Atlantic Meridional Overturning Circulation: AMOC

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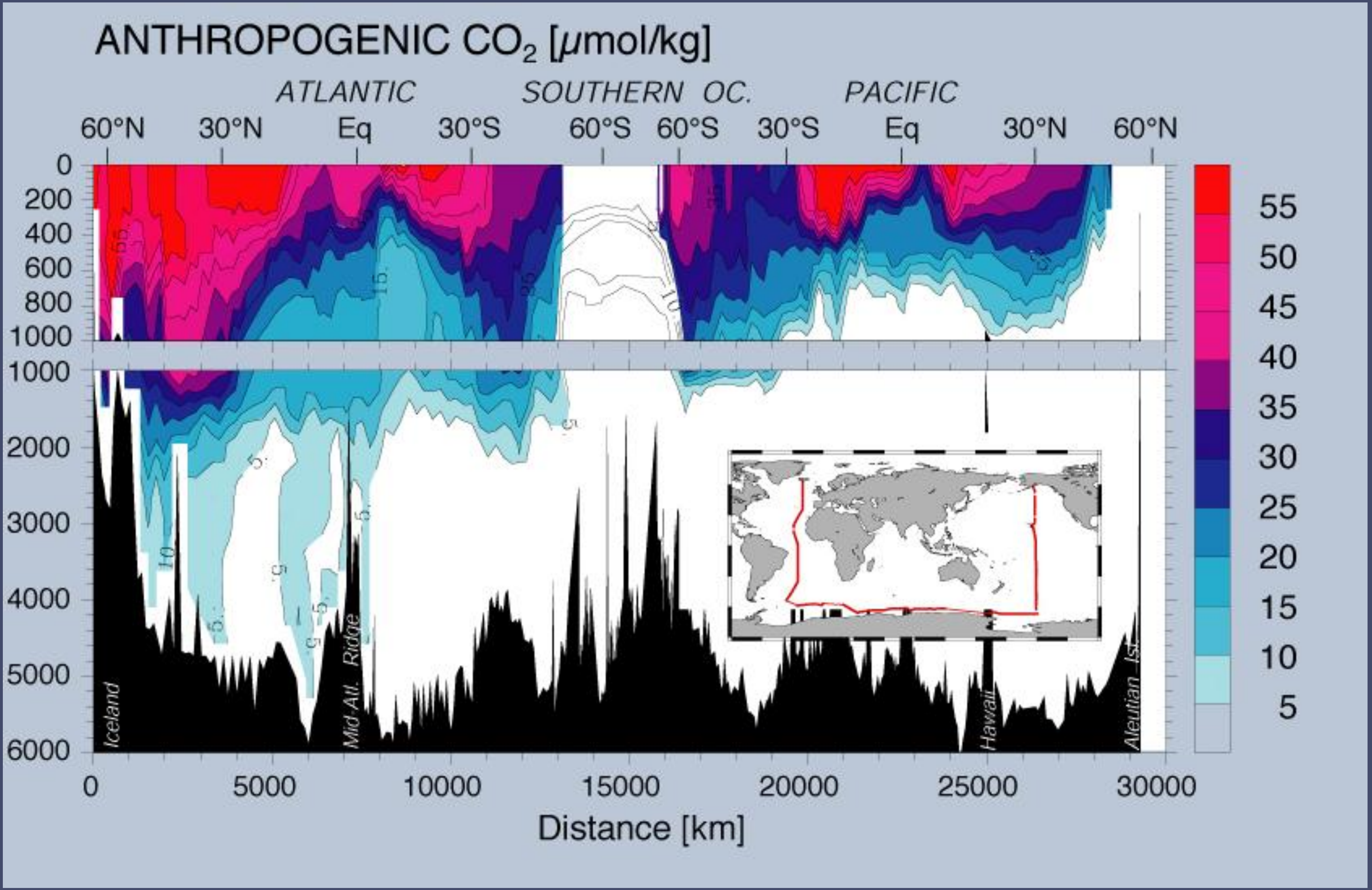
Spreading of anthropogenic CO_2 in the deep ocean



Sabine et al. 2004

Assumptions over the past decades

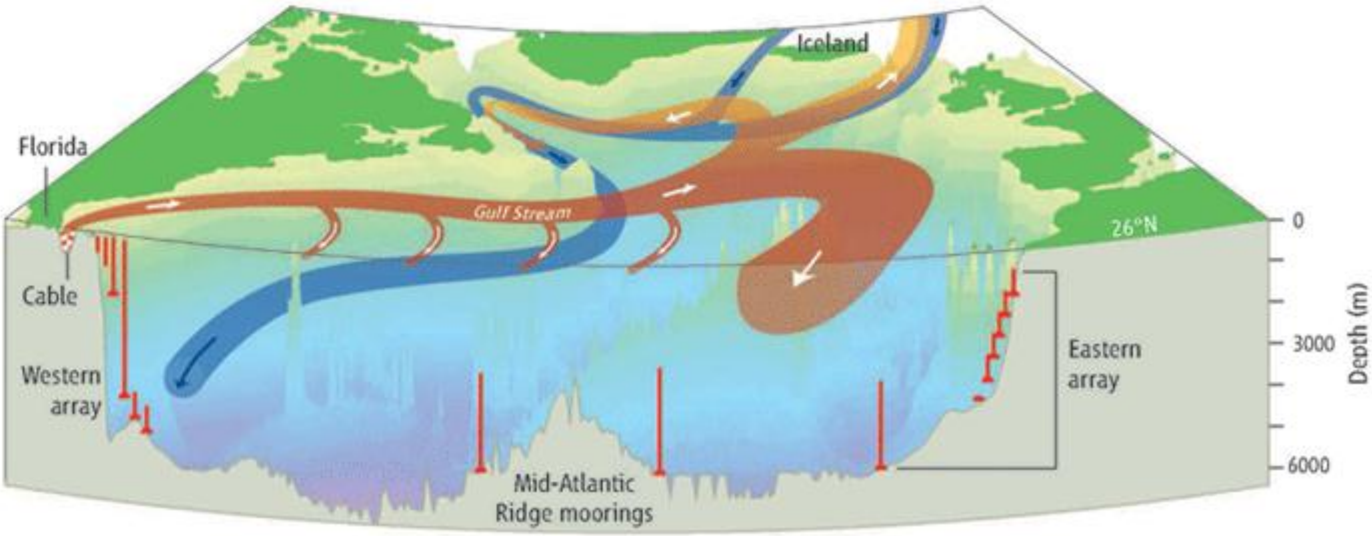
• A slowly-varying AMOC can be estimated from a synoptic measure of the full-depth, trans-basin density field.

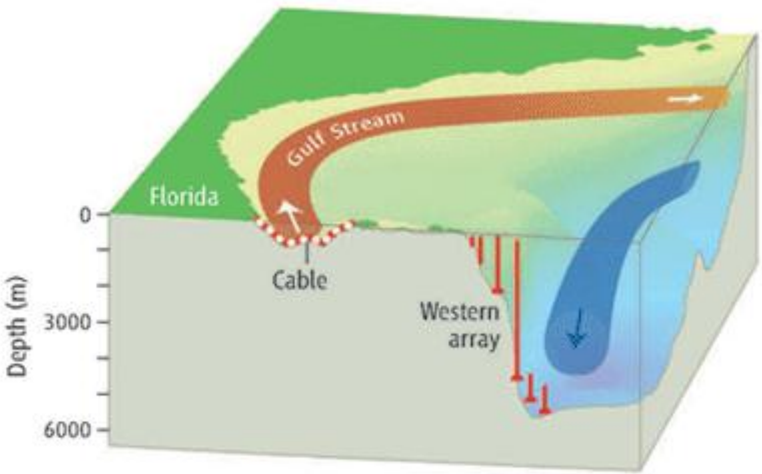
• The waters that compose the lower limb of the meridional overturning circulation are carried continuously along deep western boundary currents.

