2014 OCB Summer Science Workshop
(July 21-24, 2014; WHOI)

Atlantic Meridional Overturning Circulation (AMOC) variability and the Overturning in the Subpolar North Atlantic Program (OSNAP)

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(WHOI)

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Overviews

- **U.S. AMOC Science Team**: Brief Introduction
- **AMOC variability**: Progresses and outstanding questions emerged in the past decade or so.
- **OSNAP**: Summary of proposed field program.

U.S. AMOC Science Team
(www.usclivar.org/amoc)

- Started in March 2008
- To address the 4th near-term priority of the SOST Ocean Research Priority Plan (Jan. 2007)
- An U.S. inter-agency program (NASA, NOAA, NSF, DOE)
- 65 projects (~125 scientists) funded by four agencies
- Annual science meeting, alternating every other year between U.S.-only and U.S.-U.K. joint meeting.
- Annual report (available on the webpage)

U.S. AMOC Program Scientific Objectives

- Implementation and evaluation of AMOC observing system
- Assessment of AMOC state, variability, and change
- Assessment of AMOC variability mechanisms and predictability
- Assessment of the role of AMOC in global climate and ecosystems *(including carbon cycle)*

4 Task Teams + Executive Committee

U.S. AMOC: efforts to reach out to OCB community

- **2013 annual report: one of Task Team 4’s near-term priorities**
  “Improve understanding of how AMOC variability affects ocean-atmosphere exchanges of carbon, biogeochemical cycles, and associated changes in marine ecosystems.”

- **Mini-workshop during 2012 annual meeting**
  AMOC's Impact on the Carbon Cycle (Speakers: Scott Doney and Galen McKinley)

- **2013 annual meeting presentations**

  Climate effects of ocean overturning on heat content anomalies and atmospheric CO_2 (**Ric Williams**)

  Impacts of AMOC changes on ocean biogeochemistry and atmospheric greenhouse gases inferred from paleoclimate data and modeling (**Andreas Schmittner**)

  Biogeochemical and freshwater impacts on the tropical and subtropical Atlantic due to Amazon River plume variability (**Victoria Coles**)

- **External Review recommendation**

  Lynne Talley (SIO), Galen McKinley (U Wisc), and Noel Keenlyside (U Bergen)

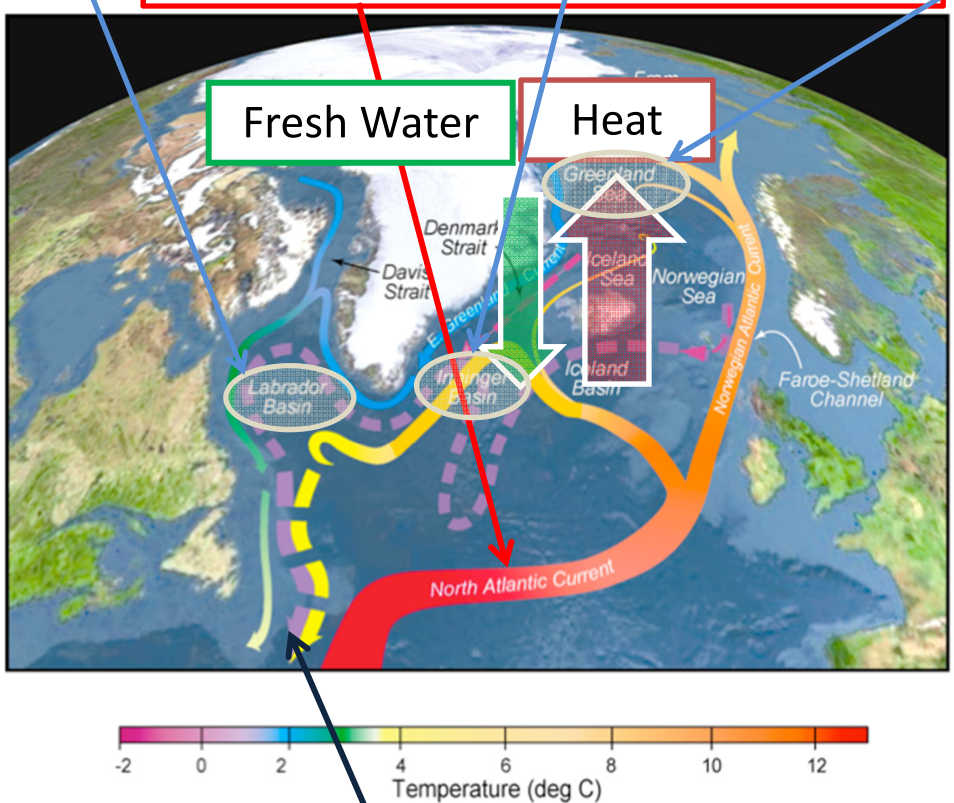
  “…the focus of U.S. AMOC on physical processes is commendable and should be continued. … Longer-Term priorities, that is, the much bigger picture, include the coupling of the ocean and atmosphere, and the carbon and ecosystem linkages; these are represented in the new Task Team structure. However, these external scientific communities are large; extension to encompass much of the associated science should be approached with deliberation. …”

AMOC Variability

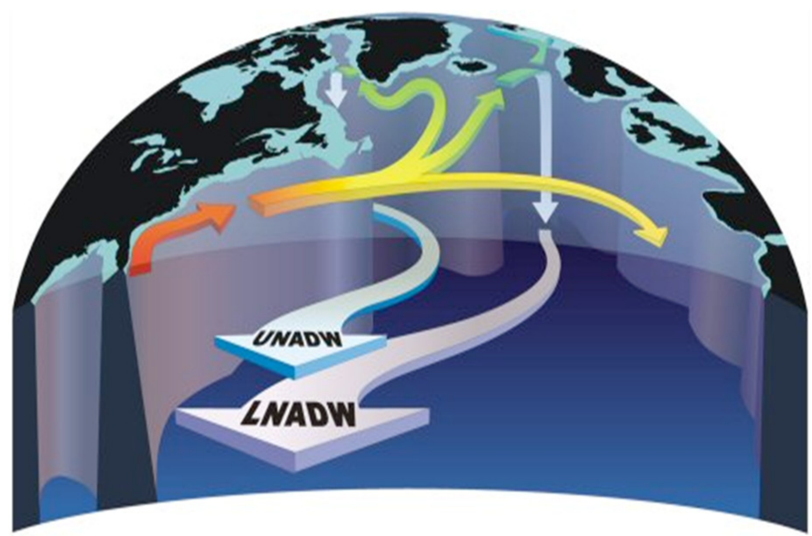
What have we learned in the past decades or so?

Progresses and outstanding questions.

AMOC: schematics



Curry and Mauritzen (2005)

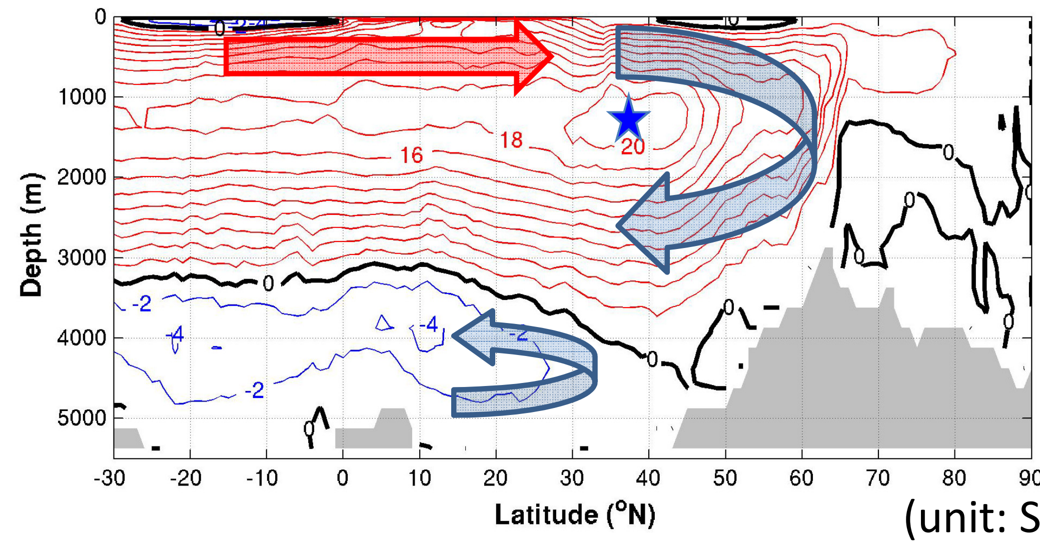


(RAPID/NERC)

