Slowdown of the Atlantic Meridional Overturning Circulation

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Outline

1. What is the Atlantic Meridional Overturning Circulation?
    - Satellite imagery, services, modes
2. What is happening?
    - Data and charts of AMOC slowdown
3. Why is this important?
    - Effects of AMOC slowdown
4. Works Cited

Atlantic Meridional Overturning Circulation

- AMOC/Gulf Stream is a major ocean current of the North Atlantic Gyre
- Circulation due to thermohaline density differences
- Typical strength of 18.5 +- 1.0 Sv
- Heat Transport of 1.3 PW
- 25% of atmosphere-ocean heat transport

Goodard et. al 2015

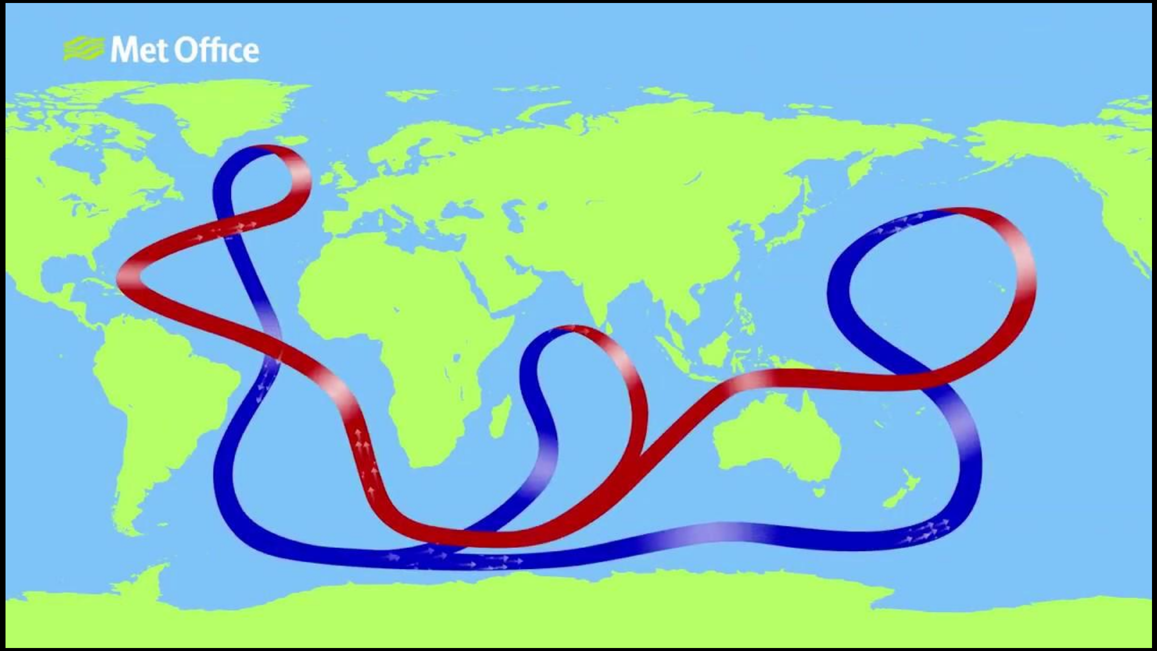


Photo: Met Office 2021

Services

TEMPERATURE MITIGATION

SALINITY CHANGES

NUTRIENT AND CARBON BALANCES

- Sea surface height
- Sea surface topography

Satellite Altimetry

- TOPEX/Poseidon
- Jason-1
- Jason-2
- Jason-3

Satellite Altimetry

- TOPEX – measured ocean surface topography and improved understanding of ocean circulation effects on climate change
- **Jason 1 –** follow up to TOPEX mission
- **Jason 2** – provides precise data regarding ocean surface topography like TOPEX and Jason 1
- **Jason 3** – the 4^{th} satellite mission to measure ocean surface topography

Photo: NASA 2020

NASA 2020; NESDIS

On Site Measurements

<u>RAPID-MOCHA-WBTS</u>

- Mooring arrays
    - Current meter moorings
    - Dynamic height moorings
    - Echo-sounders
- Measure
    - Meridional volume (in Sv)
    - Heat transport

