Structure and variability of the Deep Western Boundary Current (DWBC) from 2 years of observations at 60ºN in the Irminger Sea

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1. DWBC Mooring Array

As part of the trans-basin array of the Overturning in the Subpolar North Atlantic Programme (OSNAP), the Irminger Sea Deep Western Boundary Current (DWBC) mooring array was deployed (Figure 1).

The DWBC is a major component of the deep, south-going limb of the Atlantic Meridional Overturning Circulation in the subpolar North Atlantic. Variability in its transport likely drives much of the variability in the overturning as a whole.

The array was designed to quantify the mean and variability of the volume, heat and salinity transport of the dense northern overflow waters that enter the basin between Greenland and Scotland (having σ_θ > 27.8 kg m^{-3}).

The array is constructed of five UK-OSNAP moorings, two US Ocean Observing Initiative (OOI) flanking moorings and three moorings from the US-OSNAP East Greenland Current Array (Figure 1).

Here we use the first 2 years of data (2014-2016) to calculate the volume transport and variability of the DWBC.

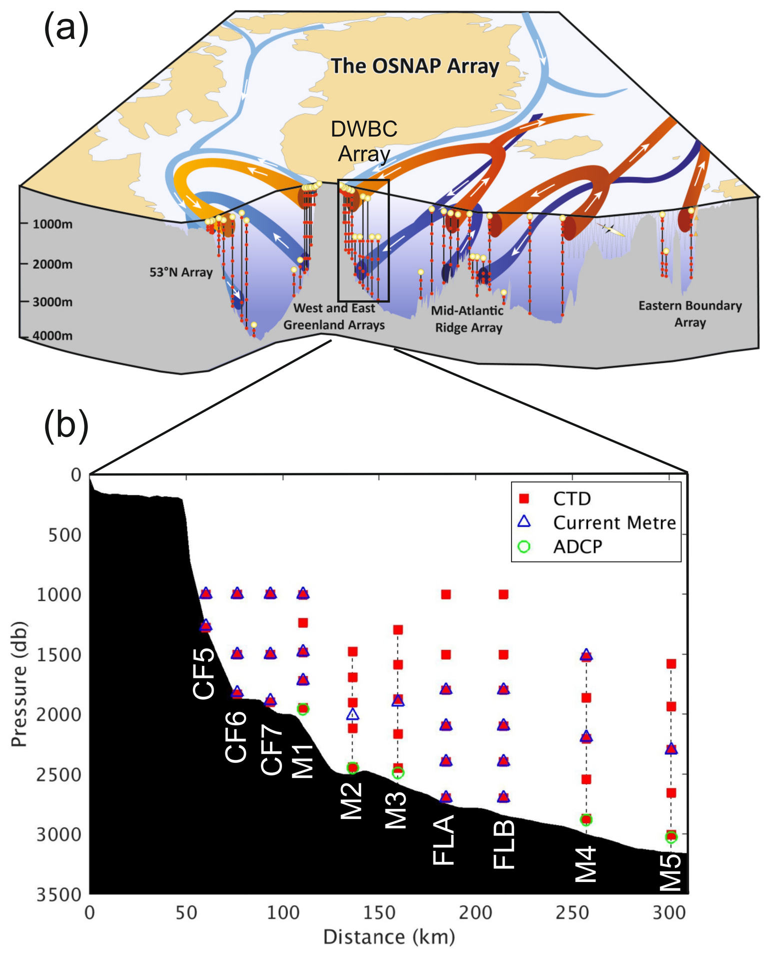

Figure 1 (a) OSNAP moorings and the DWBC array in the Irminger Sea. (b) From 10 moorings we use data collected from 49 CTDs, 24 current metres and 5 ADCPS.

2. DWBC structure

We interpolate velocity, temperature and salinity time series onto an equidistant grid. The resulting 12-hourly fields and the deployment means were validated against six CTD-LADCP sections from 2005, 2008, 2014, 2015 and 2016.

