

# The Atlantic Meridional Overturning Circulation: detecting slowdown due to climate change

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# Outline

- What is the Atlantic Meridional Overturning Circulation?
- Why should we care about it?
- Is it slowing because of climate change?
  - How do we know?

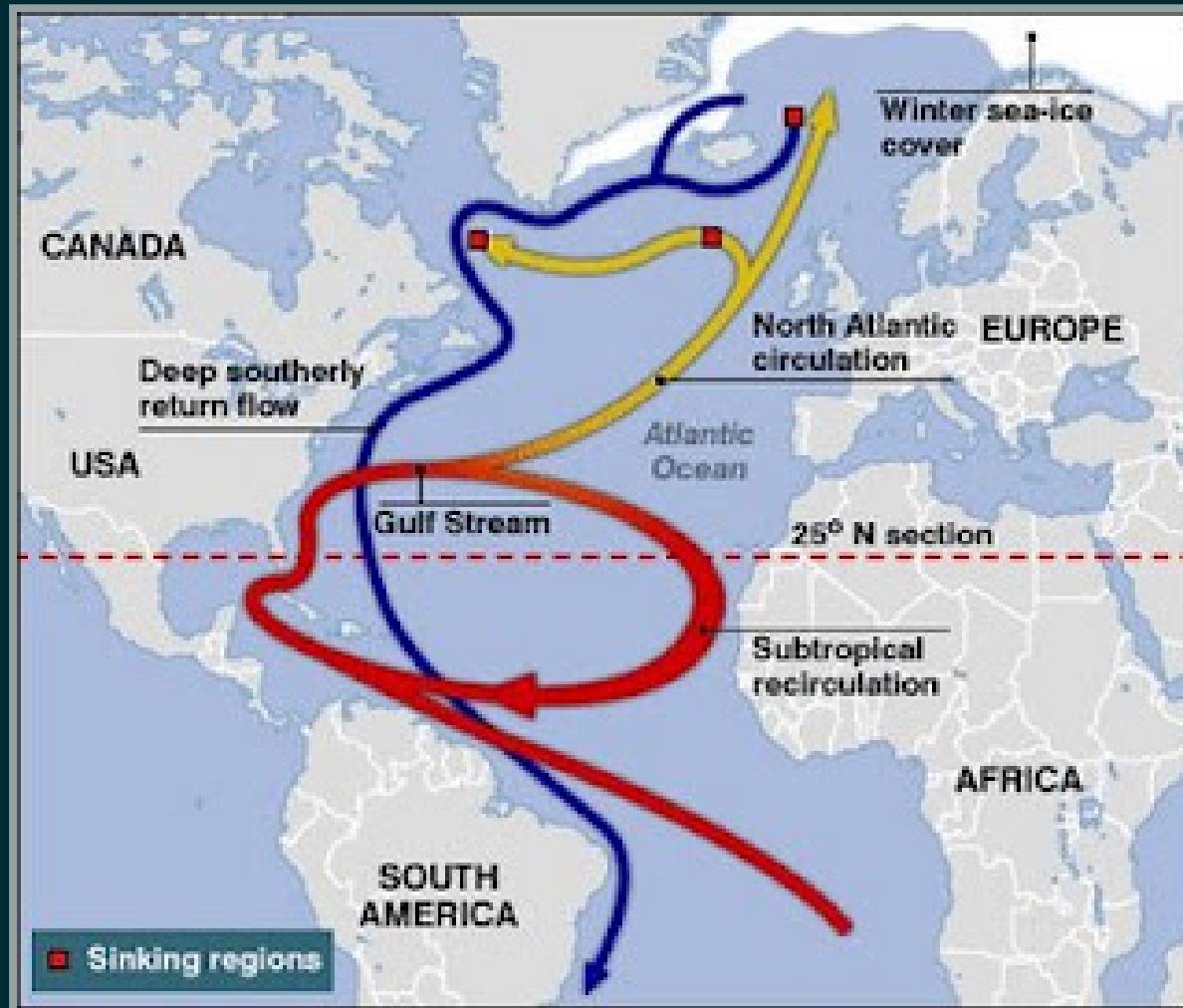
# What is the Atlantic Meridional Overturning Circulation?

