Our current understanding of the AMOC and its variability: the modern ocean view

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Overturning Assumptions

1. The overturning varies on time scales of years to decades.

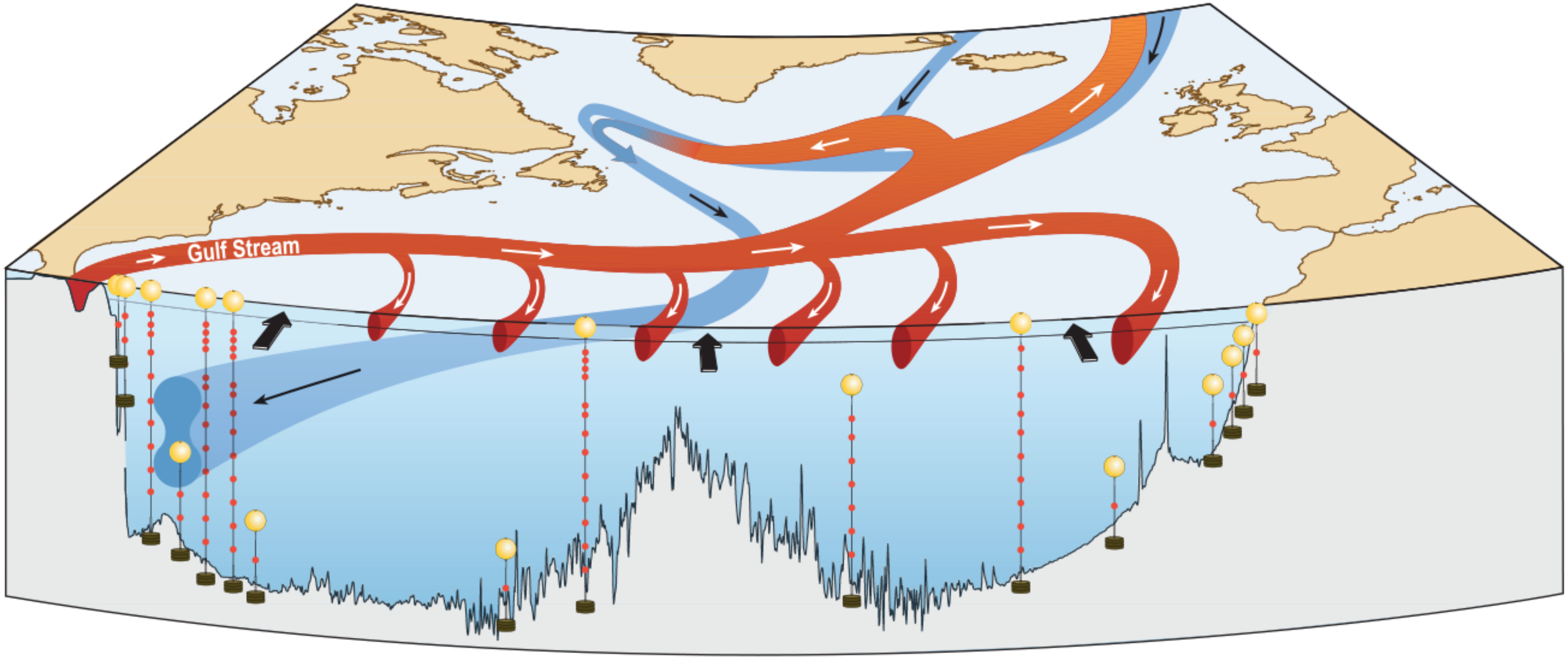
2. Waters in the lower limb of the overturning circulation are carried along deep western boundary currents.

3. Surface Gulf Stream waters constitute the upper limb of the overturning circulation.

4. Temporal variability in overturning transport is coherent from one latitude to the next.

5. Overturning variability primarily results from deep water mass formation variability.

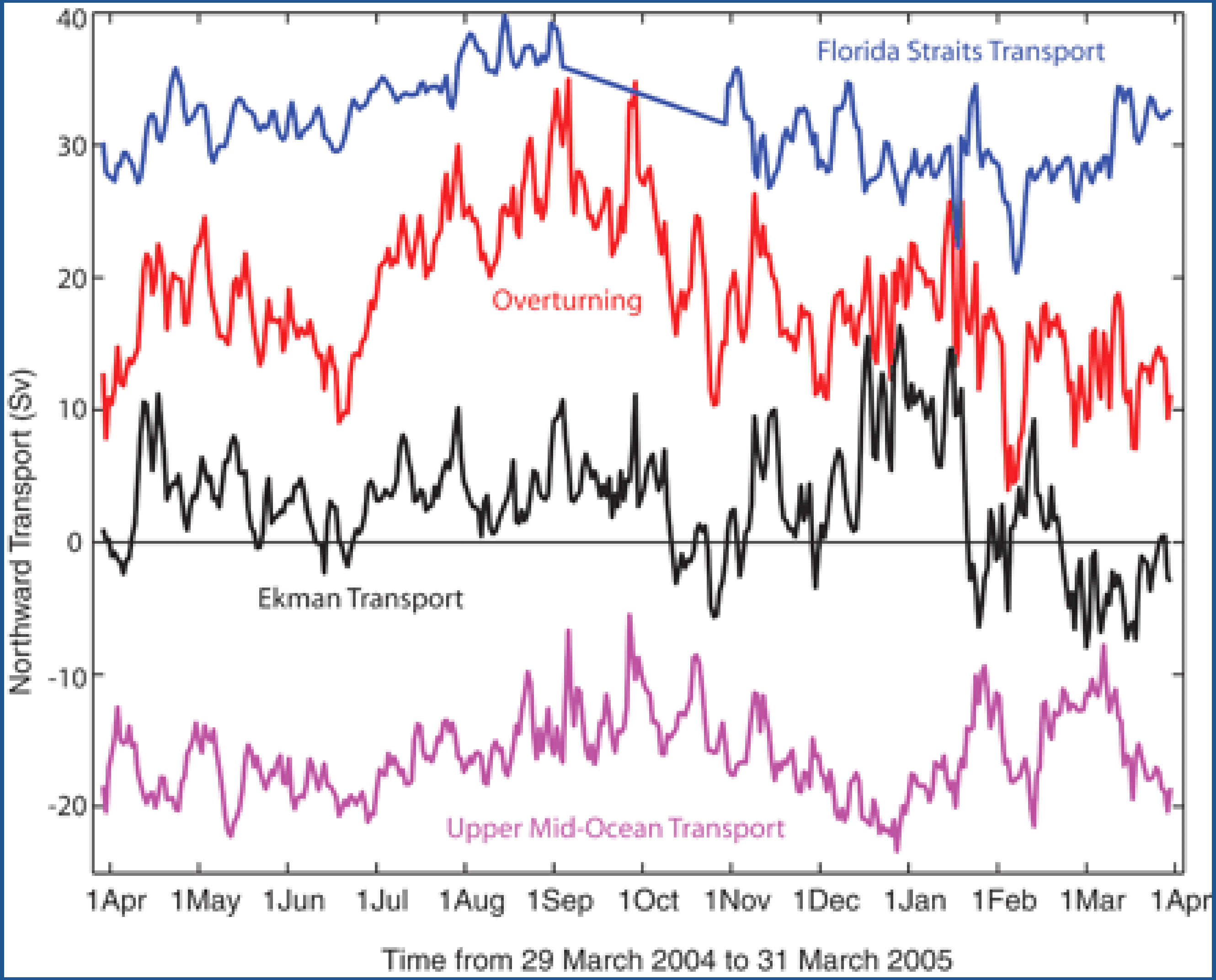
U.K. and U.S. AMOC Monitoring Array: RAPID



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.

