

**The reduced overturning state
of the North Atlantic observed
by the RAPID-MOCHA-WBTS array**

David Smeed

Bill Johns, Molly Baringer, Ben Moat, Darren Rayner,
Chris Meinen, Denis Volkov
Gerard McCarthy,
Eleanor Frajka-Williams, and Harry Bryden

July 2018



**National
Oceanography Centre**
NATURAL ENVIRONMENT RESEARCH COUNCIL

noc.ac.uk

NERC SCIENCE OF THE
ENVIRONMENT

Outline

- Introduction
- The RAPID 26°N array time series April 2004 – February 2017
- The reduced state of AMOC 2009-2017 compared with 2004-2008
- Changes in the upper and lower limbs of the AMOC
- Concurrent changes in the North Atlantic
- Conclusions

Smeed, D. A., et al. (2018). The North Atlantic Ocean Is in a State of Reduced Overturning. *Geophysical Research Letters*, 370(1962), 1228–1533.

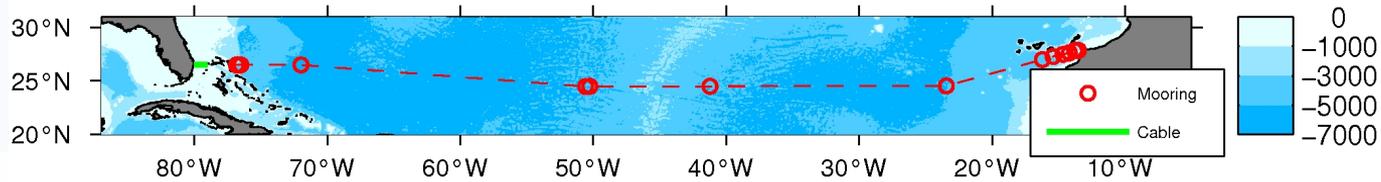
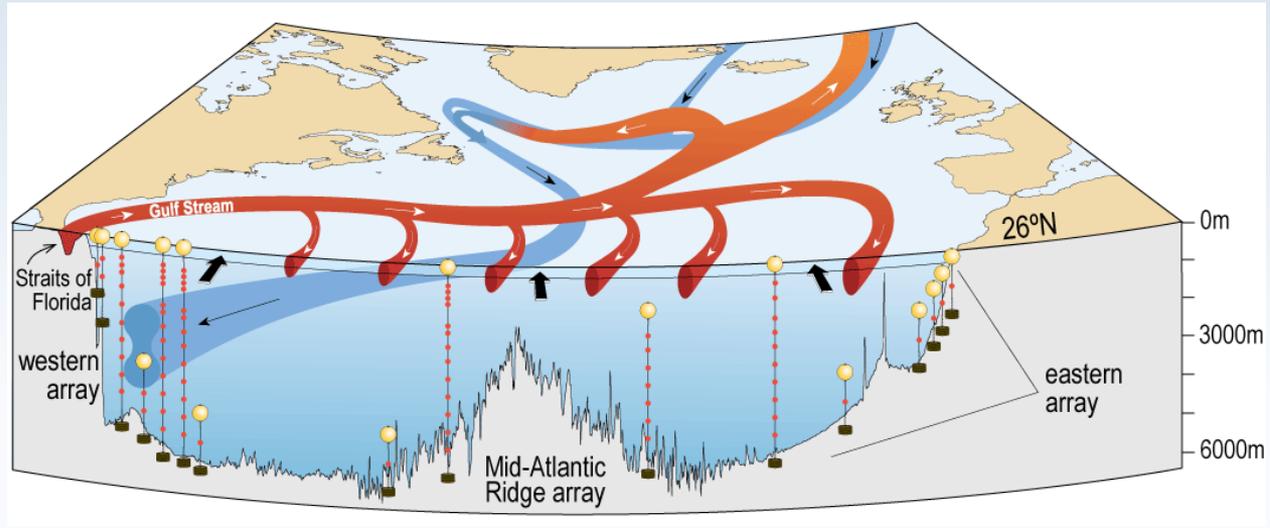


The RAPID 26°N array

- Time series from 2nd April 2004 to 28th February 2017
- The current array has 29 moorings and landers and 226 instruments
- To date there have been 28 cruises and more than 600 days at sea
- Almost 300 technicians, scientists, students, officers and crew have taken part in UK RAPID cruises
- Next cruise Autumn 2018