AMOC streamfunction

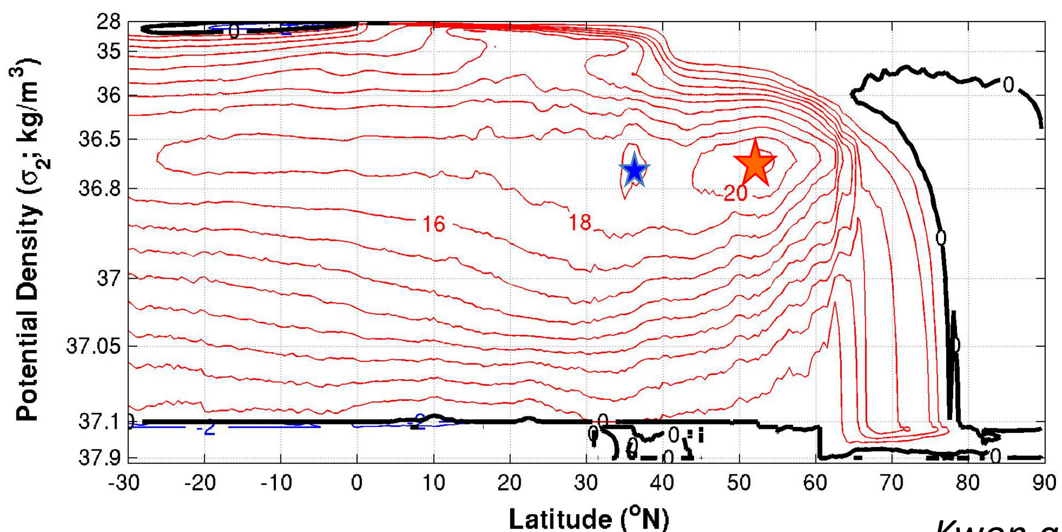
: Zonally integrated transport streamfunction

Overturning in Depth Space



(unit: Sverdrup = 10^6 m^3/s)

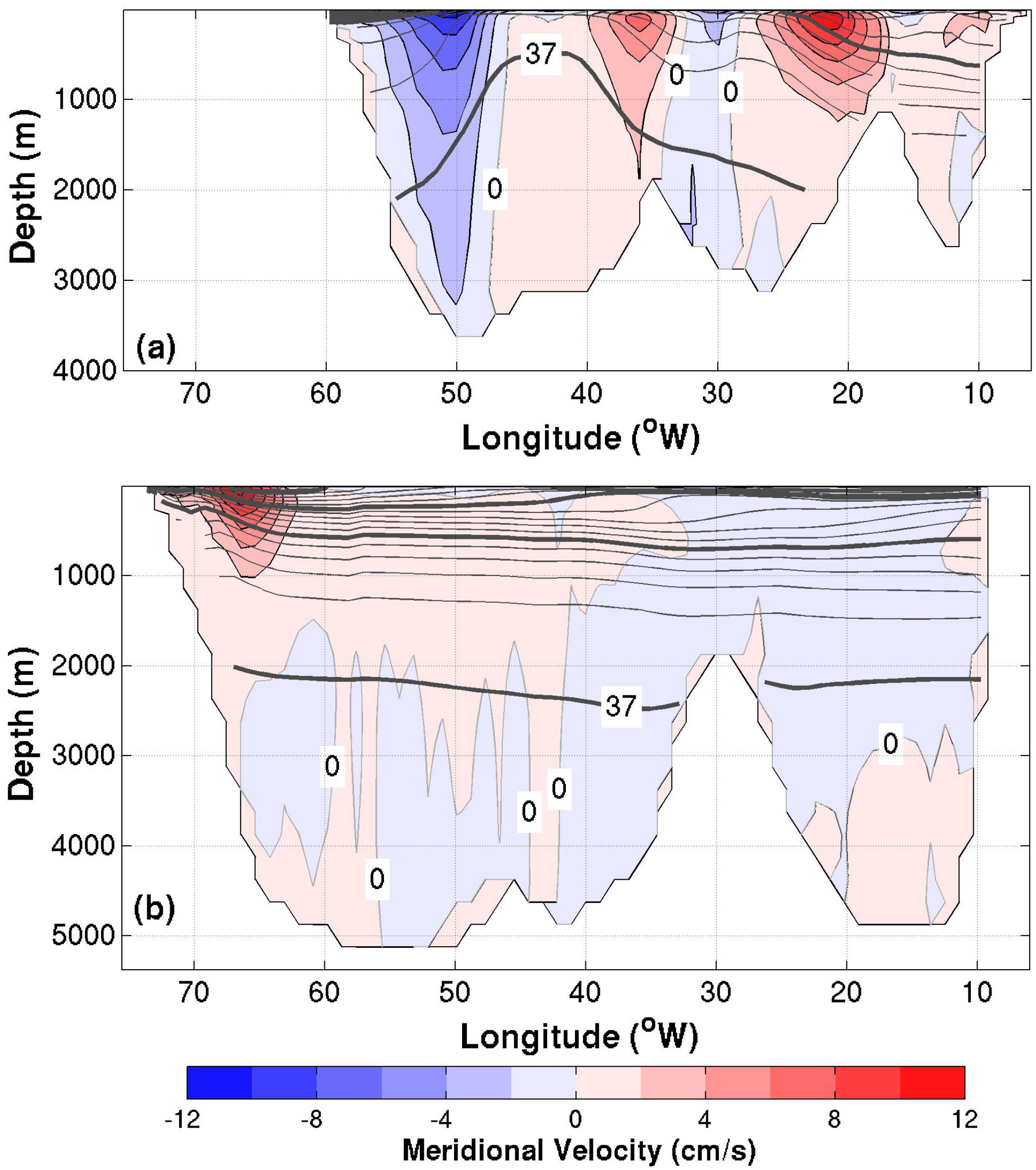
Overturning in Density Space



Kwon and Frankignoul (2014)

Meridional velocity along the zonal sections

Colors: meridional velocity (cm/s) / Contours: potential density (σ_2)