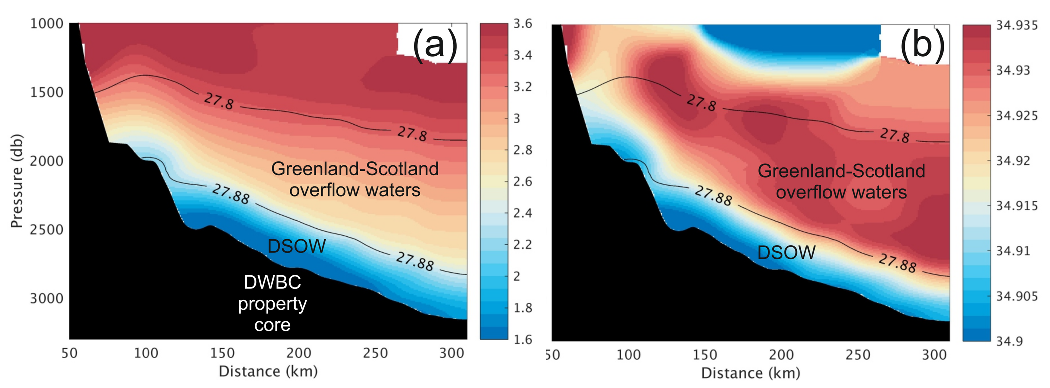

Figure 2. (a) Deployment mean potential temperature (°C) and (b) salinity from the mooring array.

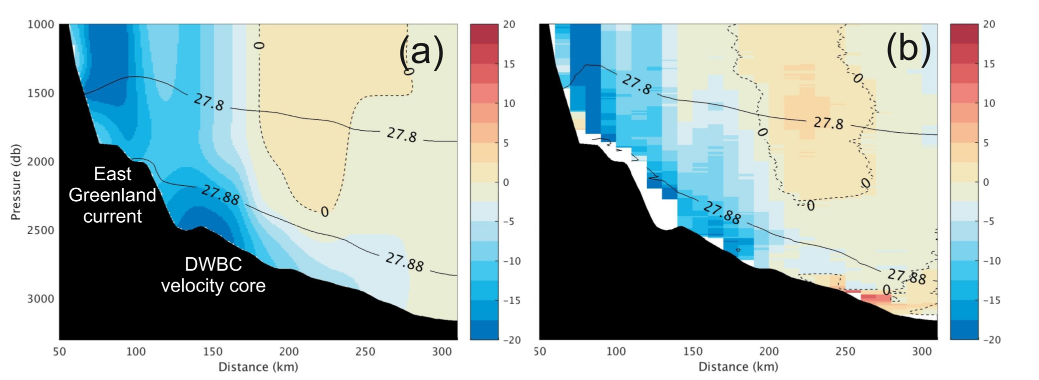

Figure 3. (a) Deployment mean along-bathymetry velocity (cm/s) from the mooring array. (b) Mean velocity and 27.8 kg m^{-3} isopycnal from 6 CTD-LADCP sections.

Greenland -Scotland overflow waters (σ_θ > 27.8 kg m^{-3}) are transported southward within the DWBC.

The densest waters originate from the Denmark Strait Overflow, DSOW (σ_θ > 27.88 kg m^{-3})

The DWBC velocity core is located in a water depth of ~2500 m and straddles a local rise in the bathymetry. It is distinct from the deep reaching East Greenland Current further up the slope.

The temperature minimum lies ~50 km downslope of the velocity core.

3. DWBC transport

Calculation of the volume transport is extremely sensitive to the direction chosen to represent the major axis of the flow. Rather than work within the coordinate system dictated by the orientation of the mooring array, we prescribe an 'along-slope' orientation that (a) matches the major-axis orientation of near-bed velocity variance ellipses around the core of the DWBC (Figure 4) and (b) maximises the DWBC transport (Figure 5).