•Temporal variability in overturning transport and properties is spatially coherent.

• The AMOC's transport and property variability primarily result from transport and property variability of deep North Atlantic water masses.

U.K. and U.S. RAPID/Mocha Monitoring Array

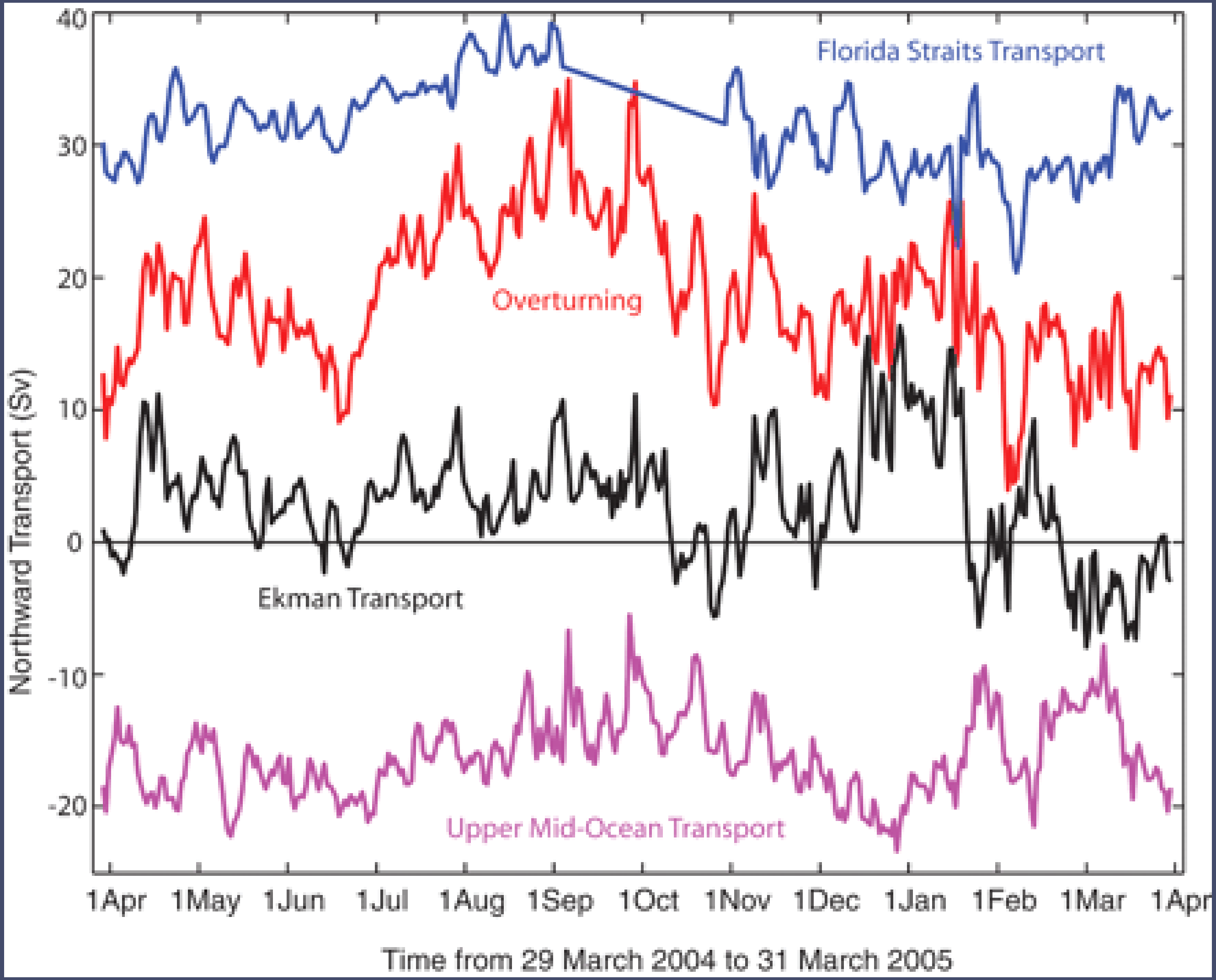




Church (2007), Credit: Louise Bell and Neil White /CSIRO

Since 2004 this program has continuously monitored the strength of the meridional overturning circulation and ocean heat transport at 26°N in the North Atlantic.

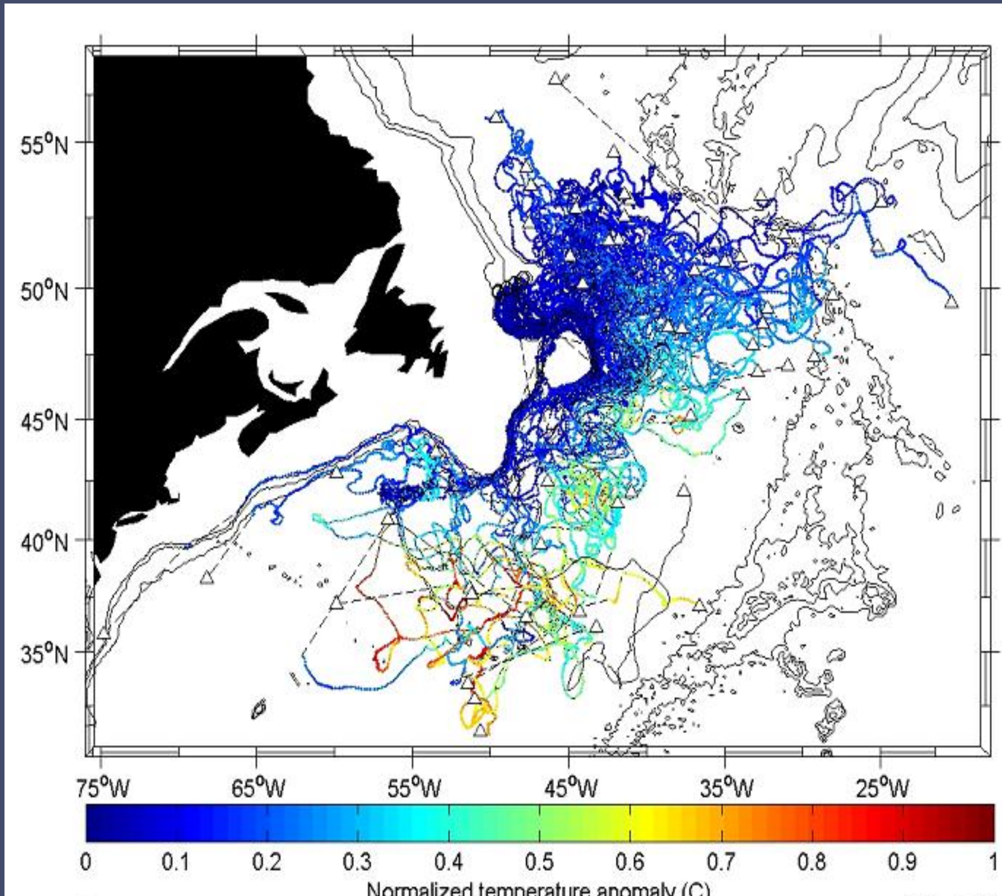
Temporal Variability of the Atlantic Meridional Overturning Circulation at 26°N

