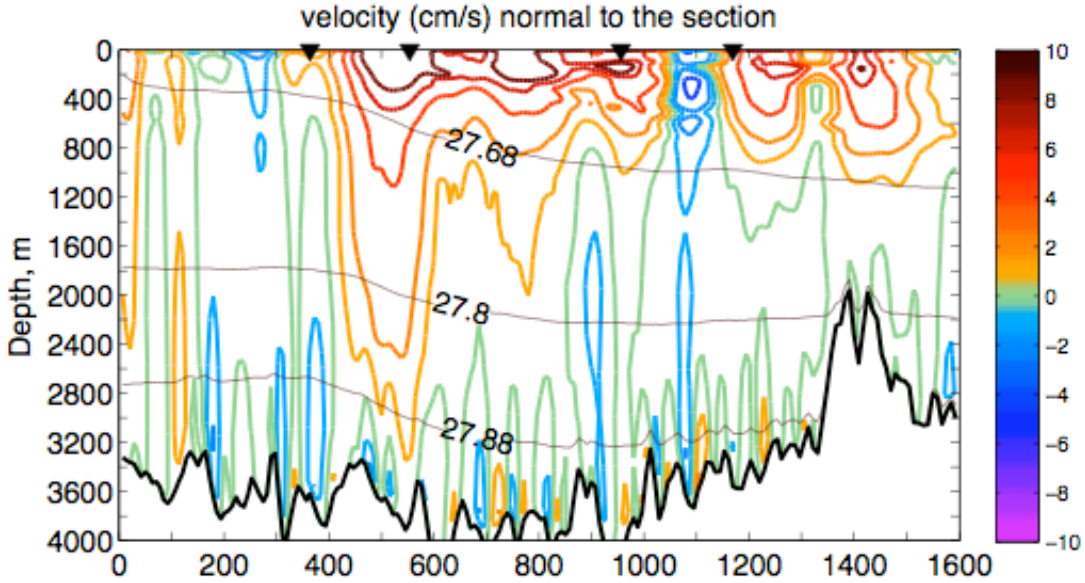


Meridional velocity (cm/s) across 47ºN in the Newfoundland Basin based on (a-c) three LADCP surveys (August, 2003; April, 2008; and July, 2009), from Figure 15 of Rhein et al., (2010) and (d) model (5-year mean)