Srokosz and Bryden 2015

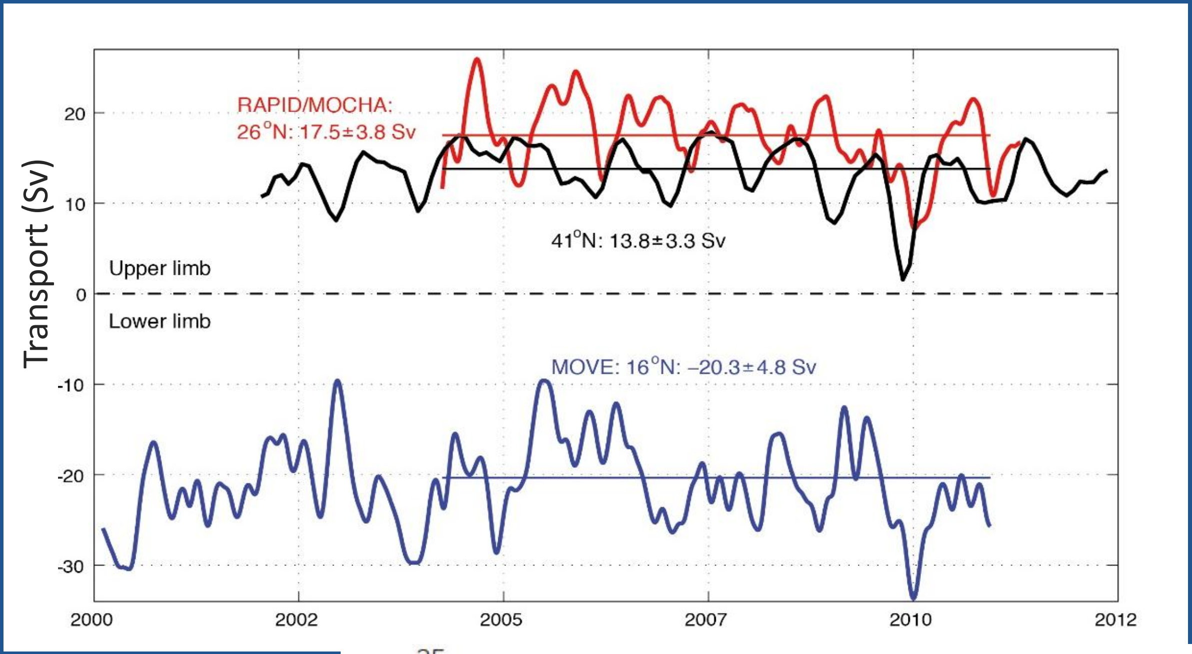
Temporal Variability of the Atlantic Meridional Overturning Circulation at 26°N



Cunningham et al. 2007

Maximum northward transport of upper-layer waters on each day

Recent AMOC assessment



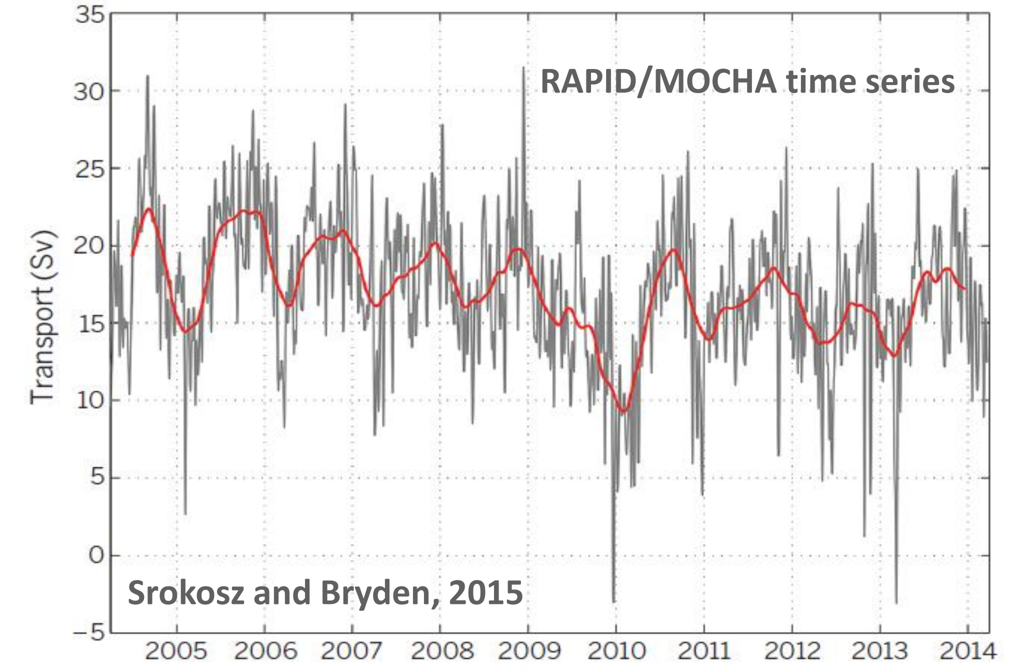
IPCC 5th Assessment Report:

There is no observational evidence of an AMOC trend, based on the decade-long record of the complete AMOC and longer records of individual AMOC components.

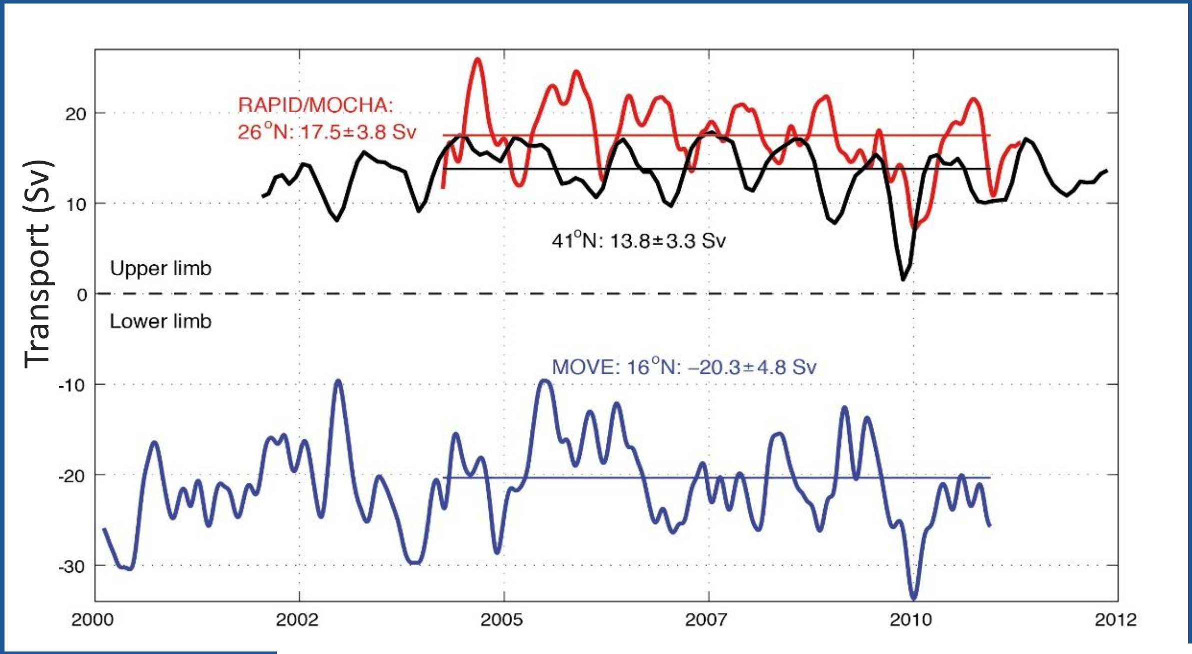
Srokosz & Bryden 2015:

The AMOC has been declining at a rate of ~ 0.5 Sv per year, 10 times as fast as predicted by climate models.

Unclear if related to global warming.



