Atlantic Meridional Overturning Circulation: Sustained Observations of Labrador Sea Outflow at 53°N

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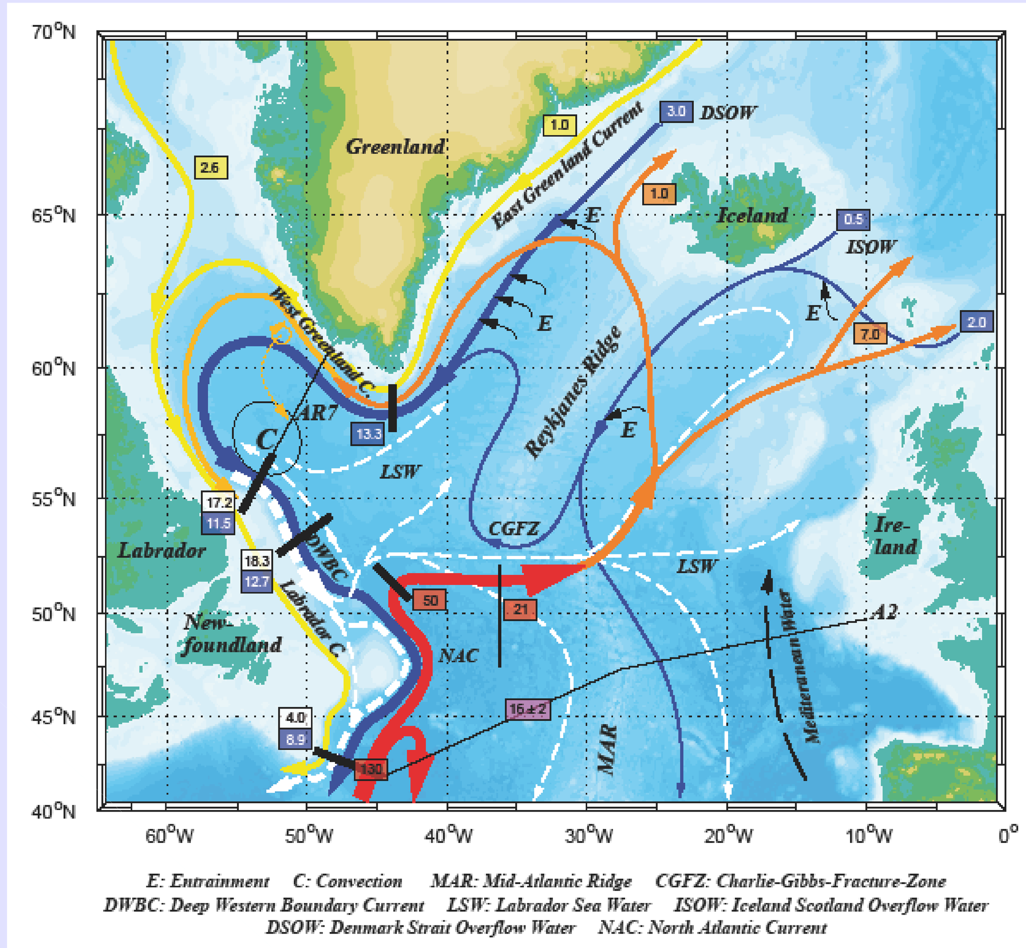
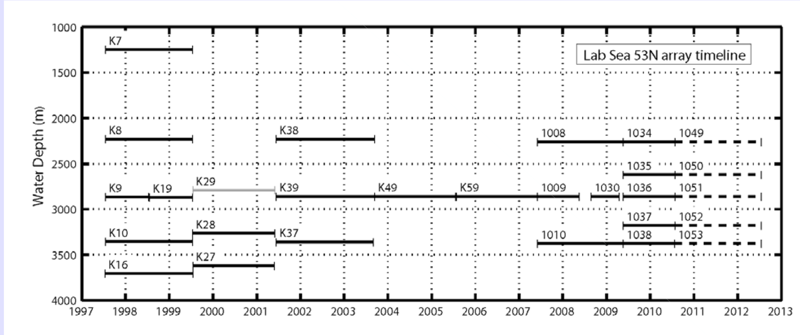
Abstract:
The formation and spreading of water masses in the Labrador Sea, characterized by a cyclonic boundary current surrounding one of the most active areas of wintertime water mass transformation in the world's ocean, are the central aspect of this OceanSites component in climate research. Along the Labrador shelf break, the three components of the North Atlantic Deep Water (NADW) merge into the Deep Western Boundary Current (DWBC) as a major contribution to the cold water limb of the Meridional Overturning Circulation (MOC). Therefore, this location at 53°N is well suited to observe – and potentially monitor – the outgoing component of those water masses which enter the subpolar North Atlantic from the Arctic Ocean.