Sanchez-Franks et al. 2021

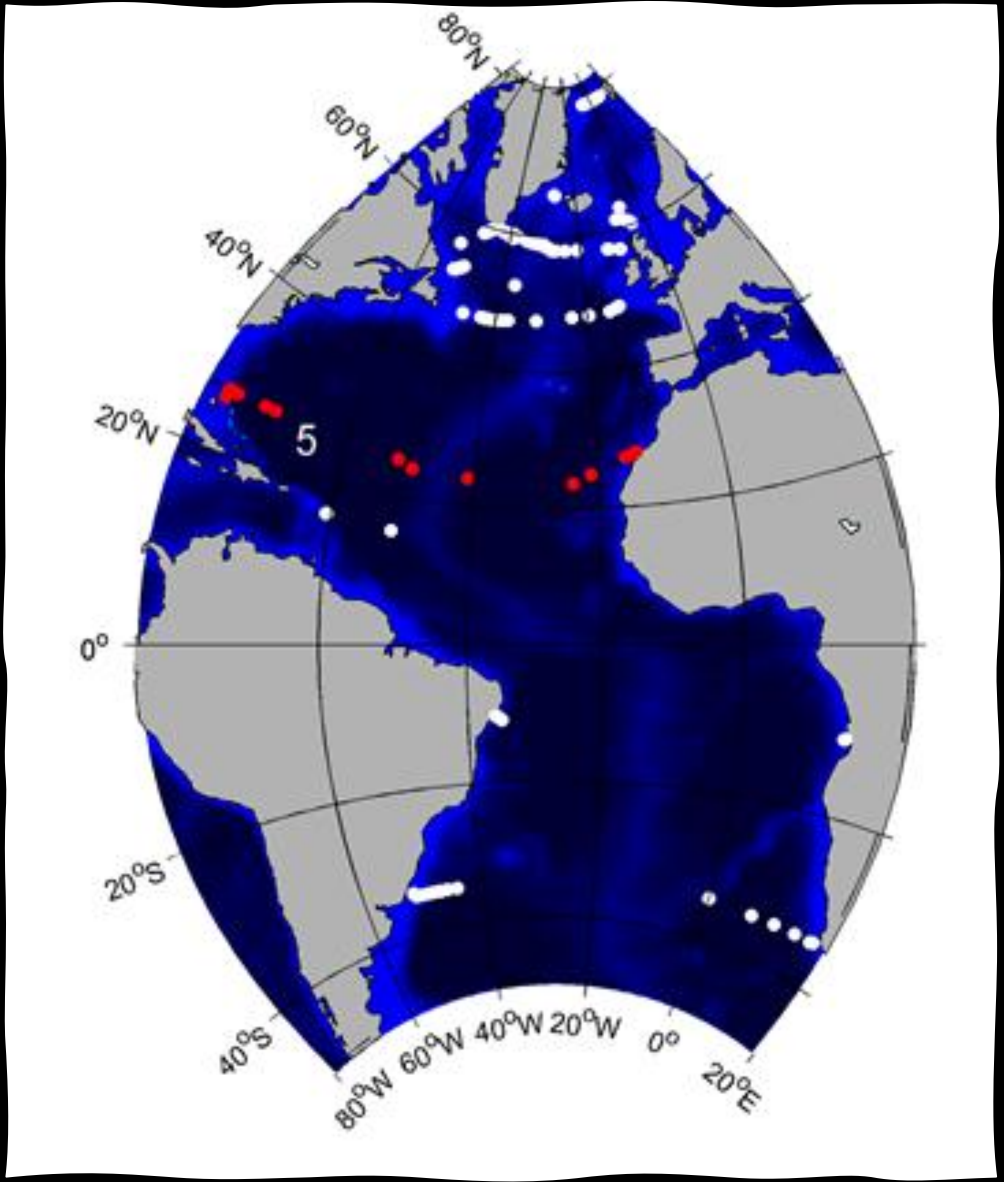


Photo: OceanSITES, n.d.

More About Moorings …

- RAPID program relies on ocean interior geostrophic balance
- It estimates basin-wide interior flow
- Measures absolute dynamic topography across North Atlantic
- Define AMOC transport as the sum of 3 components
- It estimates geostrophic transport (correlates SLA data with dynamic height data)

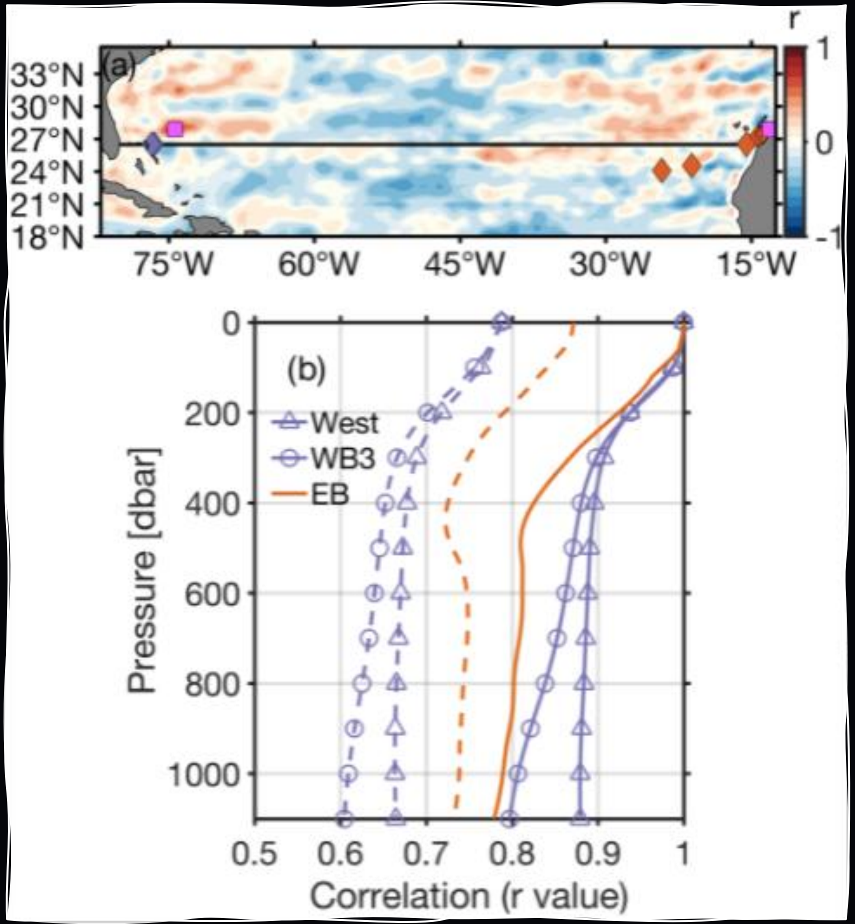
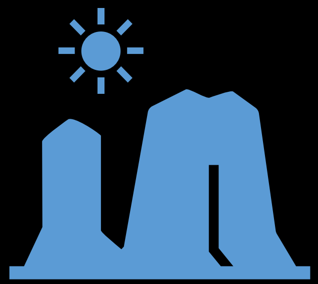