Recent AMOC assessment



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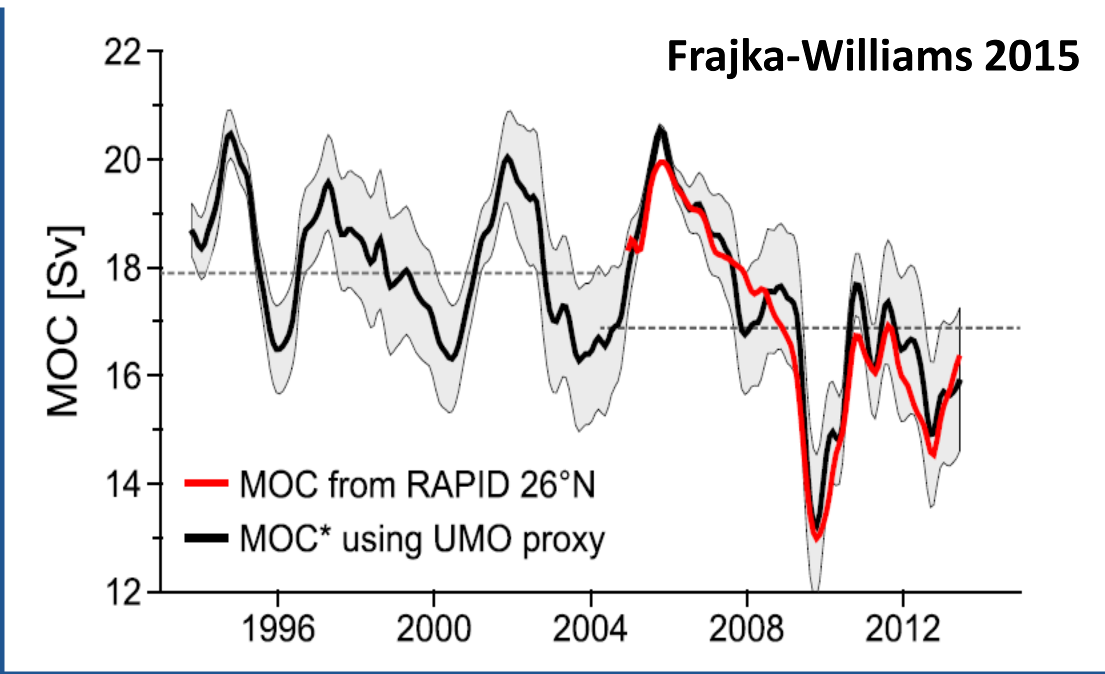
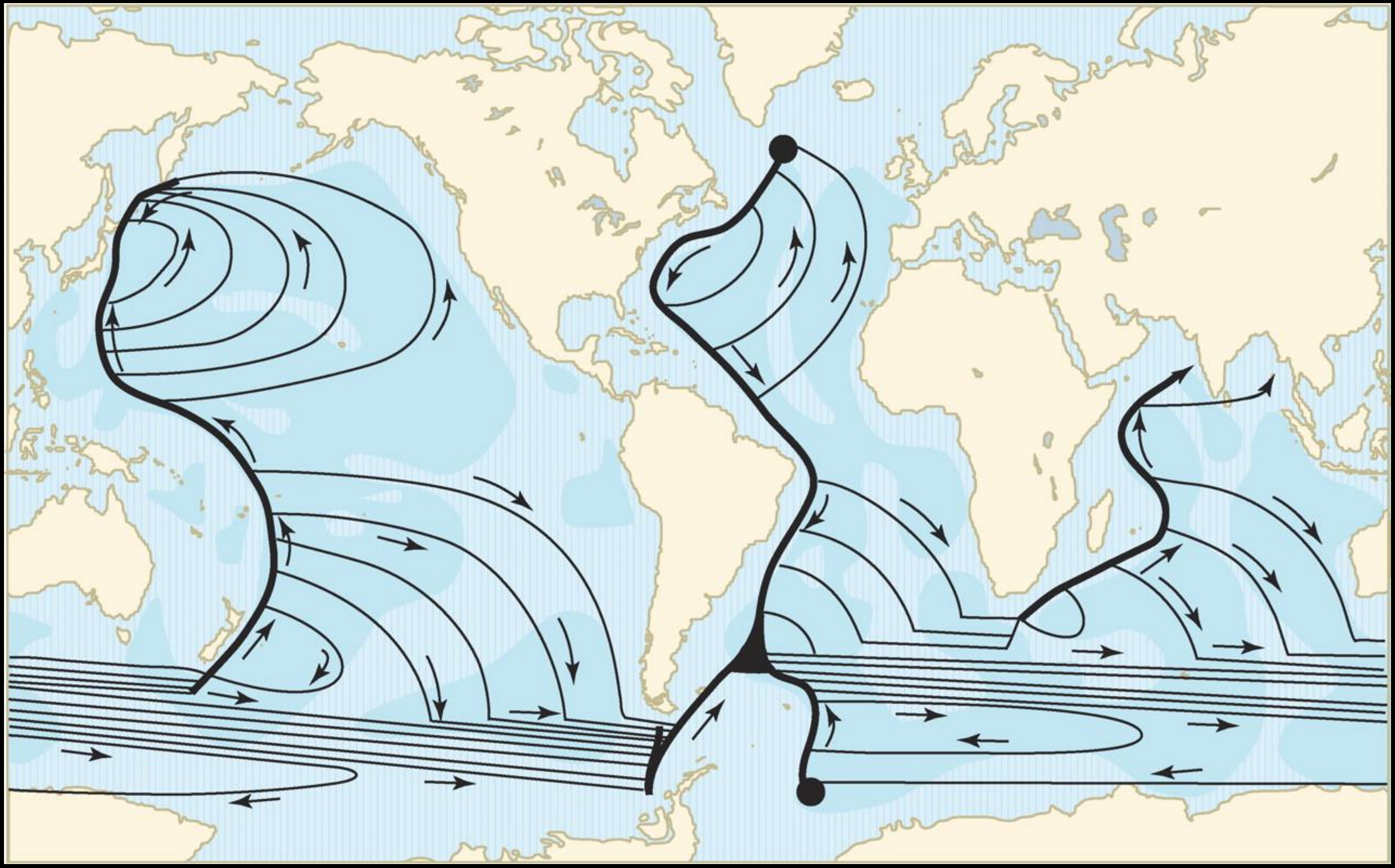


Average reduction of the MOC of −0.13 Sv/yr, yet not significant.

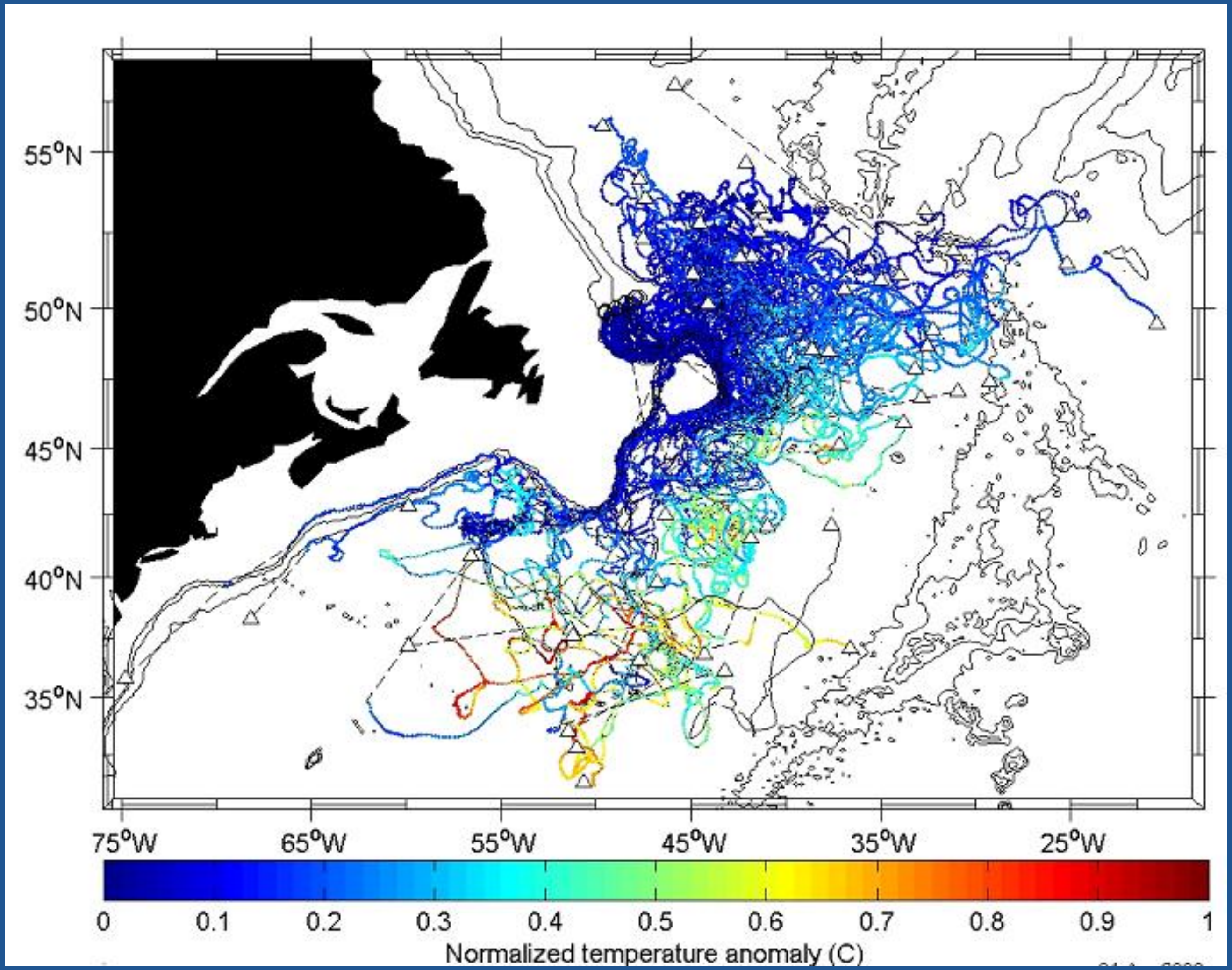
Deep Western Boundary Current as Conduit