The RAPID 26°N array

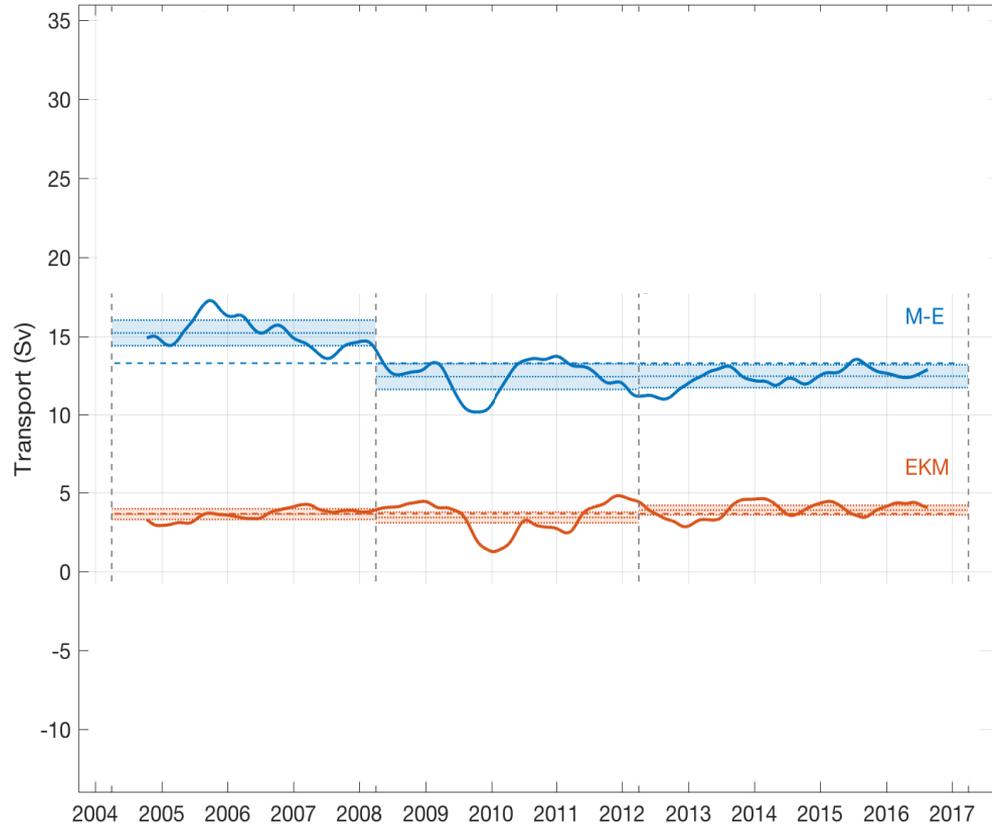


Decadal change

Mean

13.3 Sv

3.7 Sv



Change

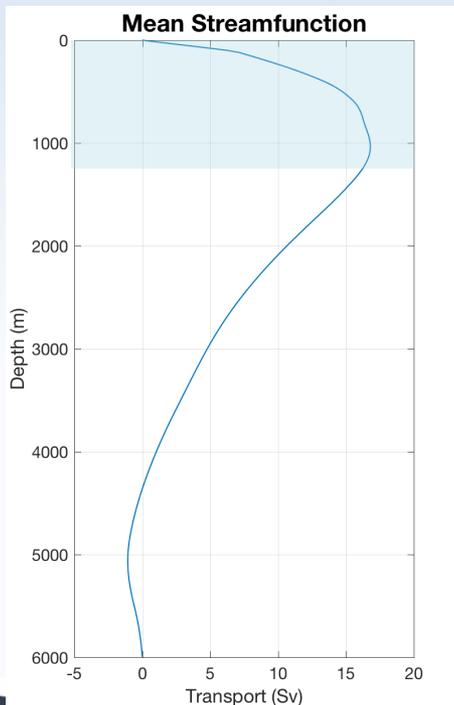
-2.7 Sv

+ 0.3 Sv

Upper-limb of the AMOC

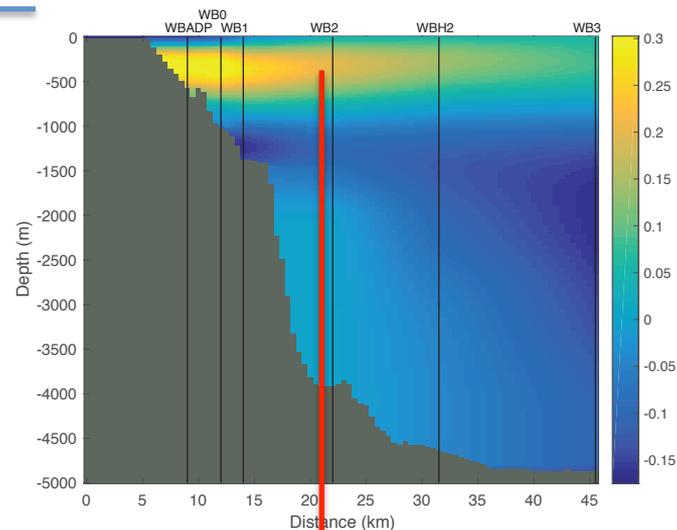
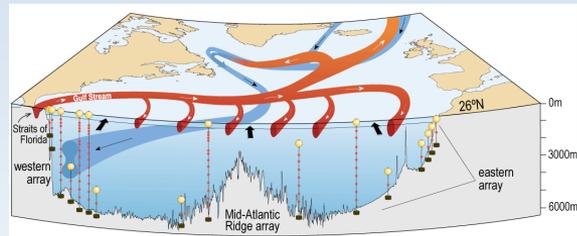
$$T_{MOC} - T_{EKM} = T_{FS} + T_{UMO}$$