Photo: Sanchez-Franks et al. 2021

Sanchez-Franks et al. 2021

Strong Mode



State for the last 10,000 years

Since last glacial period

(Henry et al. 2016)

Strong distribution of heat through planet

18.5 ± 1.0 Sverdrups

Weak Mode

- Last occurred around previous glacial ice period (Henry et al. 2016)
- Weaker distribution of heat
  - See-saw effect
- Last time it occurred:
  - Cooler northern hemisphere
  - Warmer southern hemisphere

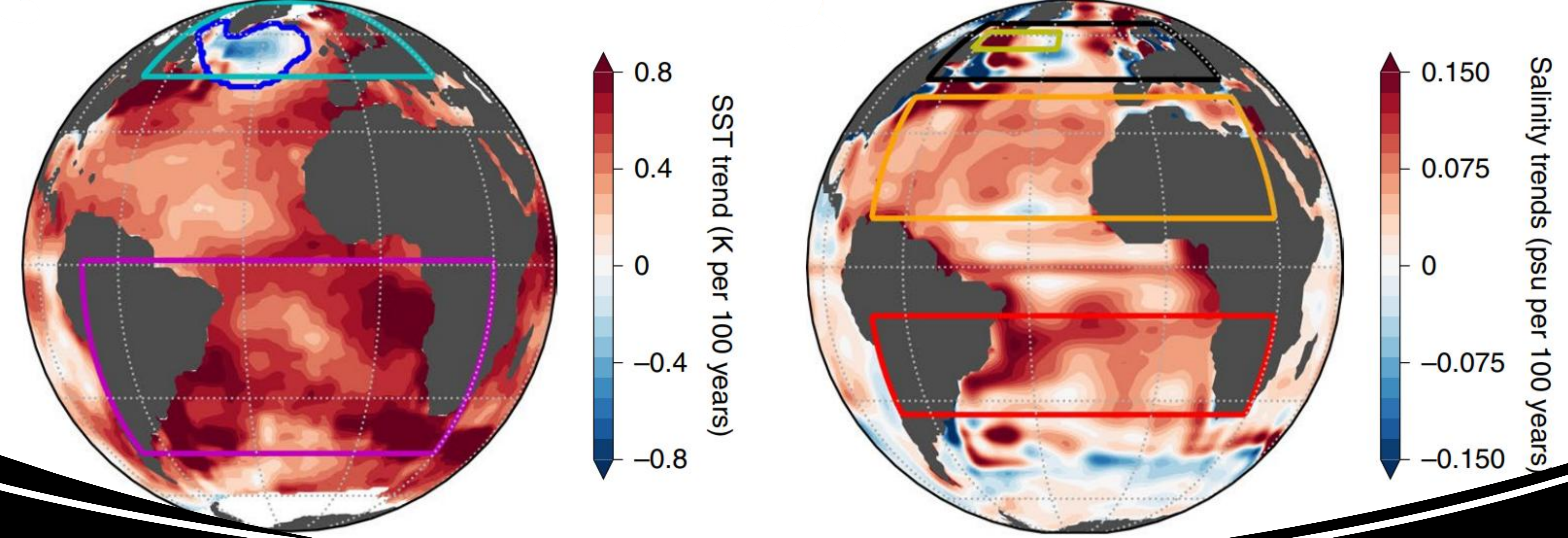
The AMOC is weakening

- Reduced salinity
- Thermal expansion

Slowdown

- Reduced salinity
- Thermal expansion

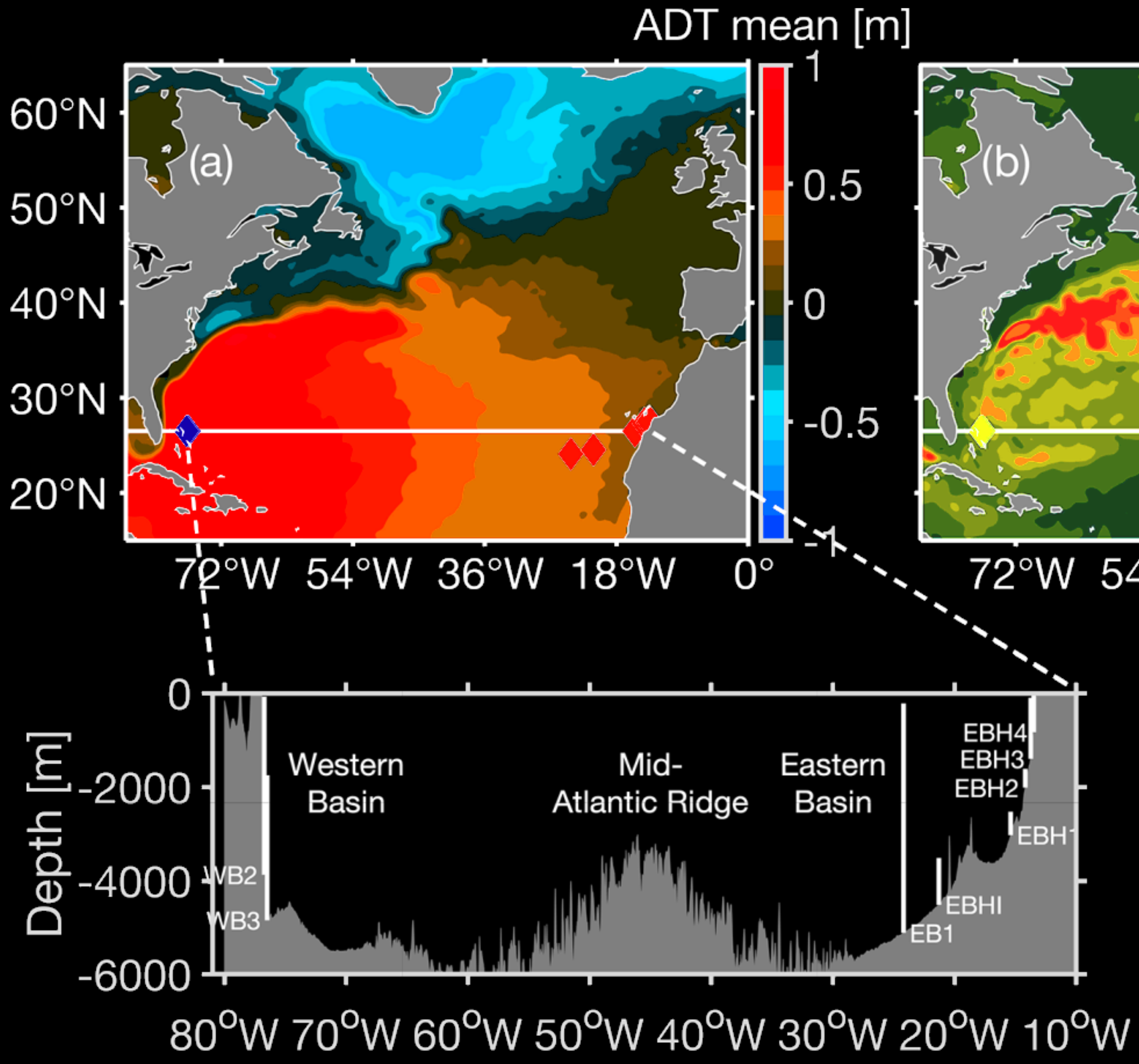
- Reduced salinity
- Thermal expansion

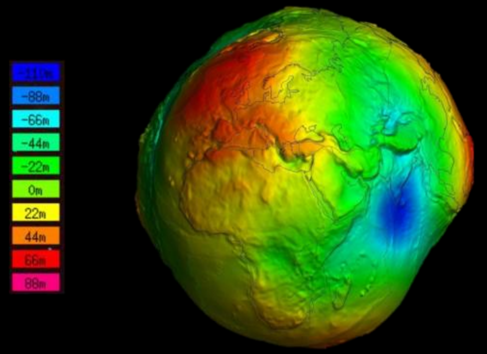


Boers et al. 2021

Early warning signs

- Increased variance in:
  - Sea surface temperature (SST)
  - Sea surface salinity (SSS)