Stommel 1958

Assumption 2: Lower limb pathways

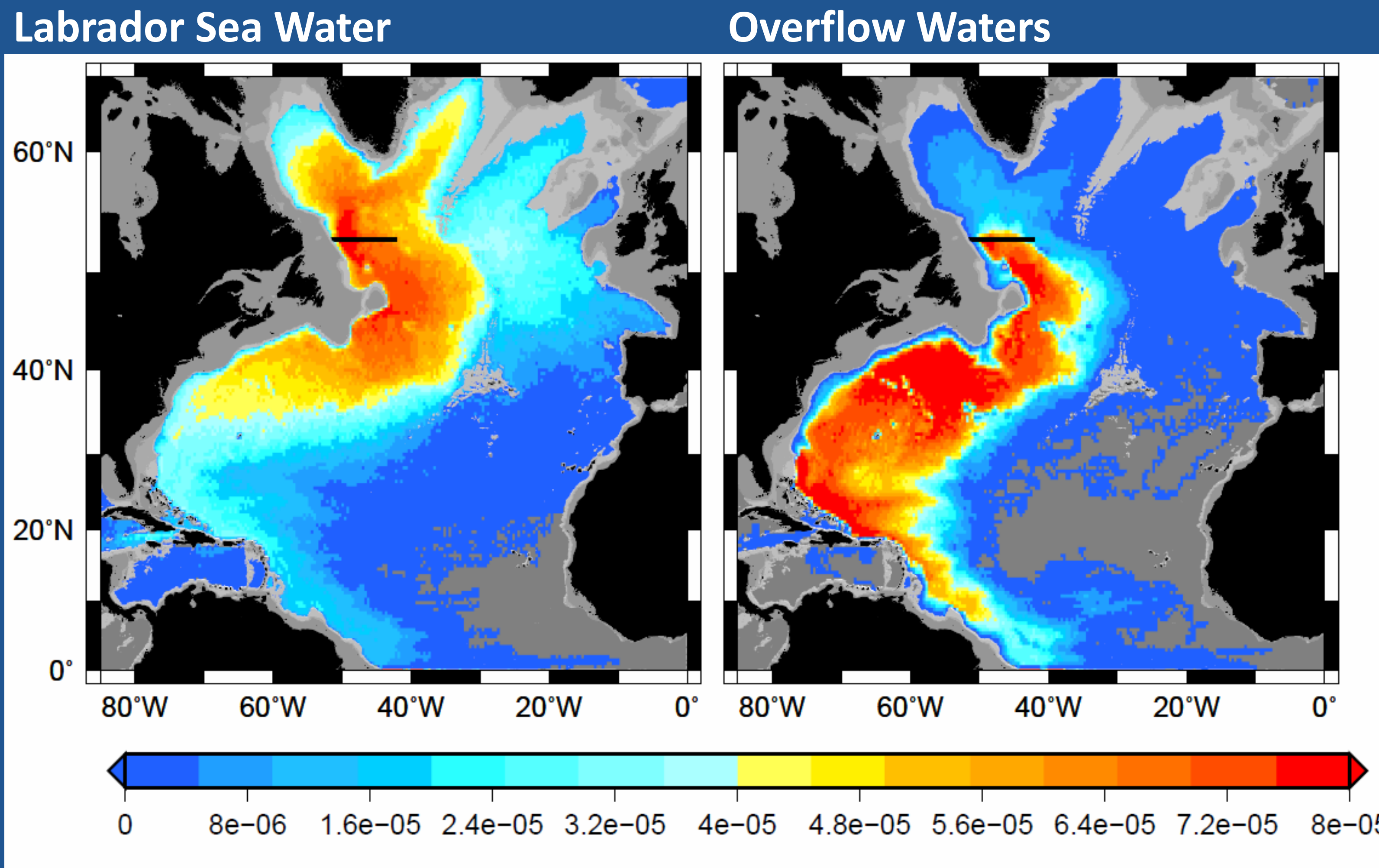
Lower Limb Subpolar to Subtropical Pathways



Trajectories of RAFOS floats deployed in the Lab Sea from 2003-2006 and tracked for 2 years.