For more than a decade, from 1996 to 2010, and currently ongoing, moored observatories were deployed over varying time intervals and spatial coverage near the western exit region of the Labrador Sea. The most prominent signal during the last decade was a well-documented warming of the upper 2000 m of the water column over the entire Labrador Sea, caused primarily by the weakened or absent formation and deep convection of Labrador Sea Water at densities less than 27.80. Our data show fluctuations on seasonal to interannual timescales, plus an initial estimate of the decadal variability, which seemingly have little to no relation to the above-mentioned warming trend, and they clearly document the remarkable stability in strength and structure of the DWBC at 53°N.

Transport estimates for the upper and deep limbs of the boundary current contributing to the MOC are reviewed for different time periods. An assessment of the monitoring scheme for the cold water export based on strategic current meter placement shows that more than 70% of the transport variability can be monitored by a single instrument.

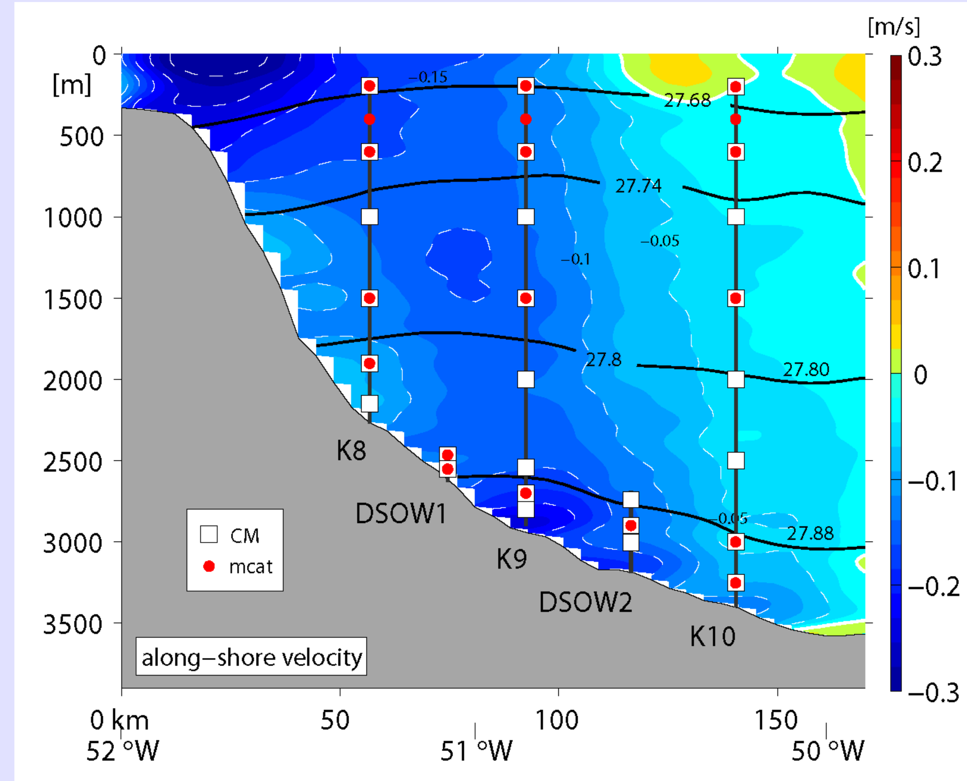


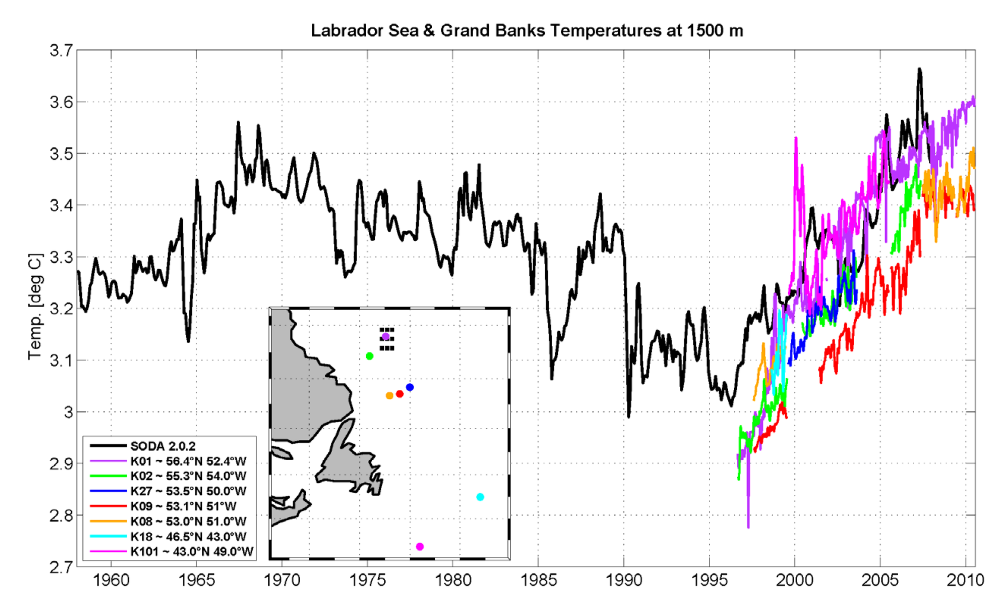
Map of the subpolar North Atlantic, incl. the paths of relevant currents, plus location of mooring arrays

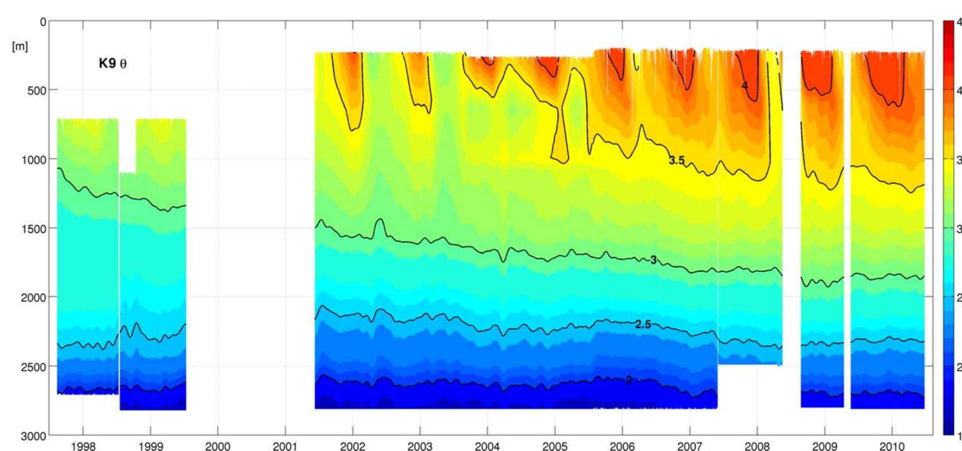


Timeline of western boundary mooring array at 53°N

Location of the moored boundary current array off the coast of Labrador in the configuration since 2009. The moorings and instrumentation (see legend) are superimposed on the average section of Labrador Sea outflow from shipboard observations since 1997. Also shown are the isopycnals (in black) indicating the boundaries between different water masses.