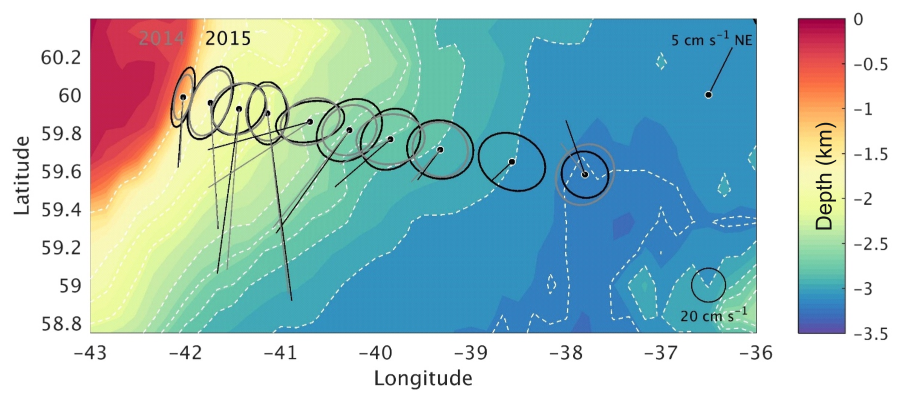

Figure 4. Variance ellipses for velocity records nearest the bottom. Sticks represent the deployment mean velocity vectors.

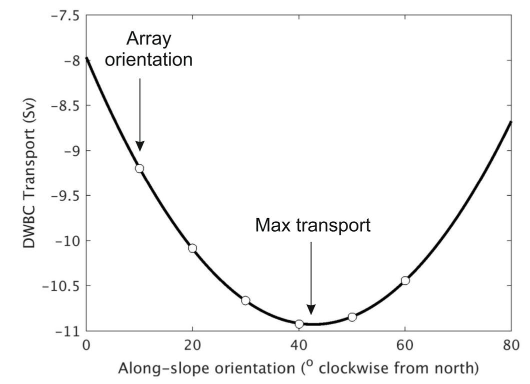

Figure 5. Sensitivity of transport estimates to the definition of 'along-slope'.

	Deployment mean (Sv)	95% Bootstrapped confidence interval
DWBC σ_θ > 27.8 kg m^{-3}	-12.3	-12.6, -12.0
DSOW σ_θ > 27.88 kg m^{-3}	-4.75	-4.84, -4.65

The total transport of the DWBC in the Irminger Sea over the 2 year deployment was -12.3 Sv, 40% of which was contained within DSOW.

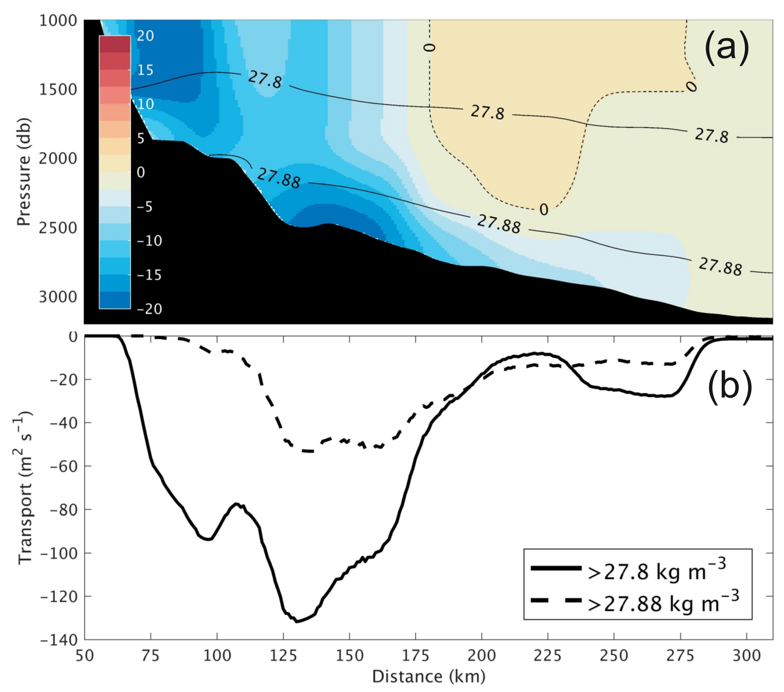

Figure 6. (a) Deployment mean along-slope velocity (cm/s) and (b) Depth integrated deployment mean transport within the DWBC (σ_θ >27.8 kg m^{-3}) and DSOW (σ_θ >27.88 kg m^{-3}).