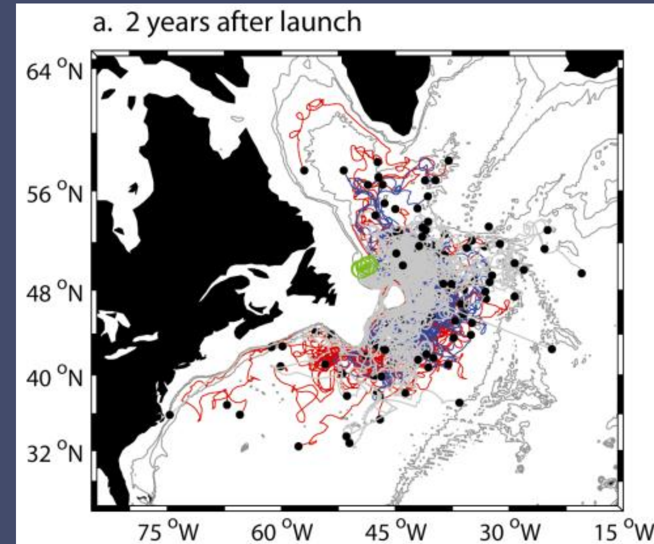


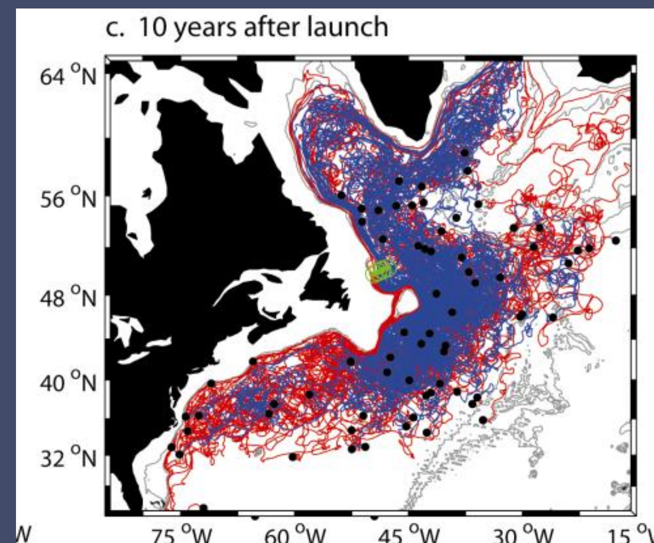
Cunningham et al. 2007

Maximum northward transport of upper-layer waters on each day

RAFOS and e-float study: subpolar to subtropical LSW pathways







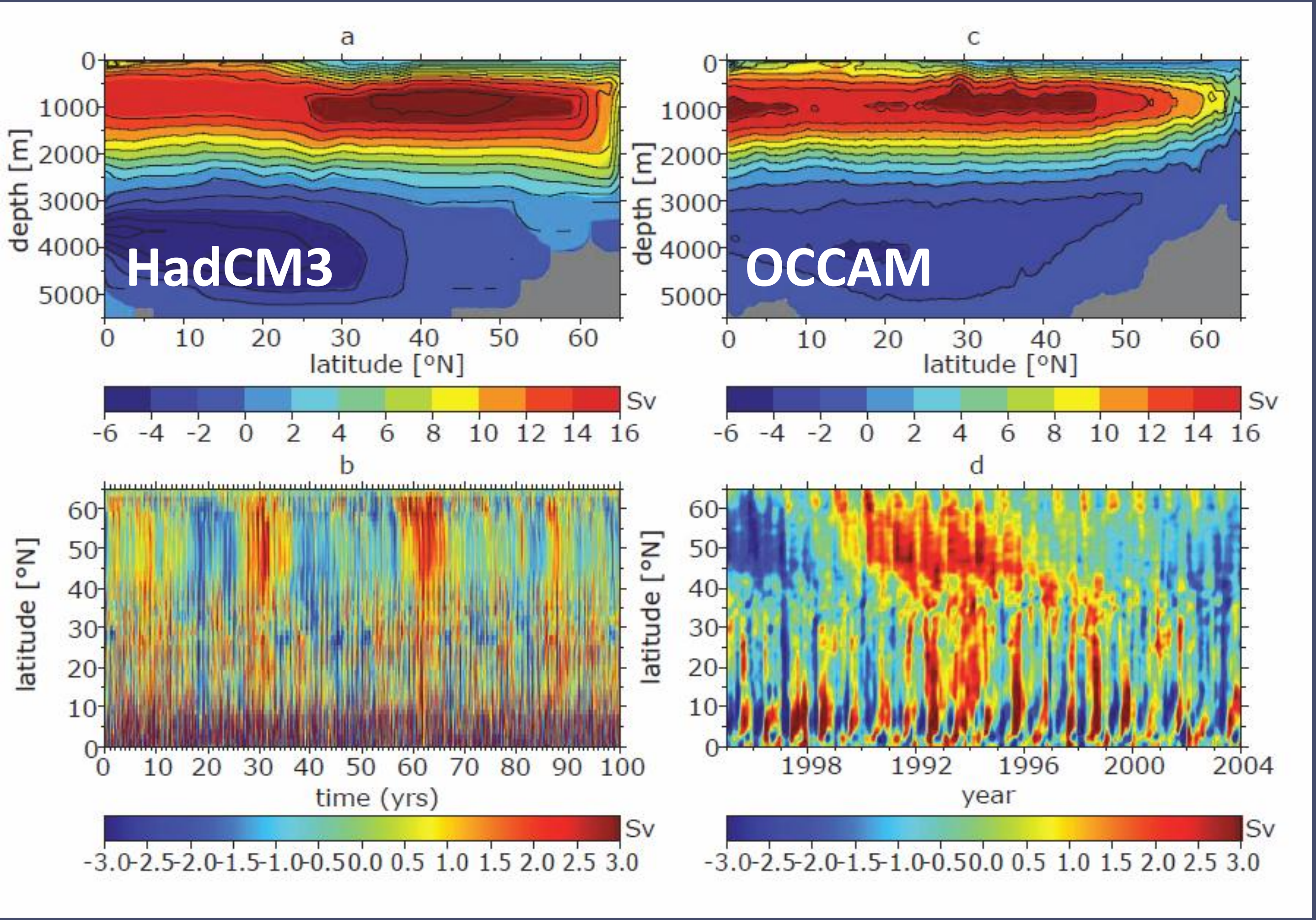
RAFOS float trajectories at 700 and 1500 m deployed in LSW in the subpolar DWBC from 2003-2006. Trajectory lengths are 2 years.