At 56° N

AMOC
≈ northward in east vs. southward in west

Doming isopycnals:
Zonal average in depth ≠ density

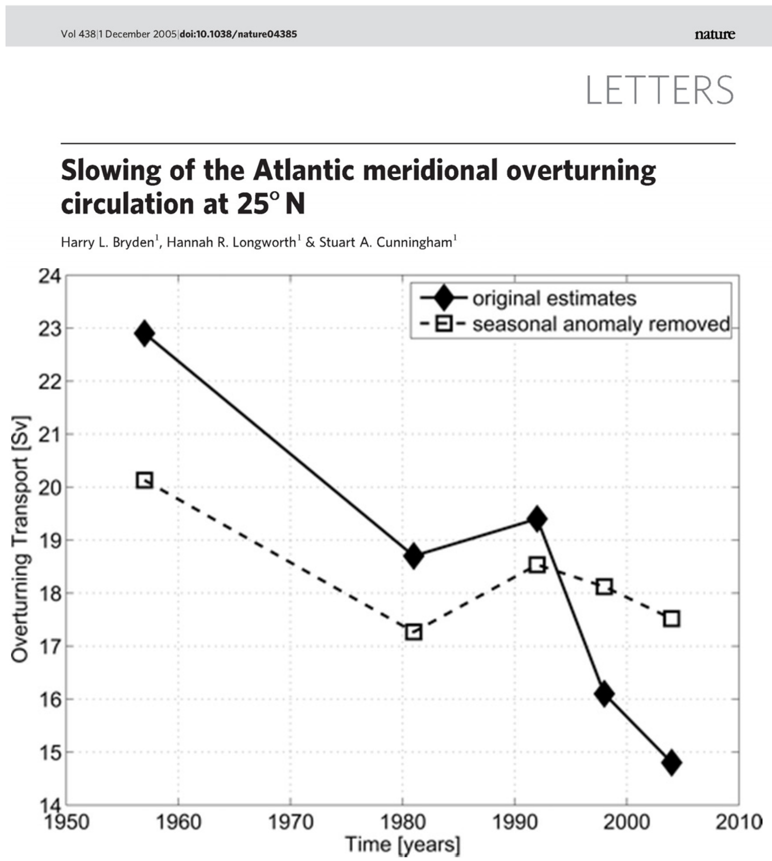
At 40N°

AMOC
≈ Surface northward vs. deep southward

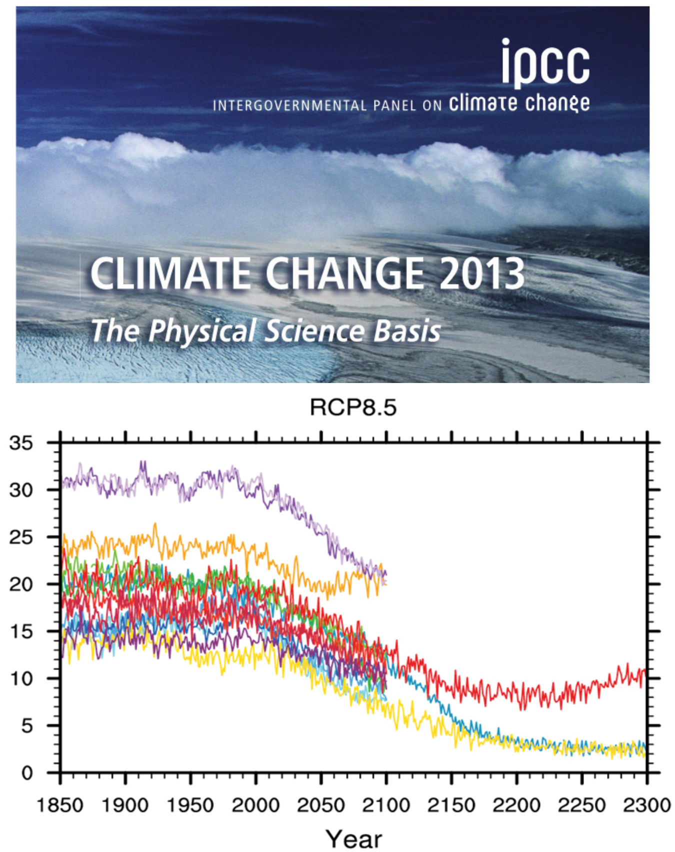
Mostly flat isopycnals:
Zonal average in depth ≈ density

Kwon and Frankignoul (2014)

Impetus for the recent AMOC research



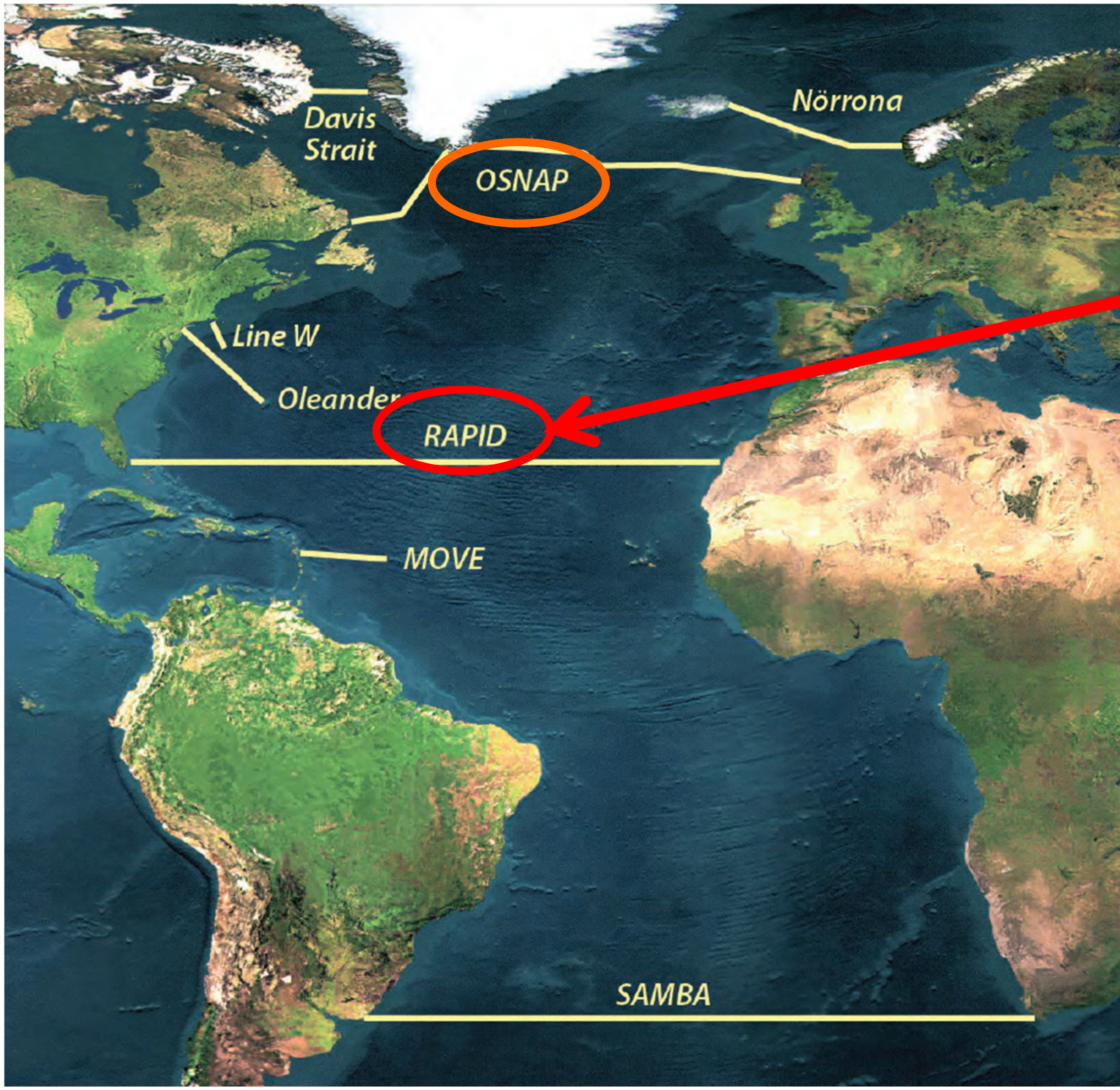
Kanzow et al. (2010) based on Bryden et al. (2005)



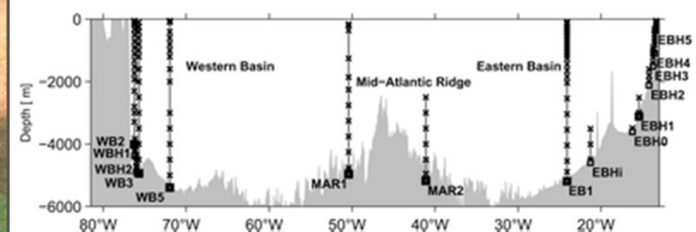
IPCC WG1 AR5 (2014)

Implications:
- **AMOC change is dominated by slow changes.**
- **T/S change near the convection sites is the dominant source of AMOC change.**
- **AMOC change primarily results from meridionally coherent changes along the DWBC.**

