Insights from the paleoceanographic record of deep circulation in the North Atlantic and Arctic Oceans

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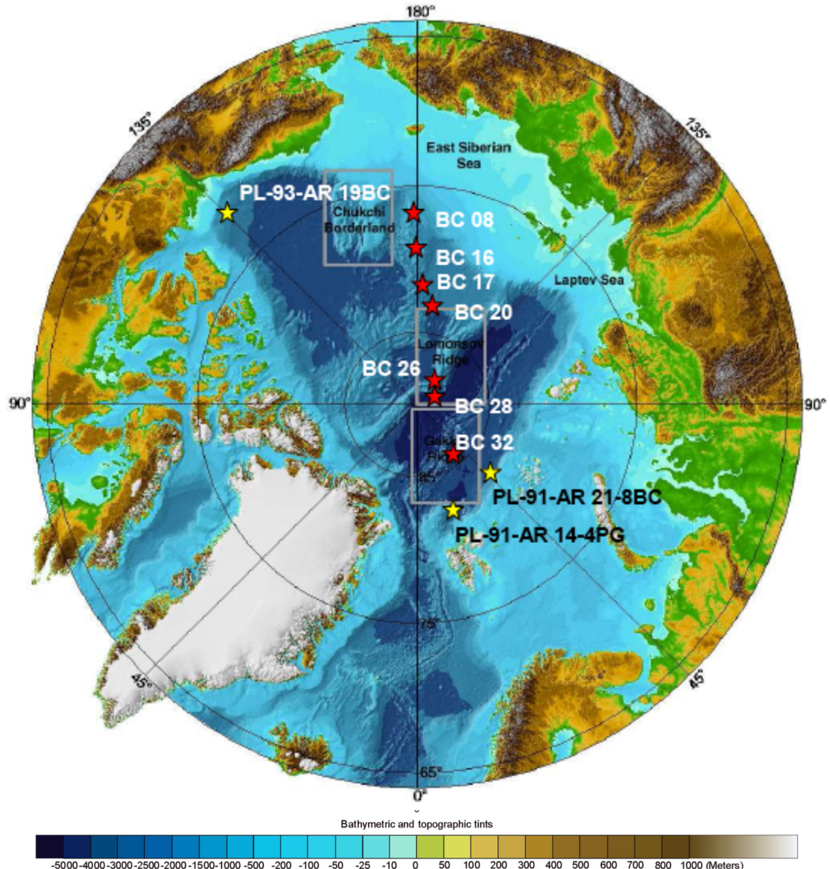
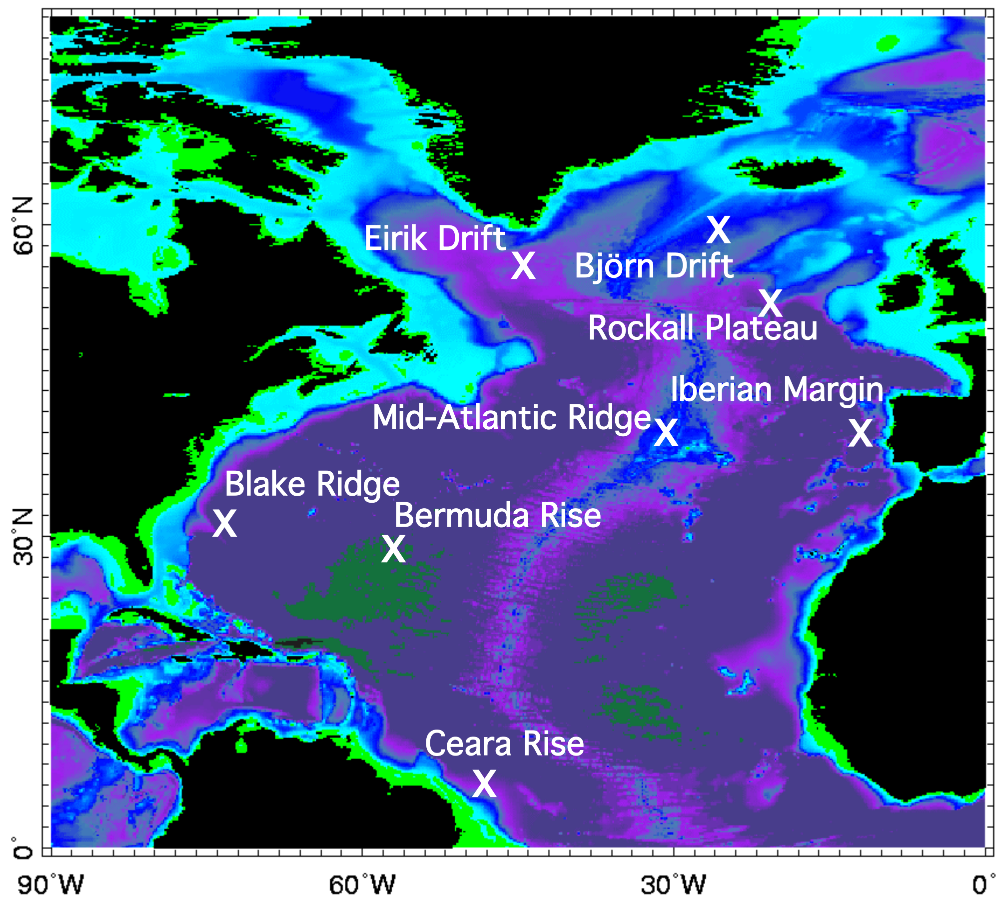


The North Atlantic and Arctic Oceans



Two classes of abyssal circulation proxies

I Water mass tracers:

Benthic $\delta^{13}C$

Benthic Cd/Ca

ε_{Nd}

Benthic B/Ca

II Kinematic indicators:

Sediment $^{231}Pa/^{230}Th$

Benthic $\Delta^{14}C$

Sortable silt grain size

Benthic $\delta^{18}O$ geostrophy

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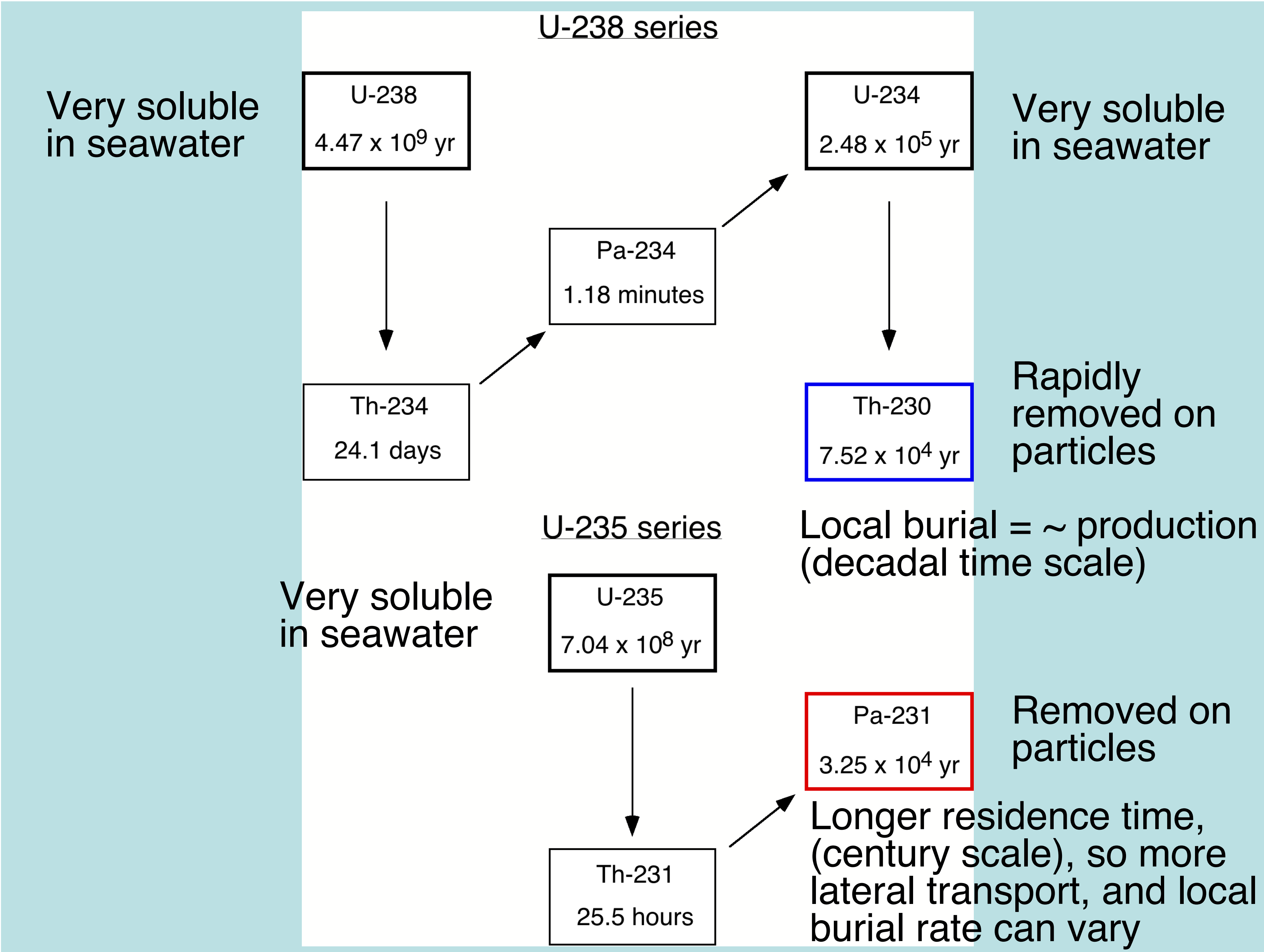
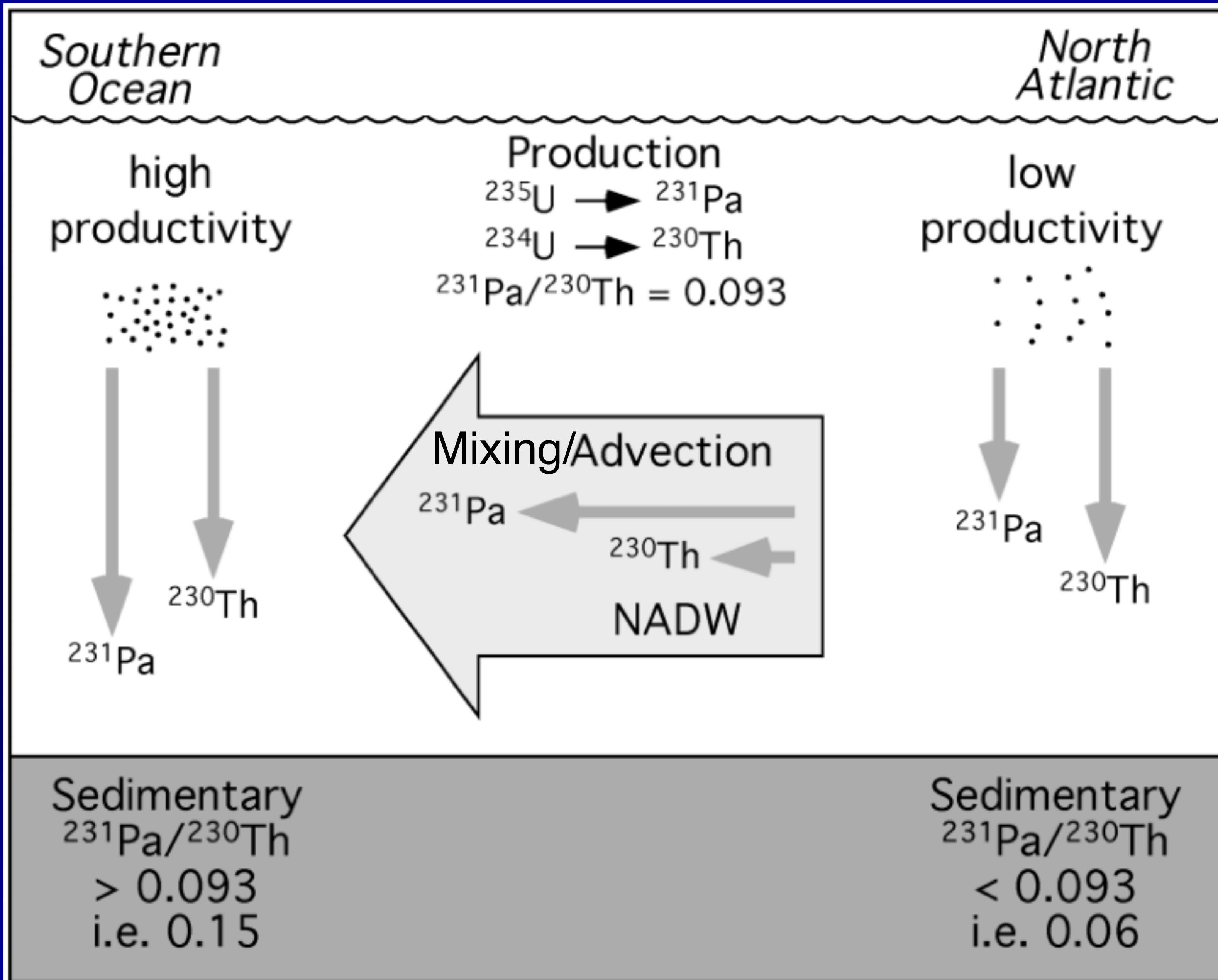
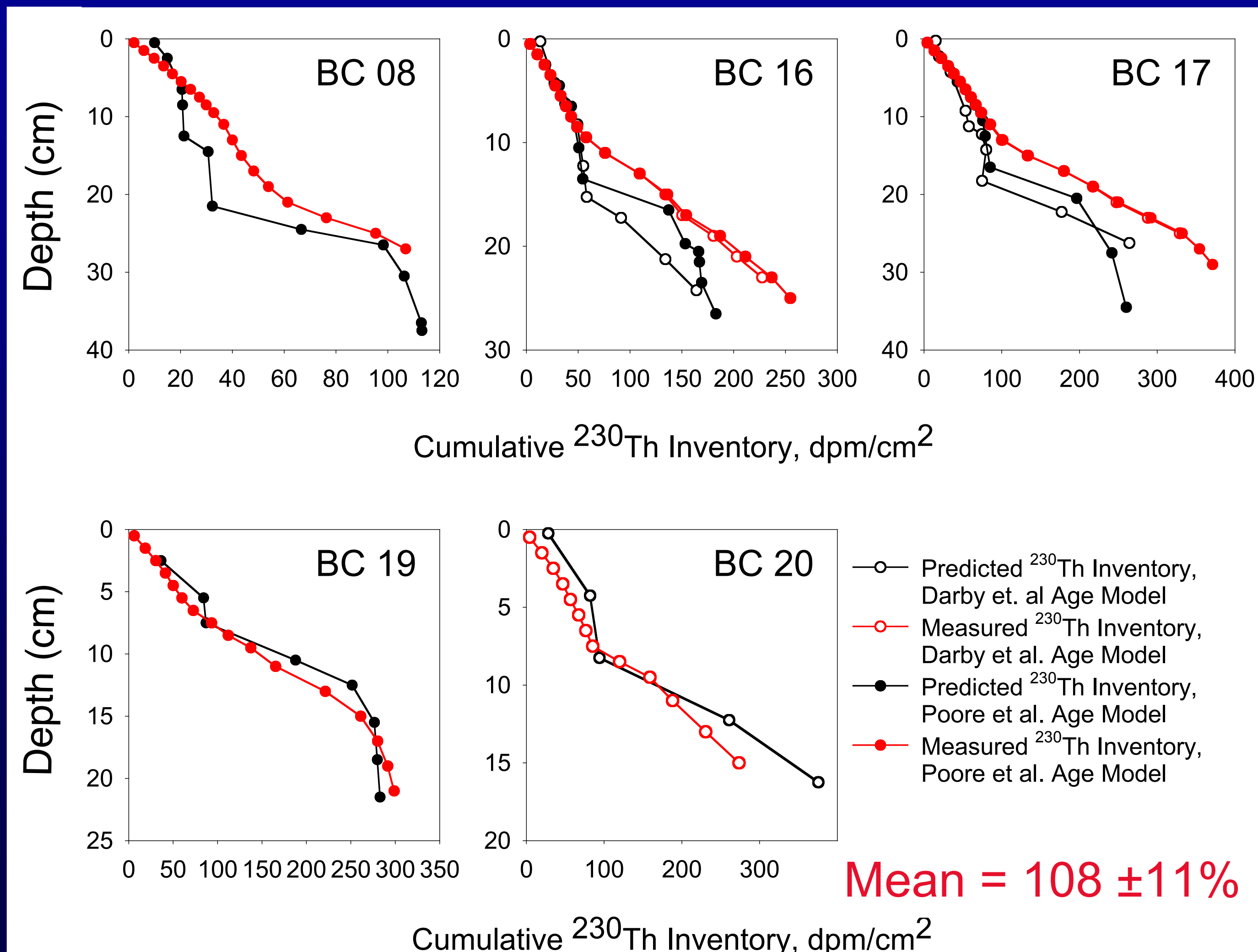