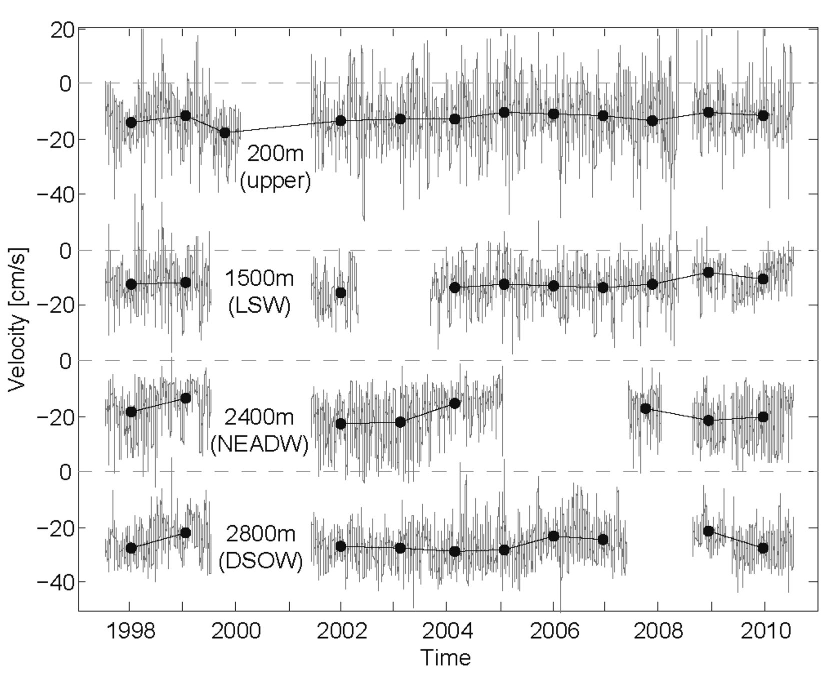




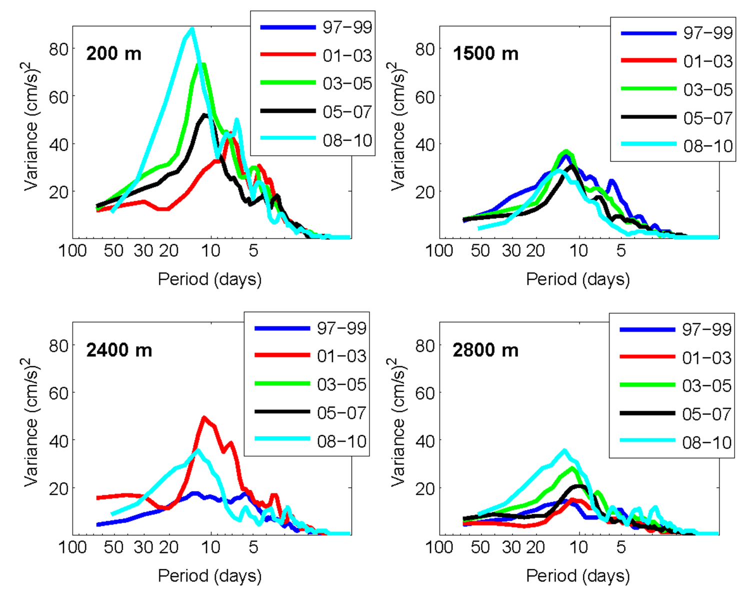


A steady temperature increase in the upper 2000m of 0.05°C per year was observed throughout the entire Labrador Sea. The SODA model (here Version 2.0.2, incl. data assimilation) shows that this warming trend is part of a decadal fluctuation. Does this temperature increase lead to significant changes in circulation and outflow from the Labrador Sea, and are we capable of measuring such changes?