$$= T_{WBC} + T_{GYR}$$



$$T_{WBC} = T_{FS} + T_{ANT}$$

$$T_{GYR} = T_{UMO} - T_{ANT}$$



Decadal change – upper limb

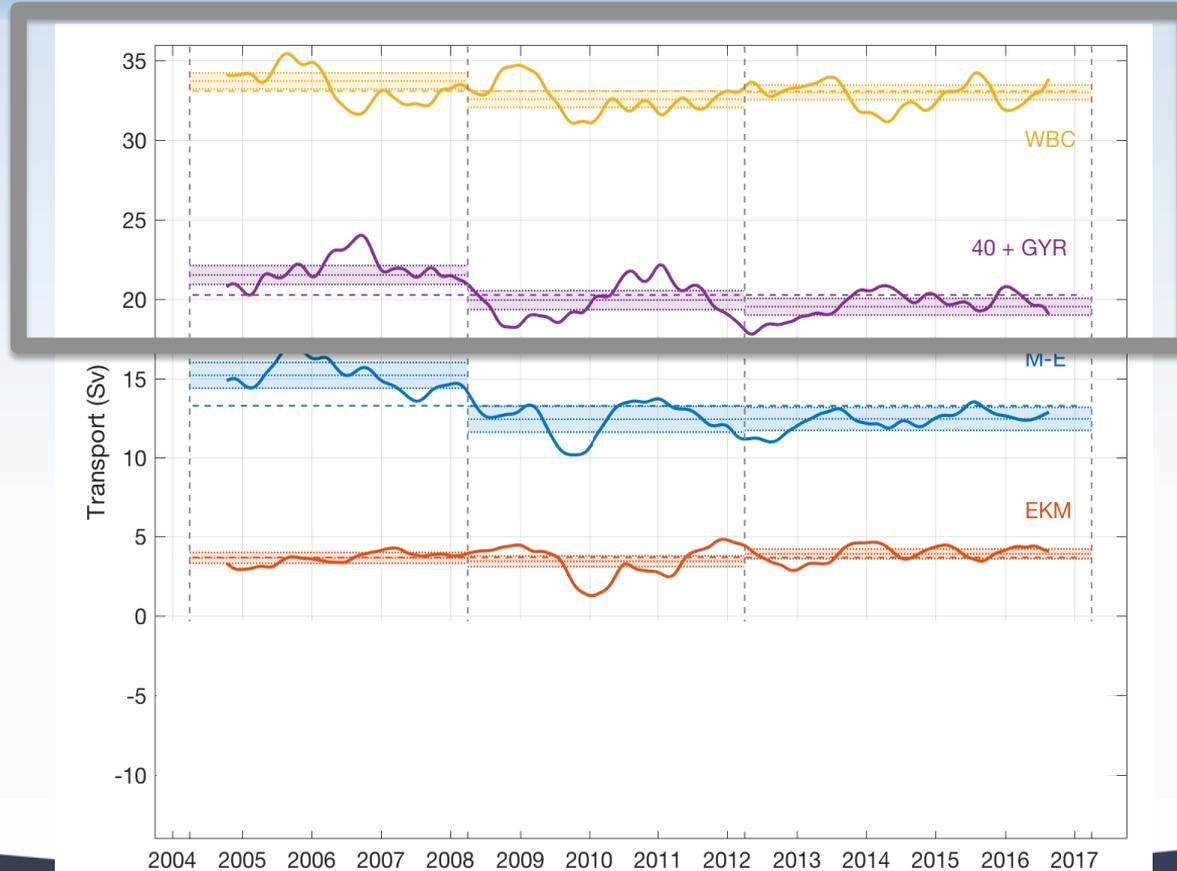
Mean

33.1 Sv

-19.7 Sv

13.3 Sv

3.7 Sv



Change

- 0.7 Sv

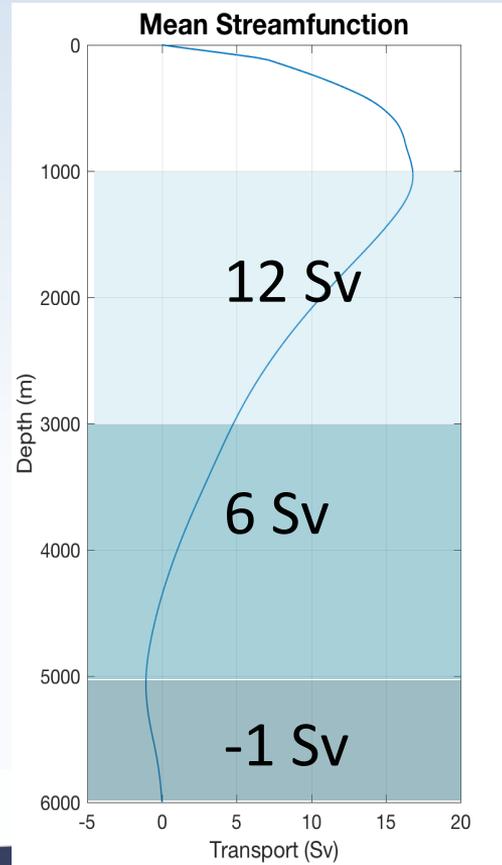
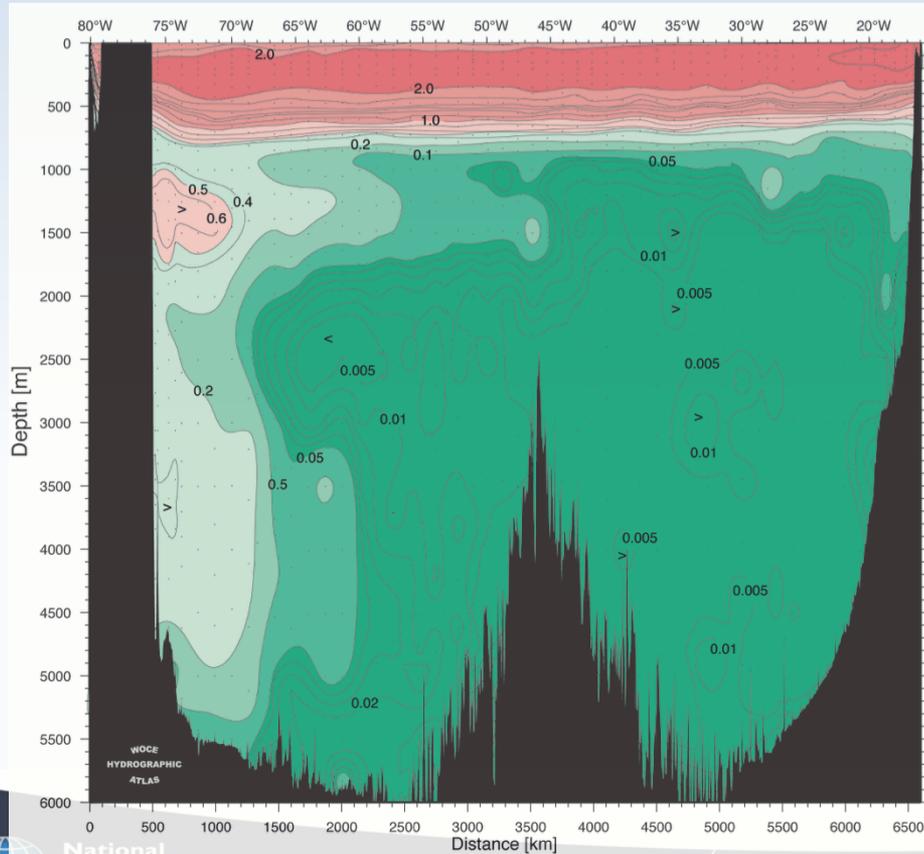
- 2.0 Sv