U-238 series
Very soluble in seawater
U-238
4.47 x 10^9 yr
Th-234
24.1 days
Pa-234
1.18 minutes
U-234
2.48 x 10^5 yr
Very soluble in seawater
Th-230
7.52 x 10^4 yr
Rapidly removed on particles
Local burial = ~ production (decadal time scale)
U-235 series
Very soluble in seawater
U-235
7.04 x 10^8 yr
Th-231
25.5 hours
Pa-231
3.25 x 10^4 yr
Removed on particles
Longer residence time, (century scale), so more lateral transport, and local burial rate can vary



Modified after Henderson and Anderson (2003)

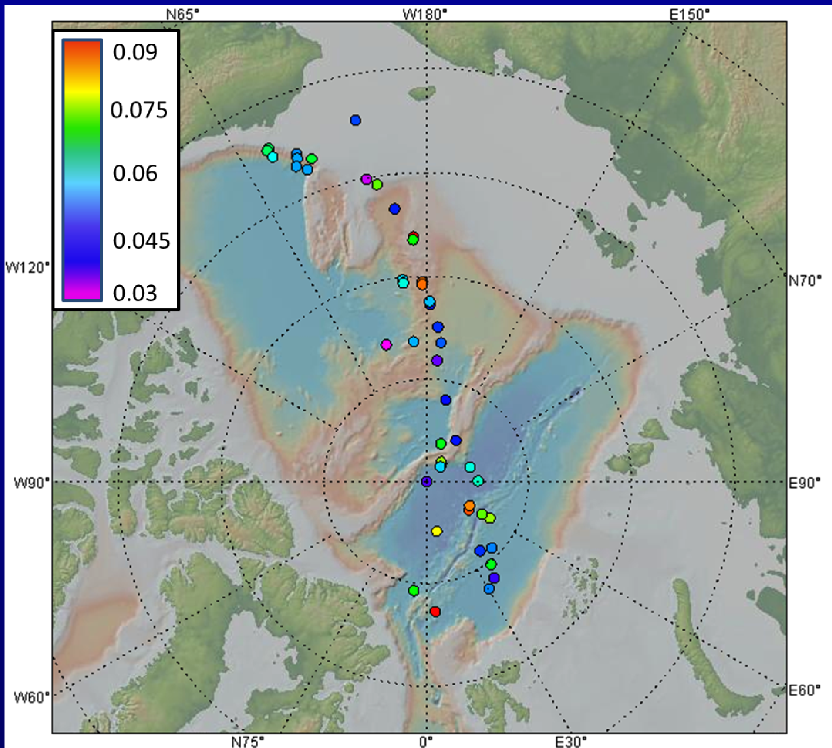
New estimates that Arctic ^{230}Th burial = ~production

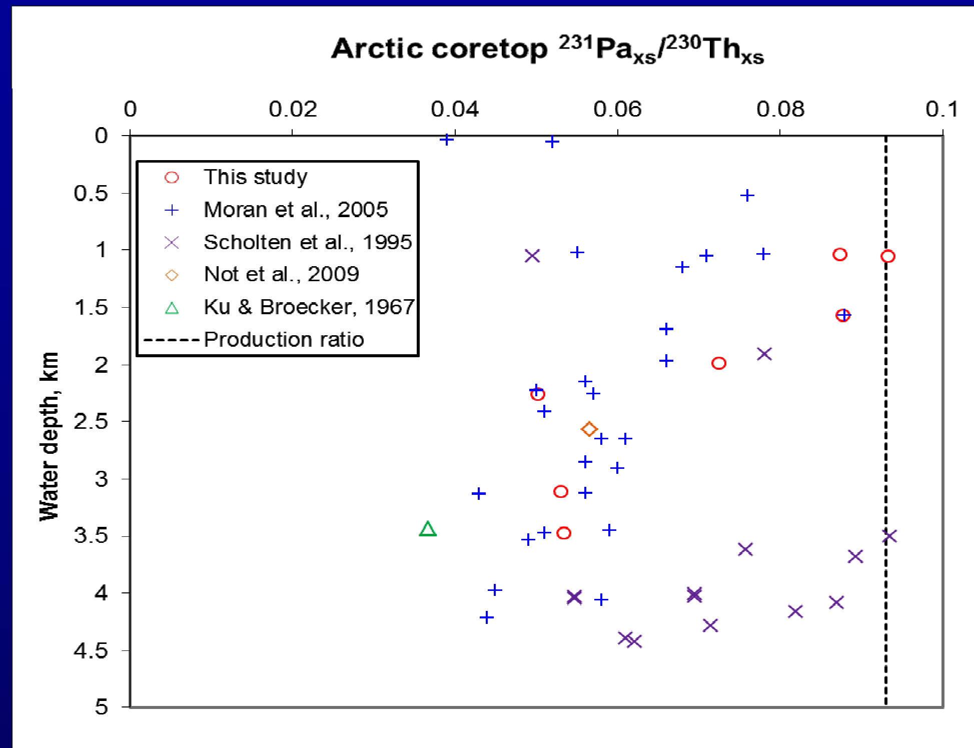
Important for use of ^{230}Th as constant-flux proxy



Hoffmann and McManus, 2007

$^{231}Pa/^{230}Th$ in surface sediments of the Arctic





Implies deep exchange through Fram Strait

Hoffmann et al., 2013, with additional data from Ku and Broecker, 1967; Scholten et al., 1995; Moran et al., 2005; and Not et al., 2010.

Core tops show low $^{231}Pa/^{230}Th$ = net export (~40%) of ^{231}Pa.

Low ratios even near margins (boundaries) where higher particle fluxes might enhance scavenging of ^{231}Pa.