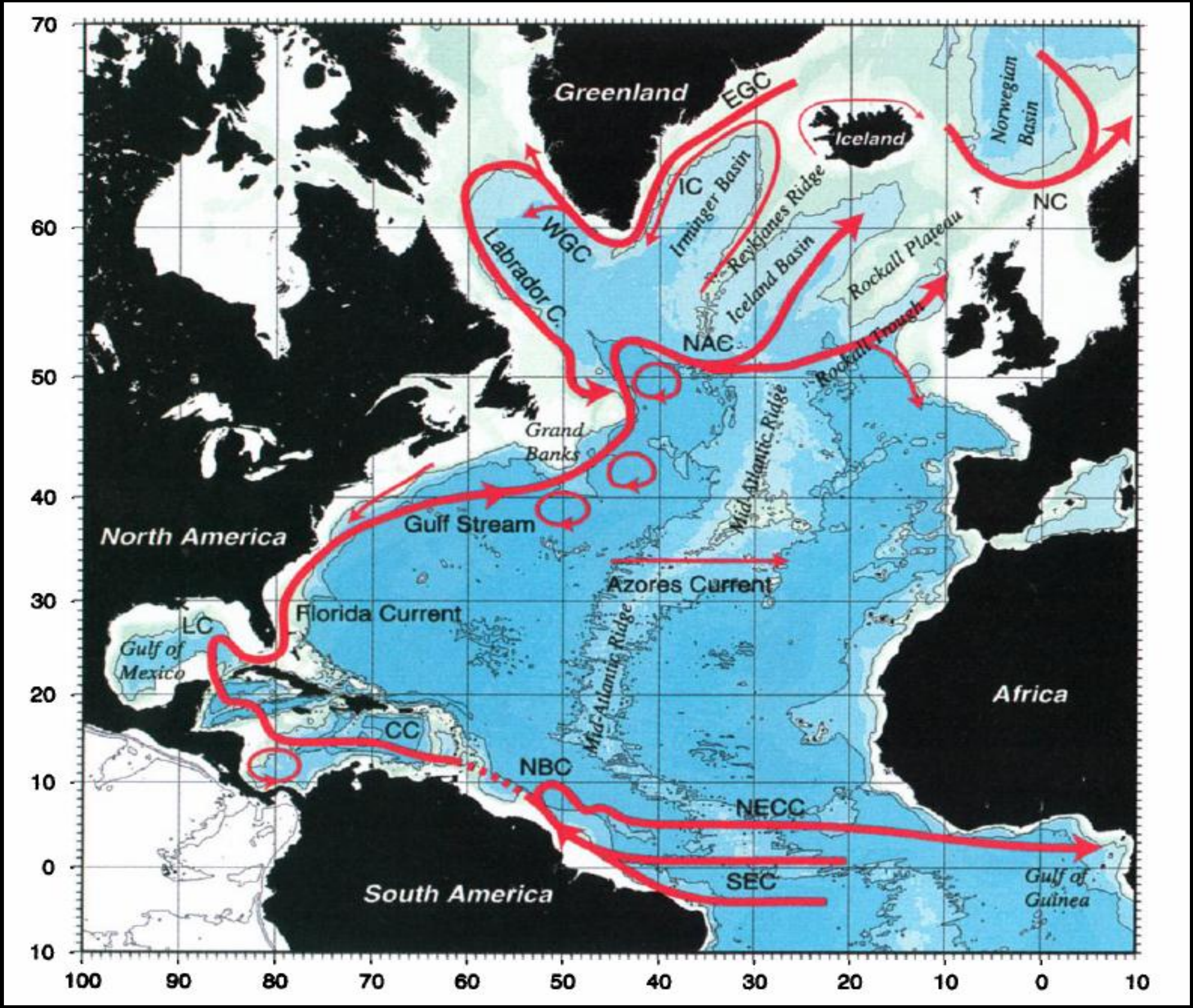
Bower et al. 2009

Equatorward spreading of deep waters



Probability map constructed from 50-yr simulated trajectories

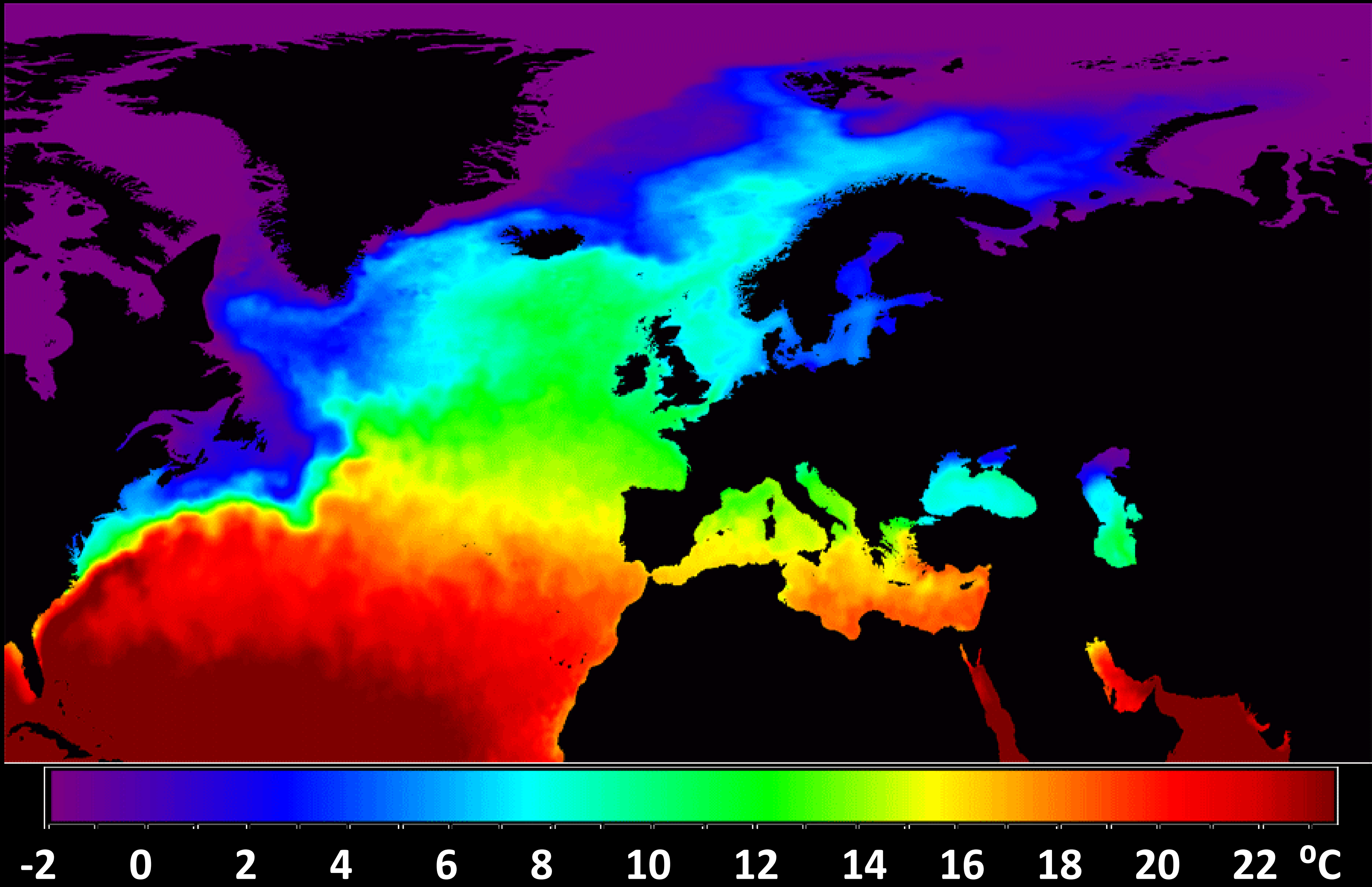
Lozier et al. 2013



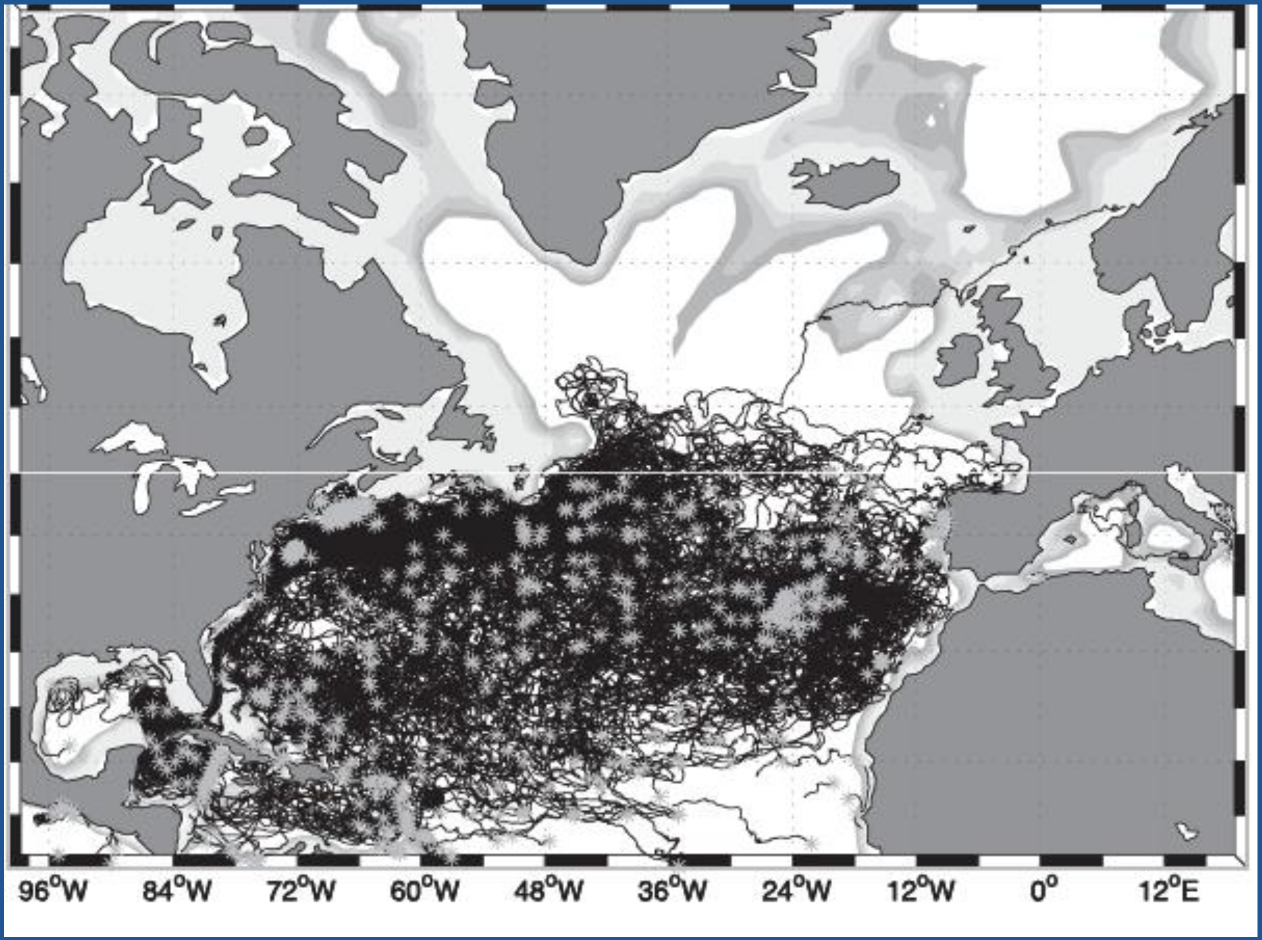
Assumption 3: Surface pathway