-2.7 Sv

+ 0.3 Sv



The lower-limb of the AMOC



Decadal change – lower limb

Mean
33.1 Sv

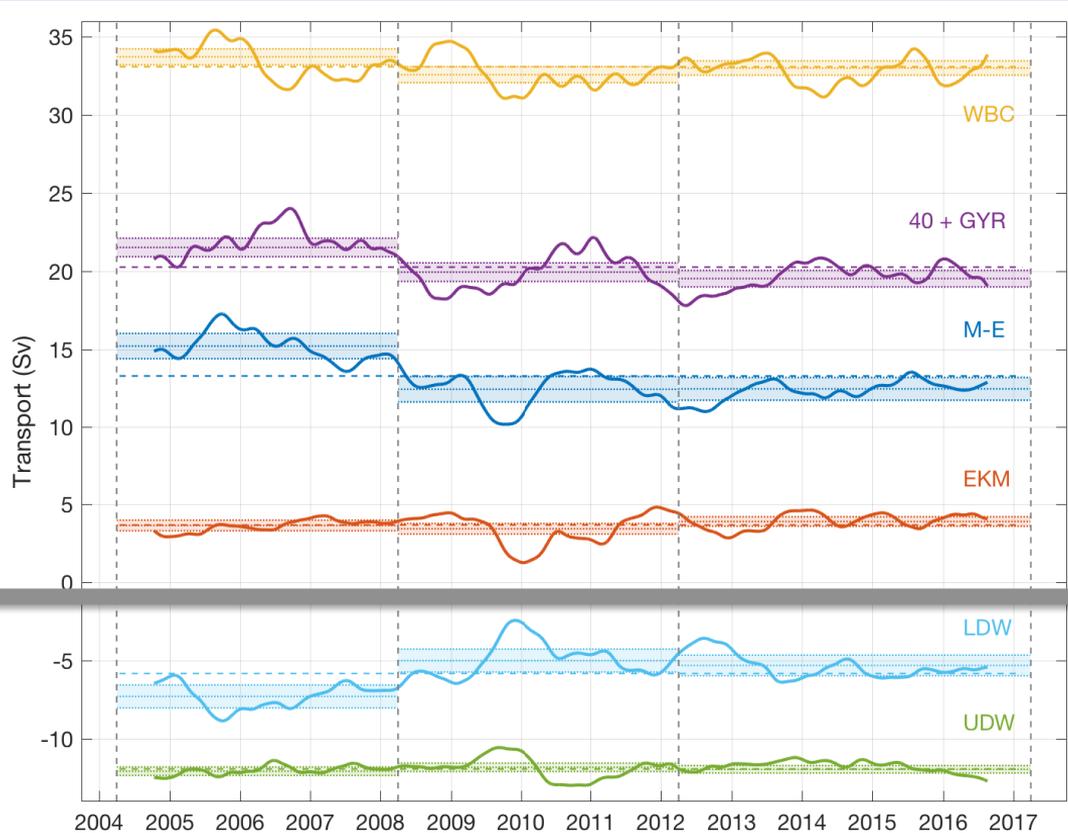
-19.7 Sv

13.3 Sv

3.7 Sv

-5.8 Sv

-12.0 Sv



Change
- 0.7 Sv