The transport maximum coincides with the DWBC velocity core in a water depth of ~2500 m. A second transport maximum is located further up-slope in 2000 m of water near the base of the East Greenland slope current.

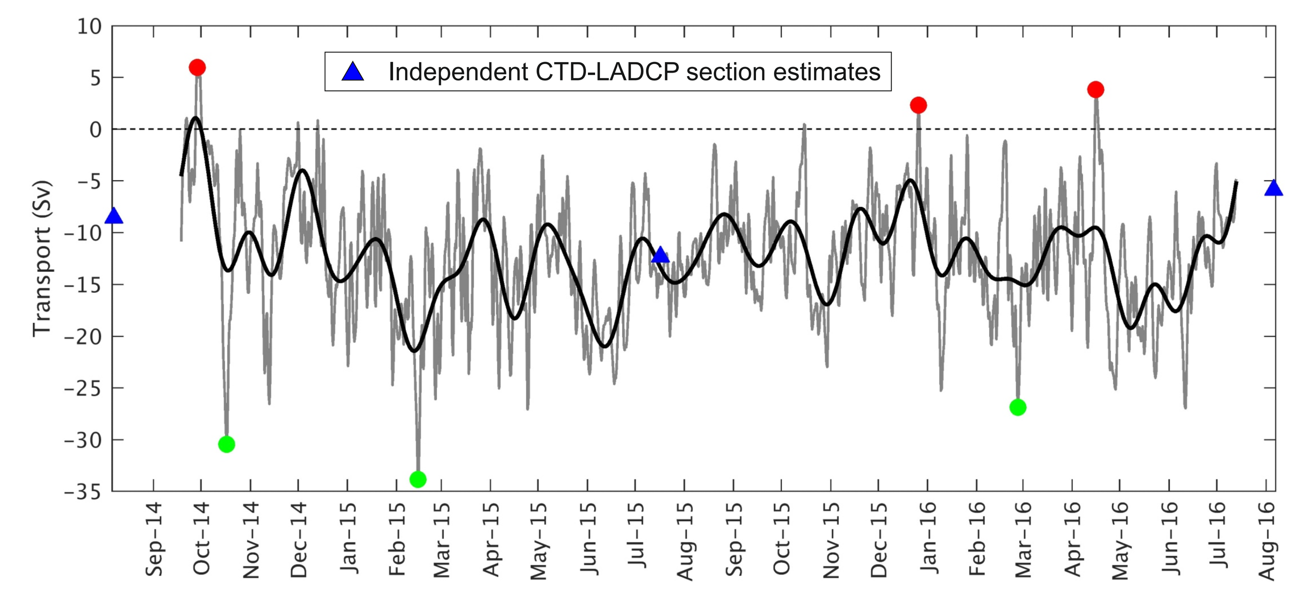

Figure 7. (grey) Time series of 12-hour average DWBC volume transport (> 27.8 kg m^{-3}) and a 30 day low-pass filter (black). There is a broad range in transport variability between 6 and 55 days. Maximum southward transport (●) and periods of weak/postive transport (●) are associated with strong barotropic eddies enhancing or supressing the southward flow of deep boundary current waters respectively.

4. Drivers of transport variability

Previous estimates of the DWBC transport at this location have (necessarily) used a 'static' background density field. The contribution that variability in the 'thickness' of the DWBC makes to the volume transport has therefore never been quantified. Decomposing the layer thickness (h) and mean layer velocity (u) into their time-mean and time-varying components at each location along the mooring array, the transport time-series (uh) can be broken down into 4 terms:

$$uh = \bar{u}\bar{h} + u'h' + \bar{u}h' + u'\bar{h}$$

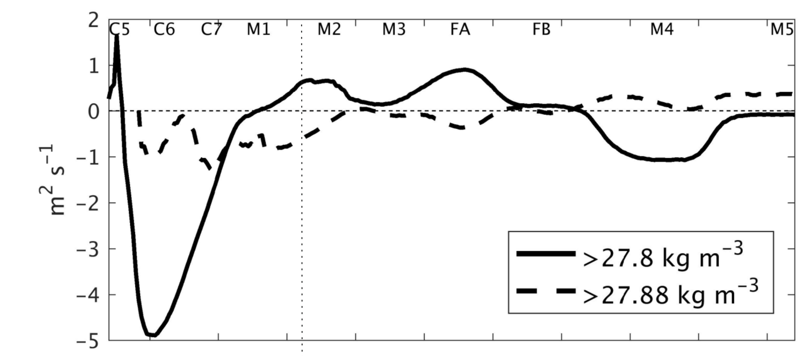

Figure 8. The contribution made by eddy-transport (the co-variance between layer thickness and velocity, $u'h'$), to the deployment mean is small (1-8%). Interesting though there is a small positive (poleward) eddy transport across the centre of the array.

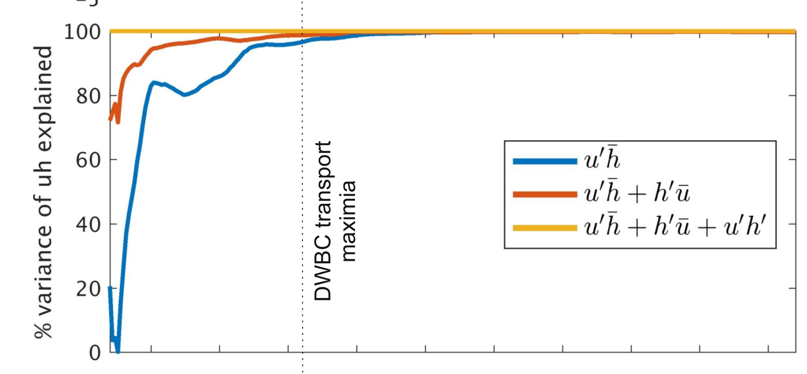

Figure 9. Percentage variance of the instantaneous transport explained by the linear combination of terms. Beyond 150 km more than 99% of the variability in uh is explained by variations in velocity acting on the mean layer thickness ($u'\bar{h}$).
In shallower water, under the East Greenland Current variations in layer thickness become increasingly important and up to 60% of the transport variability is explained by $\bar{u}h'$.

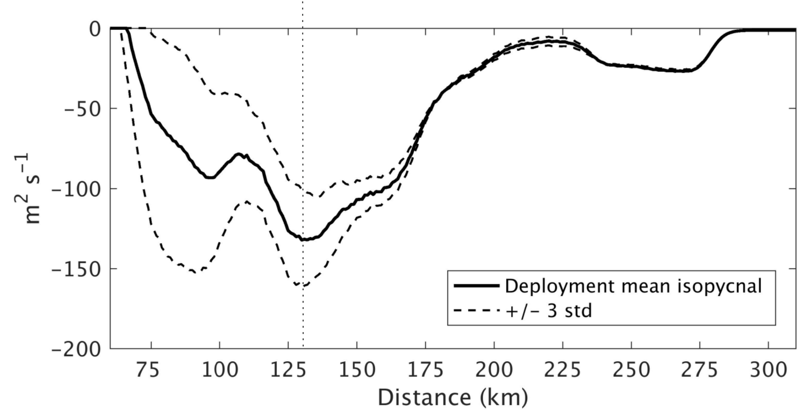

Figure 10. Deployment mean depth integrated transport re-calculated using (a) the deployment mean 27.8 kg m^{-3} isopycnal depth (solid) and (b) the mean depth ± 3 std (dashed).

Estimates of the total DWBC transport using these fixed isopycnal depths lie between -8.9 Sv and -15.8 Sv (around a mean of -12.3 Sv). Basing transport estimates on synoptic snap-shots of the denisty field can therefore introduce a ~30% error.

5. Historical context

There are a limited number of transport estimates made in this region to which our results can be compared.