Subpolar gyre across the MAR



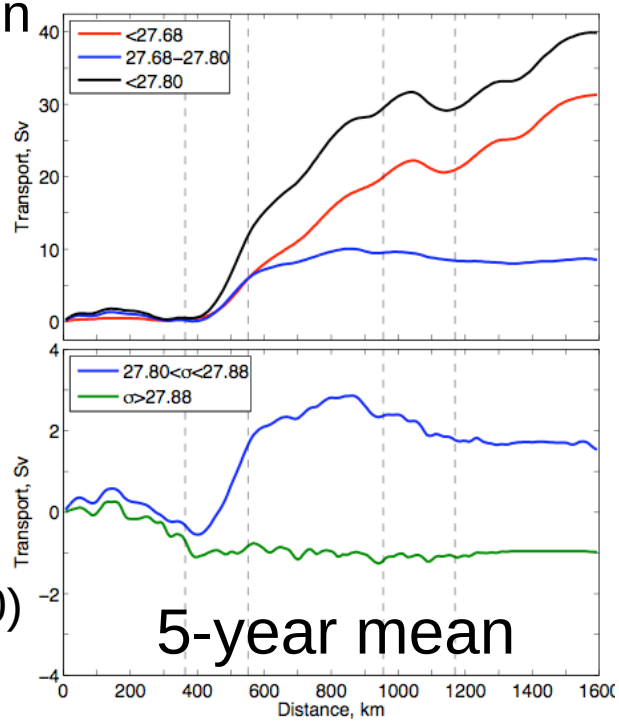
Location of PIES/section

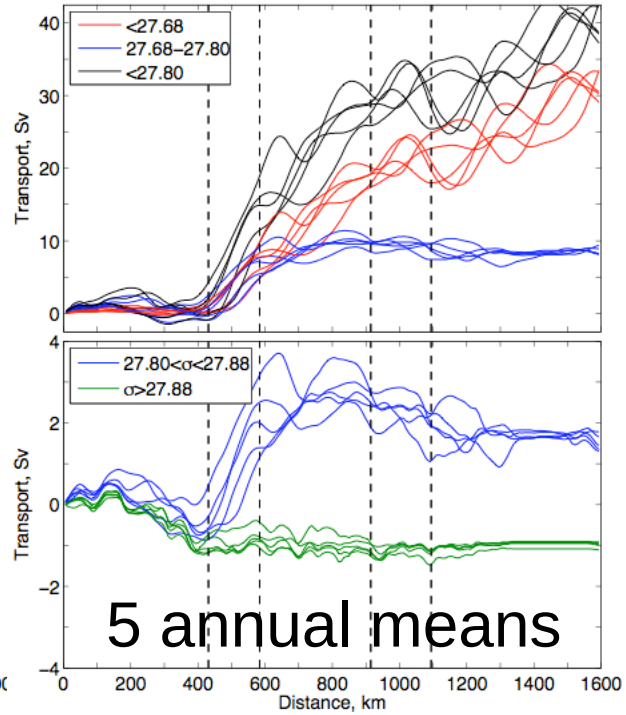


Transports:

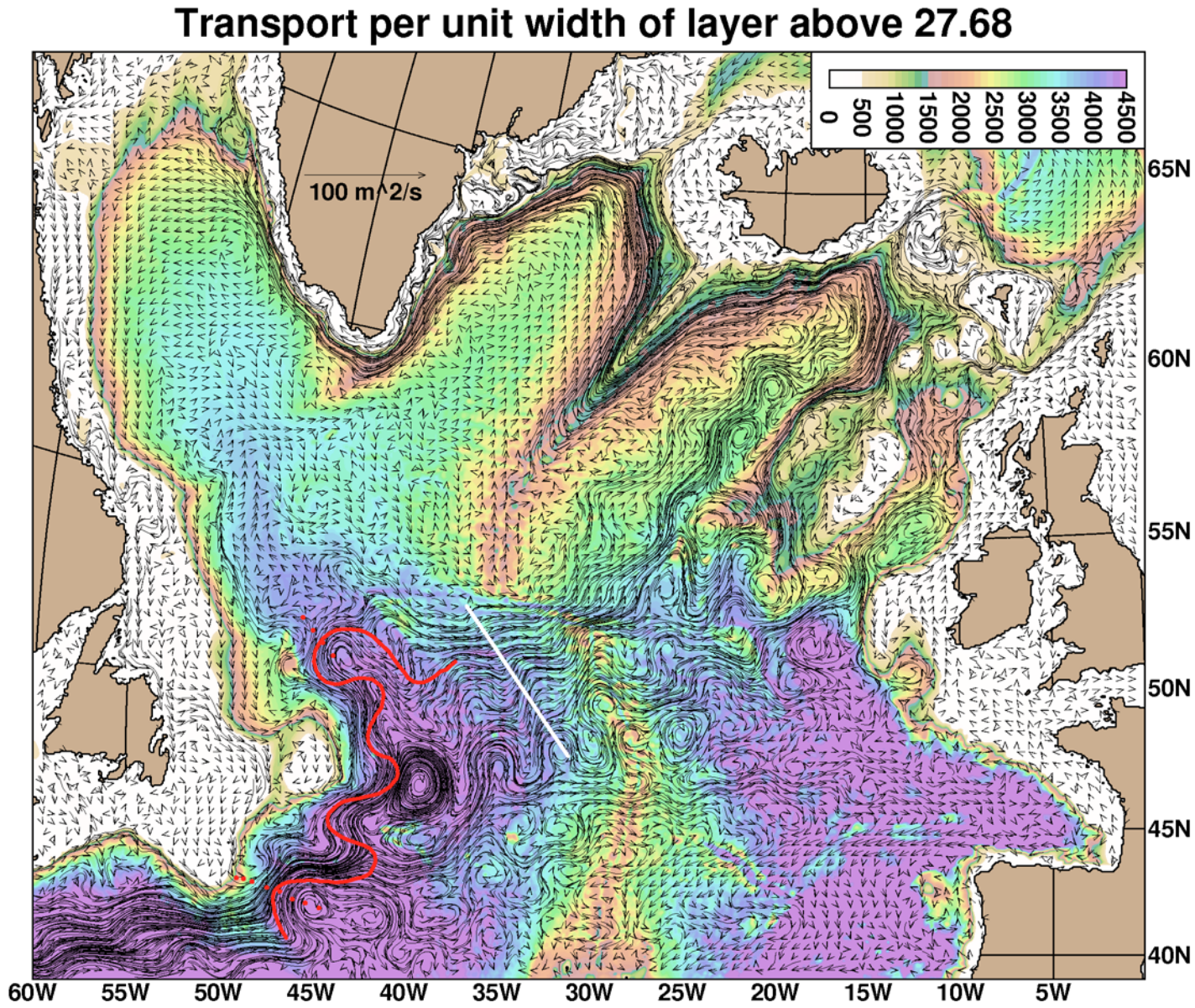
Obs.[1]	Model
18.3	20.6
7.8	7.0

[1]Figure 6 of M. Rhein (2010)