# Global thermohaline circulation

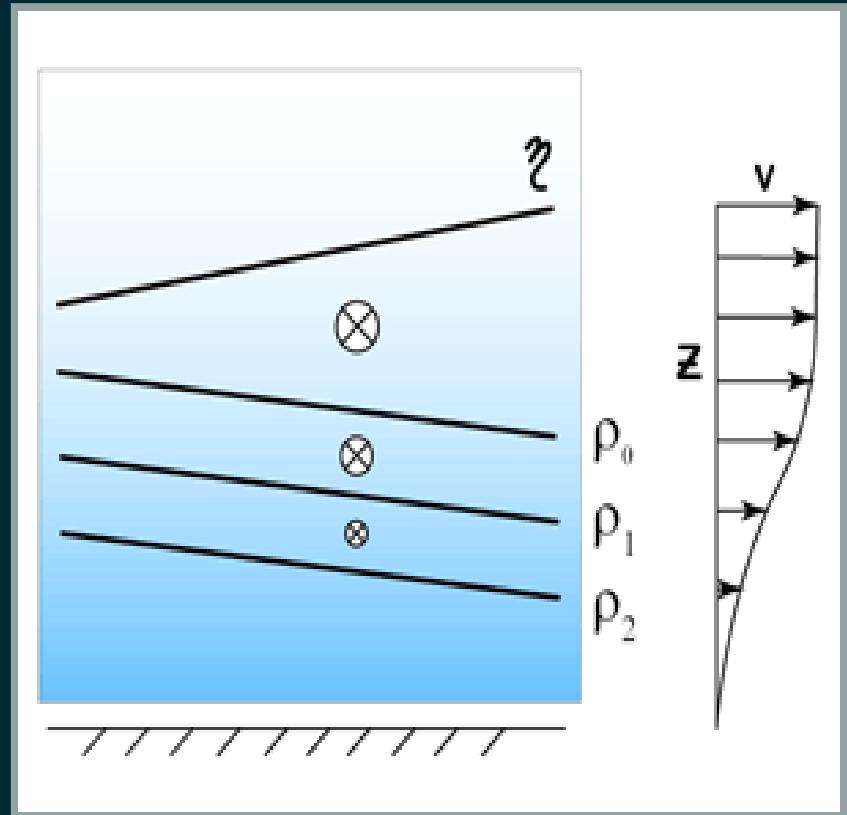
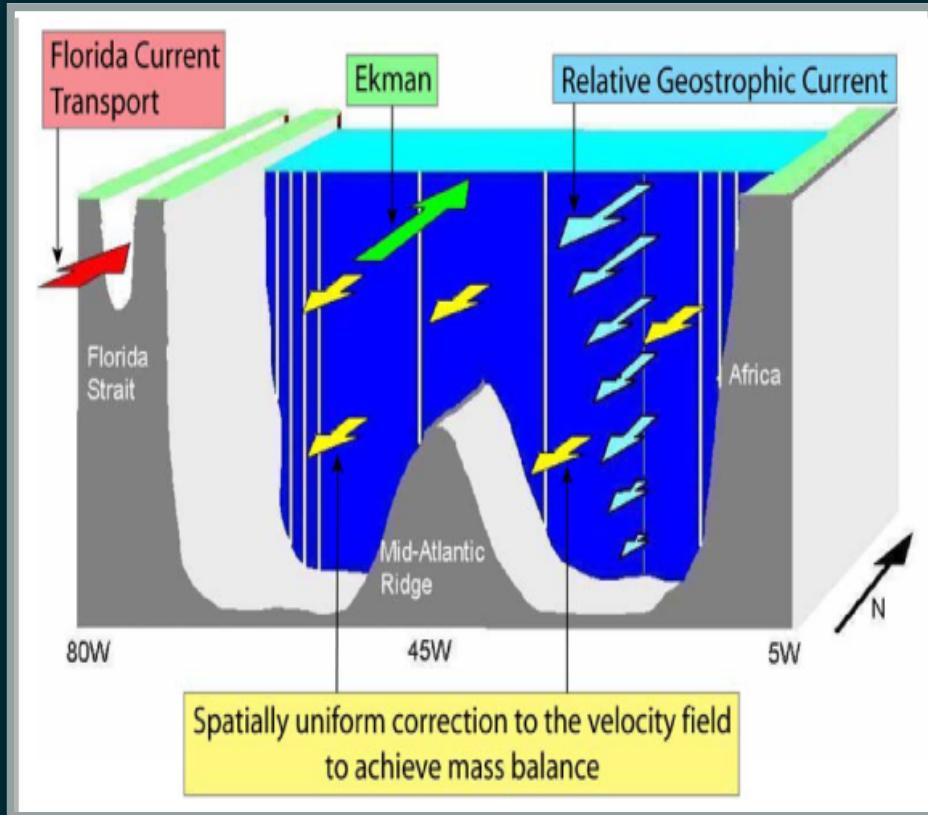


(thermo = temperature; haline = salinity)

# Atlantic Meridional Overturning Circulation (AMOC)



# How is AMOC strength measured?



## Components

- Gulf Stream (Florida Current)
- Wind-driven (Ekman)
- Density-driven (Geostrophic)
- Residual (zero net flow)

3.2

## Geostrophic transport

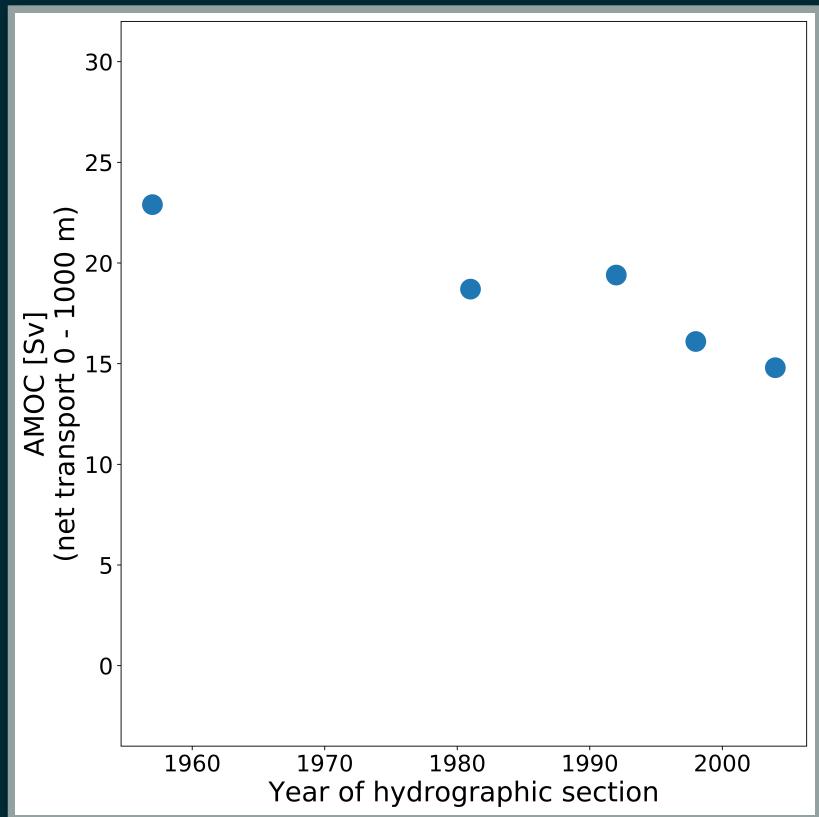
- Difference between E/W density drives N/S flow
- Density measured close to continental slopes

Before 2004, measurements were taken by research ships crossing the Atlantic



PHOTO: C. SPOONER. COLOUR: M. MINOT.