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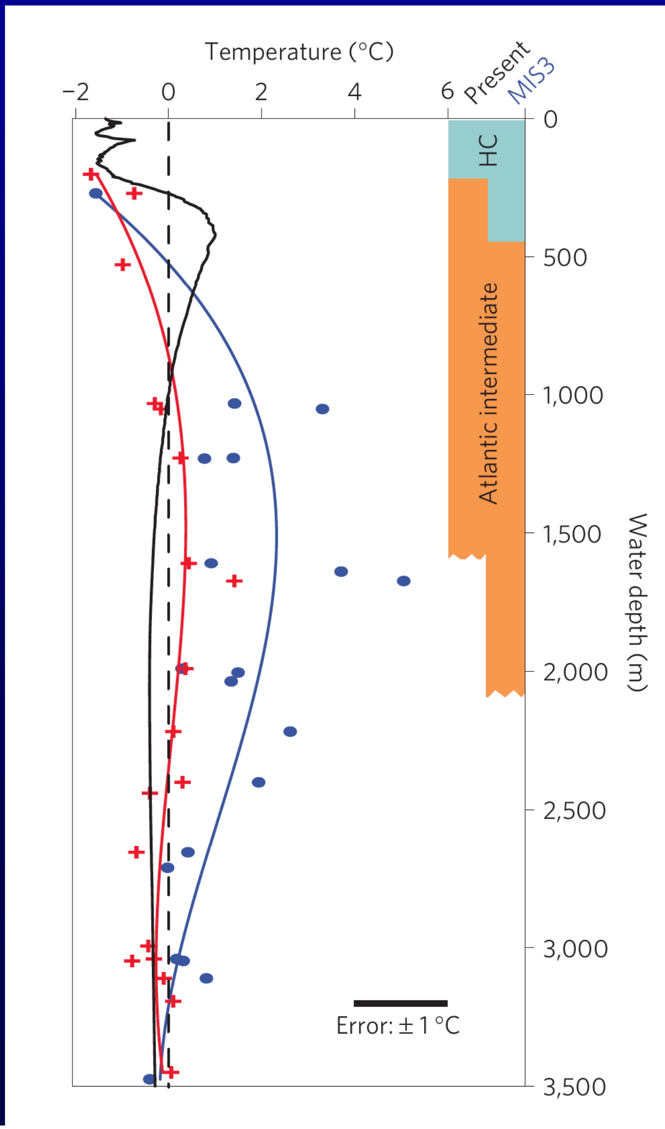
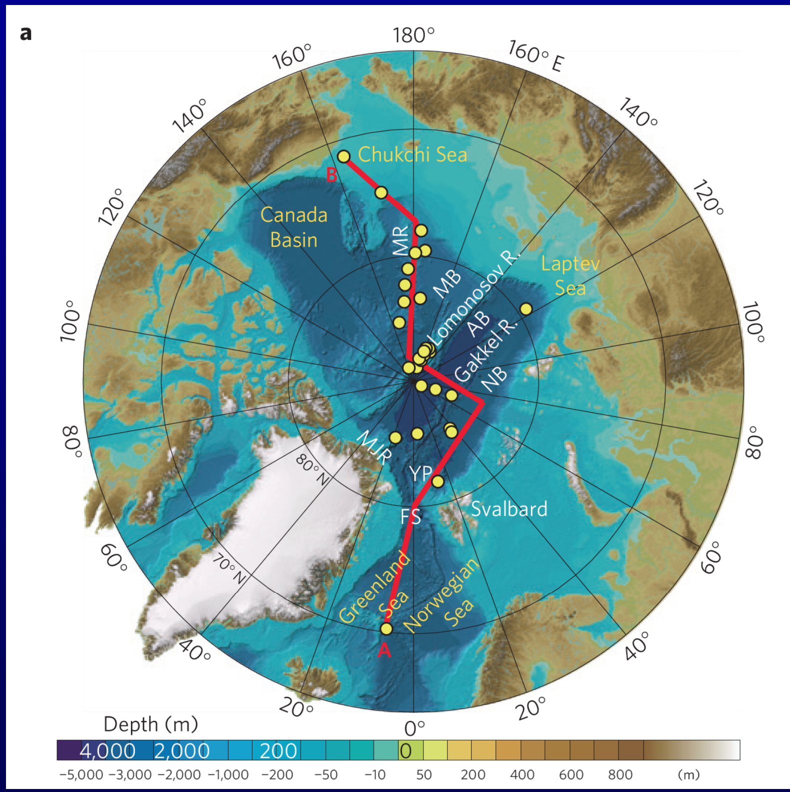
Expanded intermediate water in glacial Arctic?

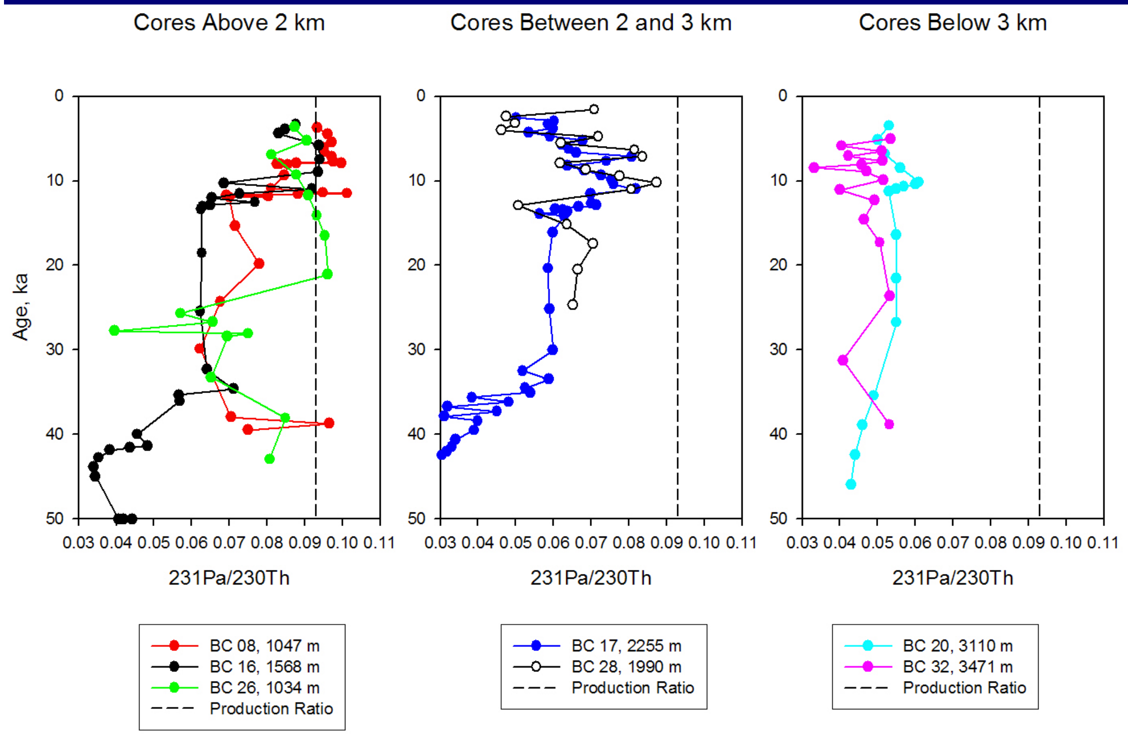
(warming at depth implies Atlantic influence)