Sustained AMOC observations



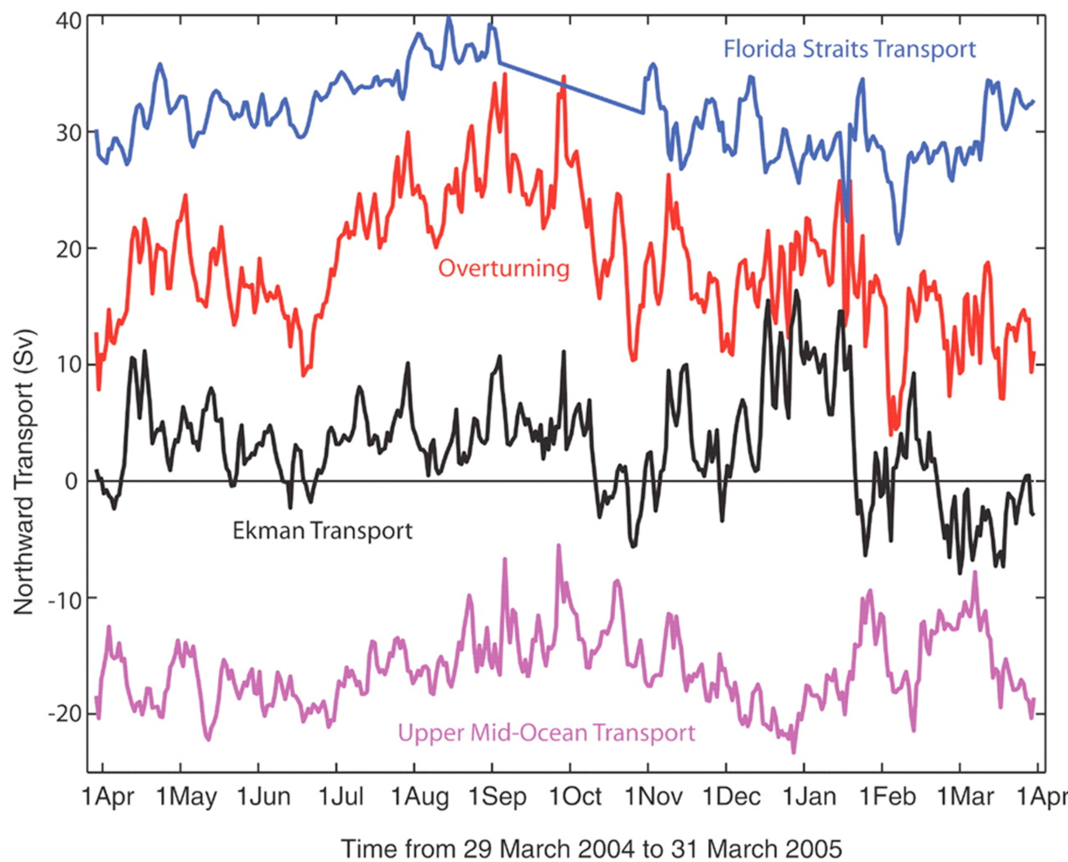
<u>RAPID-MOCHA-WBTS</u>
Sustained AMOC and meridional ocean heat transport observation at 26.5°N since April, 2004



Credit: Jack Cook, Woods Hole Oceanographic Institution

RAPID-MOCHA-WBTS

: 1st year observation of AMOC transport



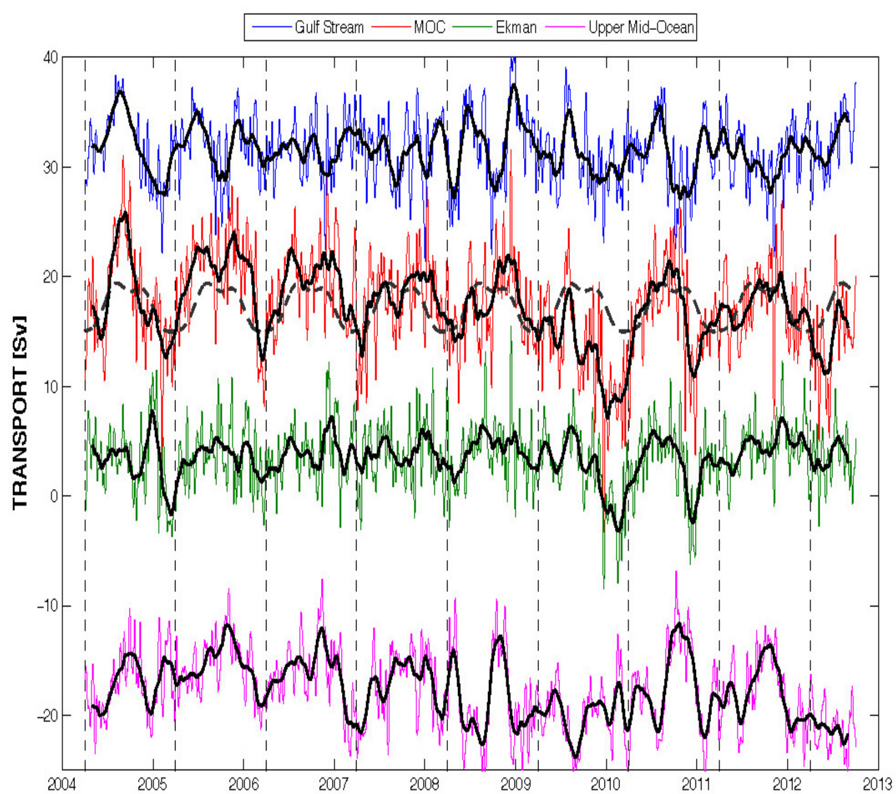
3 times larger range than Bryden et al. (2005) in 1 yr!

Cunningham et al. (2007)

RAPID-MOCHA-WBTS

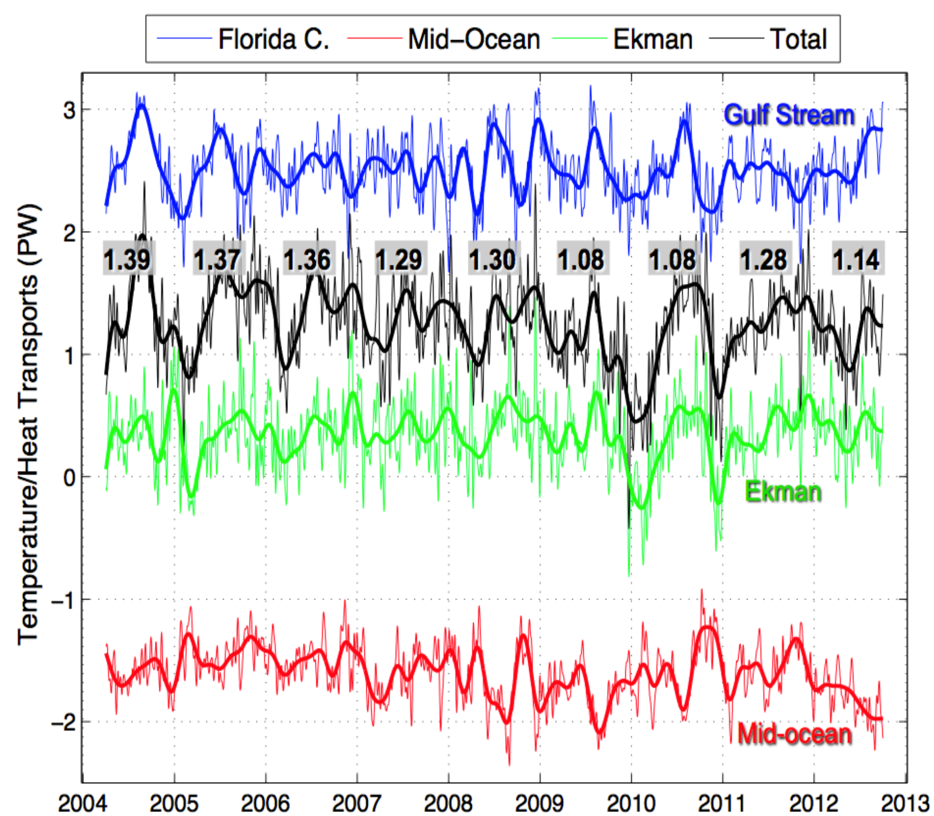
: Full time series from April 2004 to October 2012

AMOC transport
(total: red curve)