WOODS HOLE OCEANOGRAPHIC INSTITUTION • MASSACHUSETTS



RRS Discovery II leaving Woods Hole  
Oceanographic Institute in 1957

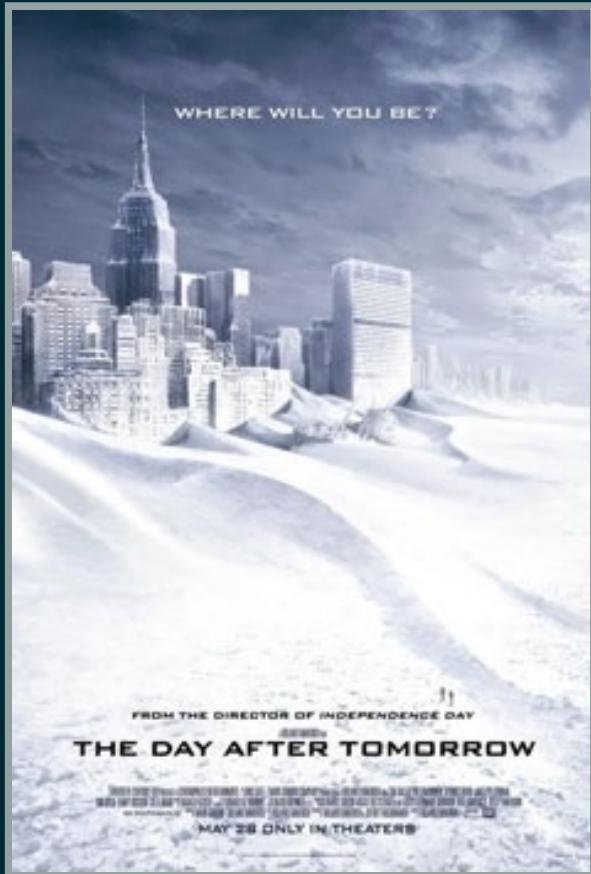
(Data from Bryden et al., (2005))

Climate simulations show that the AMOC is very likely to slow down by the end of this century

*(Intergovernmental Panel on Climate Change (IPCC), 5th Annual Report, 2013)*

So what?

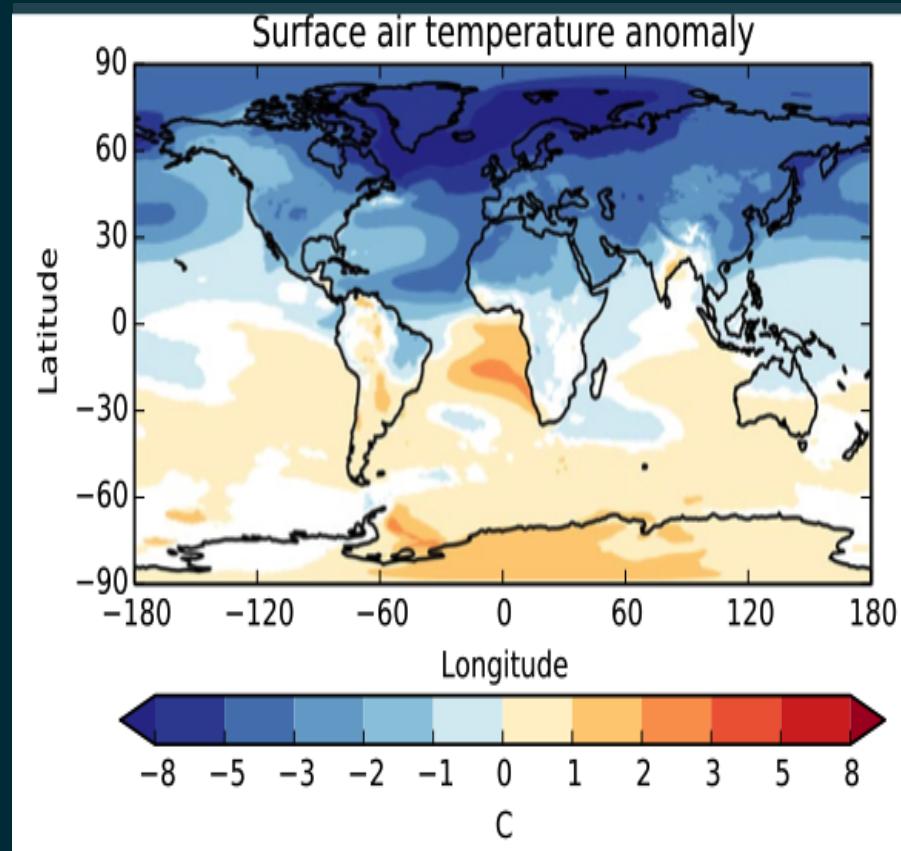
# What happens if the AMOC slows down?



Northern Hemisphere freezes over  
in days!

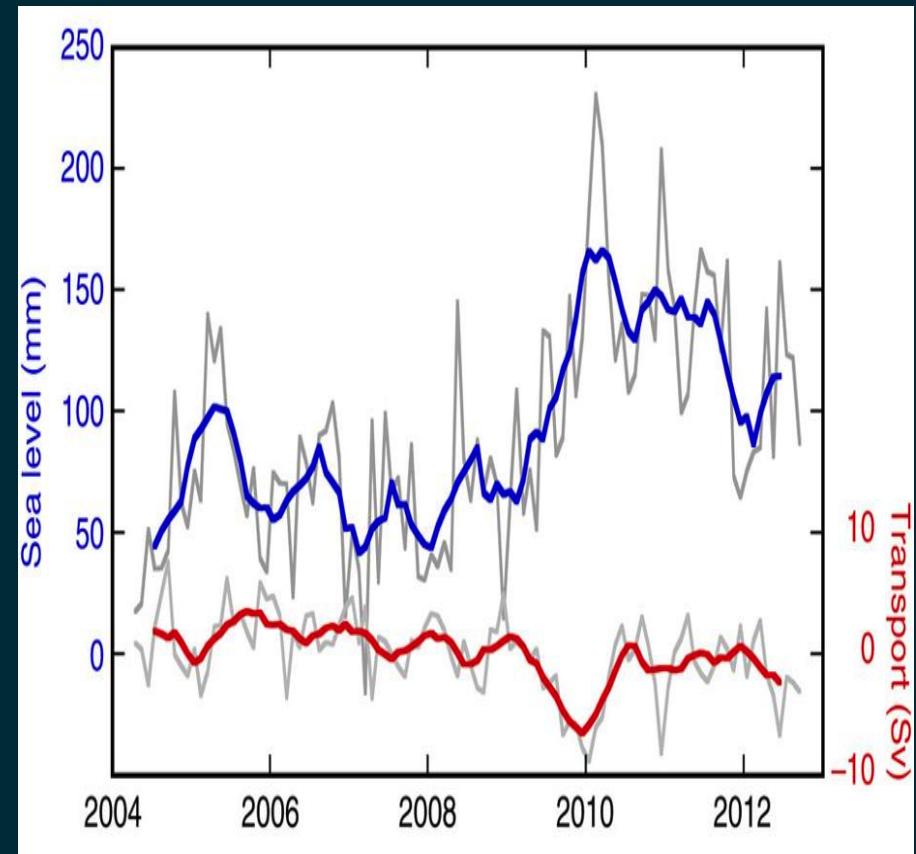
Sea level rises 25 m!