Fratantoni 2001

Sea Surface Temperature

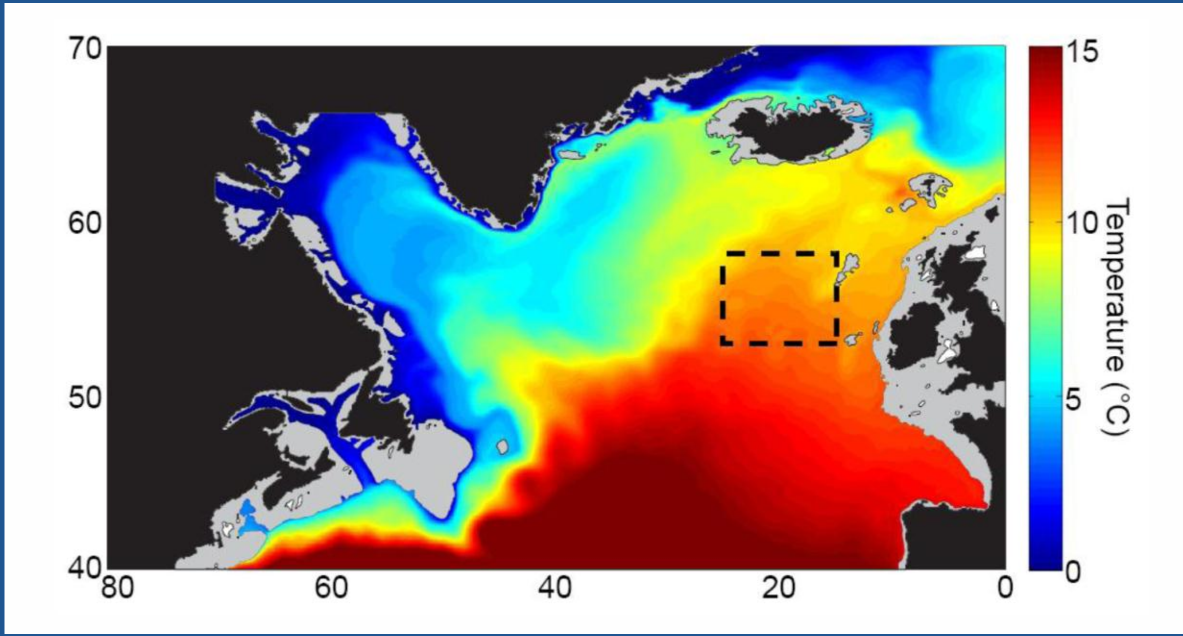


Surface Exchange Between the Subtropical and Subpolar Gyres: the Lagrangian View

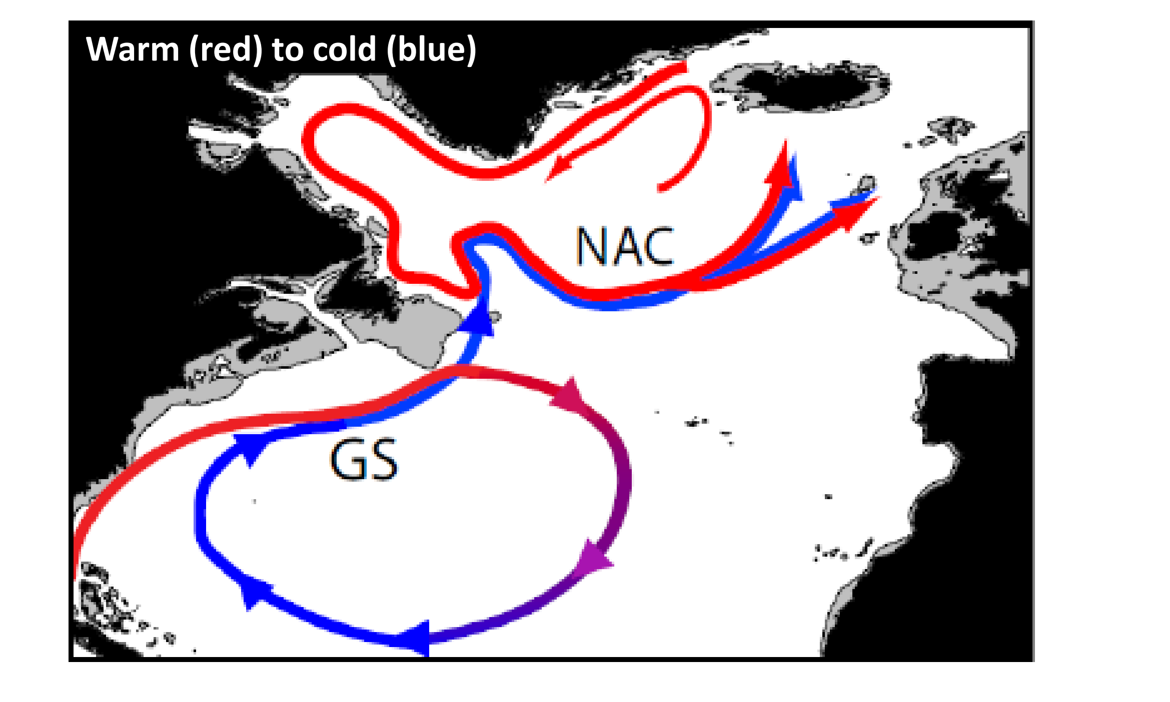


Trajectories of surface drifters deployed south of 45°N. Gray asterisks are deployment locations.