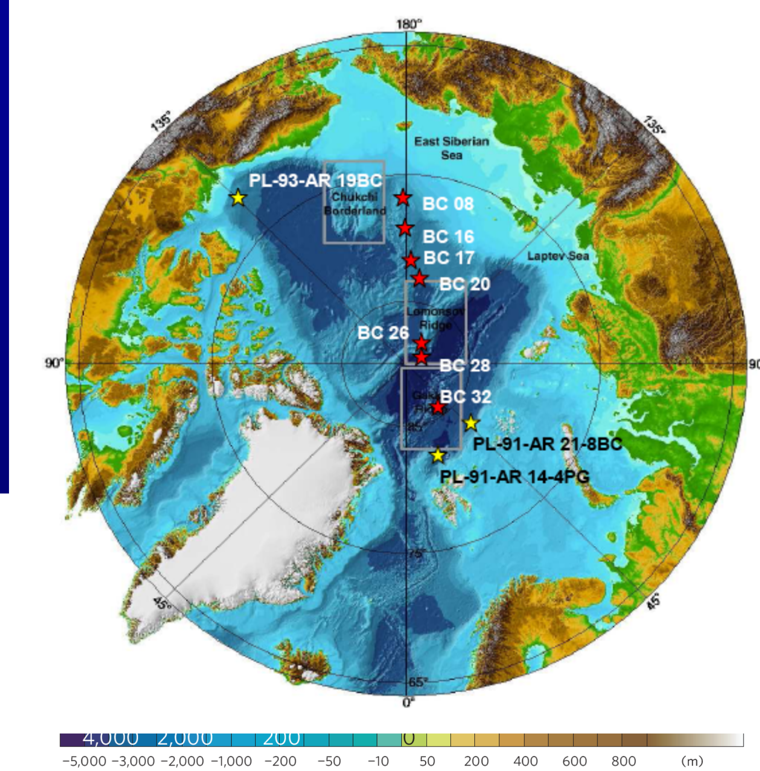




Cronin et al., 2012

Downcore $^{231}Pa/^{230}Th$ in central Arctic sediments

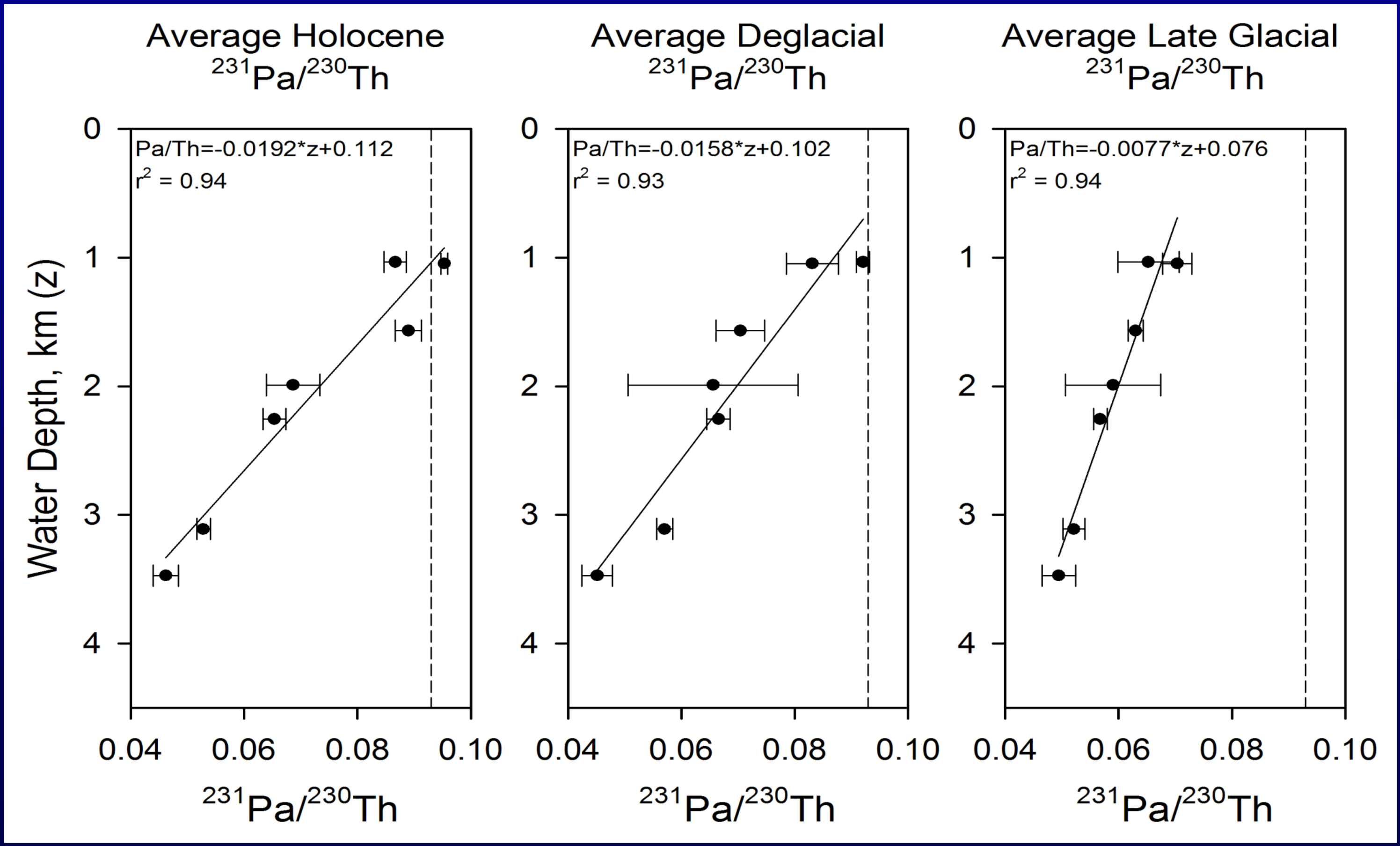




Hoffmann et al., 2013

Downcore depth transect of Arctic $^{231}Pa/^{230}Th$

Glacial ^{231}Pa deficit in Arctic implies export through Fram Strait



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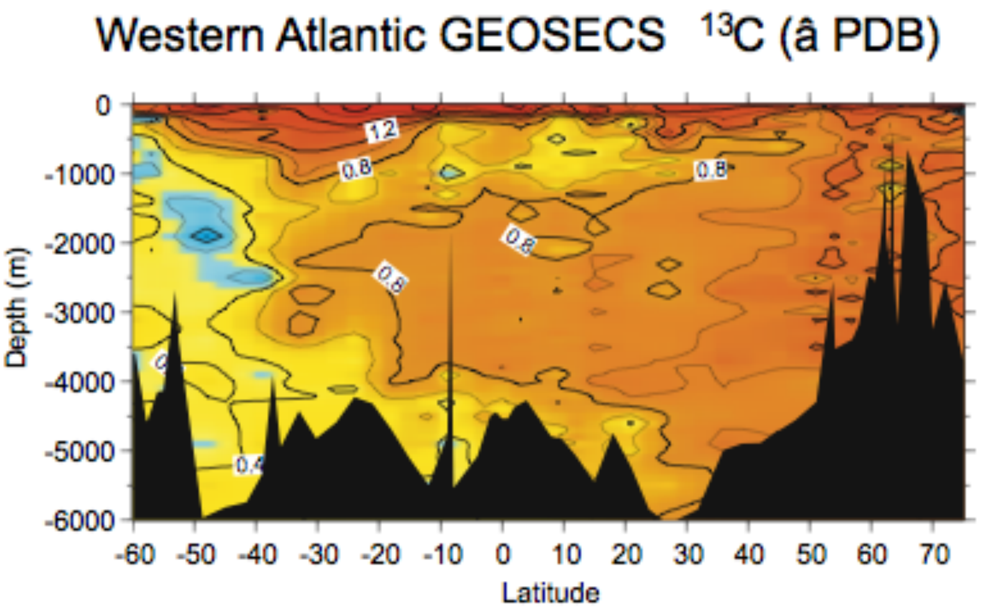
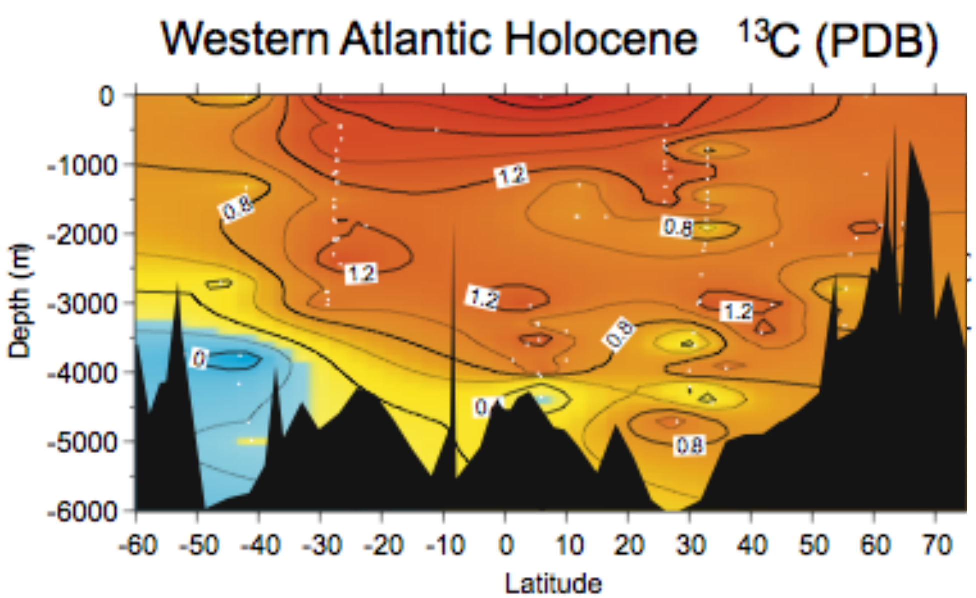
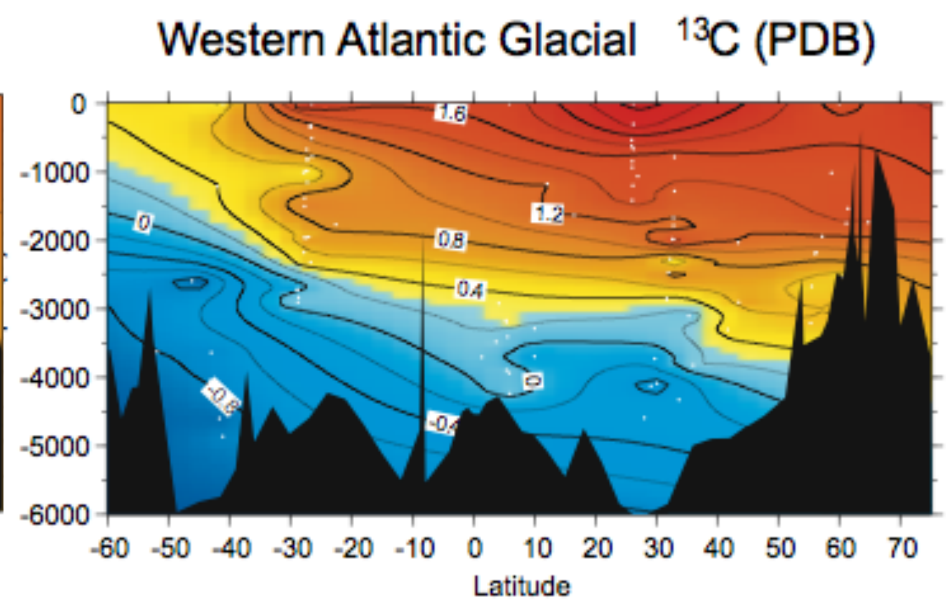