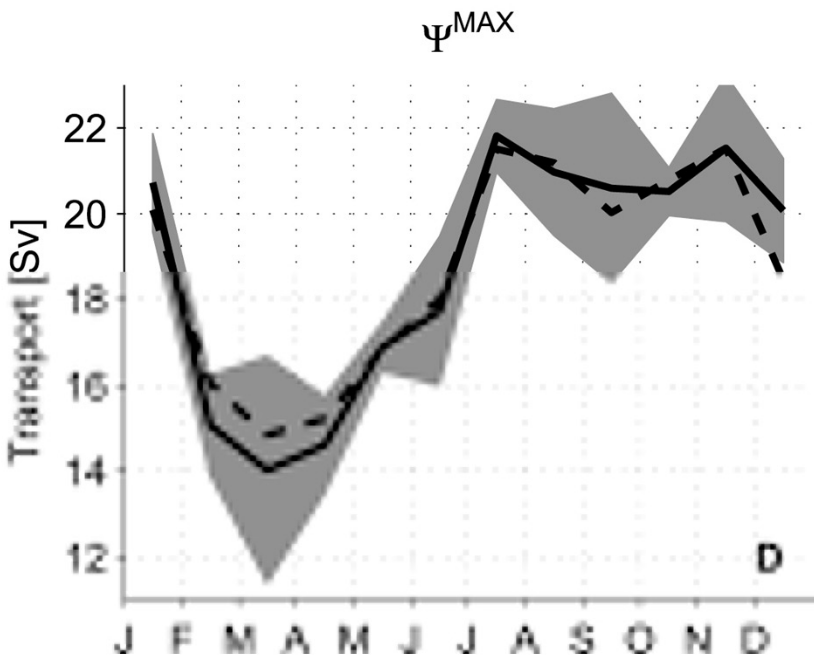
Smeed et al. (2014)

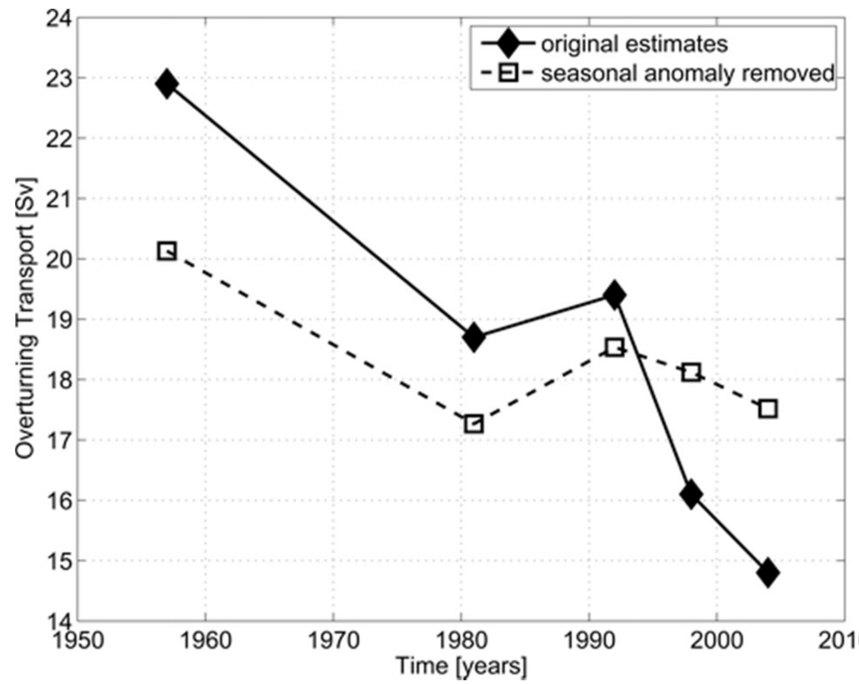
Meridional ocean heat transport
(total: black curve)



Johns et al. et al. (2014, US AMOC annual report)

RAPID-MOCHA-WBTS
: Mean seasonal cycle



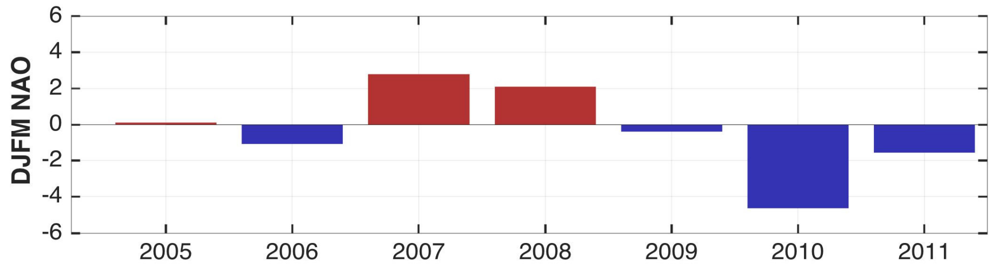


Solid line: April 2004 – April 2008
Shading: Standard error
Dashed line: Best guess for 1982-2008

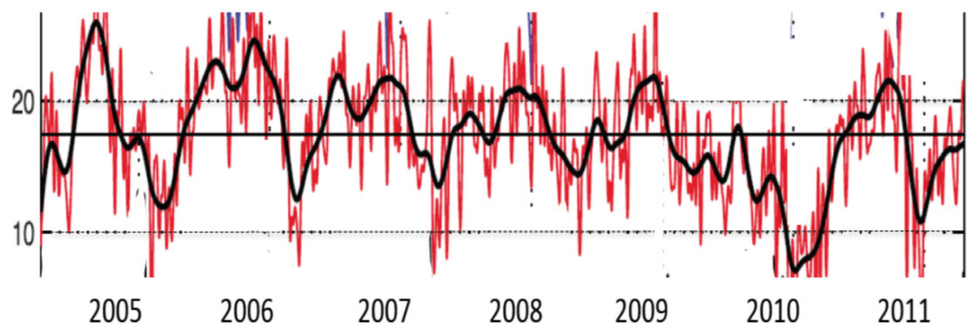
Kanzow et al. (2010)

RAPID-MOCHA-WBTS
: Role of wind stress forcing

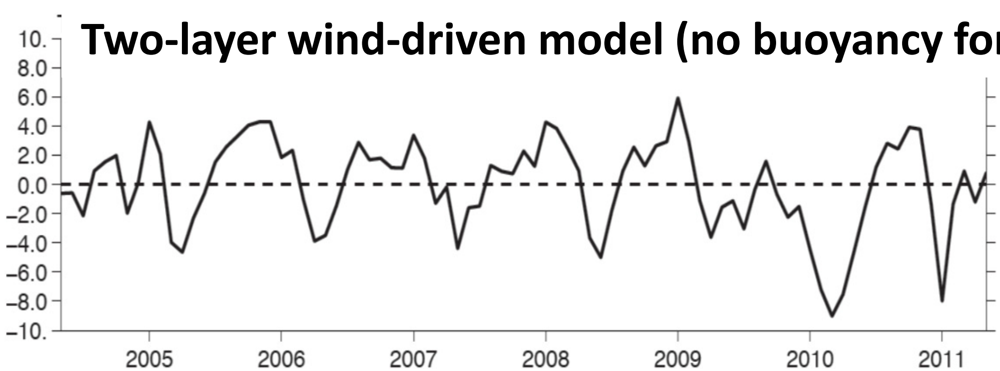
DJFM North Atlantic Oscillation (NAO)



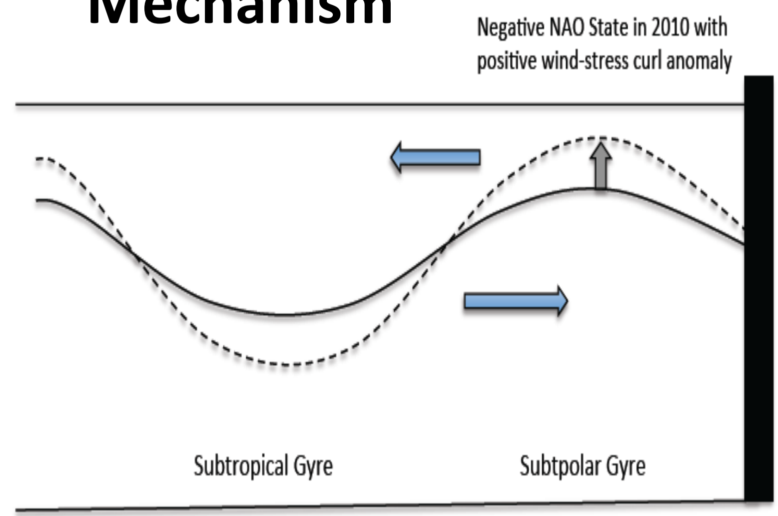
RAPID AMOC transport



Two-layer wind-driven model (no buoyancy forcing)



Mechanism

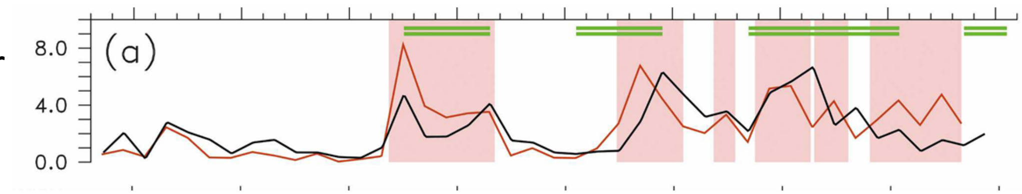


Subtropical local forcing and subpolar remote forcing are equally important for both seasonal cycle and interannual variability!