Brambilla and Talley 2006



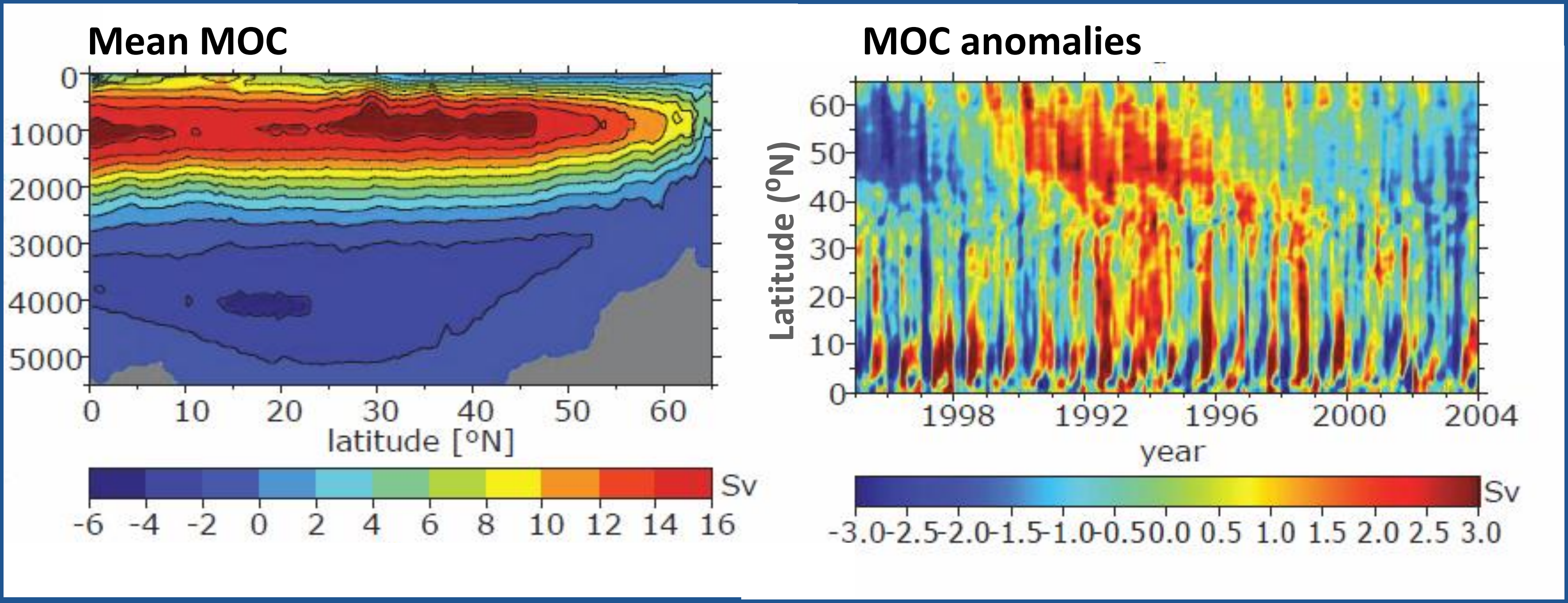
What is the source of these warm surface waters in the eastern subpolar gyre?



Revised AMOC surface throughput

Burkholder and Lozier 2014

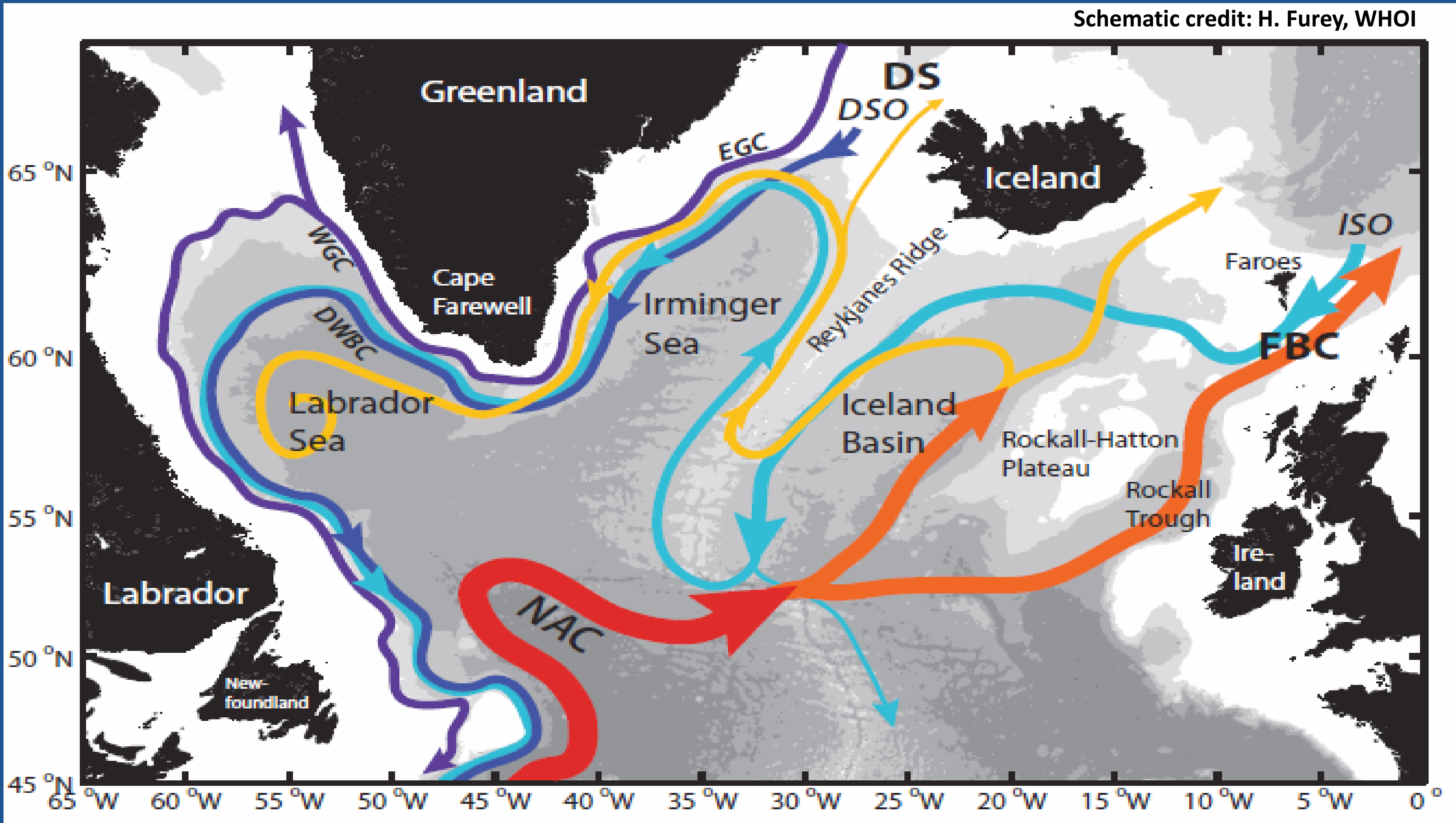
Meridional coherence of MOC anomalies



Bingham et al. 2007

Assumption 4: MOC spatial coherence

Lower Limb of the Overturning: Labrador Sea Water and Arctic Overflow Waters

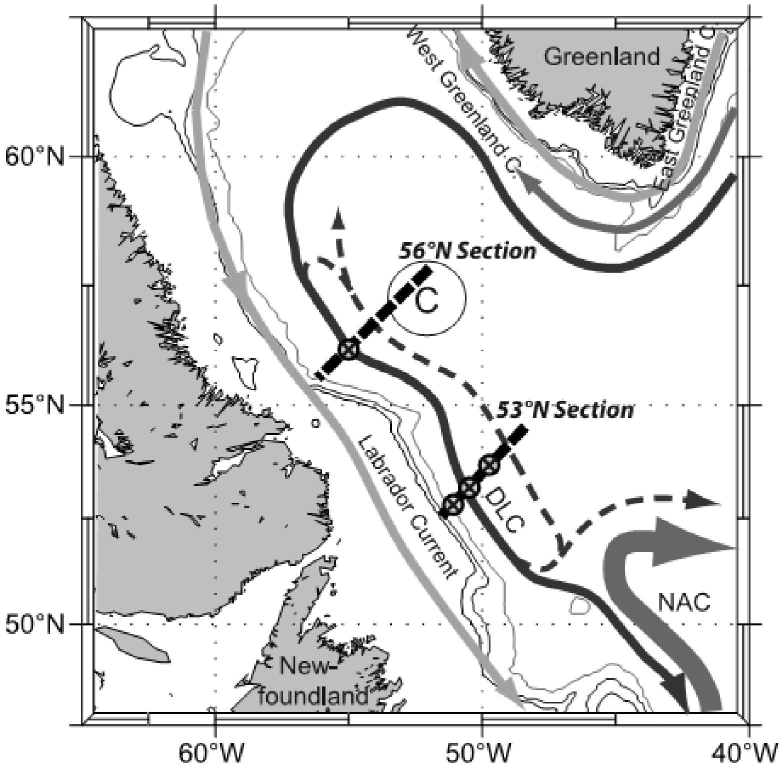


What is the *observational* basis for the linkage between convective activity in the Labrador and Nordic Seas and a temporally variable meridional overturning?