Bower et al. 2009

Assumption 2

Gray: RAFOS floats at 700 & 1500m
Red: e-floats at700m
Blue: e-floats at 1500m

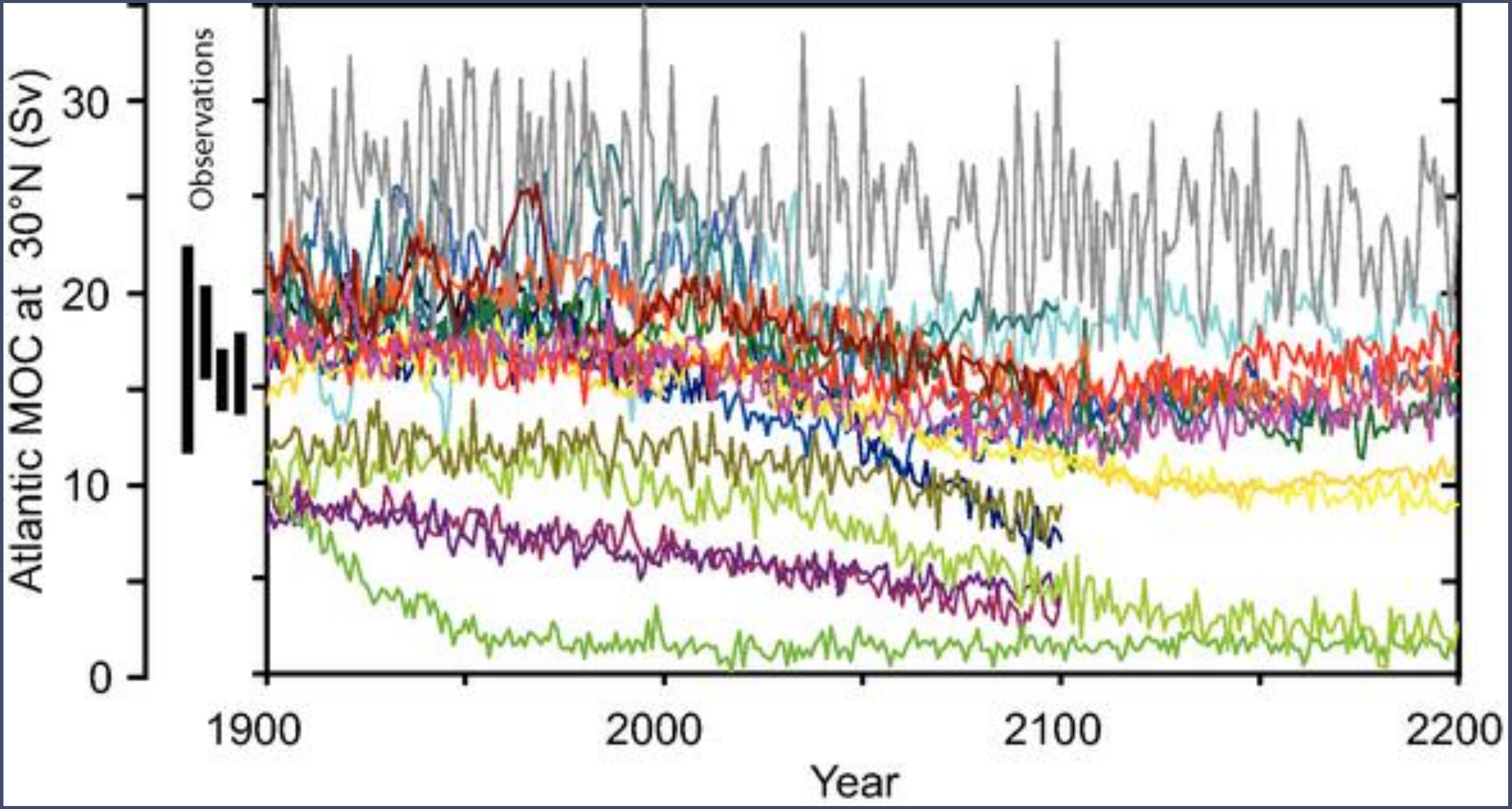
Meridional coherence of MOC anomalies



Bingham et al. 2007

Assumption 3

AMOC evolution from suite of coupled climate models

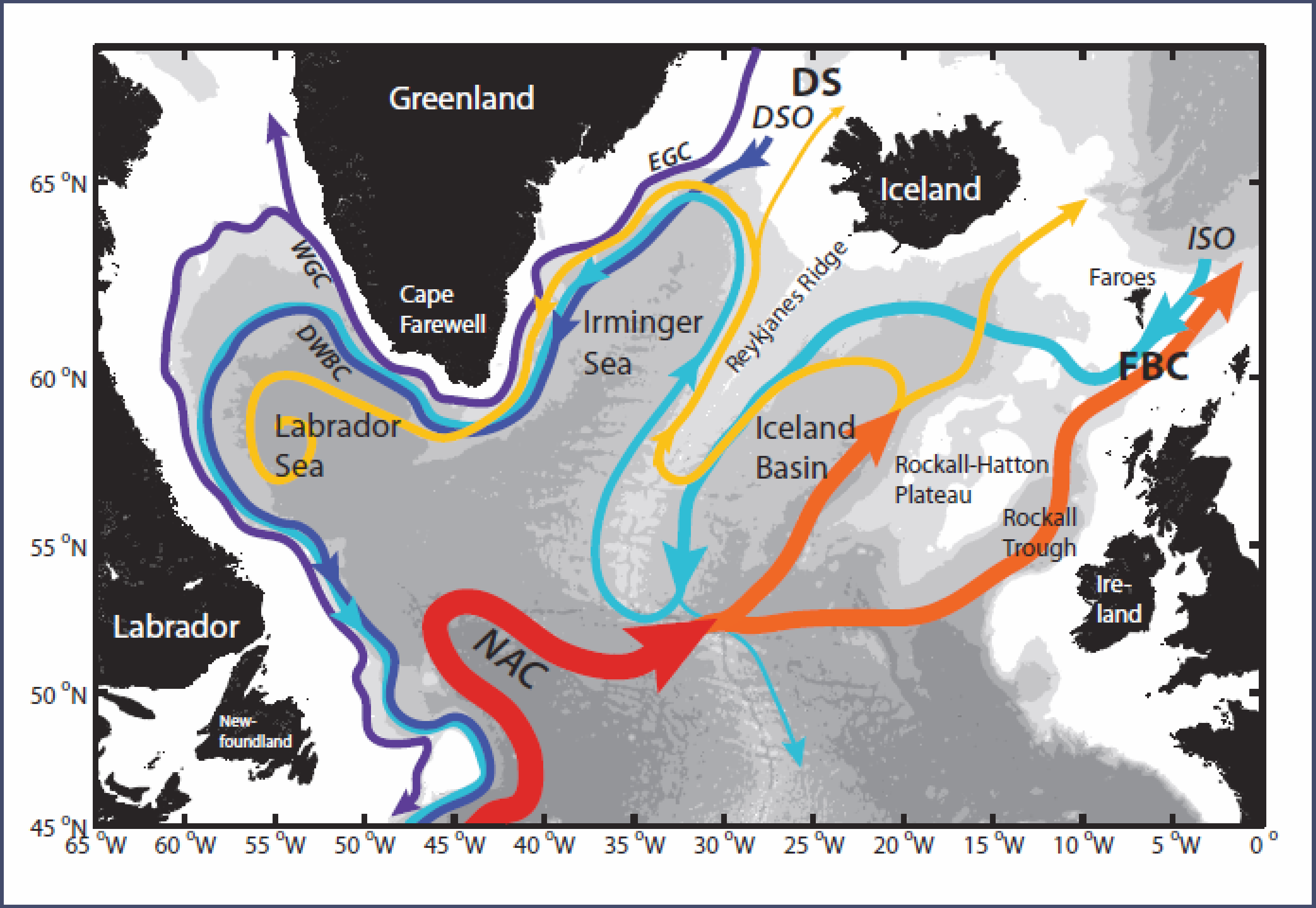


IPCC 4th Assessment Report **Forcing: 20C3M & SRES A1B**