# What happens if the AMOC slows down?



Climate model shows NH air temperatures cool by up to  $8^{\circ}\text{C}$

(*Jackson et al., 2009*)

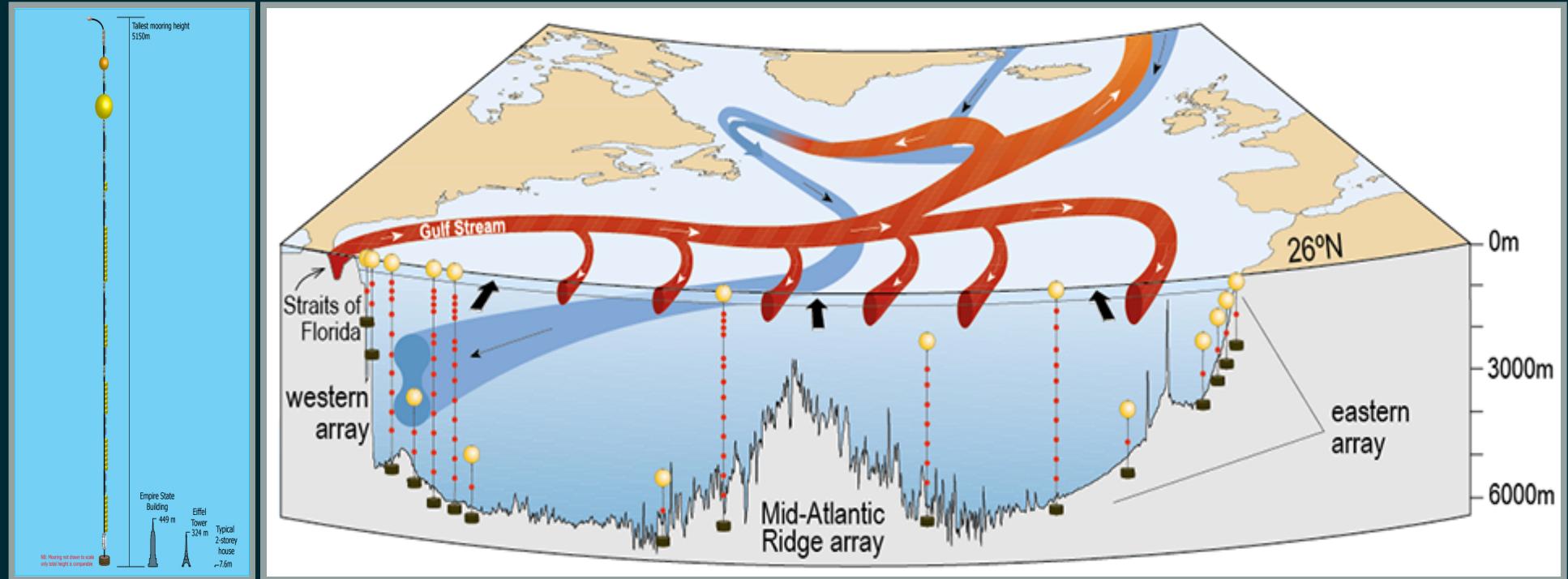


Sea level rose by 128 mm during a 30% AMOC downturn

(*Goddard et al., 2015*)

Concern about an AMOC slowdown led to a full-width observing array being deployed in 2004

# RAPID Project



(from [www.rapid.ac.uk](http://www.rapid.ac.uk))

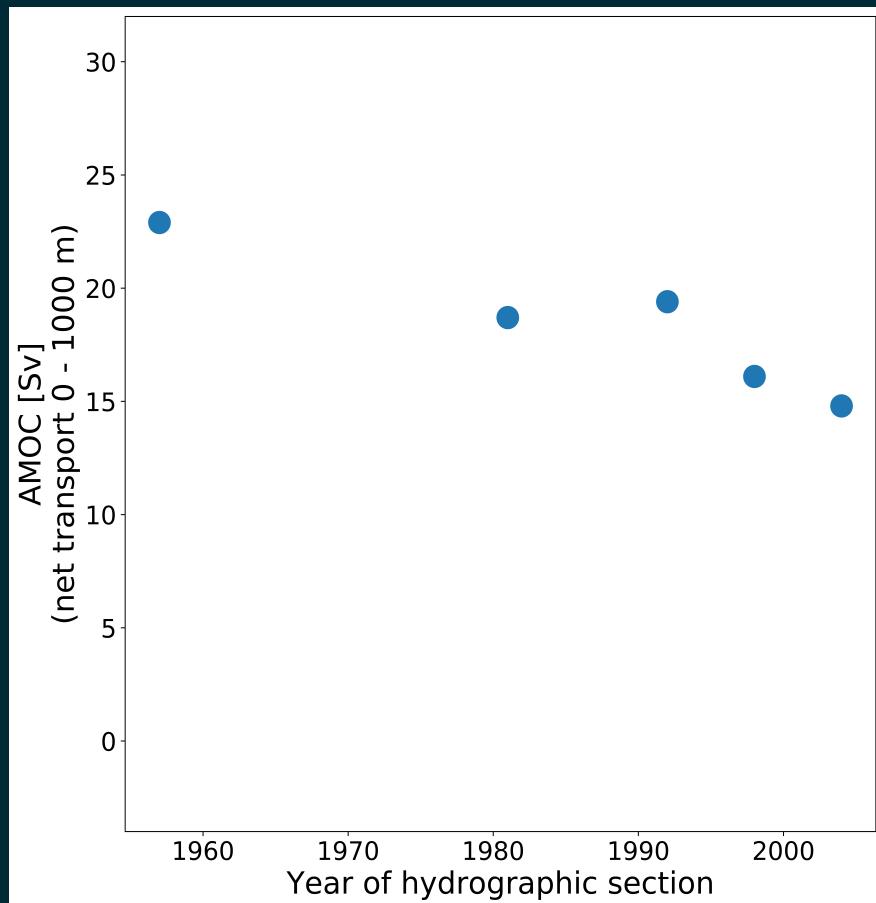
Instruments on the moorings measure temperature, salinity, pressure and current velocity - twice a day