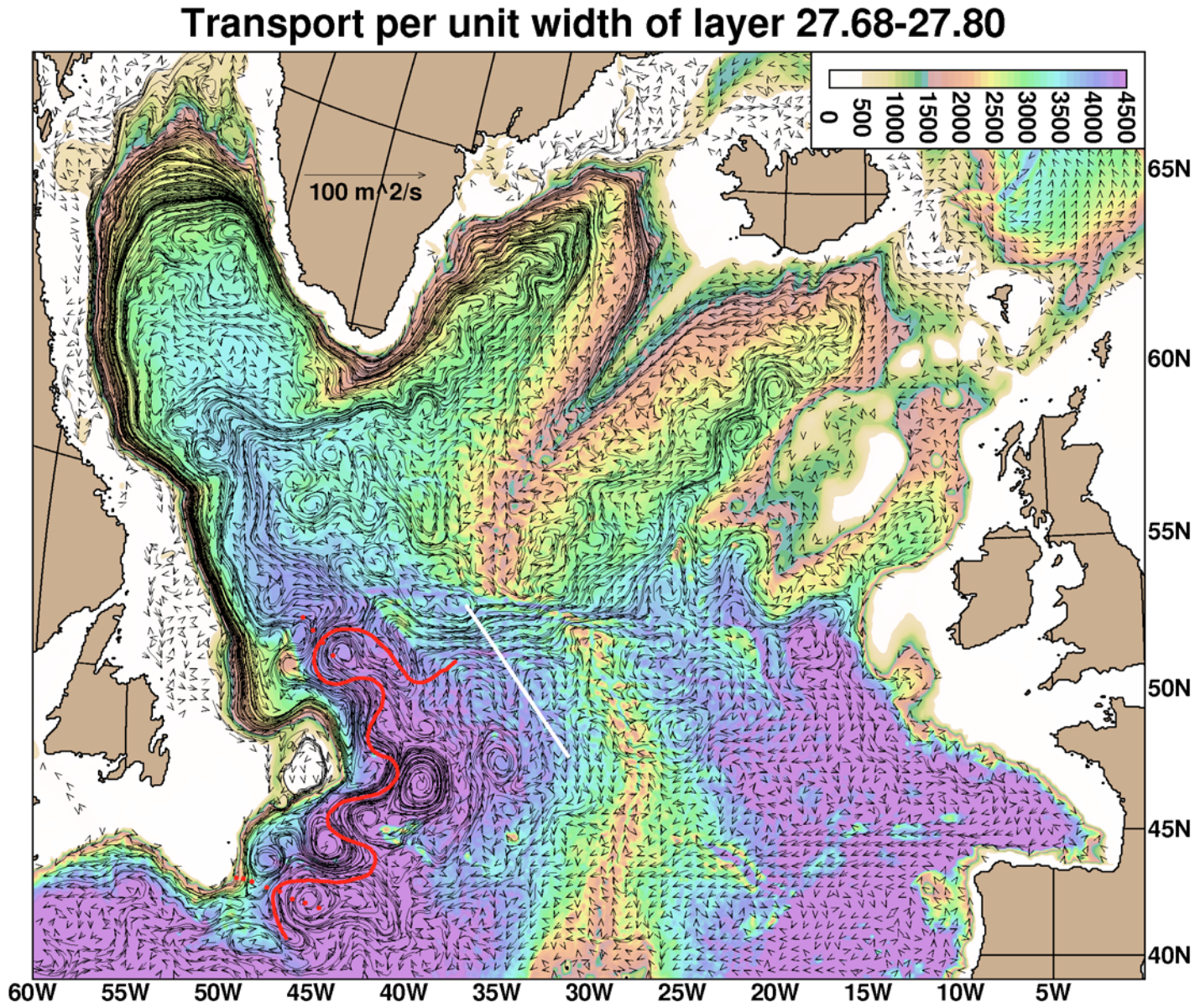




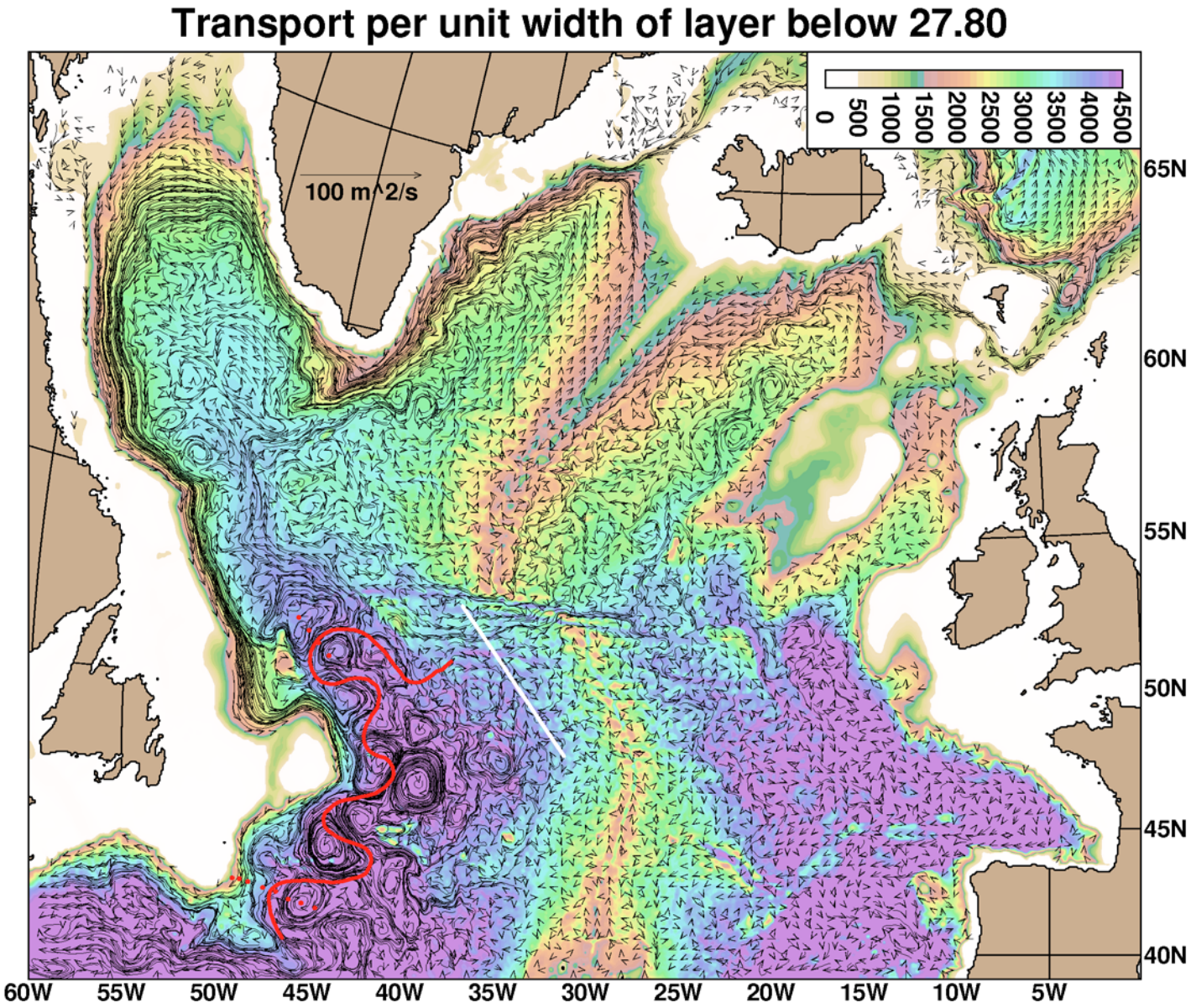
Transport in density layers: 1

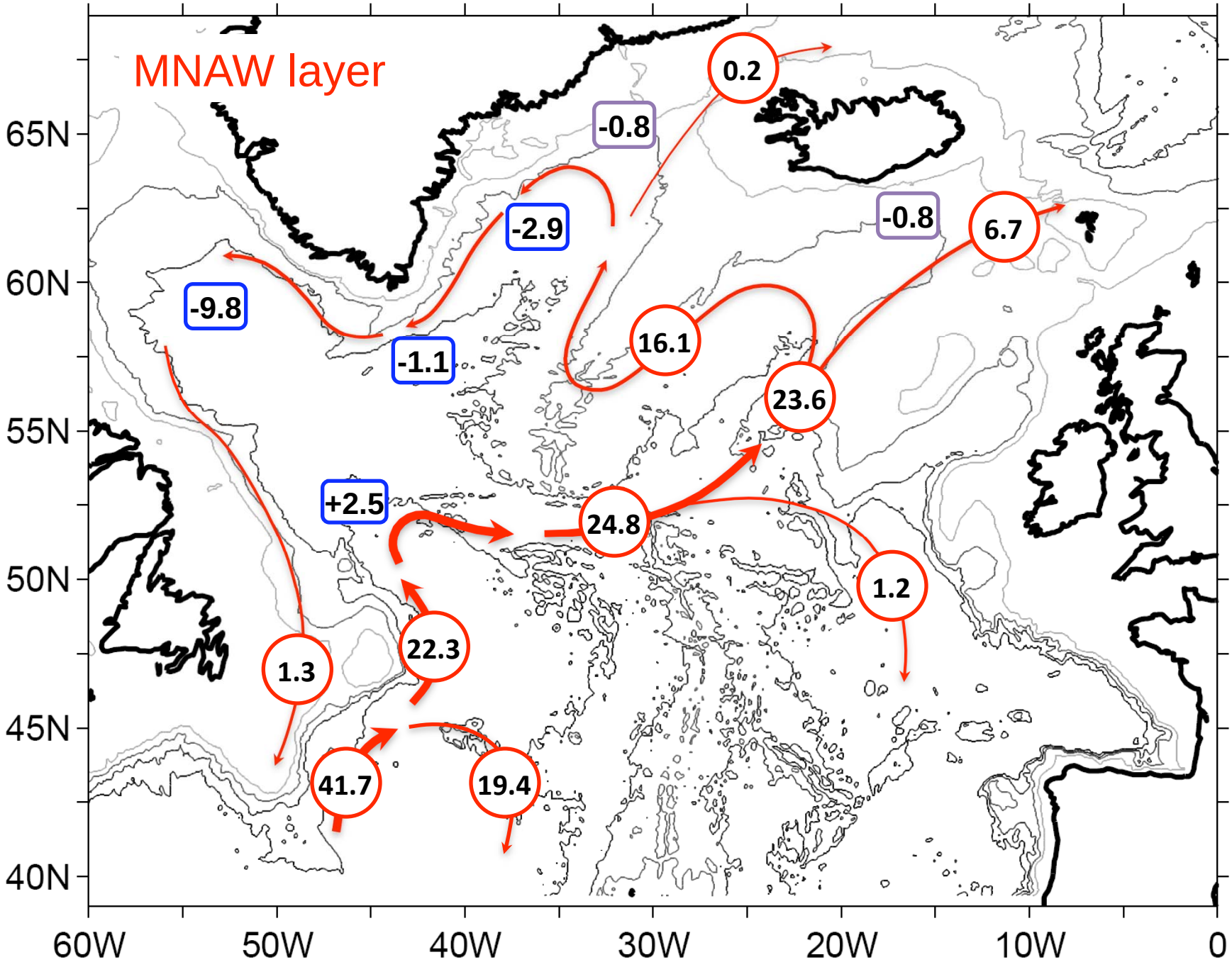


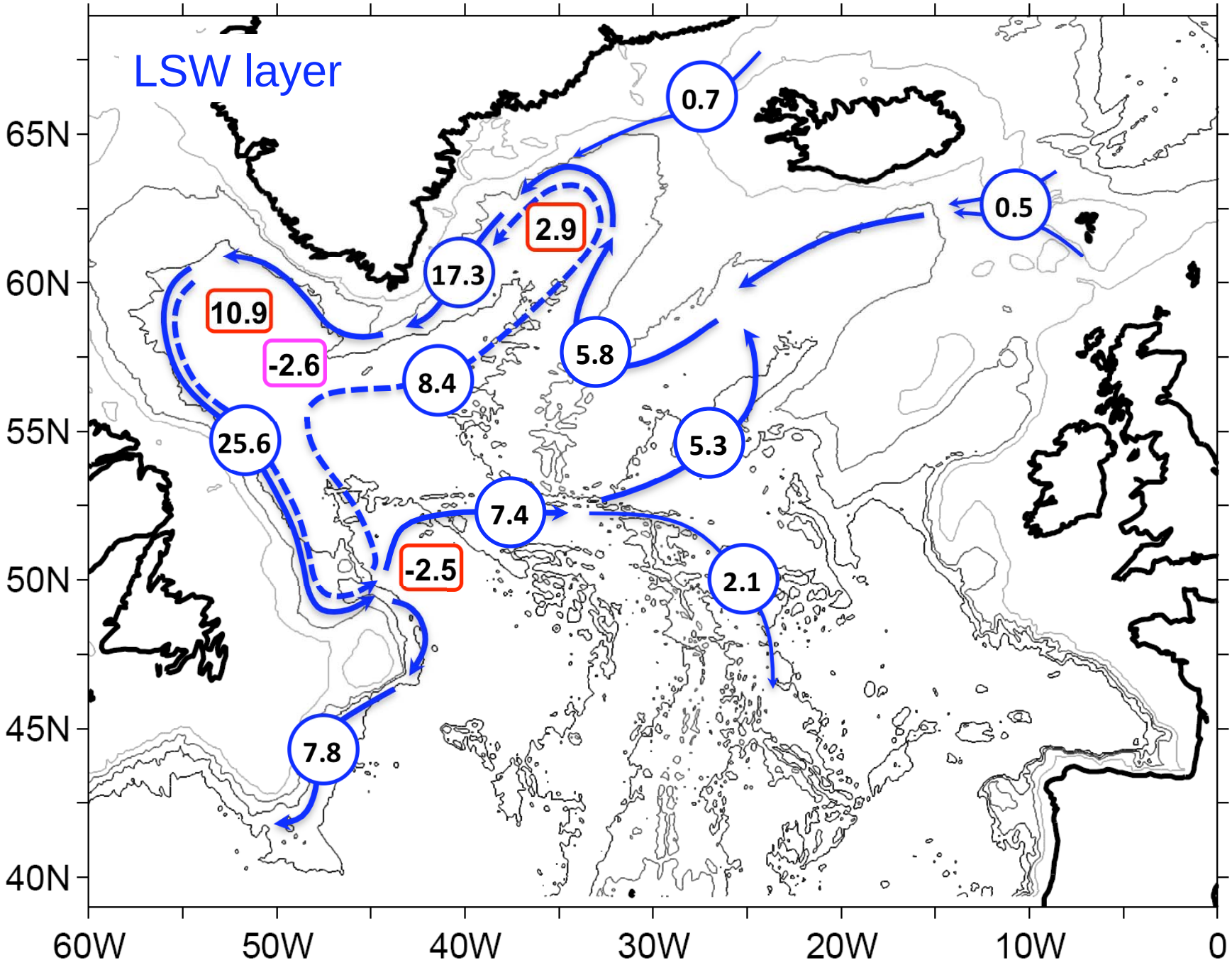
Transport in density layers: 2

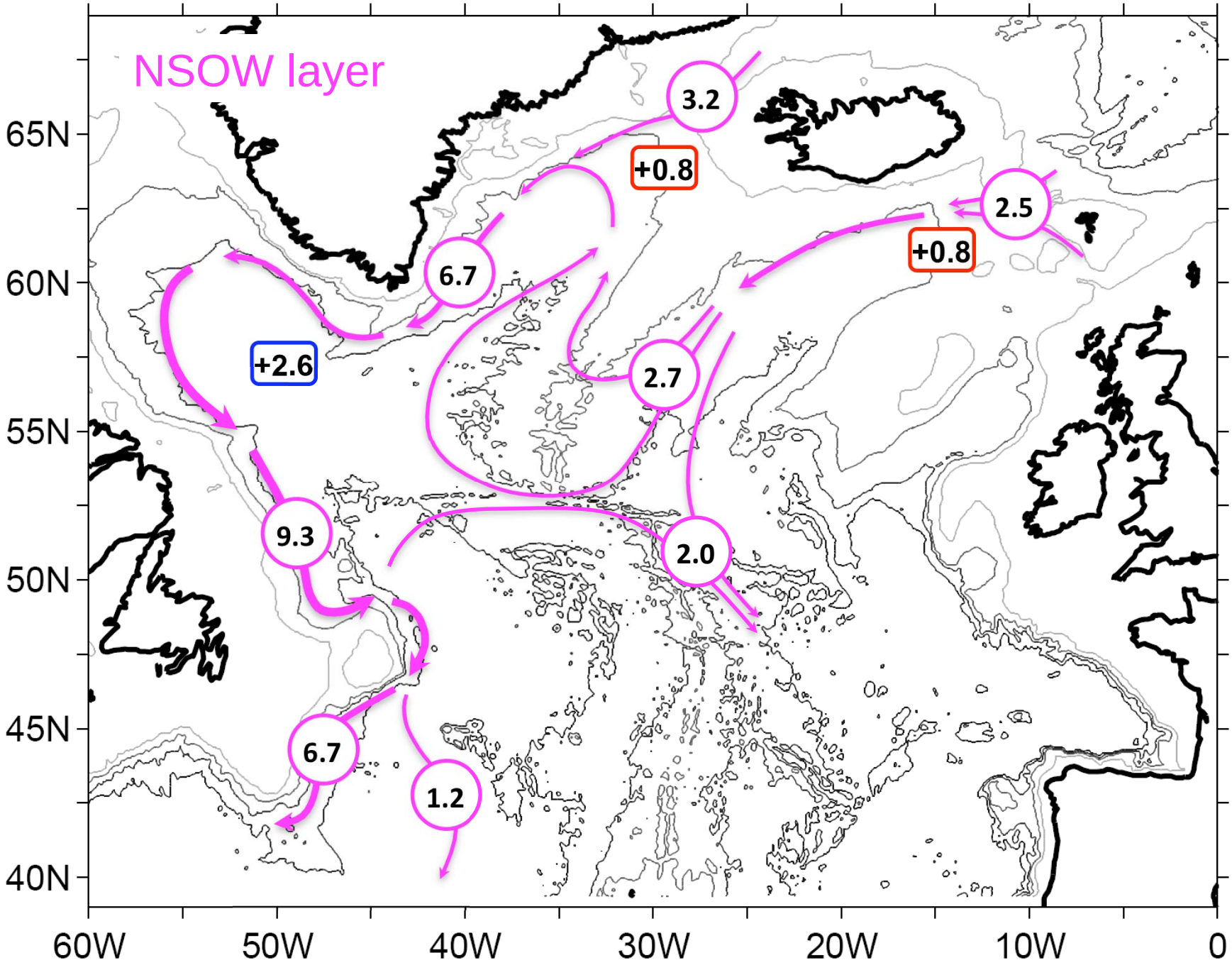


Transport in density layers: 3




MNAW layer
0.2
-0.8
-2.9
-0.8
6.7
-9.8
-1.1
16.1
23.6
+2.5
24.8
1.2
1.3
22.3
41.7
19.4