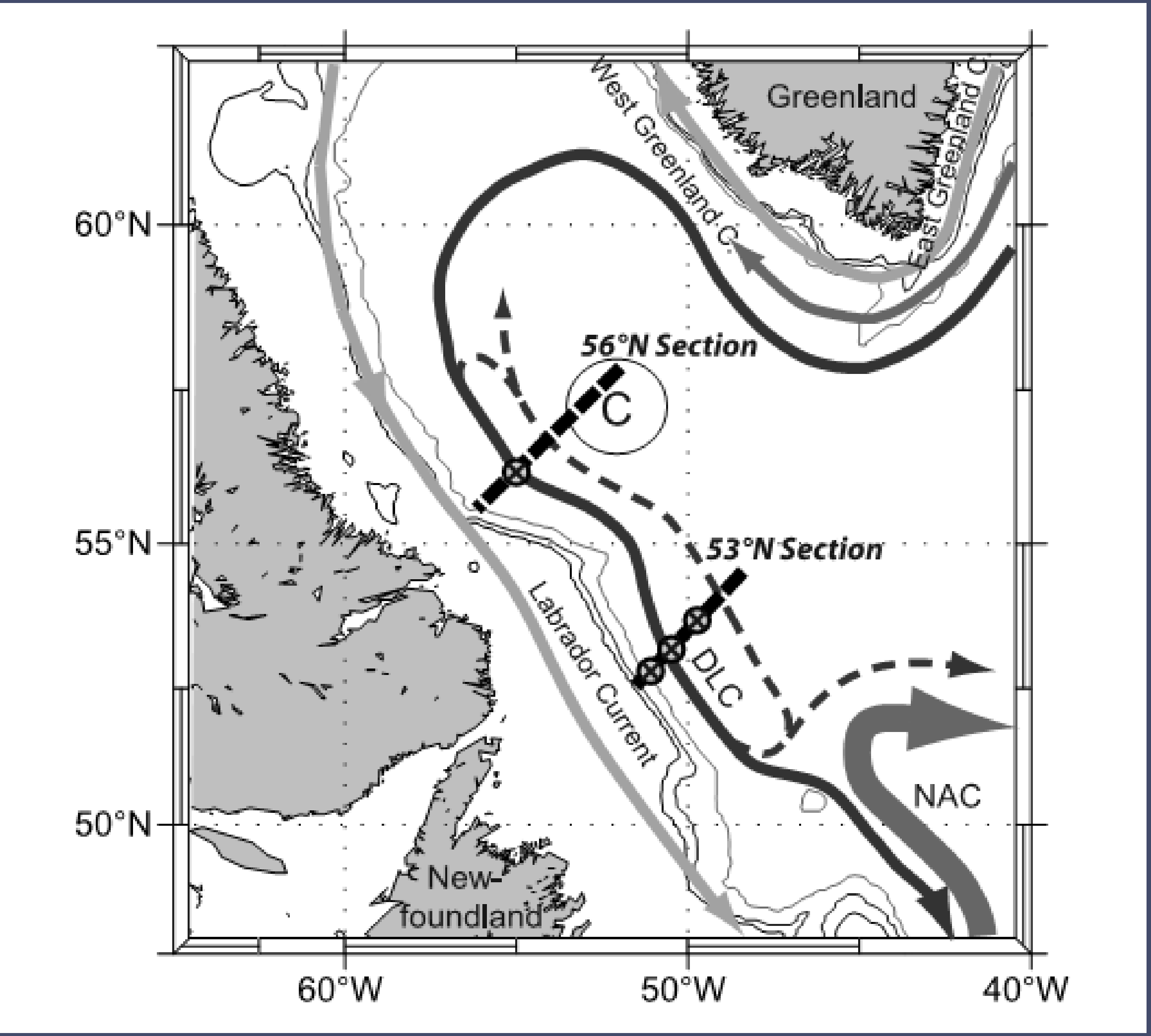
Assumption 4

Are changes in convective activity in the Labrador and Nordic Seas manifest in a temporally variable meridional overturning?

What is the *observational* basis for this linkage?



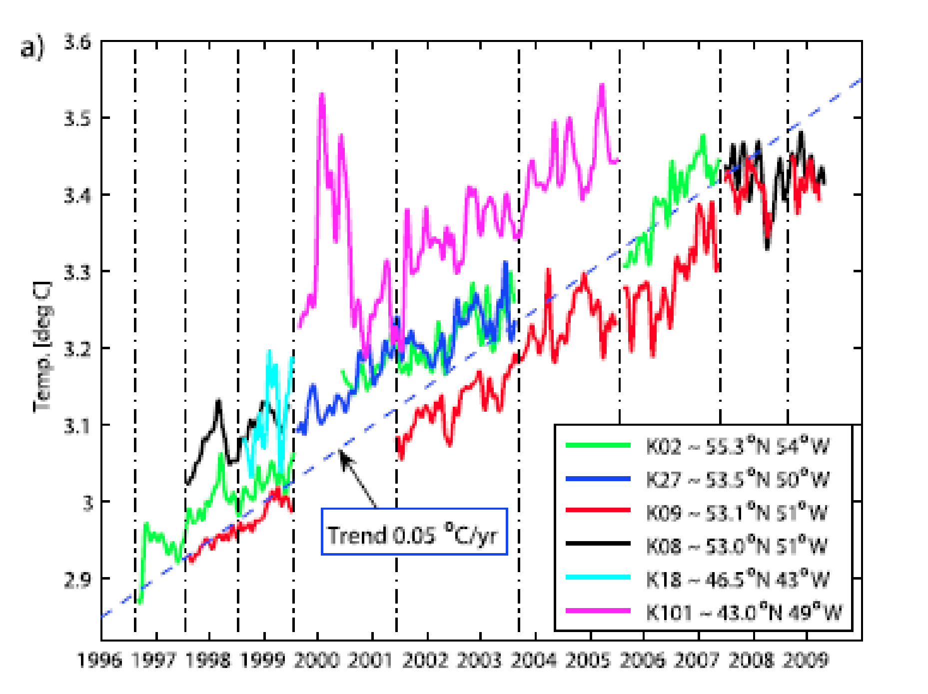
Deep Western Boundary Current (DWBC) observations from 1997 to 2009