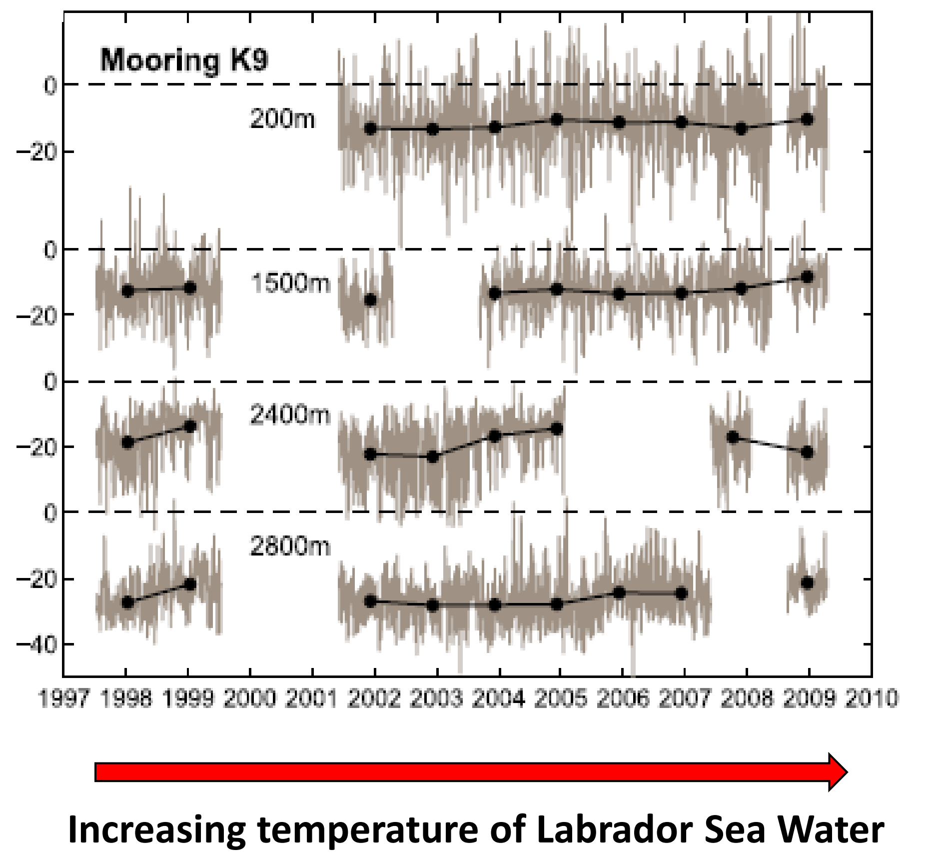
Assumption 5

Lab Sea Convective Activity Compared to DWBC Transport

Fischer et al. 2010



Dengler et al. 2006



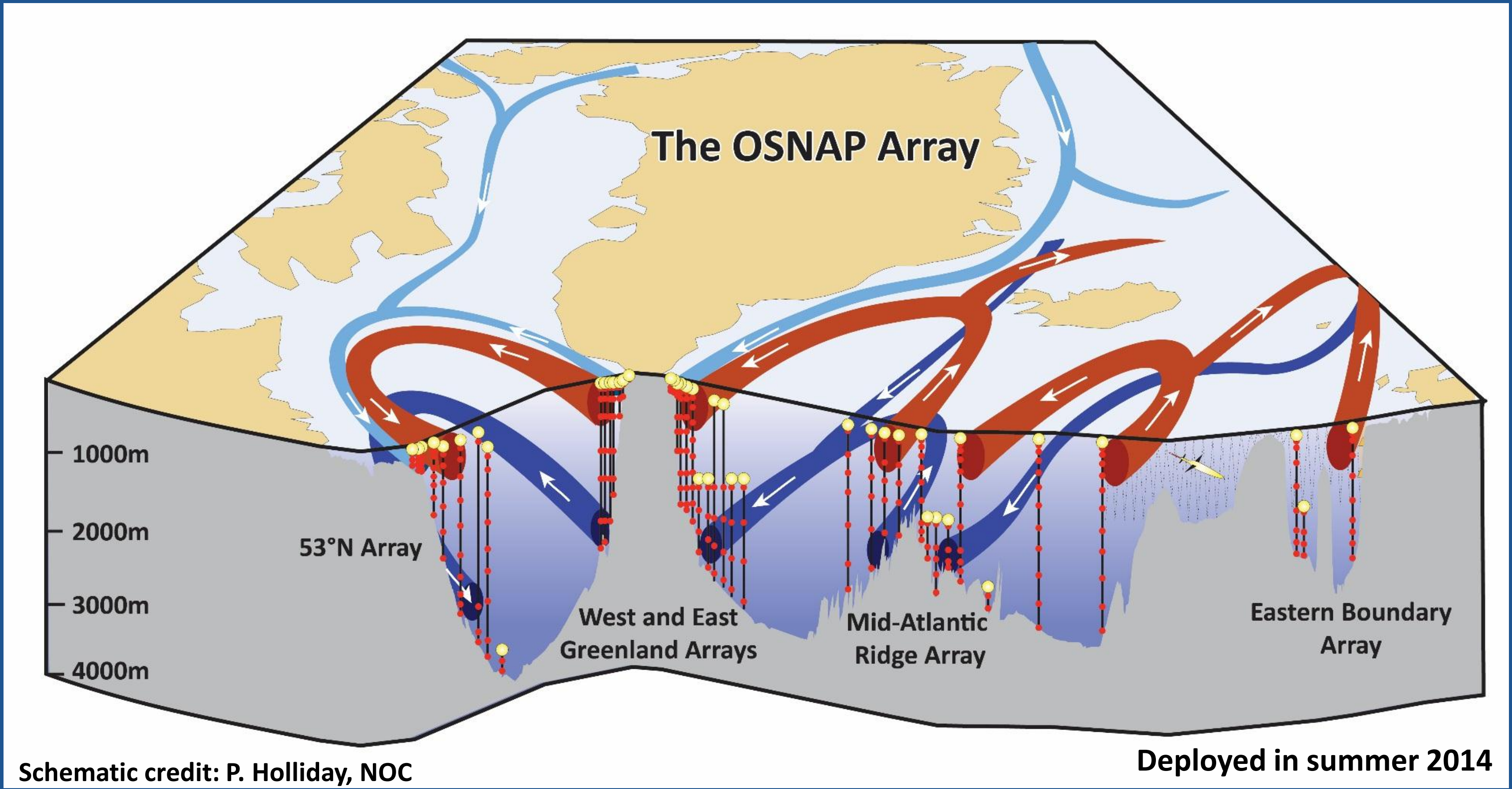
Reduction of convection in the Labrador Sea, indicated by warming temperatures, is not accompanied by a weakening DWBC.

So where are we?

- An observational linkage between convective activity and overturning variability has been elusive.
- Yet warming and freshening at high latitudes continue apace, both in the direction of stabilizing the surface waters.
- Numerous studies illustrate impact of overturning changes.

OSNAP: Overturning in the Subpolar North Atlantic Program

An international program: US, UK, Germany, Netherlands, France, Canada and China



Overall design: A transoceanic line in the subpolar North Atlantic that captures the net transport of the overflow waters from the Nordic Seas, as well as Labrador Sea export. Designed to test linkage between water mass production variability and overturning variability.

Summary of the modern view of AMOC

1. Our conceptual understanding of the modern ocean's mean overturning circulation has been significantly advanced over the past two decades.

2. The overturning circulation has strong variability on seasonal and subseasonal time scales.

3. The Deep Western Boundary Current is not the sole conduit for the lower limb of the MOC.

4. Surface Gulf Stream waters do not flow directly into the subpolar gyre as the upper MOC limb

5. The MOC is not meridionally coherent; subtropical and subpolar anomalies can differ.

6. Our understanding of the overturning *variability*- why it changes and on what time scales – is an open question.