- 2.0 Sv

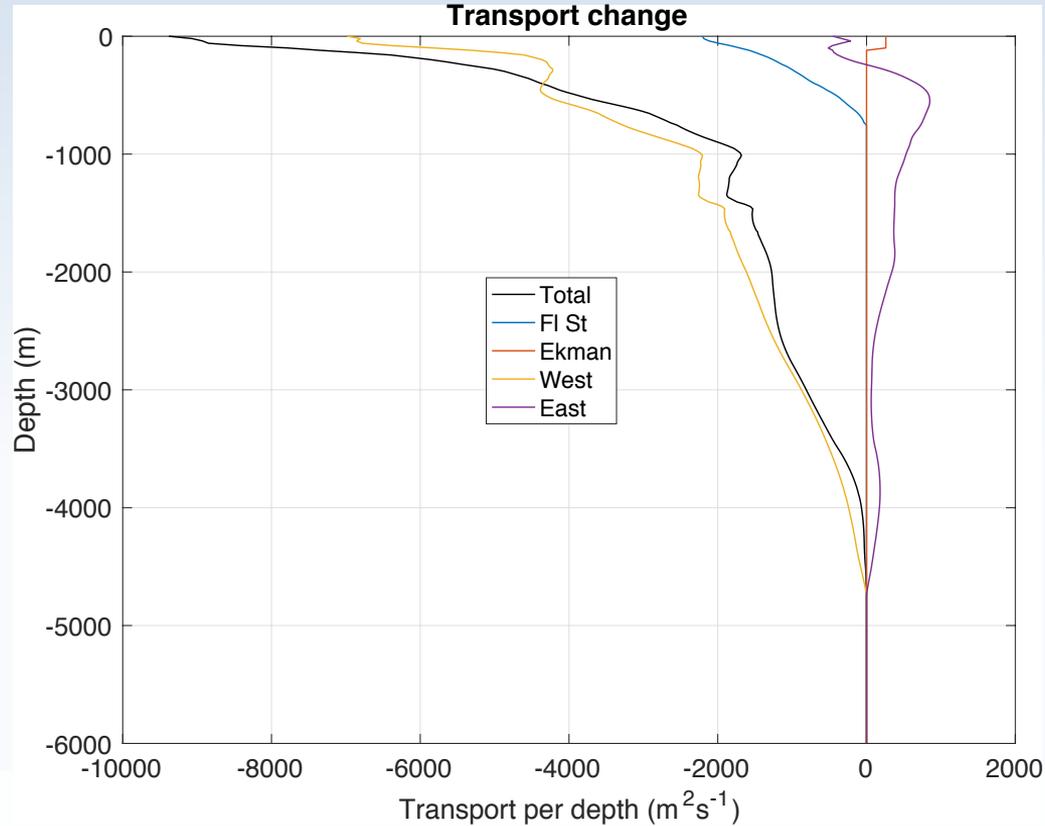
-2.7 Sv

+ 0.3 Sv

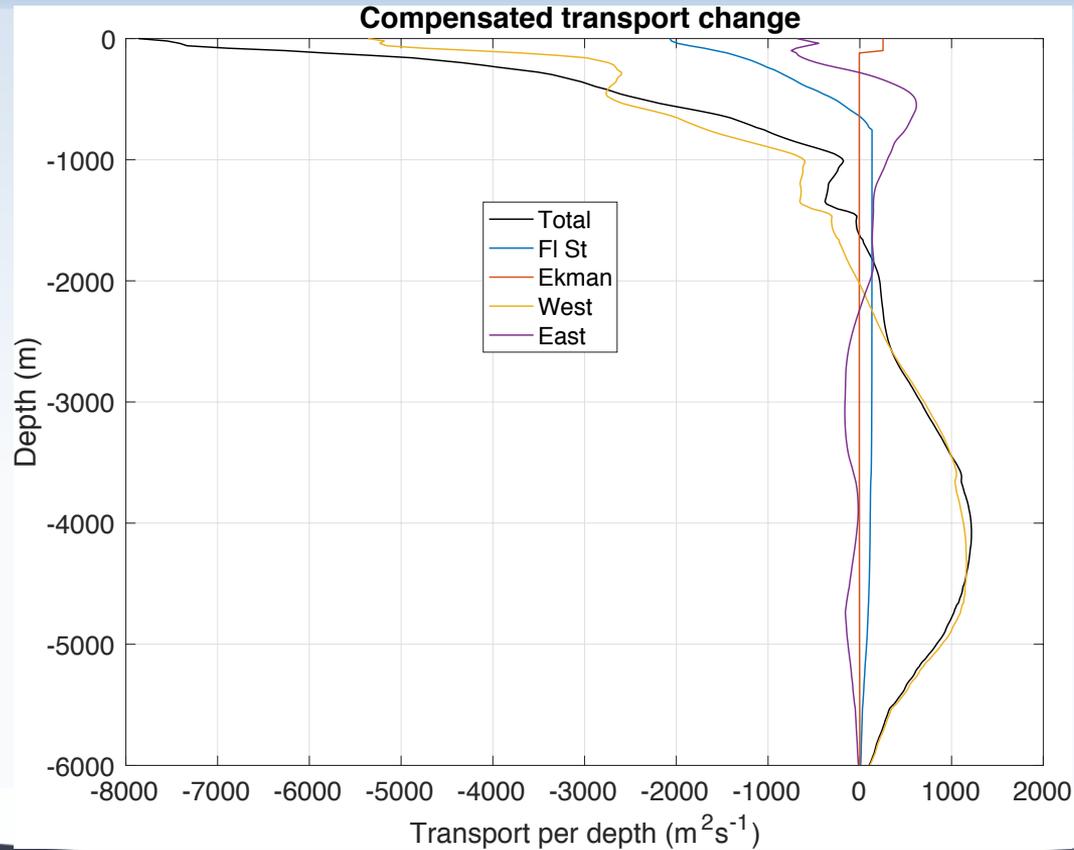
+ 2.0 Sv

+ 0.1 Sv

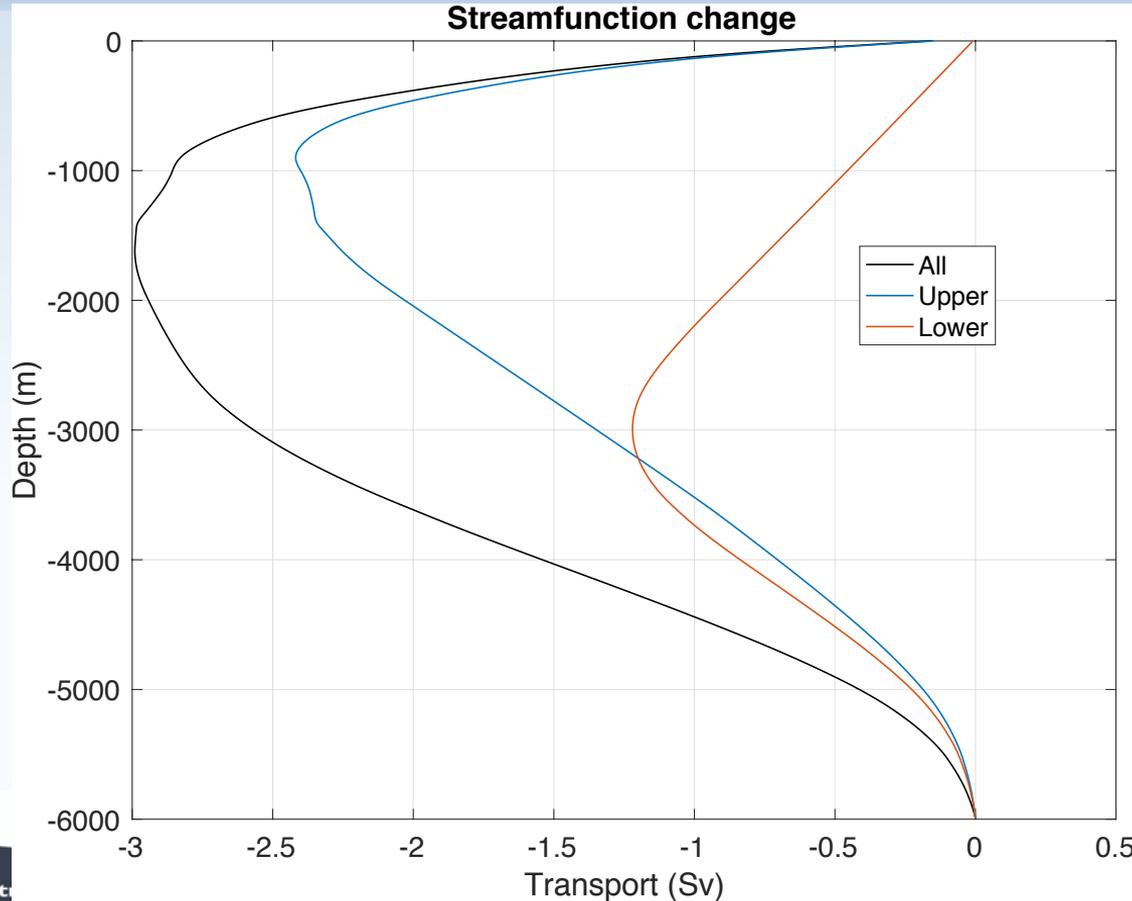
Baroclinic transport change