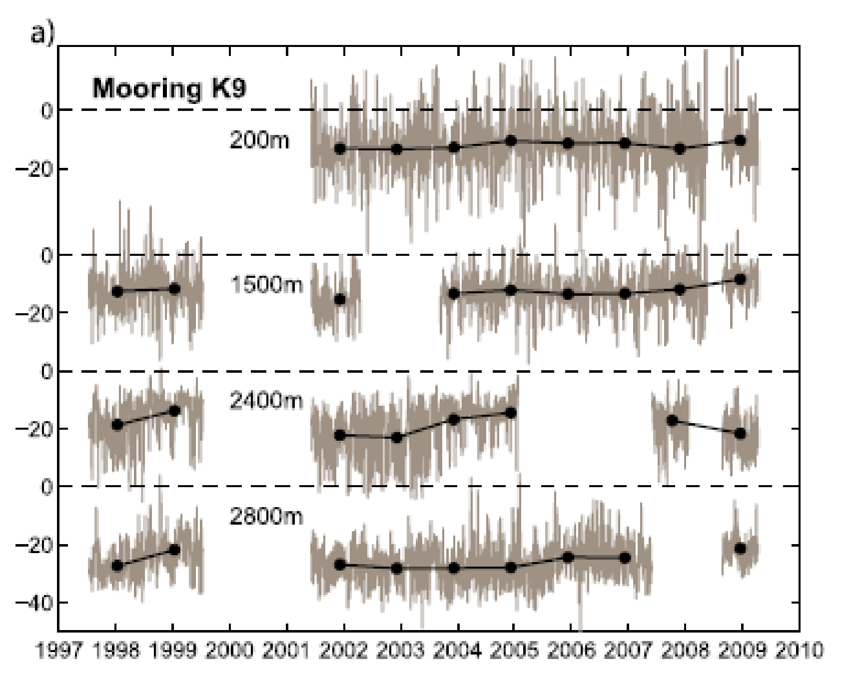


Crossed circles: mooring positions; black lines, repeated sections

Dengler et al. 2006

LSW convective activity compared to DWBC transport

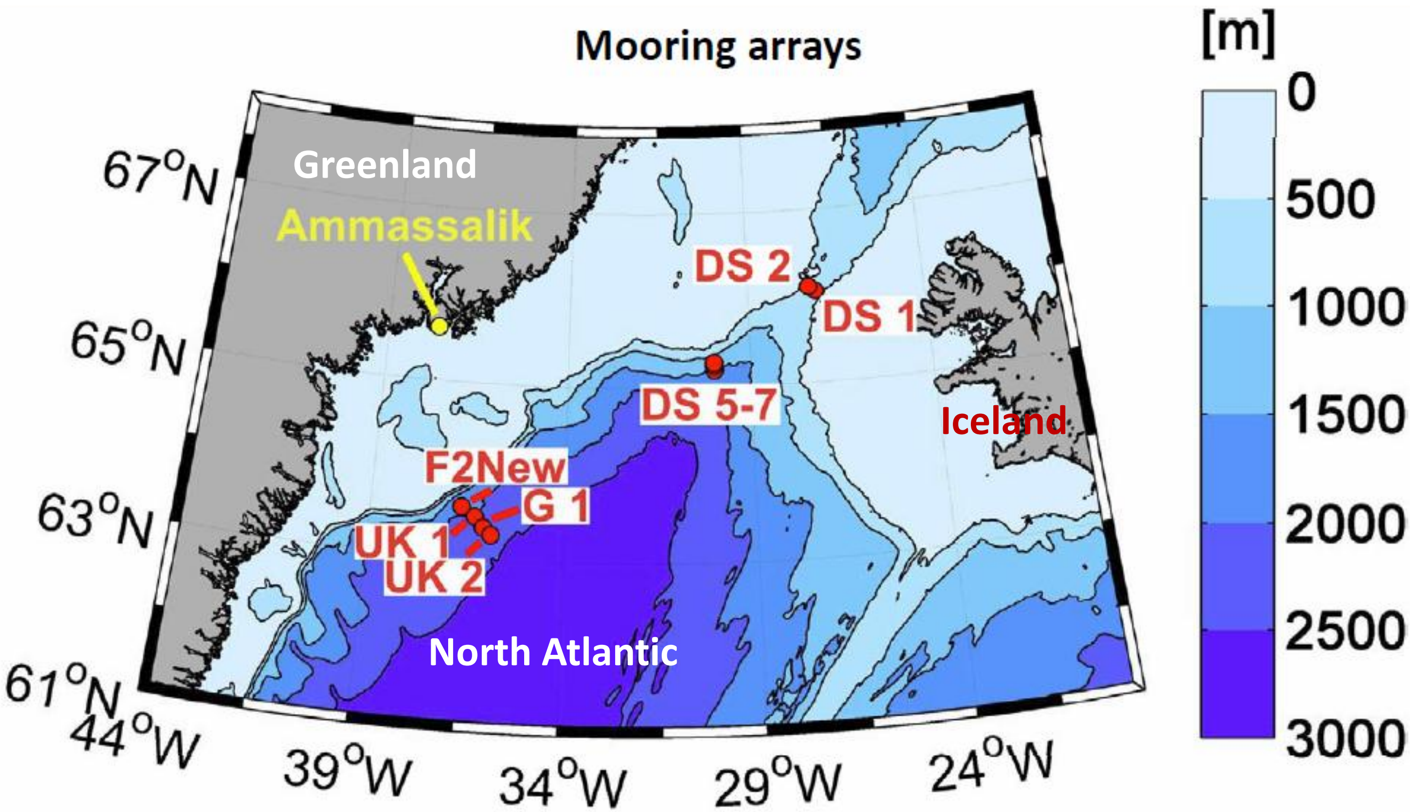




Fischer et al. 2010

Reduction of overturning in the Labrador Sea, indicated by warming temperatures, is not accompanied by a weakening DWBC.

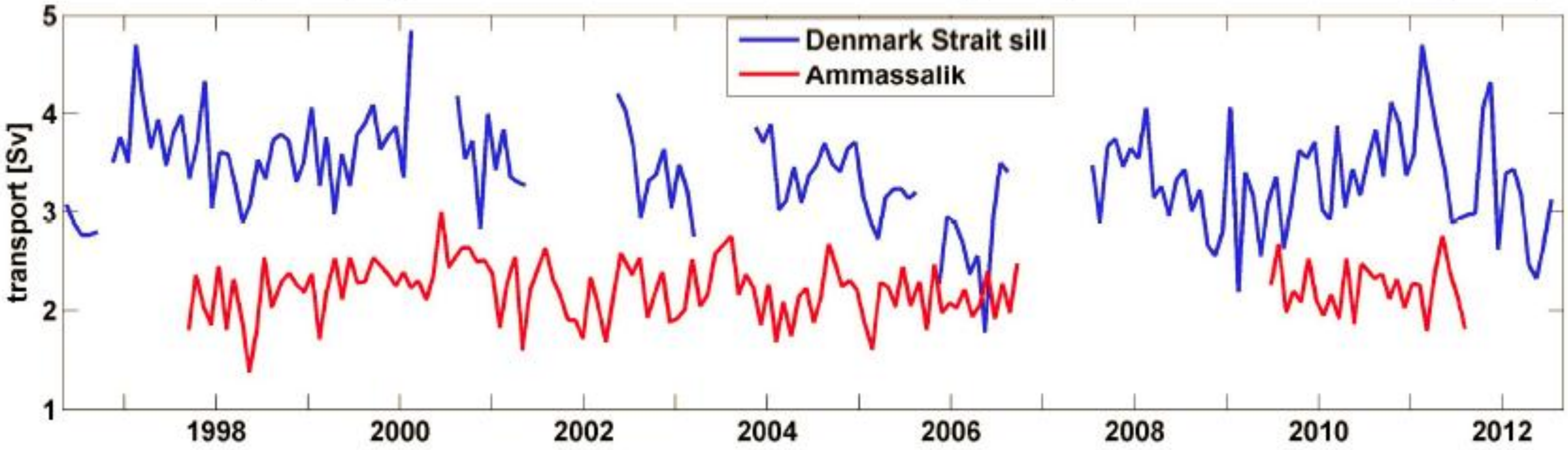
Measures of convective activity for overflow water, 1998-date