# Data is collected by a research ship every 18 months

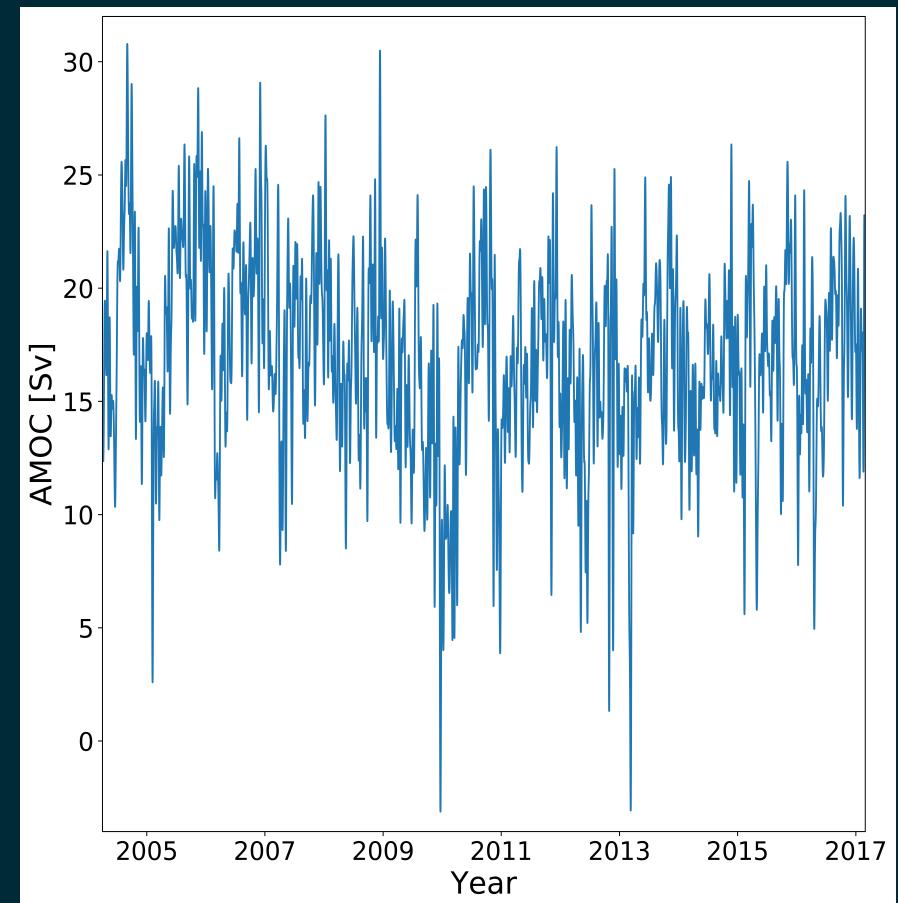


*(Photos: Ben Moat, NOC)*

# What have RAPID results shown?

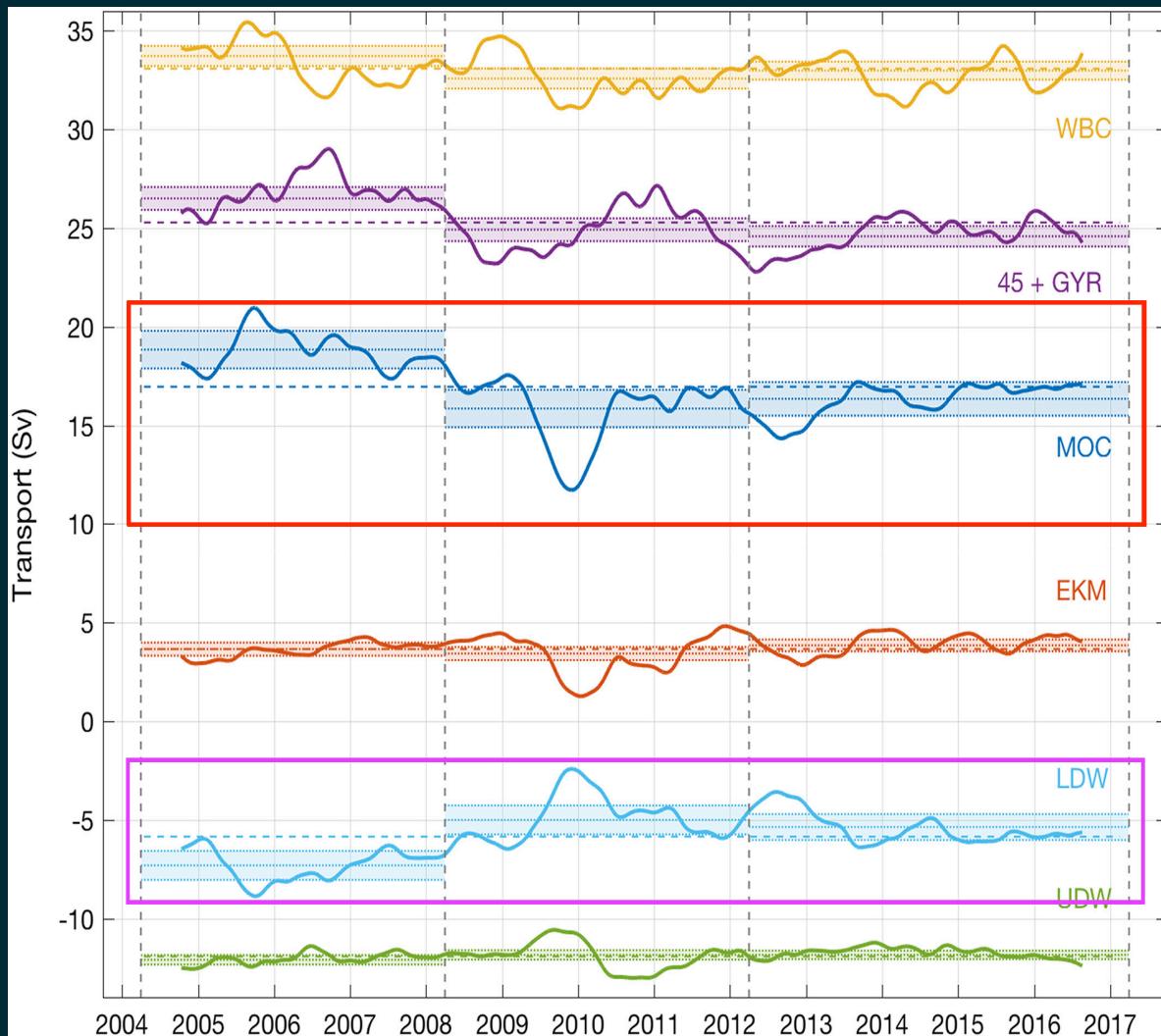


(Data from Bryden et al., (2005))