65N
60N
55N
50N
45N
40N
60W
50W
40W
30W
20W
10W
0


LSW layer
0.7
0.5
2.9
17.3
10.9
-2.6
8.4
5.8
25.6
5.3
7.4
-2.5
2.1
7.8
65N
60N
55N
50N
45N
40N
60W
50W
40W
30W
20W
10W
0


NSOW layer
3.2
+0.8
2.5
+0.8
6.7
+2.6
2.7
9.3
2.0
6.7
1.2
65N
60N
55N
50N
45N
40N
60W
50W
40W
30W
20W
10W
0

Summary

- The model results yield a MOC transport of about 19.8 Sv at about 46N (along the WOCE section AR19), with LSW and NSOW each contributing half. Most of the southward transport (14.5Sv) is via the deep western boundary current (DWBC);
- Superimposed on the AMOC, there exist two horizontal recirculation gyres in layer of LSW. One gyre transport 7.4Sv eastward through the CGFZ, with about 5.3Sv recirculating northward into the Iceland basin. The other gyre transport 8.4Sv into the Labrador and Irminger Seas within west of the MAR. The latter transport is an overestimate (due to the water property issue).
- The model results are in rough consistent with the measurements
- One issue is to maintain the water properties, especially in the Labrador Sea (*e.g., Treguier et al., 2005; Brandt et al., 2007, Chanut et al., 2008*). The warm/ saline bias would lead to stronger convection (LSW formation).
- The other key issue is that the northward transport of the NAC and recirculation offshore (Mann eddy), especially in the deep, is much weaker than observations (*e.g., Clarke et al., 1998; Meinen 2001; Schott et al. 2004*). This issue is also common in other high-resolution models (*e.g., Bryan et al., 2007*), and more severe for low-resolution models (*e.g., Schott and Brandt, 2007*).