Total transport change

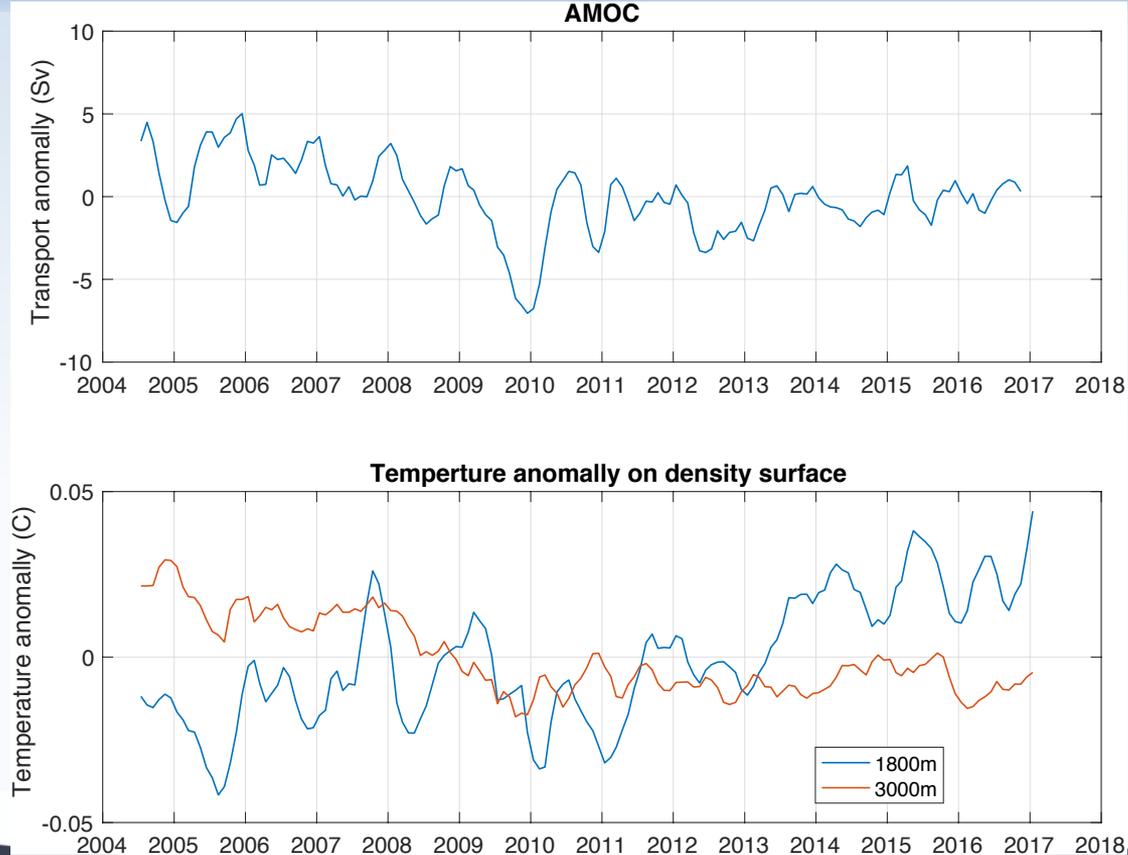


Streamfunction change

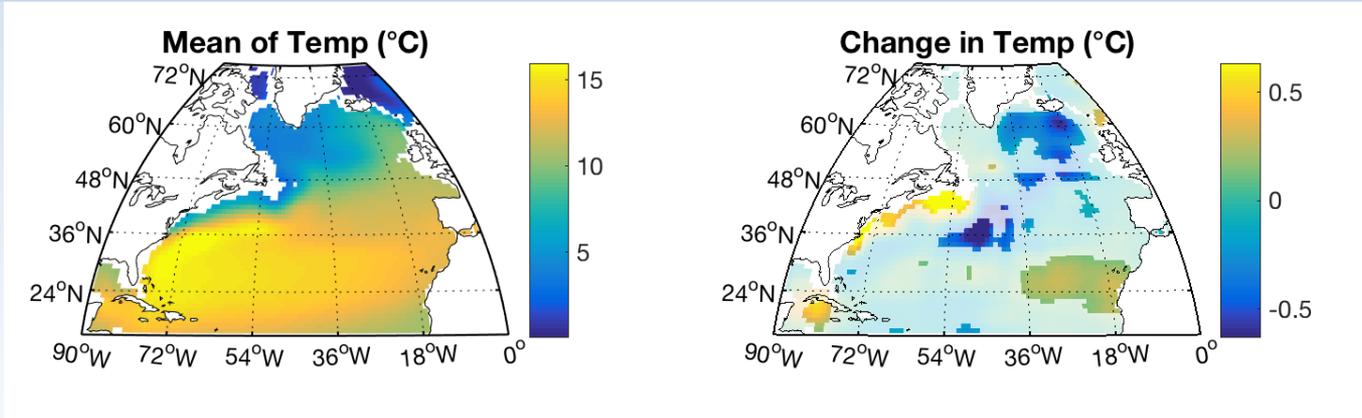


Deep (>2000db) densities changes account for about 20% change at depth of streamfunction maximum