Yang (2014)

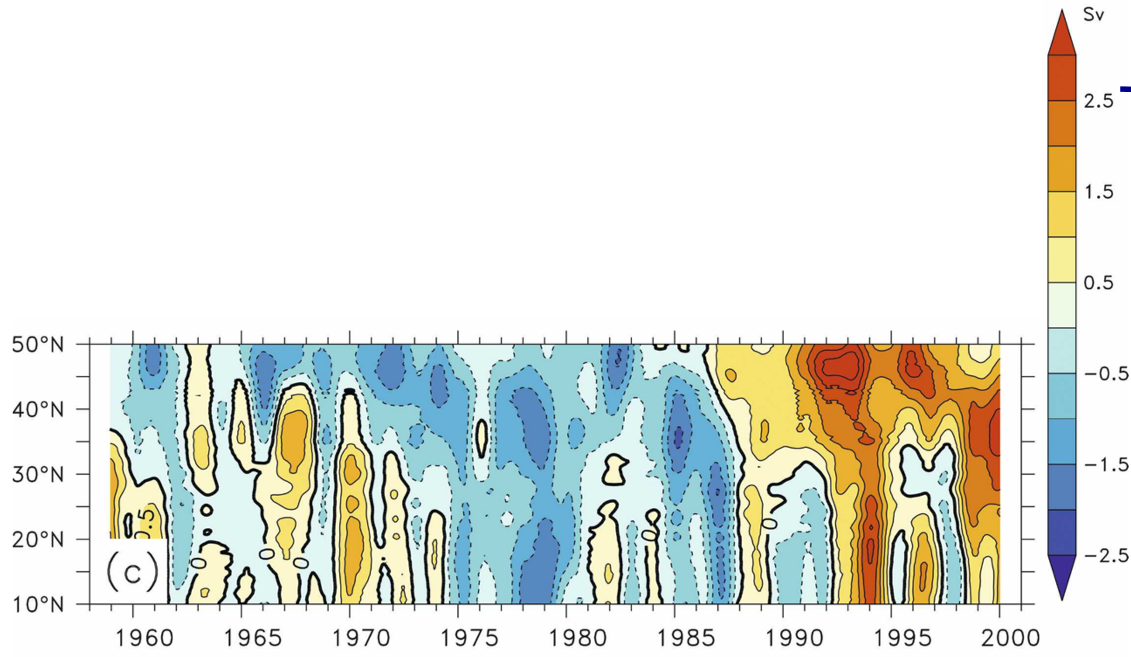
Role of wind vs. buoyancy forcing

Labrador Sea Water formation rate (Sv)



Green lines: NAO+ years

Model Experiment I
Full time-varying forcing



Dominant Multidecadal variability

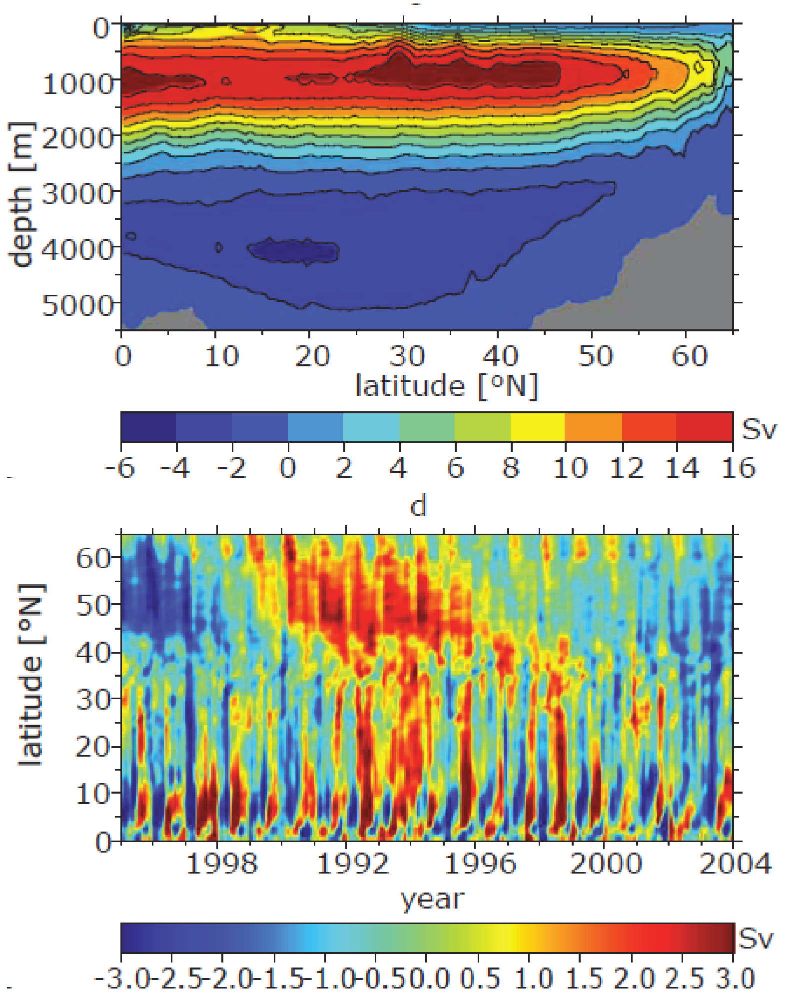
AMOC anomalies as a function of latitude & time

Dominant decadal and interannual variability

Biastoch et al. (2008)

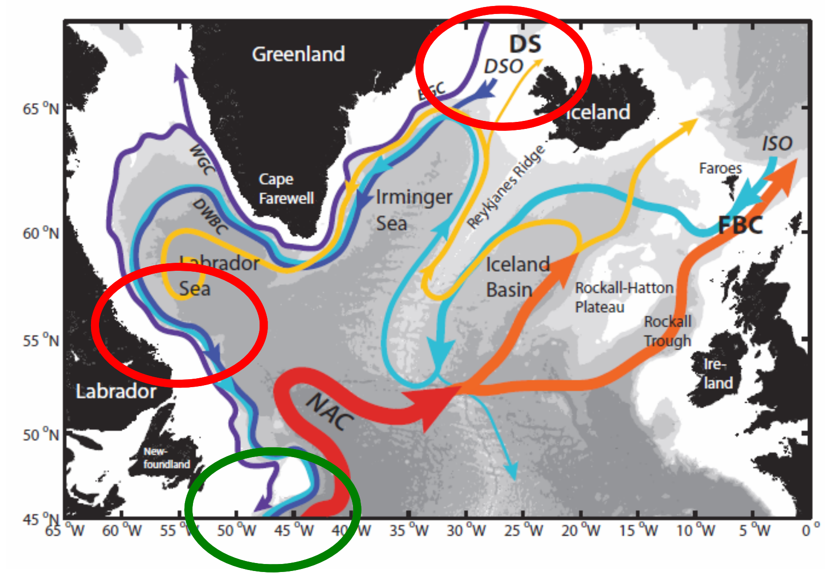
Meridional connectivity of AMOC variability

AMOC mean and anomalies from an ocean hindcast simulation



Bingham et al. (2007)

What about the observations?