(Data from [www.rapid.ac.uk](http://www.rapid.ac.uk))

# The AMOC is in a 'reduced state'



## Reduced AMOC

- 2004 - 2008: 18.8 Sv
- 2008 - 2012: 15.9 Sv
- 2012 - 2017: 16.3 Sv

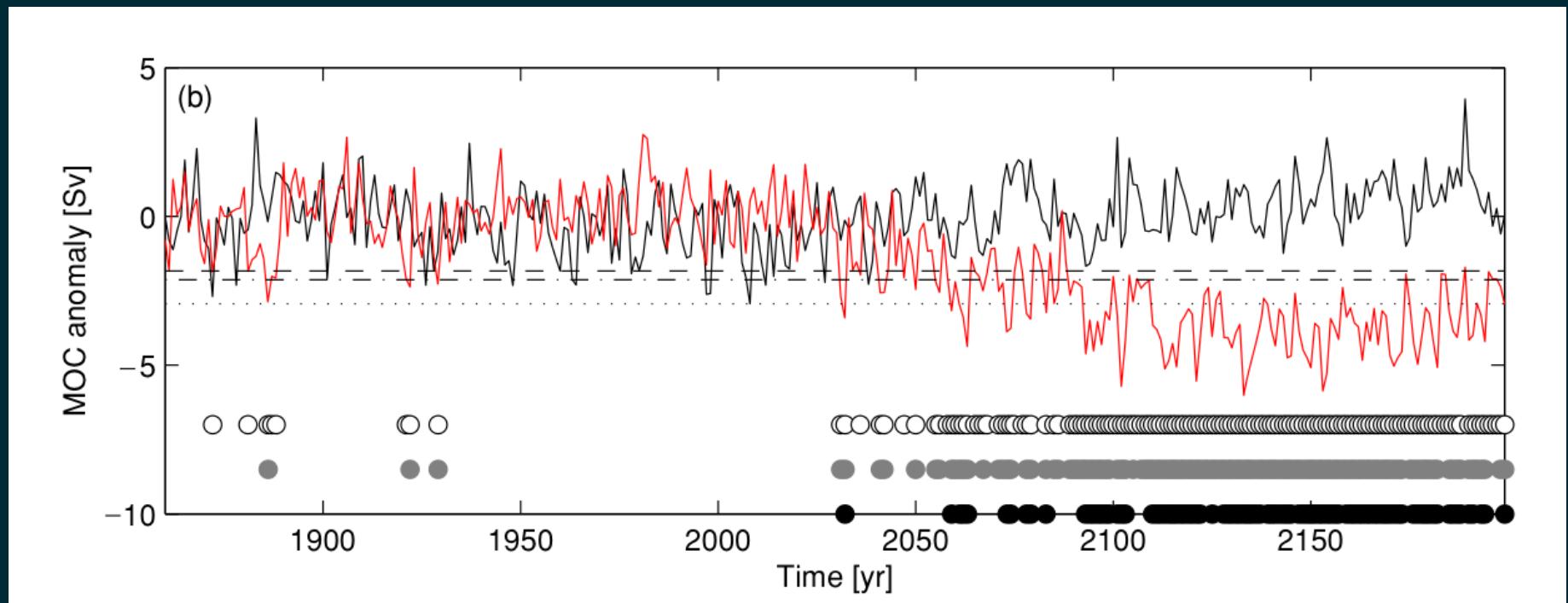
## Reduced LNADW

(3000 to 5000 m)

2008 - 2017 is 30% less than  
2004 - 2008

(*Smeed et al., 2018*)

# Detecting long-term change in the AMOC



(Baehr et al., 2008)

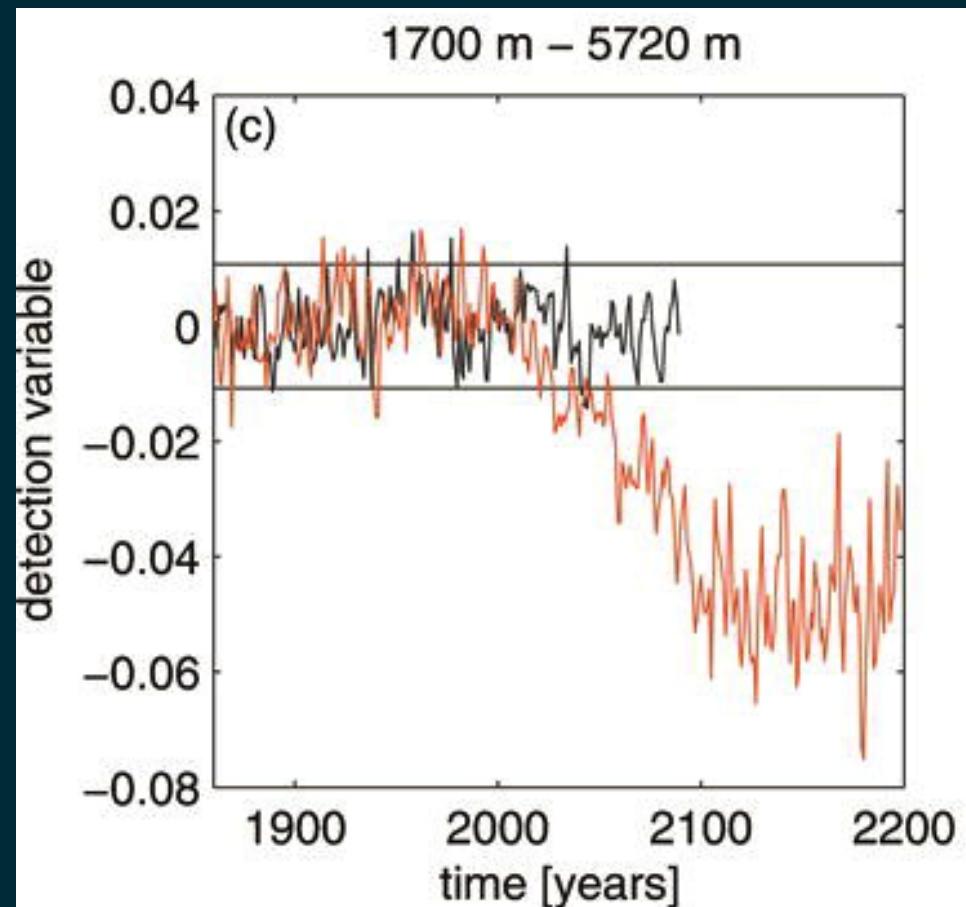
Using the AMOC time series alone means a change takes 40-60 years to detect