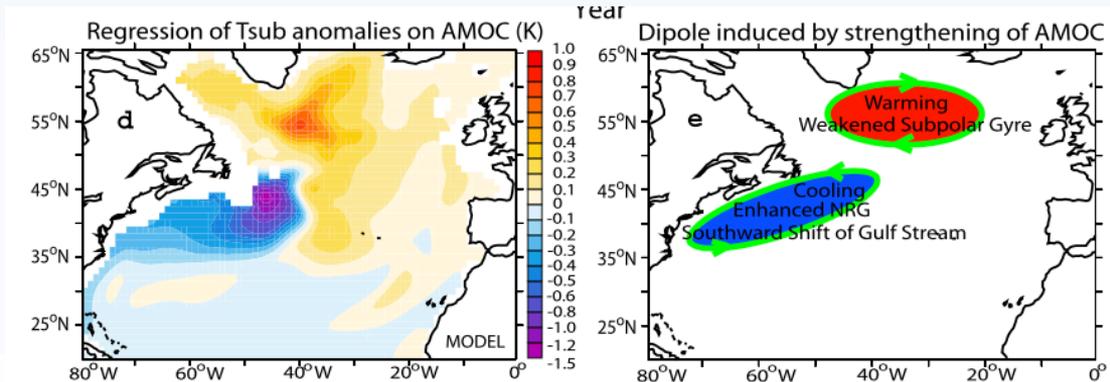
Water mass changes concurrent with AMOC change



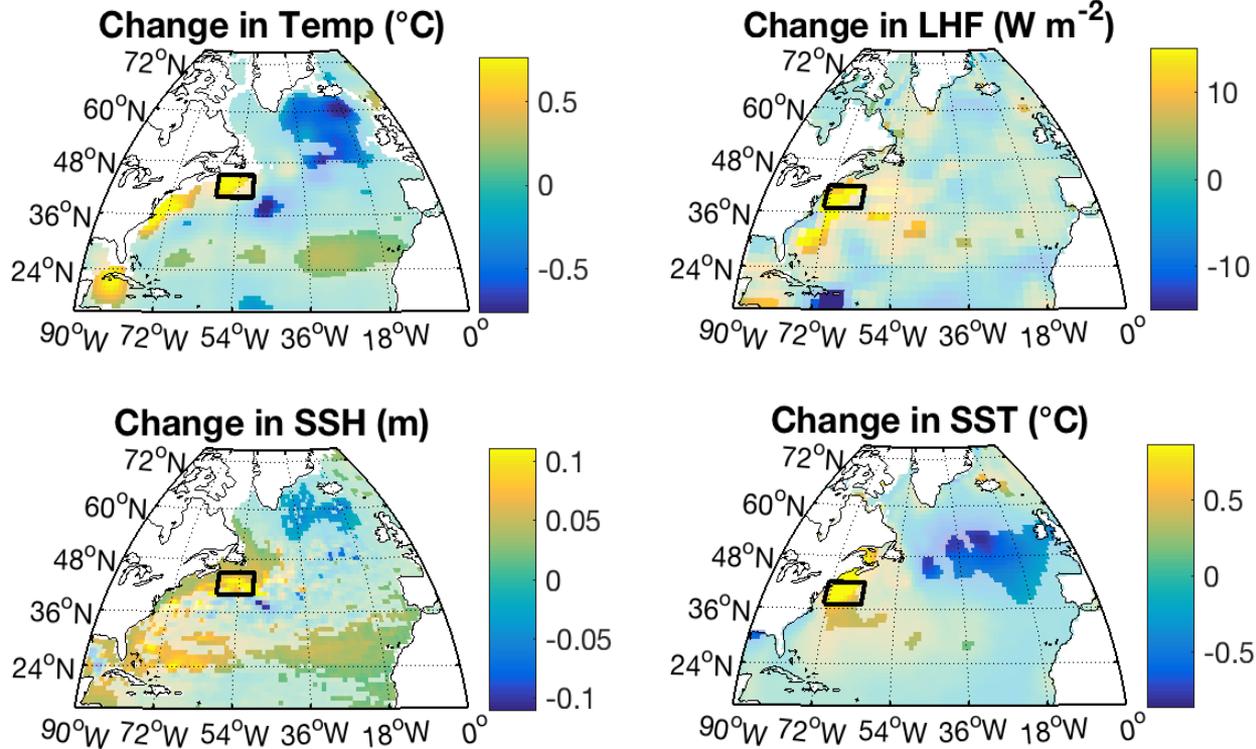
Concurrent changes in the north Atlantic