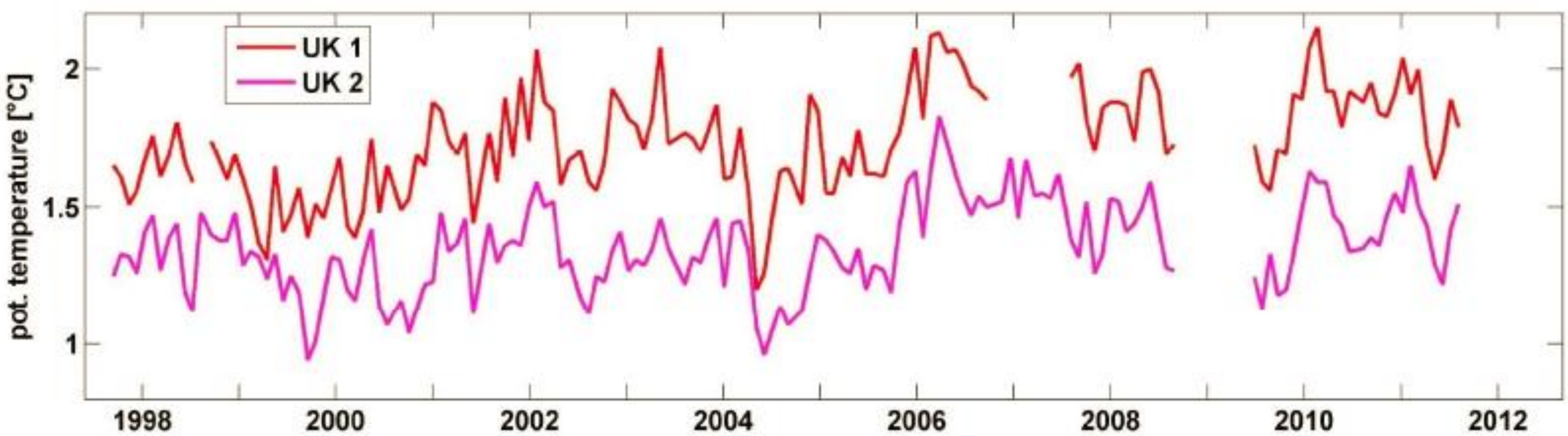
Denmark Strait sill (NORTH) – DSOW entrainment region (CENTRAL) – DSOW at Ammassalik (SOUTH)

Transport and temperature at and downstream of the sill

Jochumsen et al. 2012; Dickson et al. 2007



No trends in transports; warming from 1998-2006, then stable



Where are we?

• A linkage between convective activity and AMOC transport variability in observations has been elusive.

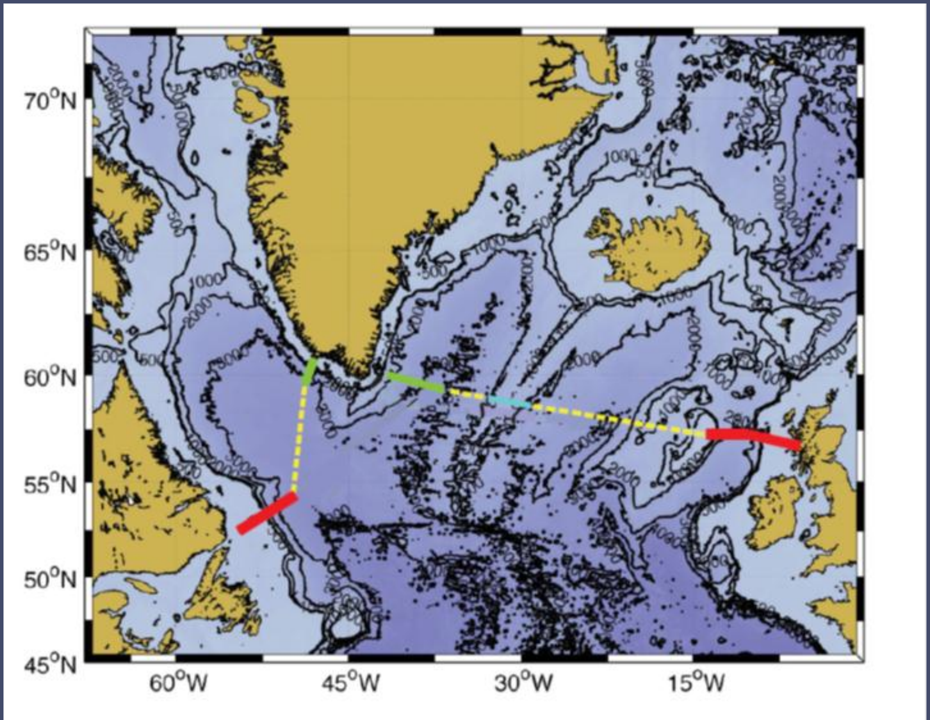
• Yet warming and freshwater at high latitudes are projected to continue apace, both in the direction of stabilizing the surface waters.

• Sustained, purposeful trans-basin measurement system in the subpolar North Atlantic can investigate the nature of this linkage.

• Measurement system in the subpolar North Atlantic has been a US AMOC Program priority since its inception.

OSNAP: Overturning in the Subpolar North Atlantic Program

A US-led program with UK, Germany, Netherlands, France and Canada



U.S. : Susan Lozier (Duke); Bill Johns (U. Miami); Amy Bower, Bob Pickart and Fiamma Straneo (WHOI)

UK: Sheldon Bacon, Penny Holliday and Chris Wilson (NOC); Stuart Cunningham and Mark Inall (SAMS); David Marshall and Helen Johnson (Oxford) and Ric Williams (Liverpool)

Netherlands: Laura de Steur (NIOZ)

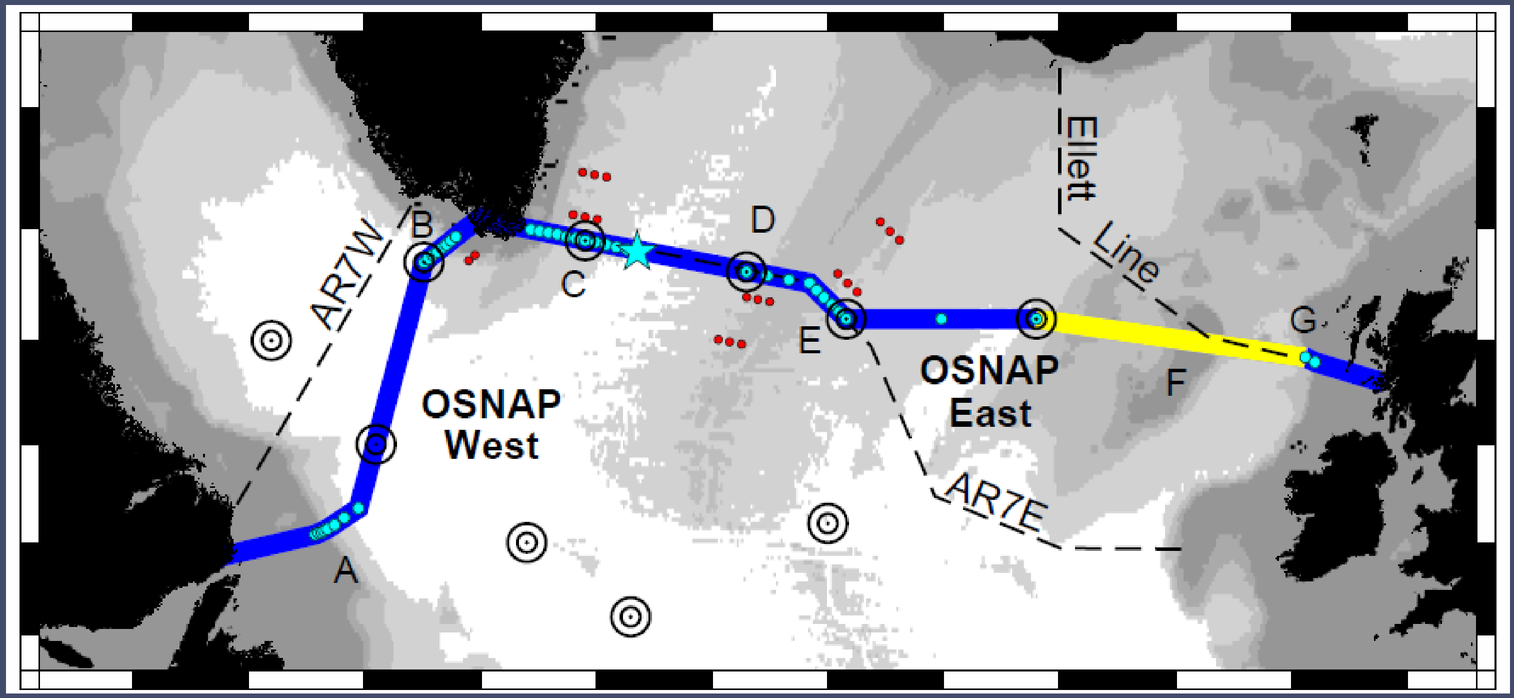
Germany: Jürgen Fischer and Johannes Karstensen (GEOMAR)