Central mooring K9

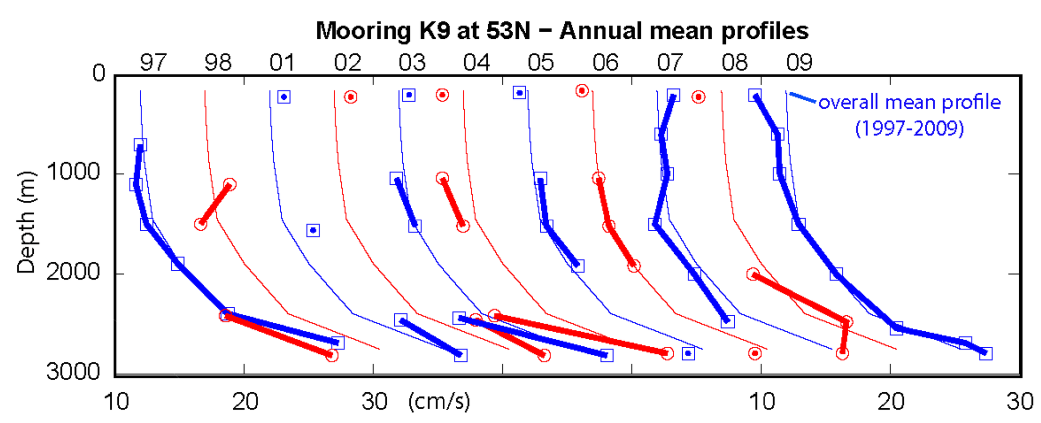


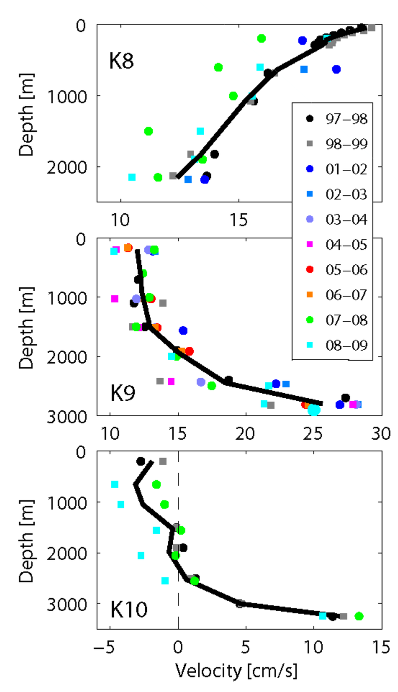
Time series of flow component along the topography at 53°N for mooring K9 for 1997 - 2010. The four levels shown represent the central depths of different water masses: Upper layer (200m), Labrador Sea Water (1500m), Northeast Atlantic Deep Water (2499m) and Denmark Strait Overflow Water (~2800m). The grey curves represent the original data (detided), black dots and lines are annual averages. Note the remarkable stability of the DSOW over the entire 13 years of data.



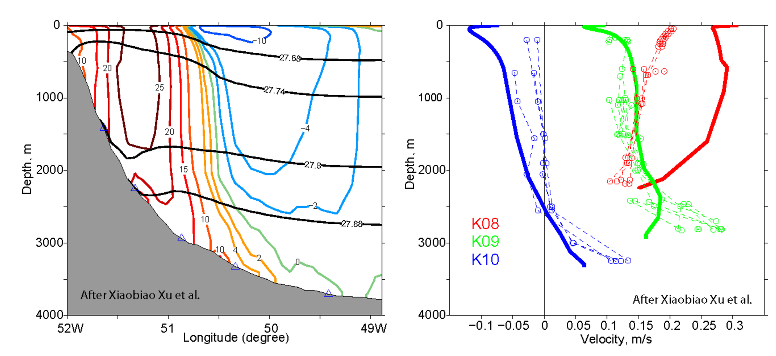
Interannual changes of the intraseasonal variability: The variability of the Deep Labrador Current shows a spectral peak at approx. 20 days, with variance decreasing with depth, and stability of the mean increasing.

There is no obvious interannual change in the intraseasonal variability (see color code), and in particular there is no significant trend detectable in the eddy and meander activities of the Deep Labrador Current.

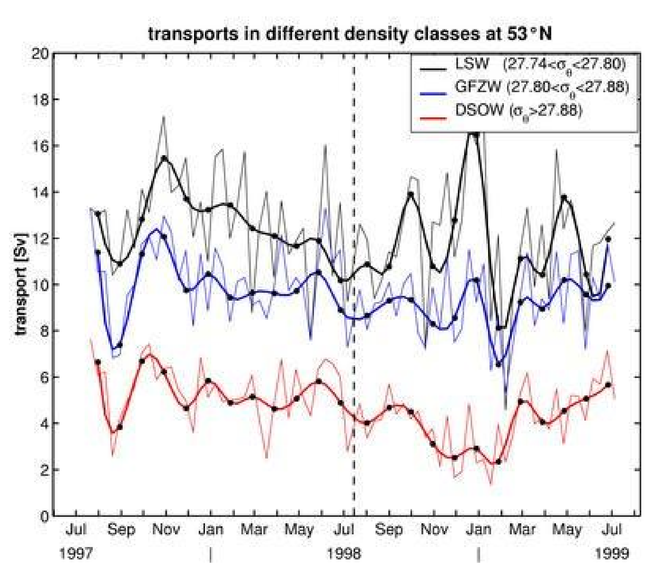




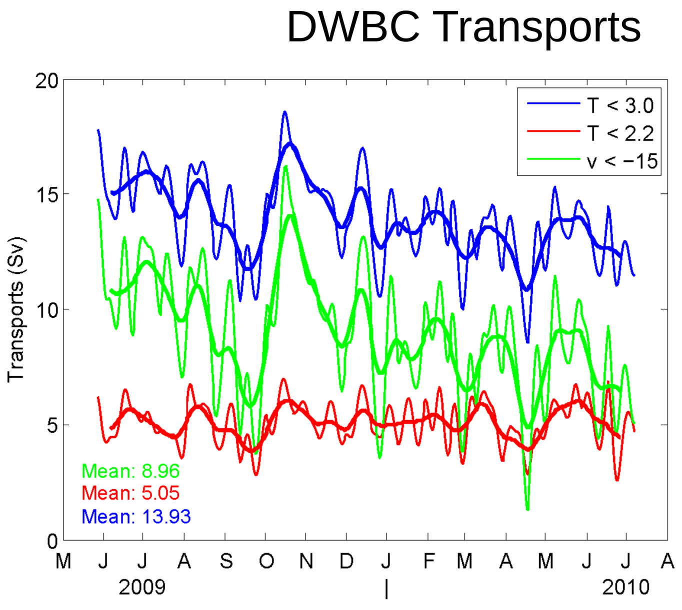
Annual means of the current profiles oriented along the topography from moorings K8, K9 and K10 at 53°N. The upper figure shows consecutive annual means superimposed on the overall mean (alternating in blue/red). The bottom intensification of the DSOW outflow remains as the dominating feature throughout the entire 13-year period of observations.