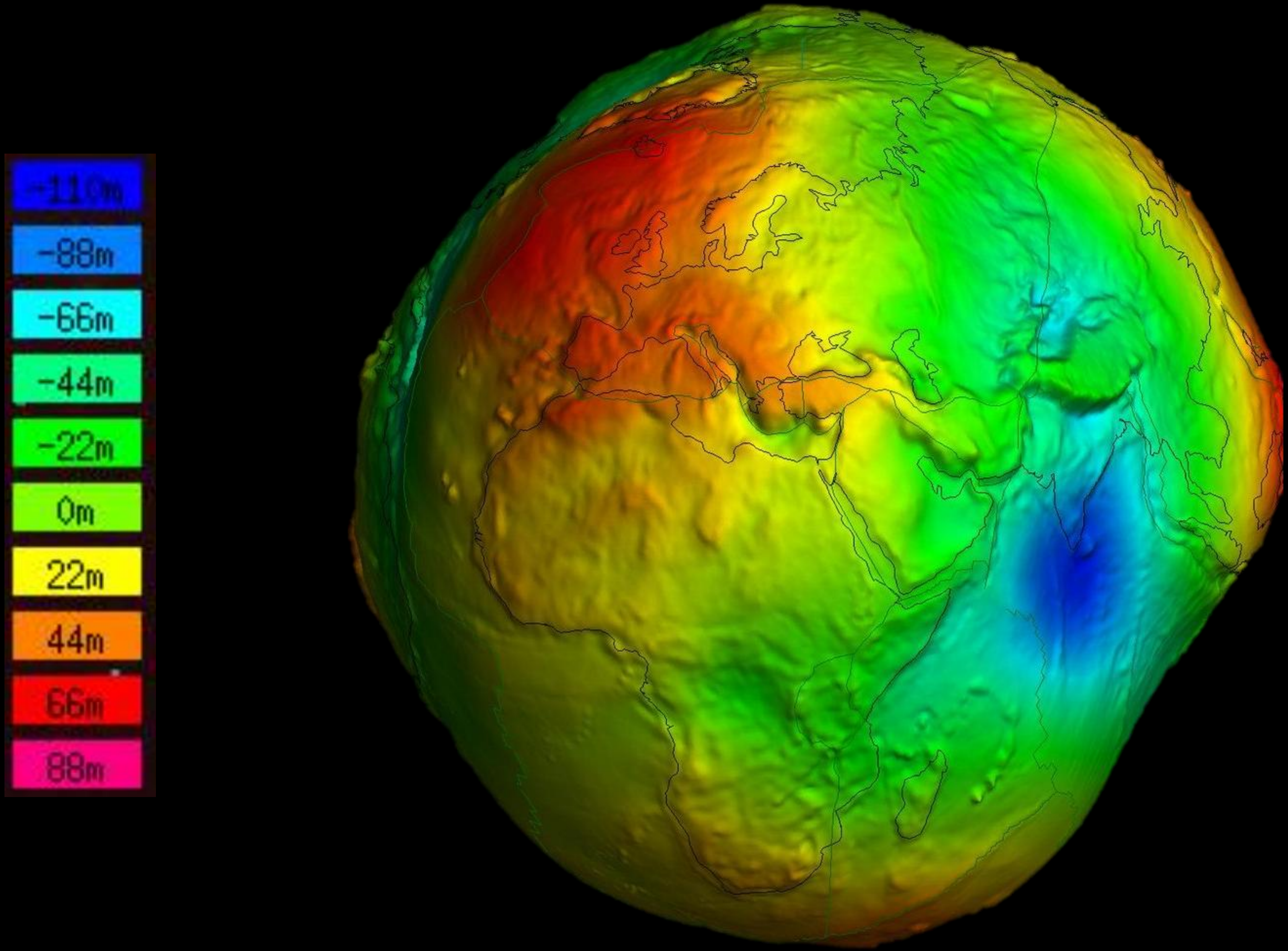




Ince et al. 2019

Slowdown

Sanchez-Franks et al. 2021



Ince et al. 2019

Quantifying the slowdown

<u>19th century</u>
initial, small weakening

<u>Mid-20th century</u>
strong, rapid decline in AMOC strength

Quantifying the slowdown

General information			Change-point testing		Significance testing	
Proxy	Time interval	Long (L)/short (S)	95% interval	Significant reduction	Lowest interval	Significantly lower
Temperature anomaly[5]	900–1995	L	1874–1902	Yes	1946–1995	Yes
Subsurface temperature proxy[3]	400–2000	L	1817–1856	Yes	1951–2000	Yes
$\delta^{15}N$ data[6]	1926–2002[a]	S	1970–1976	Yes	1953–2002	Yes
Sortable-silt data 48JPC[3]	380–1995[b]	L	1763–1878	Yes	1876–1925	No
Sortable-silt data 56JPC[3]	1475–2003	L	1863–1883	Yes	1904–1953	No
$\delta^{18}O$ data[7]	708–1962	L	1881–1916	Yes	1913–1962	Yes
T. quinqueloba abundance[10]	392–2013	L	1920–1958	Yes	1914–2013	Yes
Temperature proxy[2]	1871–2016	S	1967–1970	Yes	1967–2016	Yes
$\delta^{18}O$ data[7]	1904–2001	S	1960–1975	Yes	1952–2001	Yes
Marine productivity[9]	1767–2013	S	1950–1956	Yes	1964–2013	Yes
Ocean heat content[8]	1955–2019	S	For this dataset, the algorithm did not find a significant change point.		1990–2019	Yes