Canada: Blair Greenan (BIO); Brad de Young (Memorial U.)

France: Herlé Mercier, Virginie Thierry and the OVIDE group (IFREMER)

Overall design: A transoceanic line in the subpolar North Atlantic that can capture the net transport of the overflow waters from the Nordic Seas, as well as that from the Labrador Sea. Designed to complement the RAPID array and EU NACLIM observations, thereby providing measurements to evaluate intergyre connectivity within the North Atlantic.

OSNAP overall goal: To quantify the large-scale, low-frequency, full water-column net fluxes of mass, heat and fresh water associated with the meridional overturning circulation in the subpolar North Atlantic.



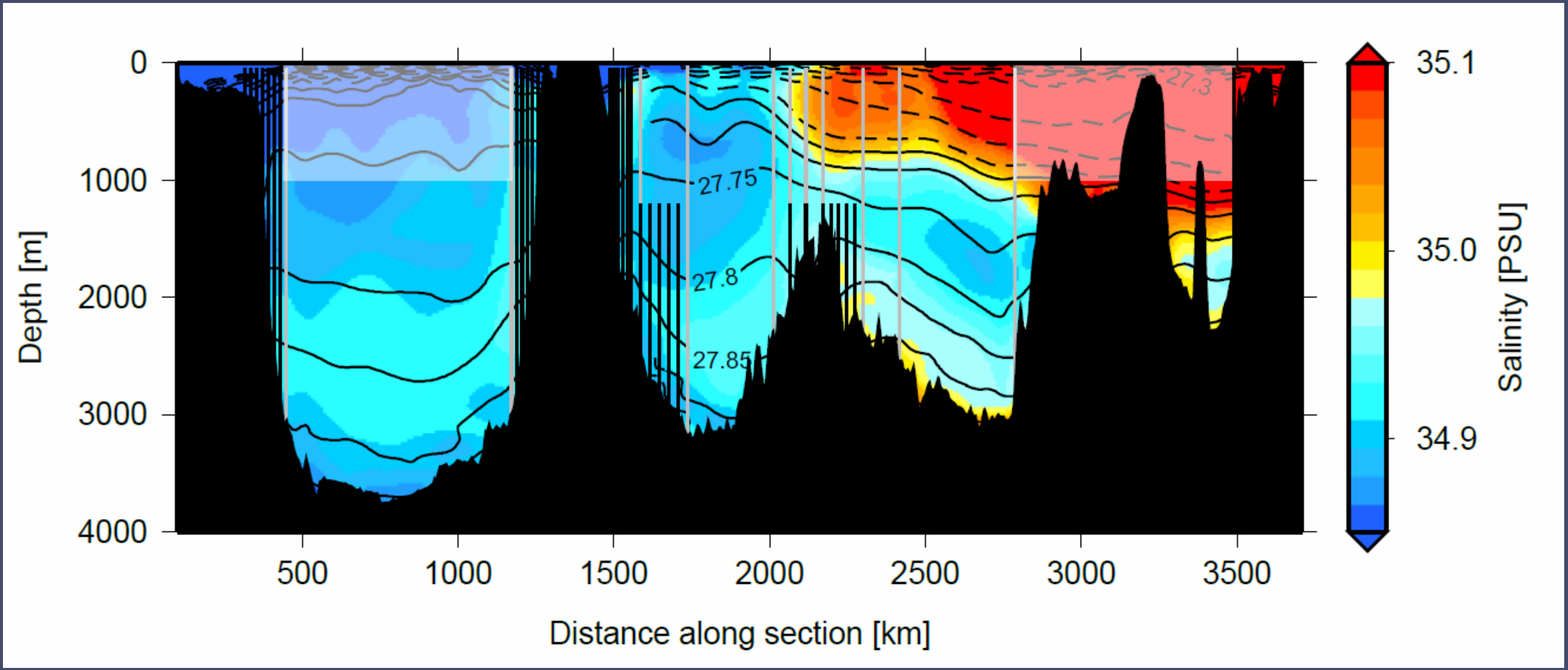
(A) German 53°N western boundary array and Canadian shelfbreak array;
(B) US West Greenland boundary array;
(C) US/UK East Greenland boundary array;
(D) Netherlands western Mid-Atlantic Ridge array;
(E) US eastern Mid-Atlantic Ridge array;
(F) UK glider survey over the Hatton-Rockall Bank and Rockall Trough;
(G) UK Rockall Trough current array.

Red dots: US float launch sites.

Blue star: US OOI Irminger Sea global node.

Black concentric circles: US sound sources.

OSNAP array superposed on climatological salinity along the OSNAP West (leftmost basin) and East lines.



Mooring locations (vertical lines) and glider domains (shaded boxes) are indicated. To reconstruct the velocity field, we plan to directly measure the currents at the boundaries and the flanks of the Reykjanes Ridge and then use T/S sensors and gliders to estimate the interior geostrophic velocities. Black moorings indicate where the velocity field is directly sampled. Gray moorings double as direct velocity measures and endpoints for the geostrophic regions.

The specific OSNAP objectives are to:

1. Relate AMOC variability to deep water mass variability and basin-scale wind forcing.
2. Determine the pathways of overflow waters in the NASPG to investigate the connectivity of the deep boundary current system.
3. Determine the nature and degree of the overflow-subpolar-subtropical AMOC connectivity.
4. Determine from new OSNAP measurements the configuration of an optimally efficient long-term AMOC monitoring system in the NASPG.

Summary

• Synoptic measures of the overturning cannot provide annual measure.

• Boundary currents are not the sole conduit for the lower limb of the AMOC.

•AMOC intra- and inter-gyre meridional coherence is time-scale dependent.

• Despite abundant modeling evidence for a strong link between North Atlantic convective activity and AMOC variability, observational evidence for such a linkage has been elusive.

• Given the breadth of expected impacts from AMOC variability, the international community is launching a new observational program, OSNAP, in summer of 2014 to explicitly test for this linkage.

• Together, OSNAP, NACLIM and the RAPID 26°N observational systems will provide a means to evaluate intergyre connectivity and to establish a long-term comprehensive observing system in the North Atlantic.