## How can we improve detection of AMOC changes?

Reduce variability

Increase length of timeseries

# Reduce variability by combining AMOC with a less noisy climate signal

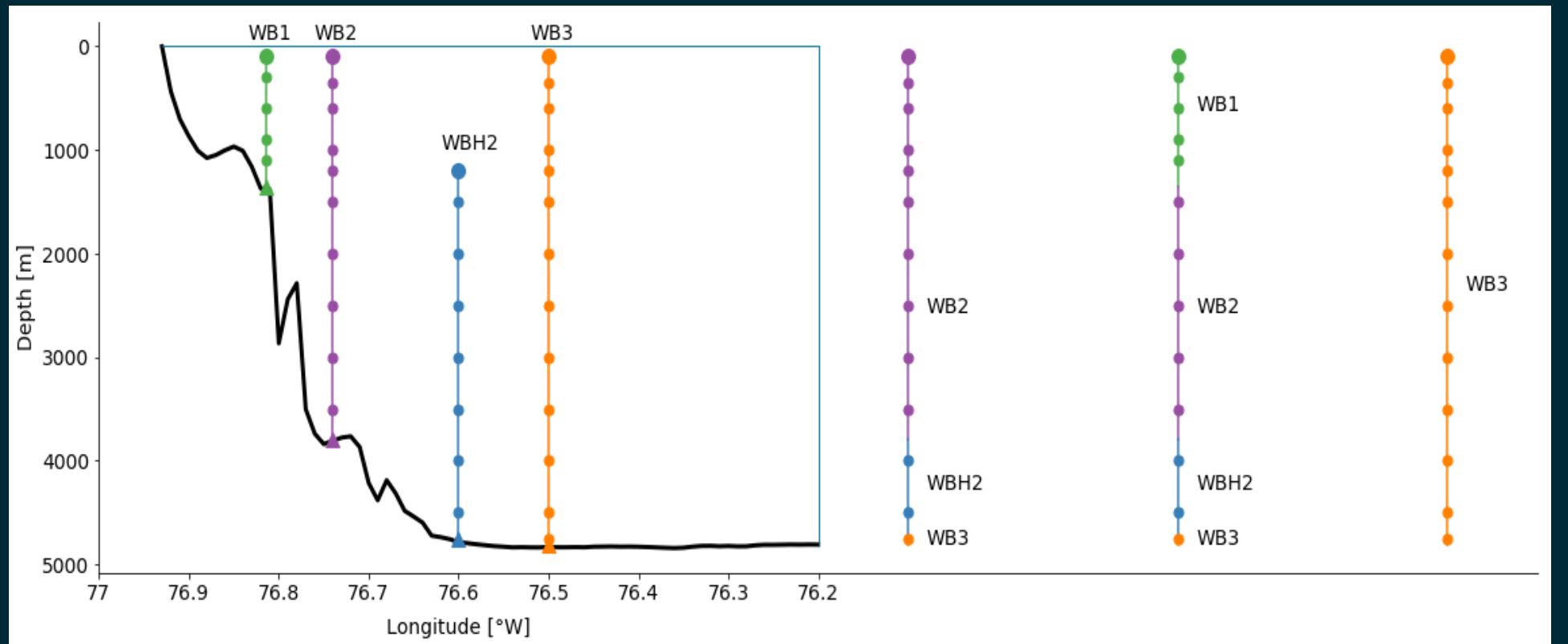


Using deep cross-basin density difference reduces the detection time to 30 years.

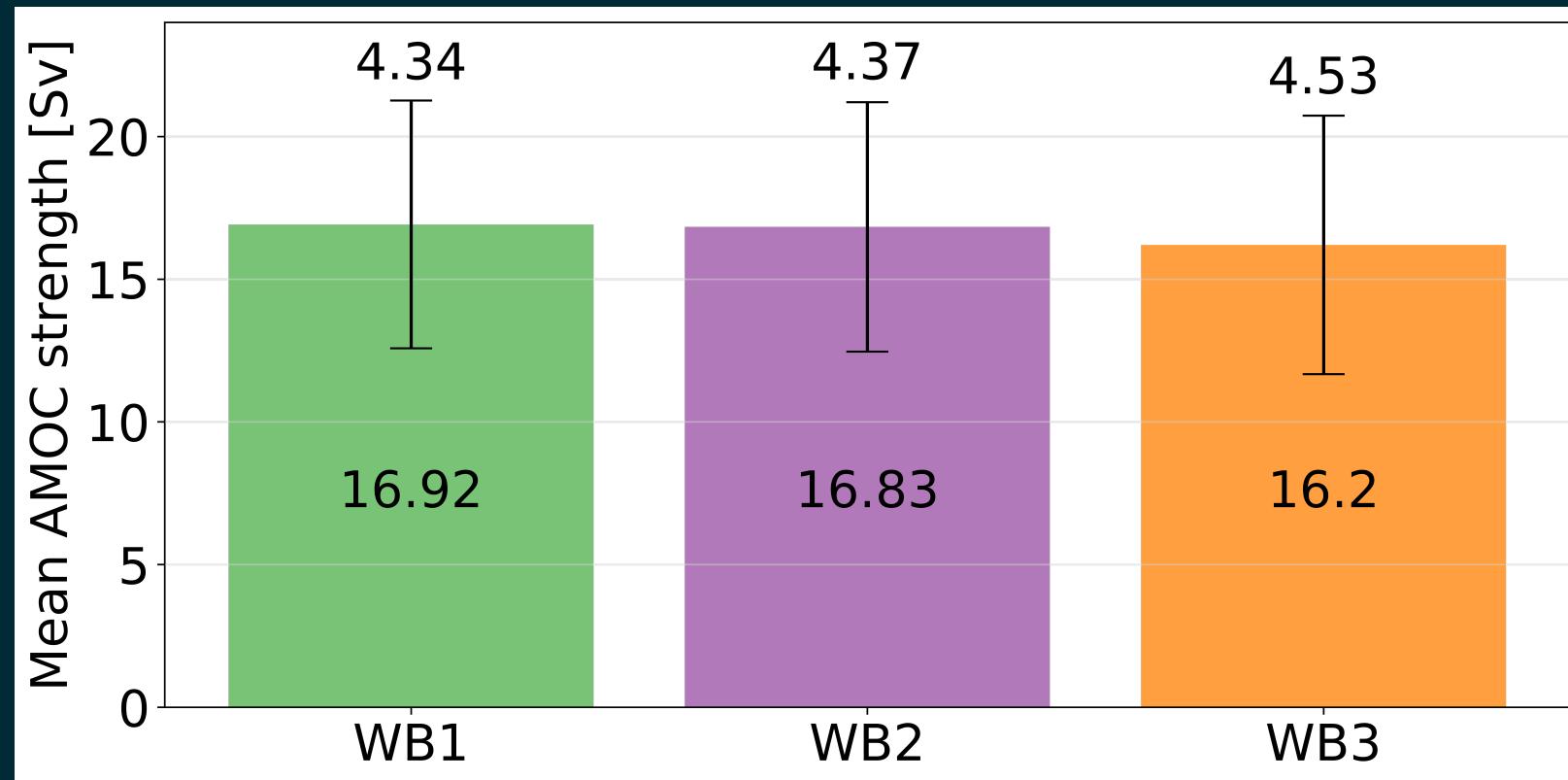
(Baehr et al., 2007)