Caeser et al. 2021

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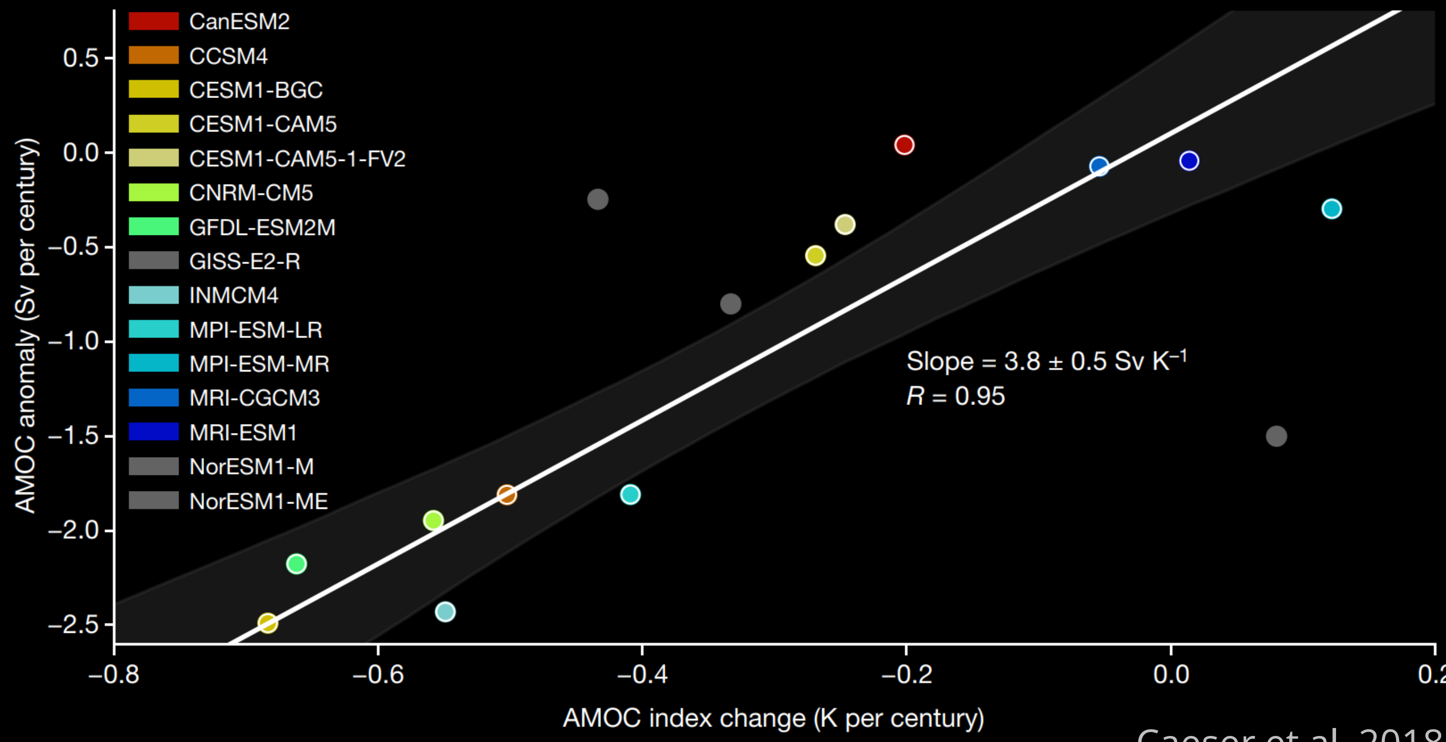
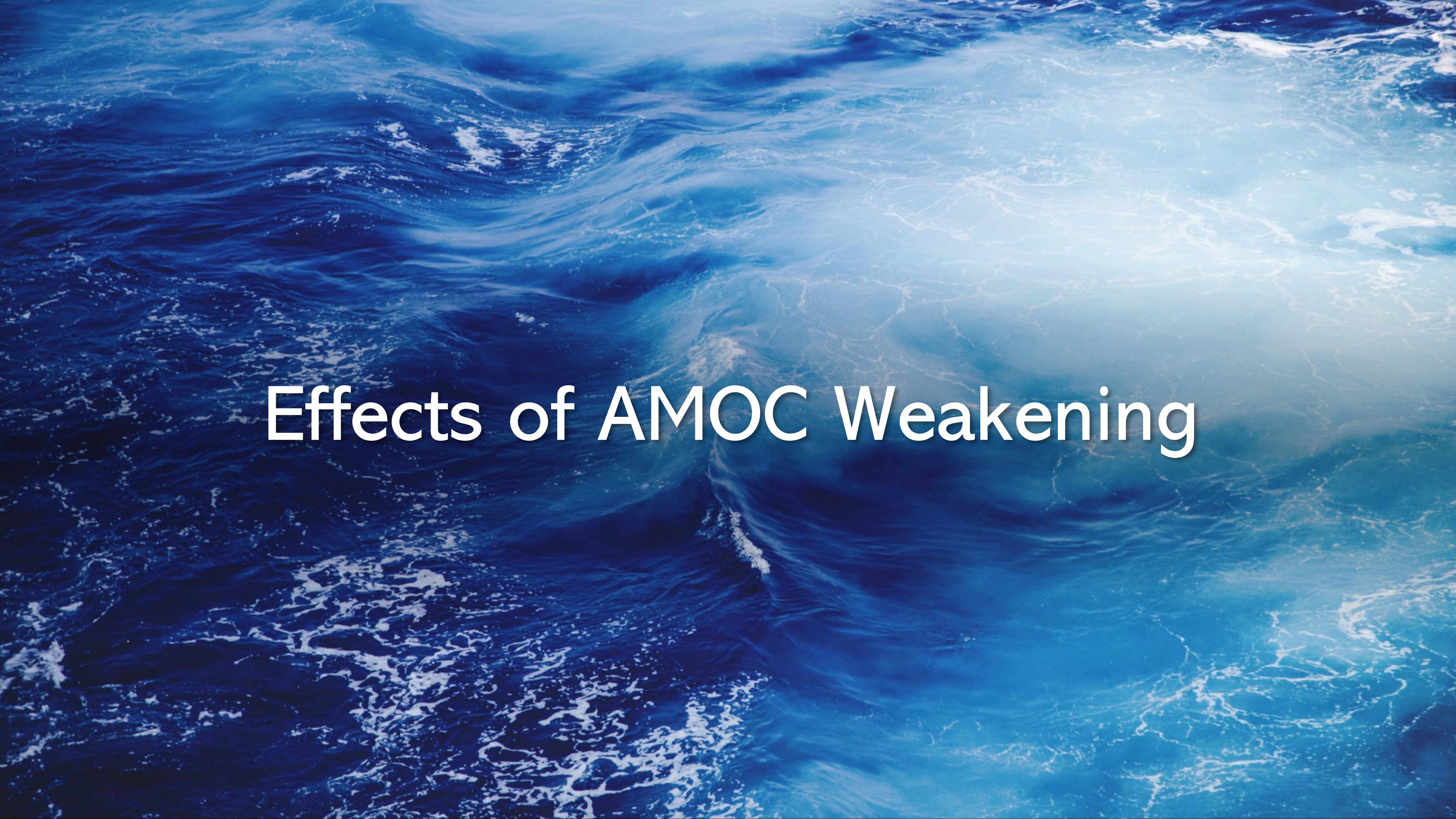
Quantifying the slowdown