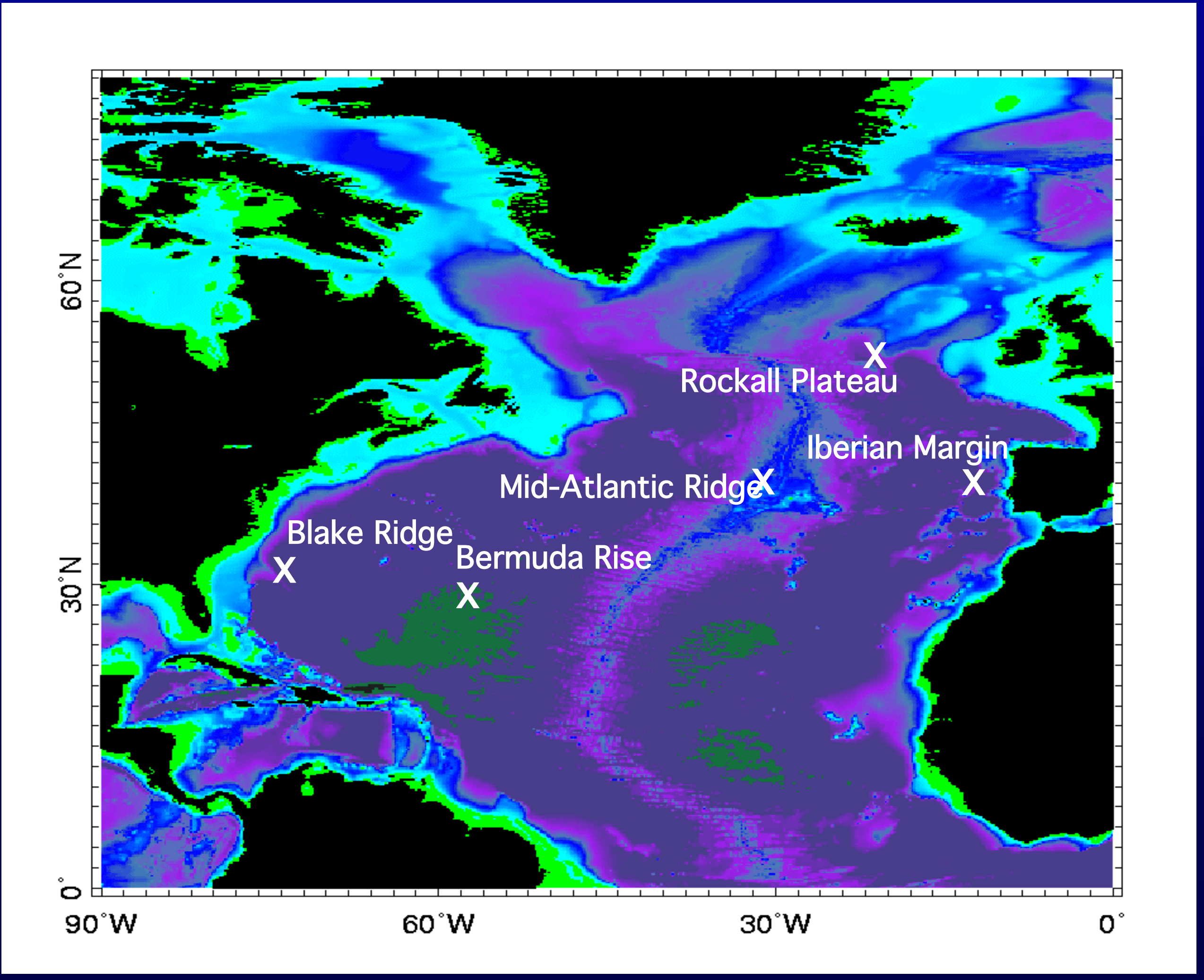
The nutrient-proxy tracer based on stable carbon isotope ratios in benthic foraminifera reveals very different pattern of subsurface water mass distributions at the last glacial maximum (LGM).