# Can we reduce variability of AMOC?

Variability due to mesoscale (~100 km, 1 month) eddies is suppressed close to steep continental slopes, e.g., off the Bahamas

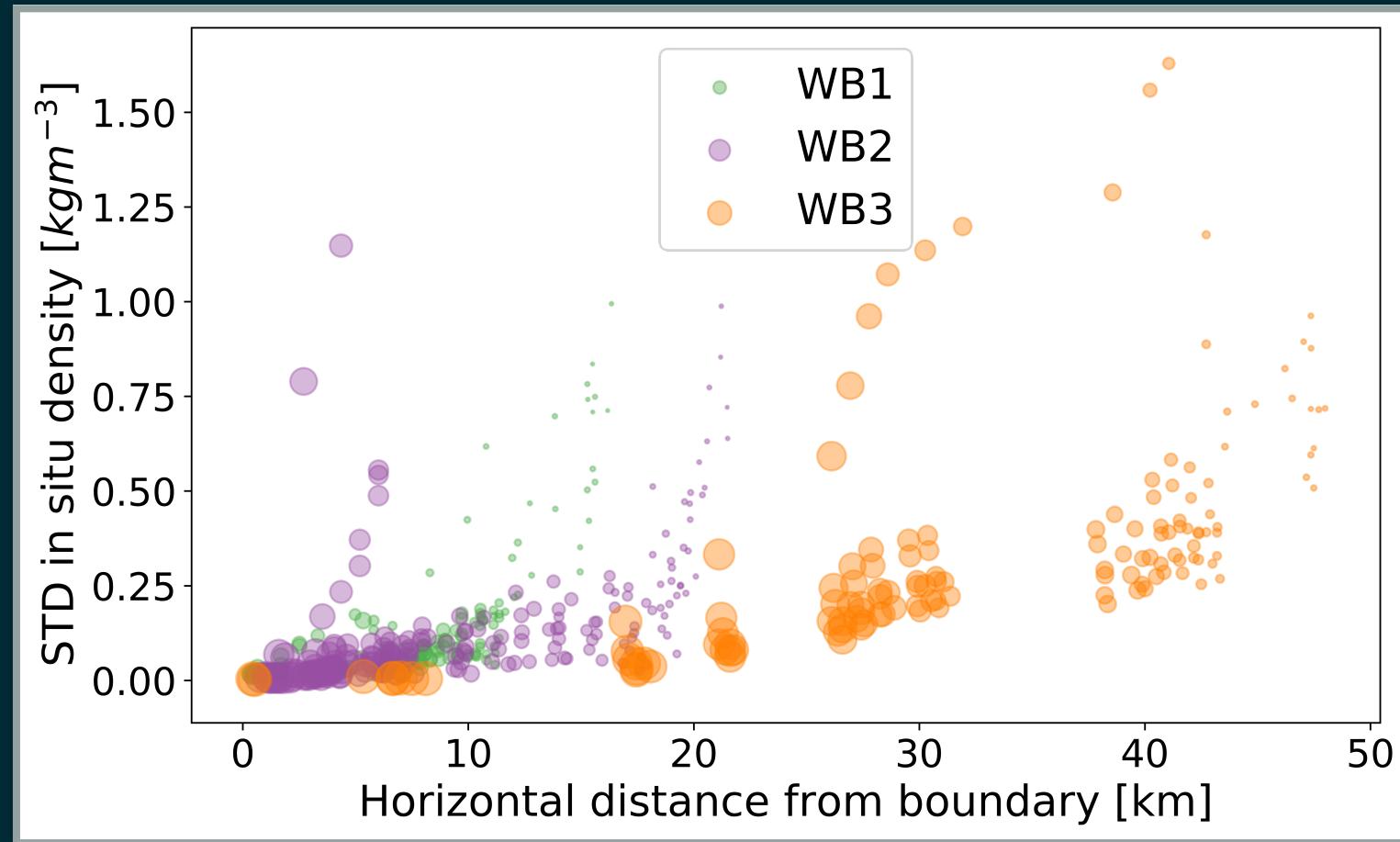


# Mean AMOC transport and variability for different mooring configurations



AMOC noise is suppressed slightly by using measurements closer to the boundary

# Variability of density with distance from boundary



Identifying where variability is lowest may allow us to say more about historical 'snapshot' data, i.e., increase the length of the timeseries.

## Summary

- A slowdown will impact climate in Ireland, UK and further afield
- Detecting slowdown using the AMOC itself may need a timeseries 60+ years long
- Using climate signals with low variability may reduce detection time by half
  - e.g., deep density measured close to steep continental slopes

Thank you!  
Any questions?



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If you were wondering how a 5 km long mooring is deployed from a ship...