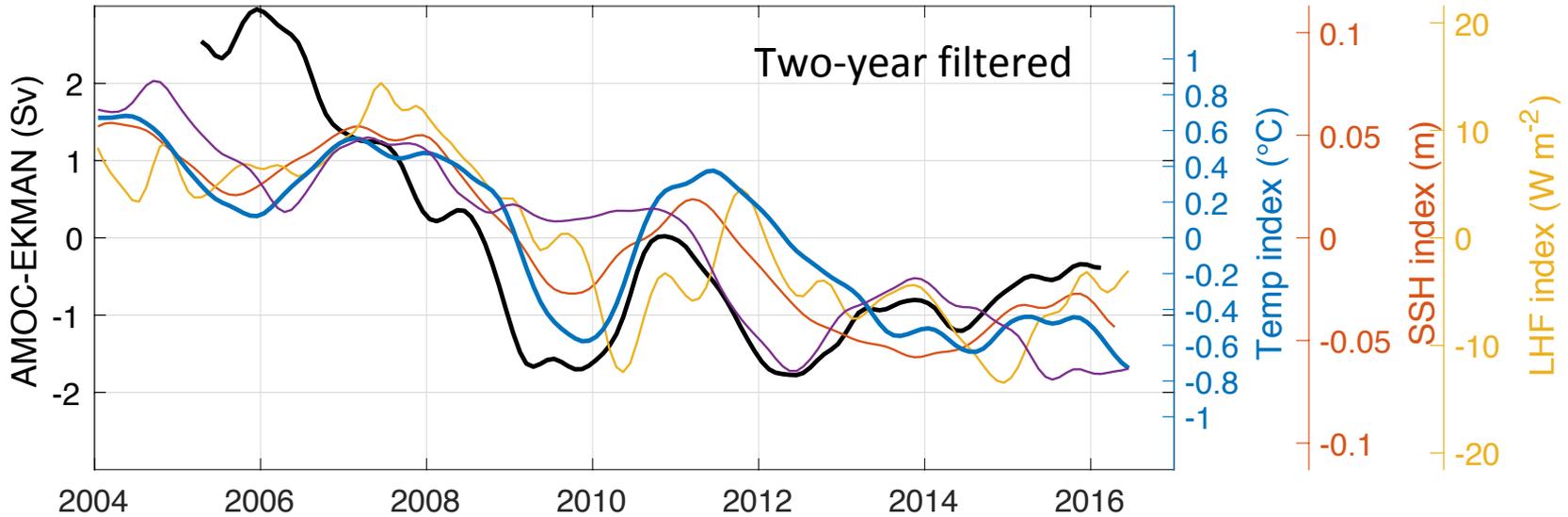
Model predicted response to increasing AMOC
Zhang (2008)



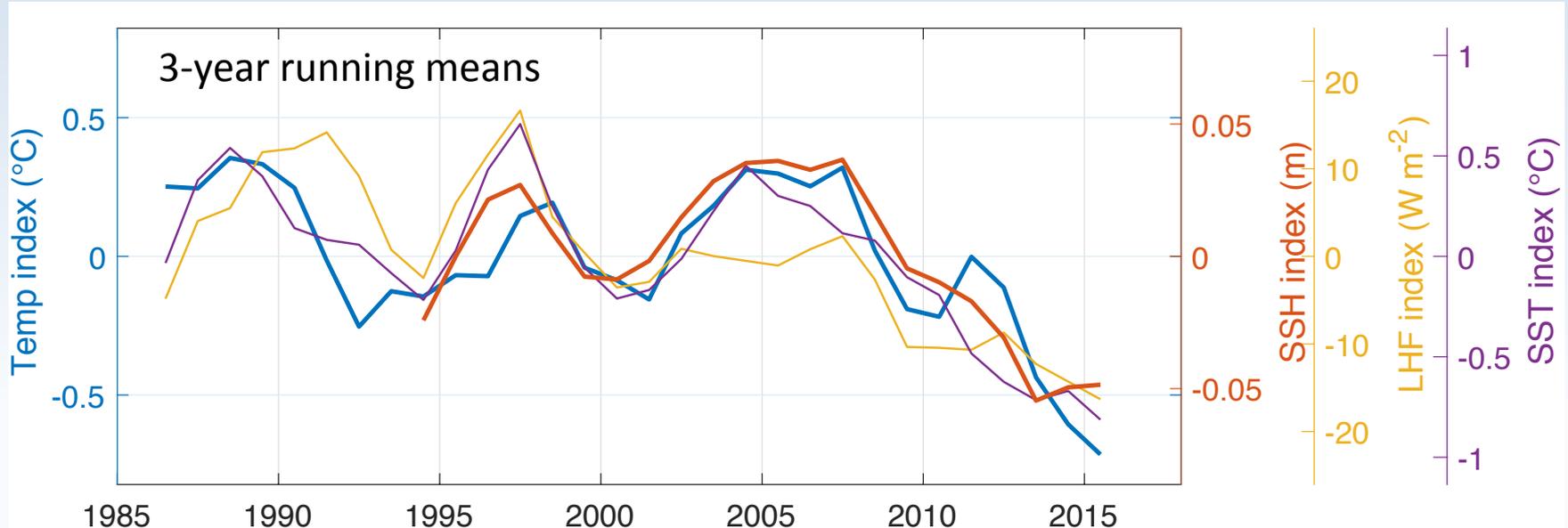
Concurrent changes in the north Atlantic



Indices of change



Indices of change since 1985



Historical values of indices suggest:

- Variability with 8 - 10 years time scale
- RAPID observation began at a time when AMOC was at a maximum
- In recent years the indices are the lowest since 1985

Summary

- The RAPID 26°N time series now spans April 2004 – February 2017
- Since 2009 the AMOC has been 2.5 Sv less than from 2004 to 2008
- Changes in the lower limb are almost all in the lower-NADW
- There have been concurrent changes in the North Atlantic that are similar to those predicted by climate models in response to a reduced AMOC



www.rapid.ac.uk/rapidmoc

das@noc.ac.uk

noc.ac.uk



National
Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

NERC SCIENCE OF THE
ENVIRONMENT