Curry and Oppo, 2005



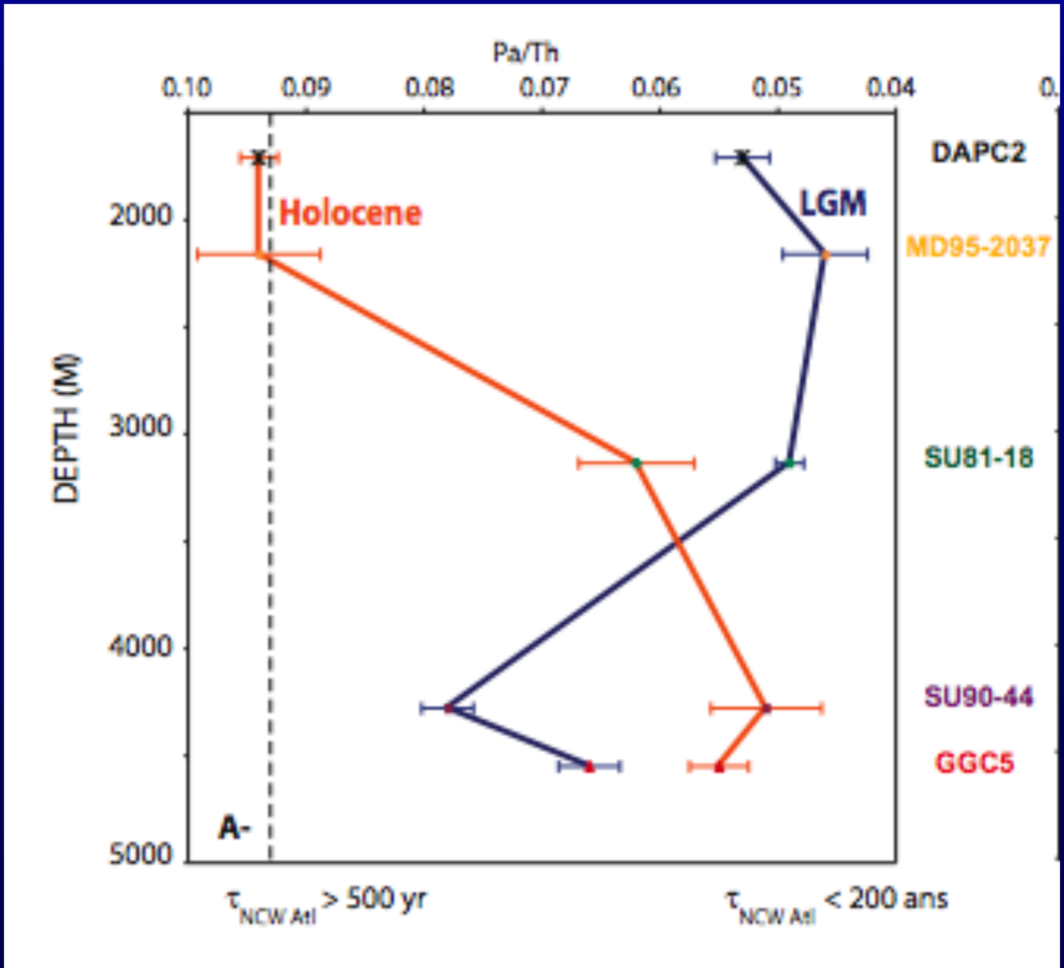


North Atlantic coretop and glacial $^{231}Pa/^{230}Th$



Coretop and glacial $^{231}Pa/^{230}Th$ vertical profiles.

- Persistent net export at last glacial maximum (LGM).
- Lower ratios imply LGM export at intermediate depths.



Gherardi et al., 2009

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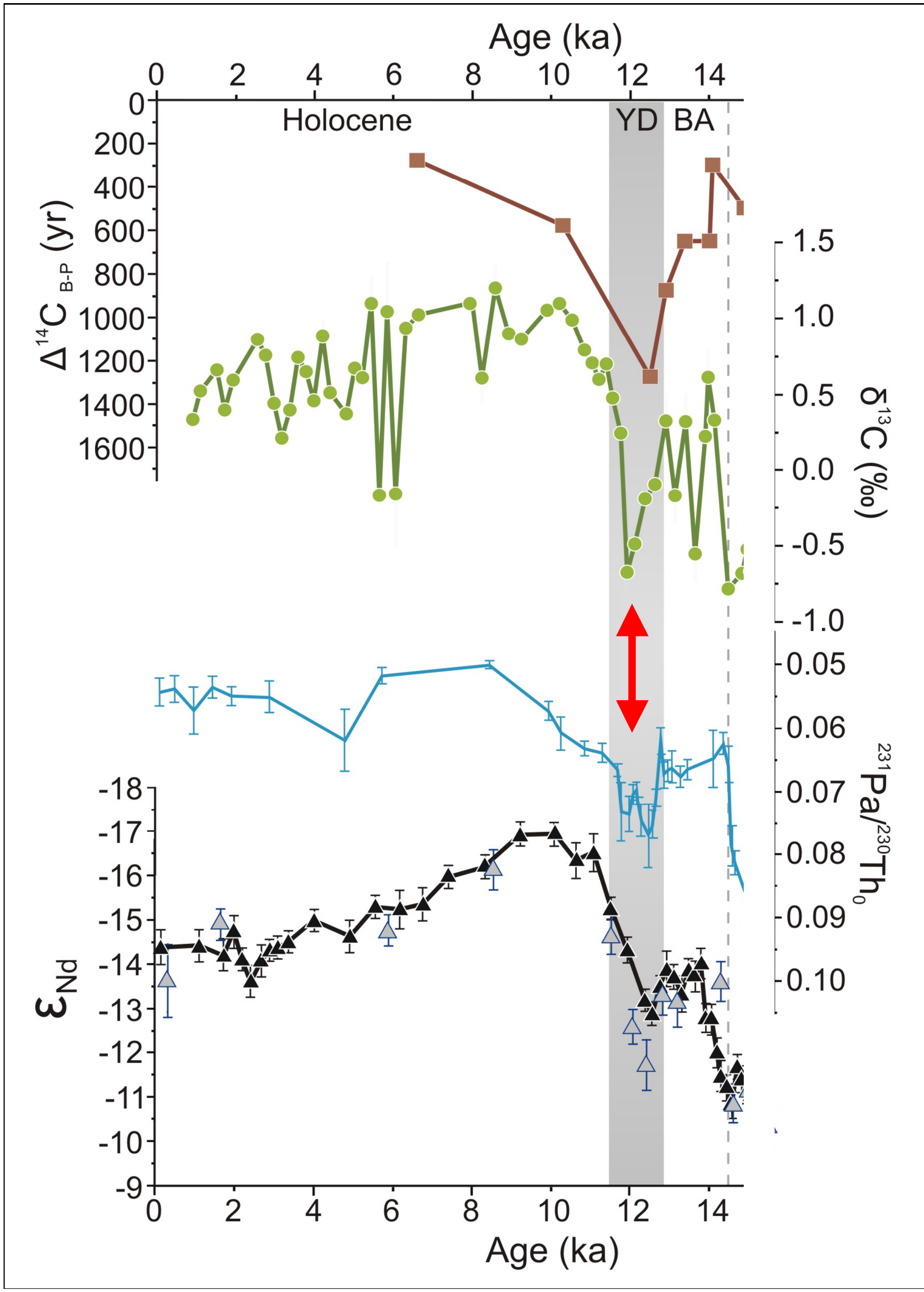

Multi-proxy approach

Each of the four AMOC proxies (two water mass, two rate-related proxies) displays changes indicating reduction in the deep circulation of the western North Atlantic at the time of the Younger Dryas event.

Modified after N. Roberts, PhD thesis, 2012

Data from Roberts et al., 2010; Keigwin, 2004; Robinson et al., 2005; Boyle and Keigwin, 1987; and McManus et al., 2004