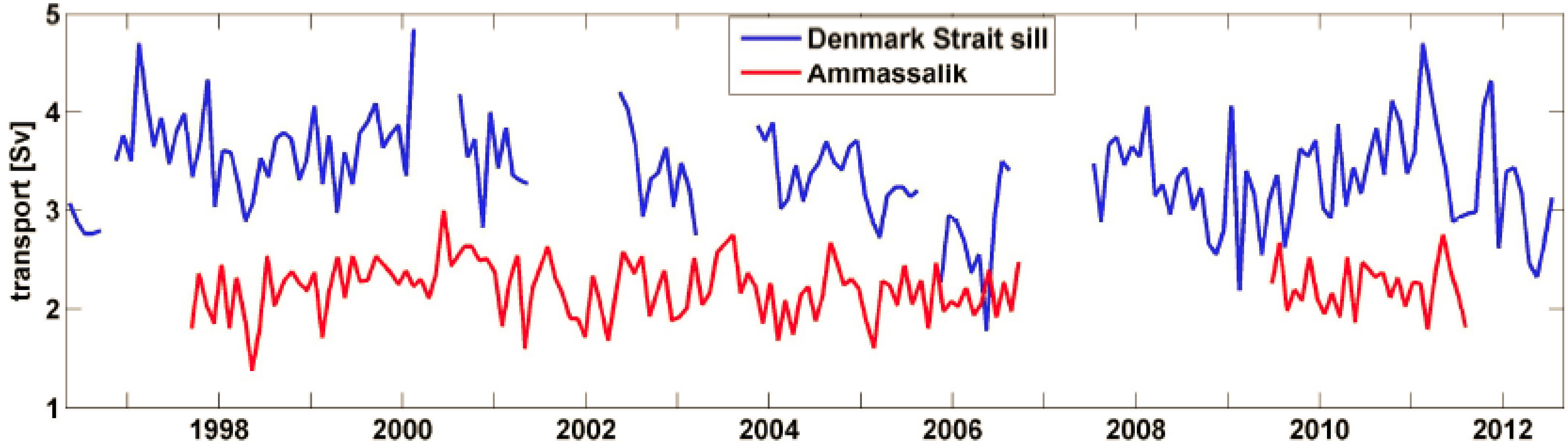


Are T/S properties of deep water correlated with DWBC transport change?

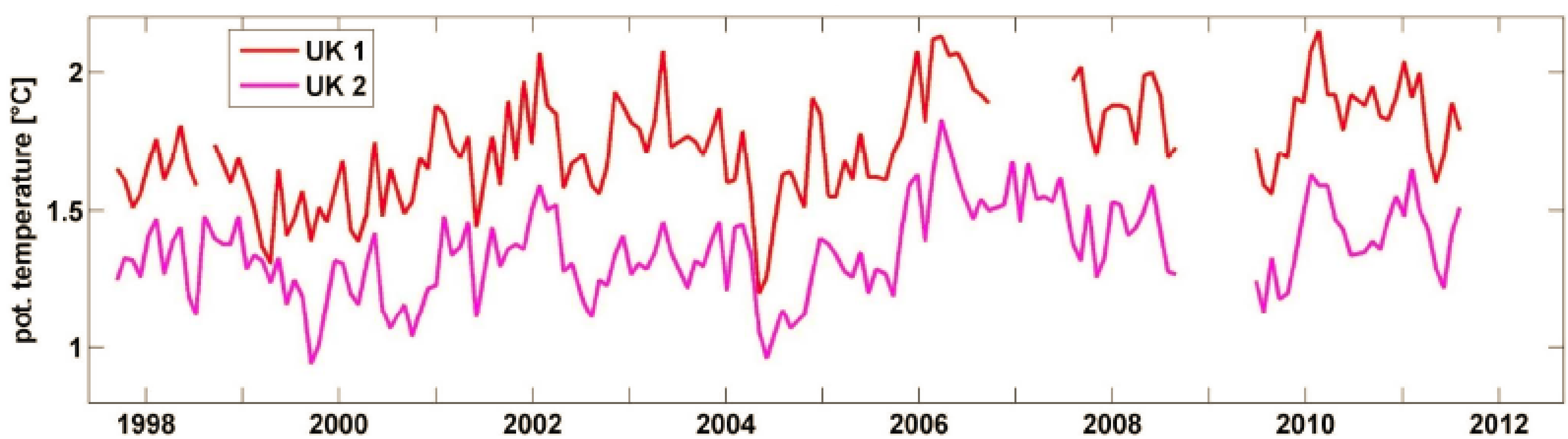
Is the DWBC continuous from the subpolar gyre to the subtropical gyre?

Nordic Sea convection and overflow transport

DSOW transports, updated from Jochumsen et al. (2012) and Dickson et al. (2007)



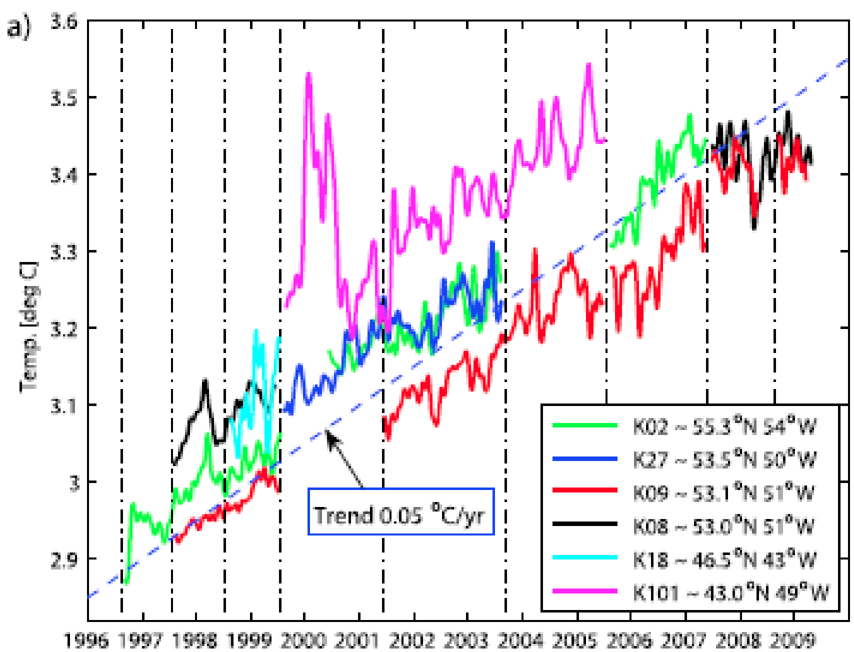
Potential temperature



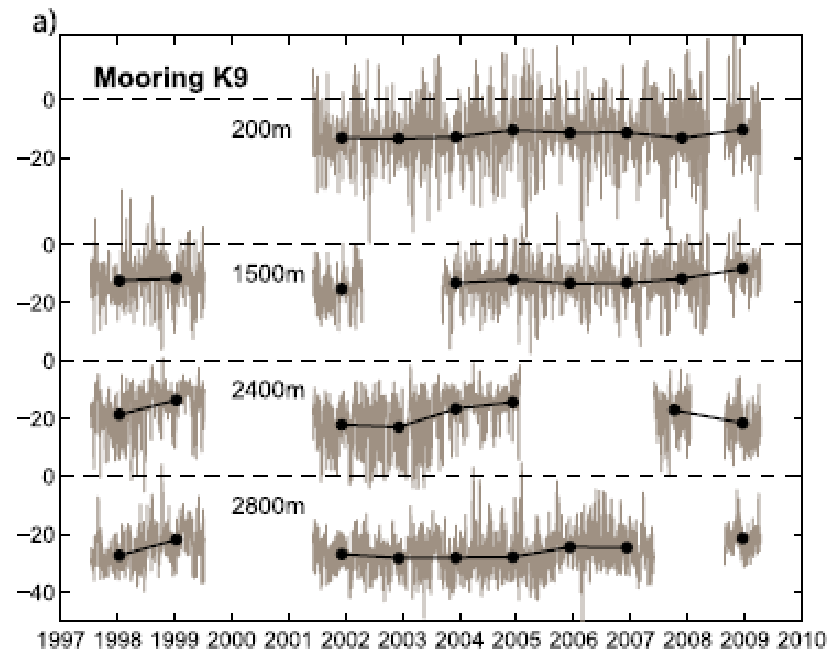
No trend in transports, warming from 1998-2006, since then T is rather stable