- AMOC weakened by 3 ± 1 sverdrups
- 15% reduction in AMOC strength

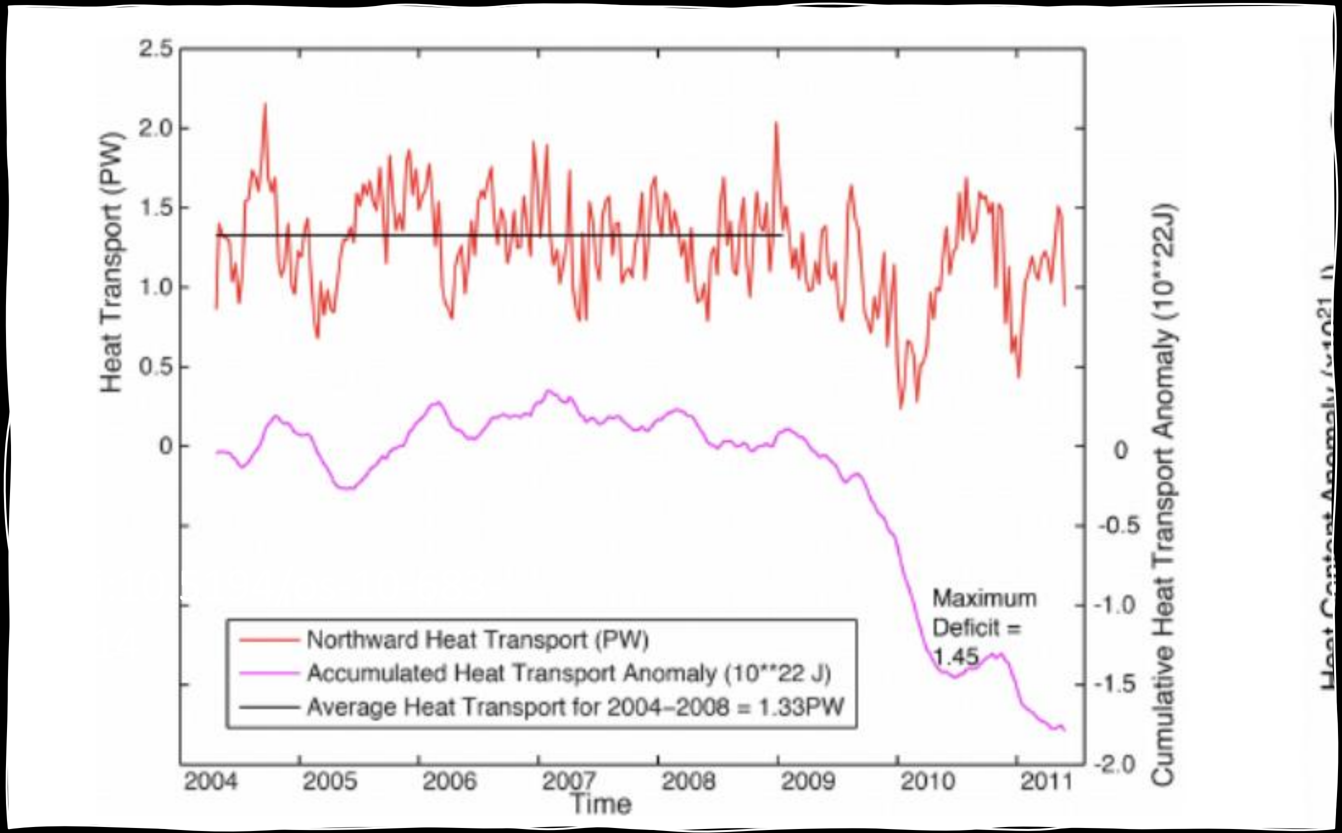


Caeser et al. 2018



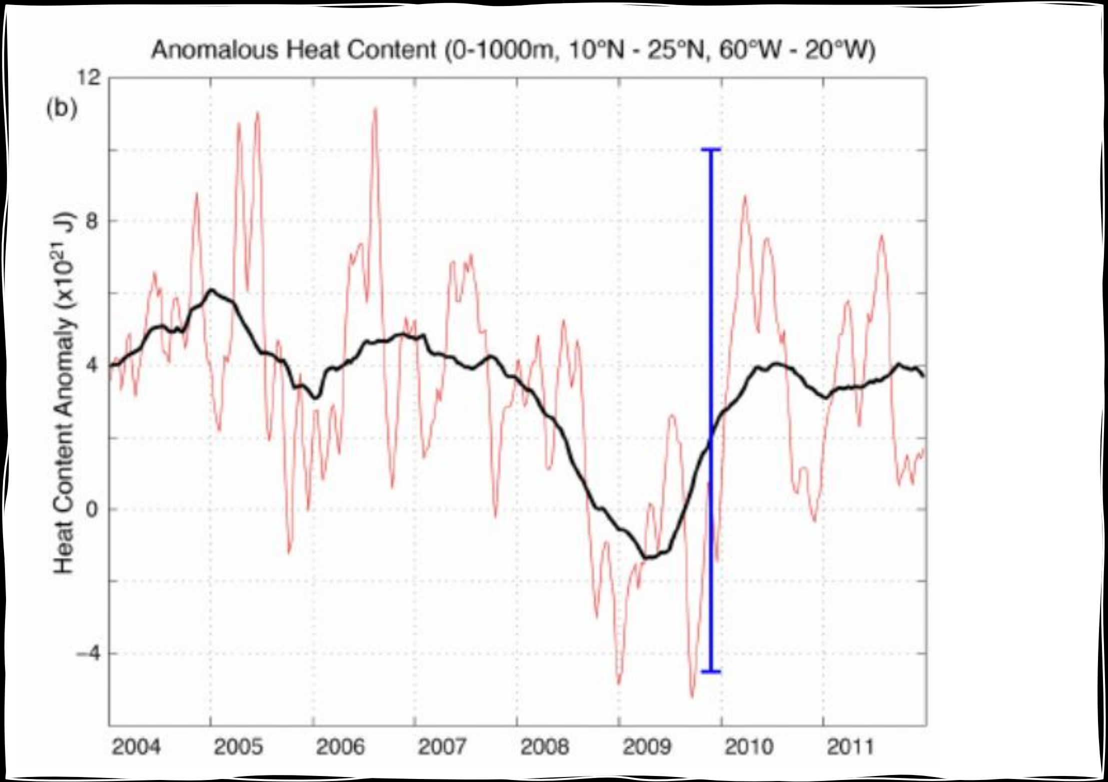
Effects of AMOC Weakening

Reduction in Heat Transport

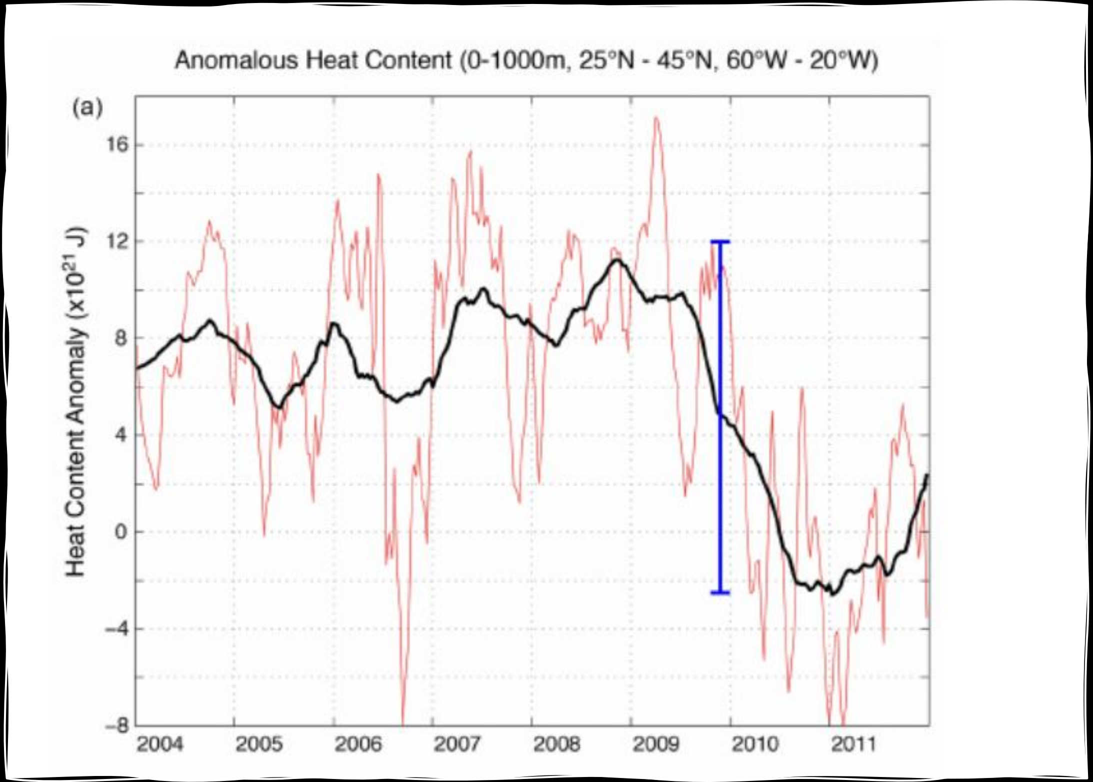


Bryden et. al. 2010

Reduction in Heat Transport



Bryden et. al. 2010



Bryden et. al. 2010

Effects

Record Low NAO temperatures 2010-2011

Record low NAO index of –1.67

Coldest winter in United States in 25 years

03

Average Central England Temperature was 2.43

Bryden et. al 2010

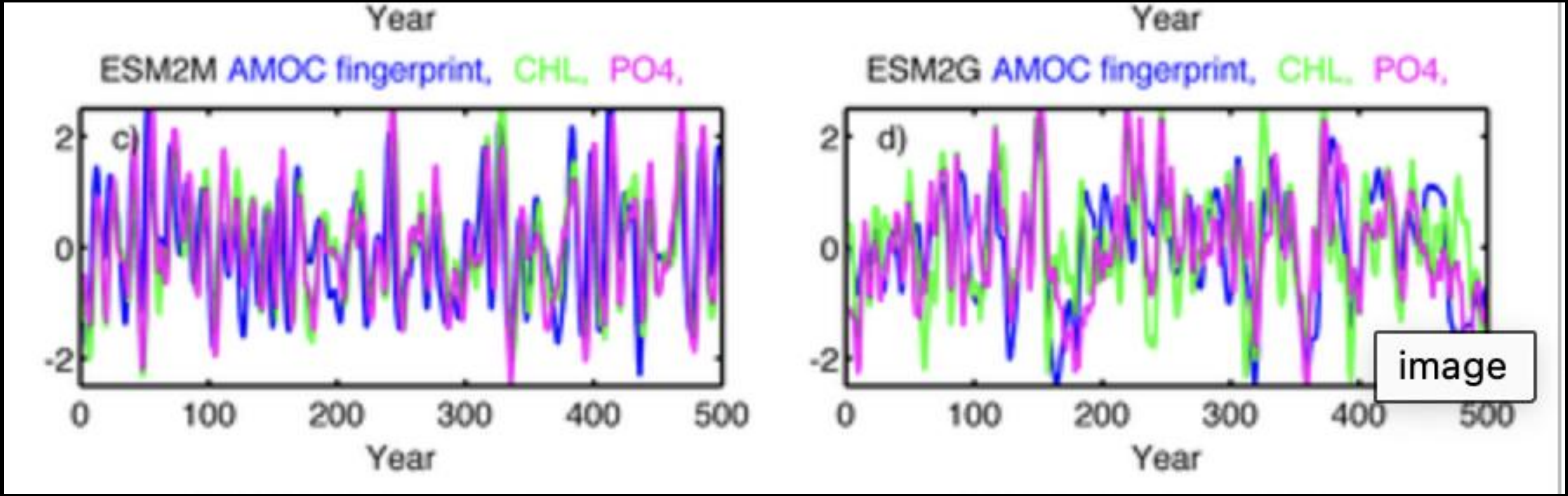
Sea Level Rise

- Disrupts the sea level gradient across greater North Atlantic Current
- Rise in Coastal Sea Level
- Extreme SLR event 2009-2010
  - Coastal sea levels rise of 100 mm in off NYC
  - 1 in 850 year event

Goodard et. al 2015

Nutrient flows

- AMOC in strong mode is positively correlated to levels of chlorophyll and nutrient upwelling (PO4)
- Important for changes in the localized carbon cycle and fisheries



Sanchez-Franks et al. 2015

Effects

Sustainability/Resilience

- Weakening of the AMOC projected under all Representative Concentration Pathways
- Collapse unlikely
- Long term effects could compound/increase in frequency
- Resilience of AMOC tied to Climate Change mitigation and low RCP

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Works Cited

Thank You