Simulated 5-year mean flow at 53N from HYCOM model



DWBC Transports

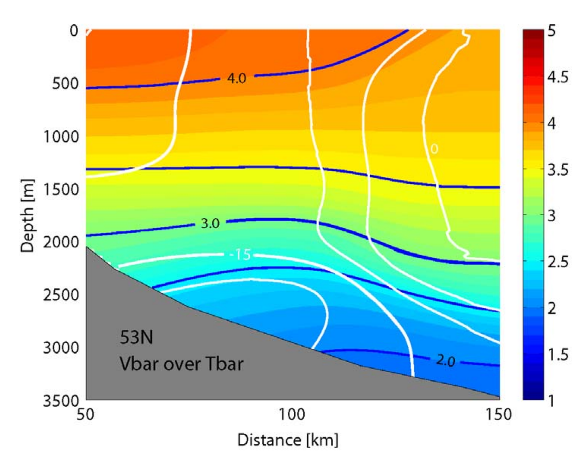


Left: Transport time series of the NEADW and DSOW from moored observations, using different criteria to assess the current boundaries. The transports agree well with previous estimates from the 1997-99 period.

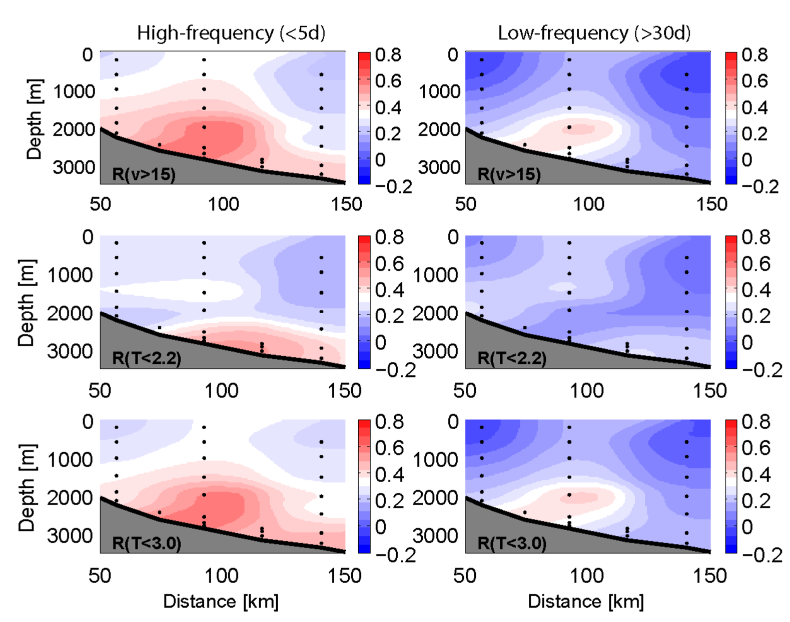
Comparison of DWBC Transports (in Sv)		
	1997-99	2009-10
NEADW	9.7 ± 2.2	9.0 ± 2.1
DSOW	4.5 ± 1.3	5.1 ± 1.3
NEADW + DSOW	13.8 ± 3.3	14.1 ± 3.2

Two array deployments more than a decade apart: Remarkable stability of mean DWBC transports

Average temperature section and outflow from the Labrador Sea from the mooring array 2009 – 2010.



Right: Correlations in high (<5d) and low-frequency (>30d) fluctuations between individual current measurements and the respective transports. It is shown that approx. 70% of the variability can be determined through strategic placement of instruments in the core of the DSOW. This may be of major relevance for monotoring the deep outflow components.



Project-relevant literature:

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