Bacon and Saunders (2010) estimate a DWBC transport of -9 Sv based on 9.5 months of data collected in 2005-2006 (BS10).

Carke (1984) used 2 months of data from 1978 and found the transport to be -13 Sv (C85i). Bacon and Saunders (2010) later argued that this should have been -16 Sv (C85ii).

Neither set of estimates were made using a time-varying density field.

Based on PDFs of all the possible transport estimates that could have been made using 2 month and 9.5 month windows within our observational period (Figure 11) we conclude that it is not possible to detect any long term trends.

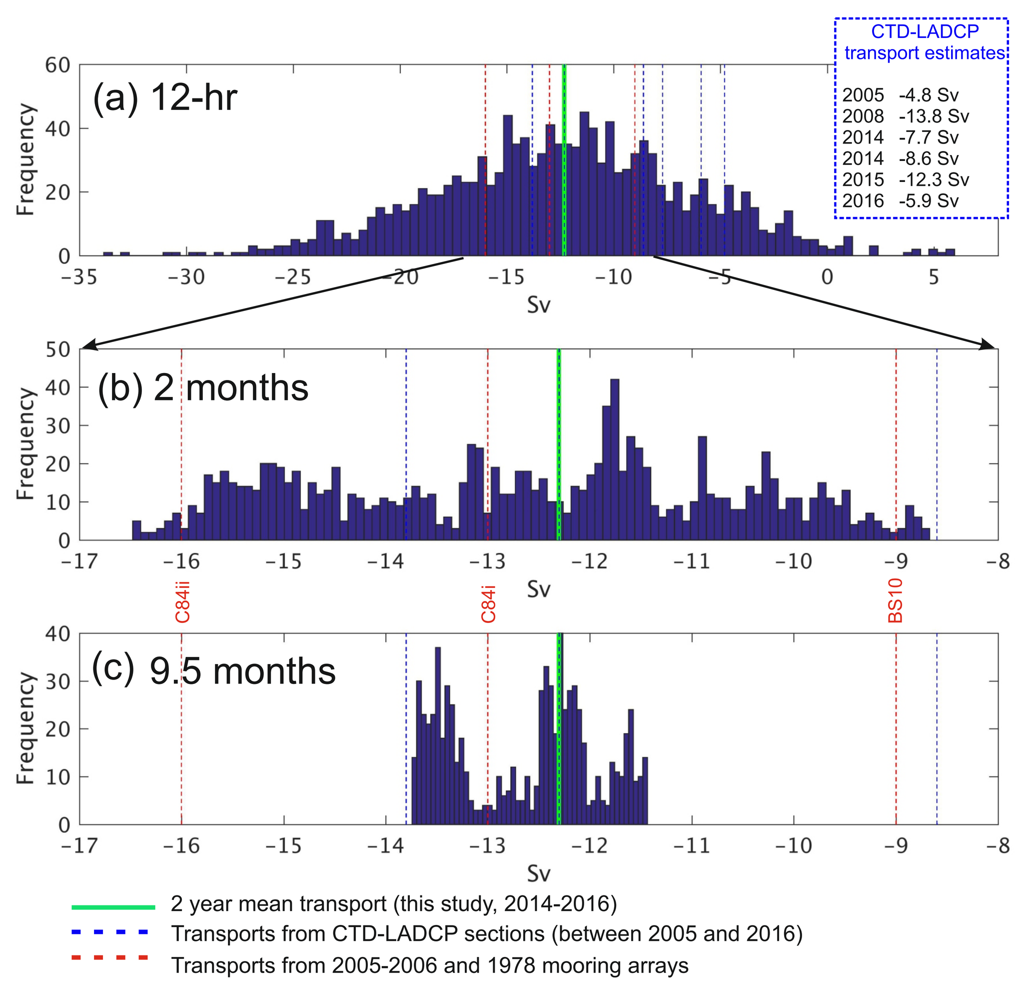

Figure 11. PDFs of all the possible transport estimates that could have been made using (a) 12-hour, (b) 2 month and (c) 9.5 month long data sets (from within our 2 year deployment).