Labrador Sea convection and DWBC transport

Temperature at LSW level



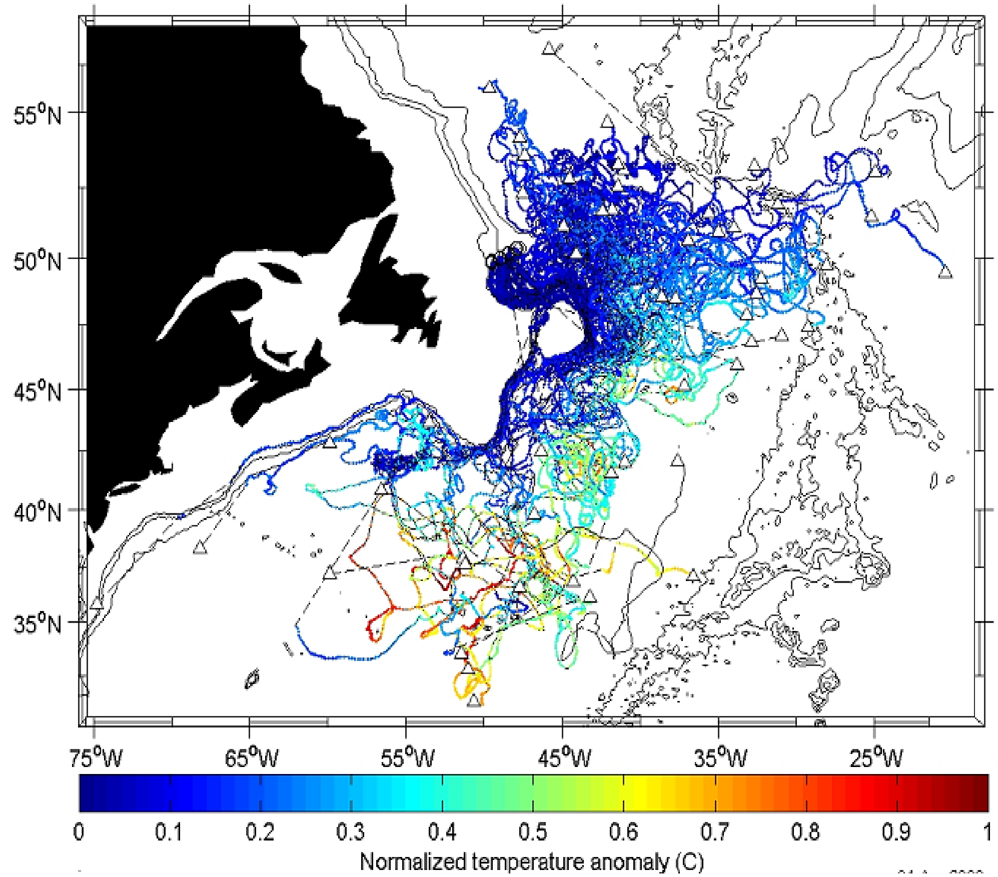
Alongshore velocity at 53°N



Fisher et al. (2010)

Again no trend in transports, warming from 1997-2009.

Subpolar – subtropics connectivity
: DWBC vs. Interior Pathway



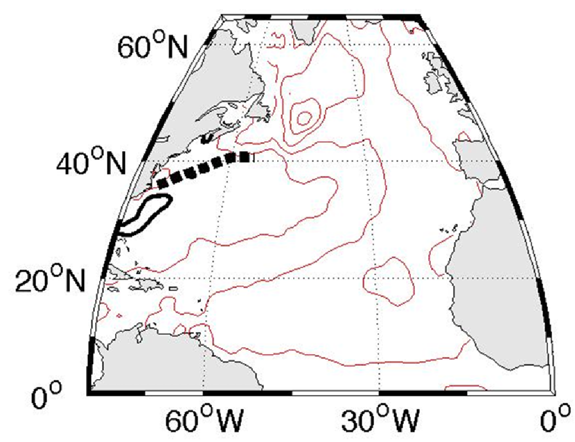
Bower et al. (2009)

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

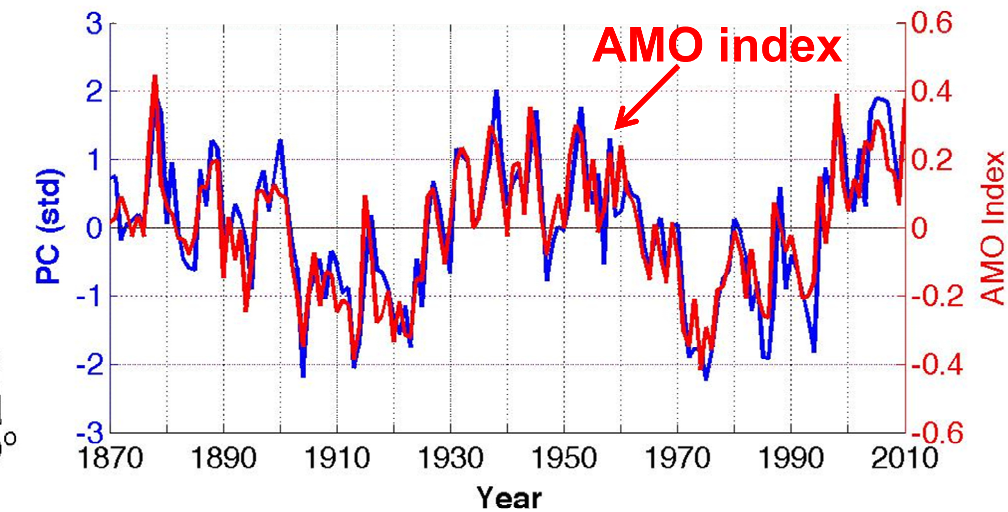
Only 8% (3/40) followed DWBC around the Tail of Grand Banks
About 23% (9/40) reached the subtropics via an interior pathway

Atlantic Multidecadal Variability (AMV/AMO)
SST EOFs in the North Atlantic

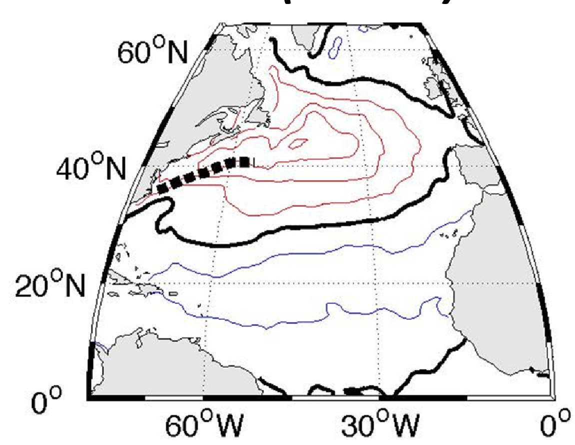
EOF 1 (38.5 %)



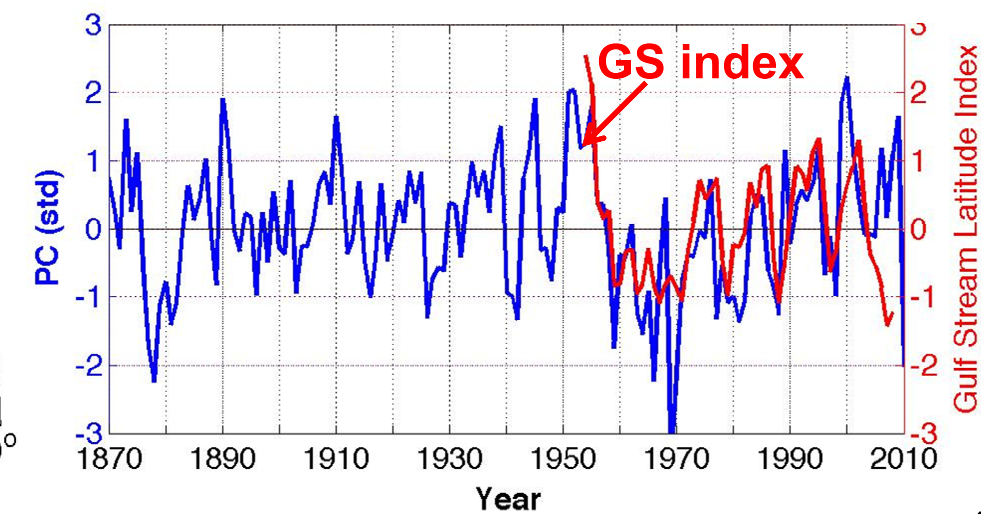
PC 1



EOF 2 (14.1 %)



PC 2



Kwon (2014)