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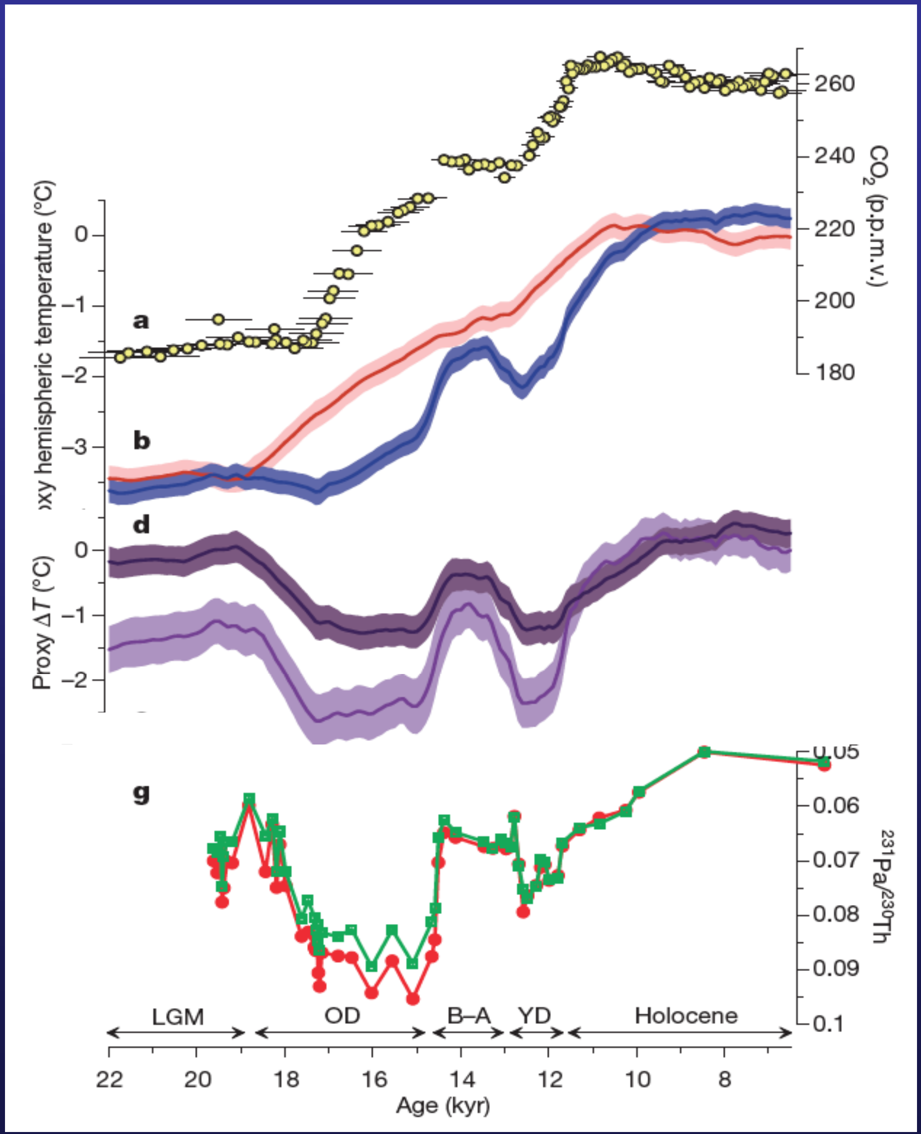
AMOC and deglacial climate change



CO2

Proxy temperature (n=80) of South (red) and North (blue) hemisphere

ΔTemperature N-S (dark) and N-S Atlantic (pale)

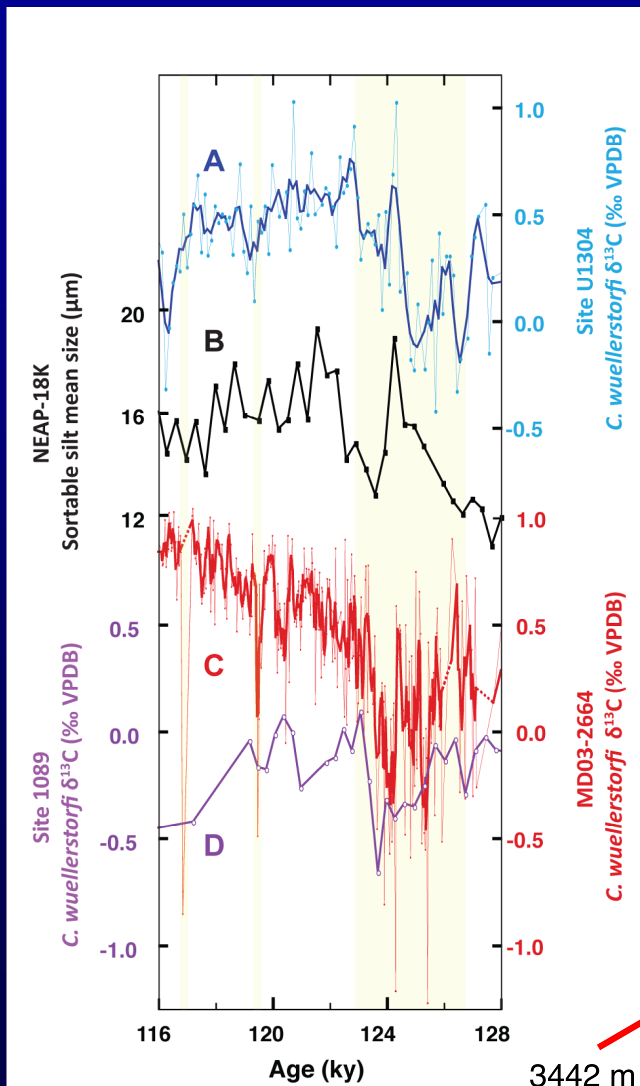
AMOC proxy ($^{231}Pa/^{230}Th$)

Shakun et al., 2012

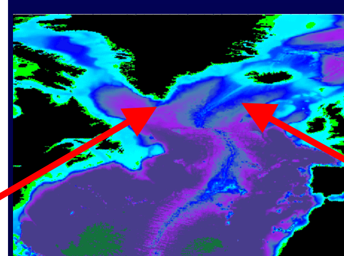
One last point…

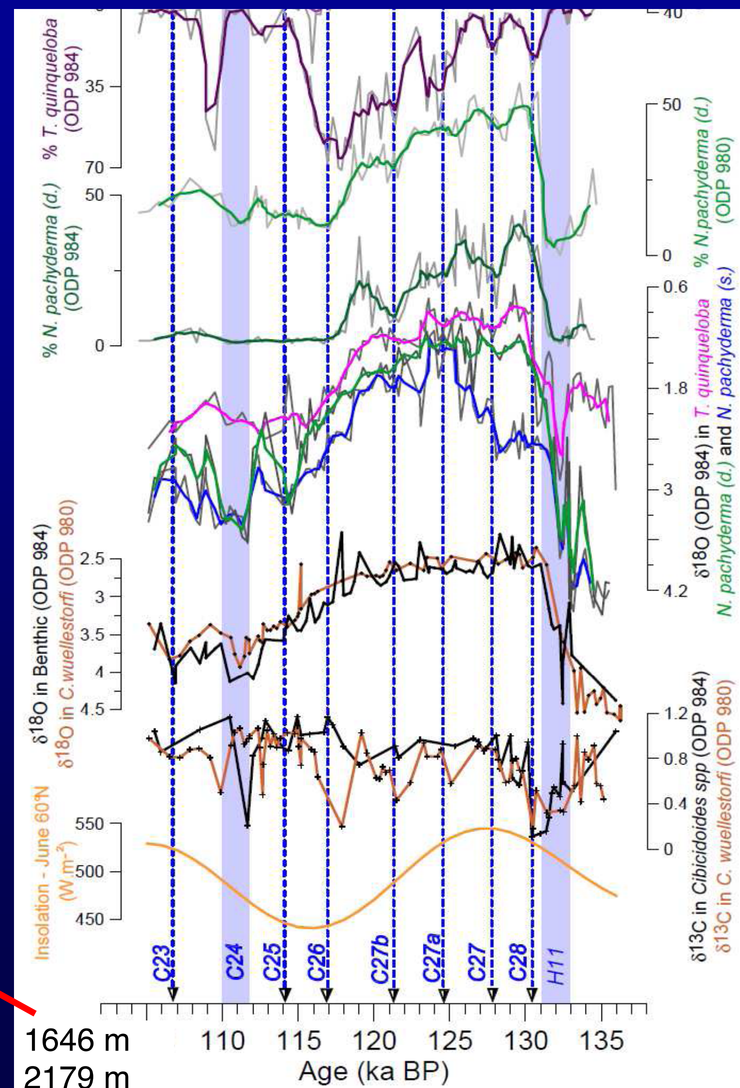
AMOC change during the last interglacial period?

New evidence suggests that possibility.



Benthic $\delta^{13}C$





Galaasen et al., 2014

Mokeddem et al., in rev.

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