Reconstructing the dynamics of Atlantic Meridional Overturning Circulation changes over the last 40 ky

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Elucidating the Causes and Effects of Atlantic Circulation Changes through Model-Data Integration

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Outline

1. Timing of AMOC slowdown with respect to tropical rainfall events and Greenland stadials associated with Heinrich event 2 and 4 [*Burckel et al.*, GRL 2015]

2. AMOC slowdowns during Dansgaard-Oeschger stadials

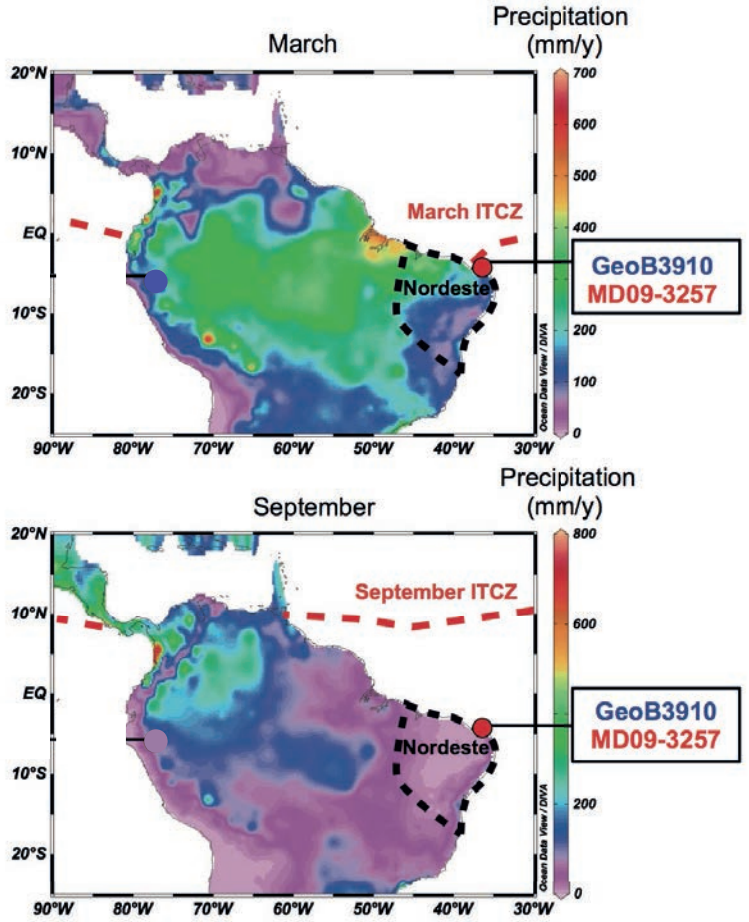
3. AMOC geometry and strength over the last 40 ky [*Burckel et al*., Clim. Past 2016; *Vazquez Riveiros* et al., in prep].

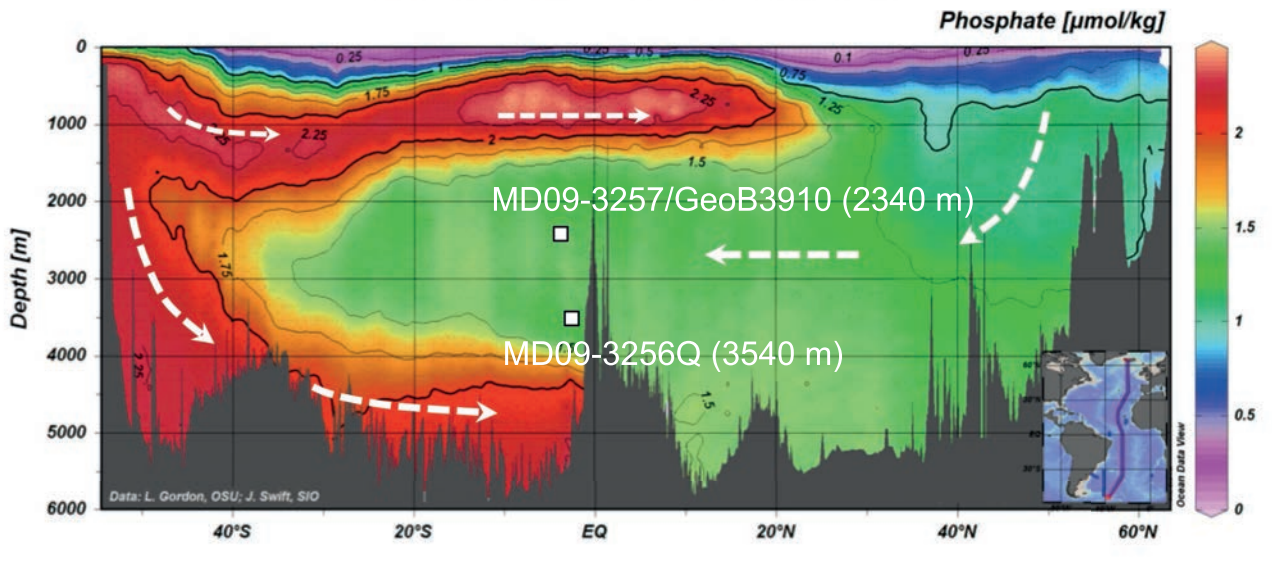
Cores location

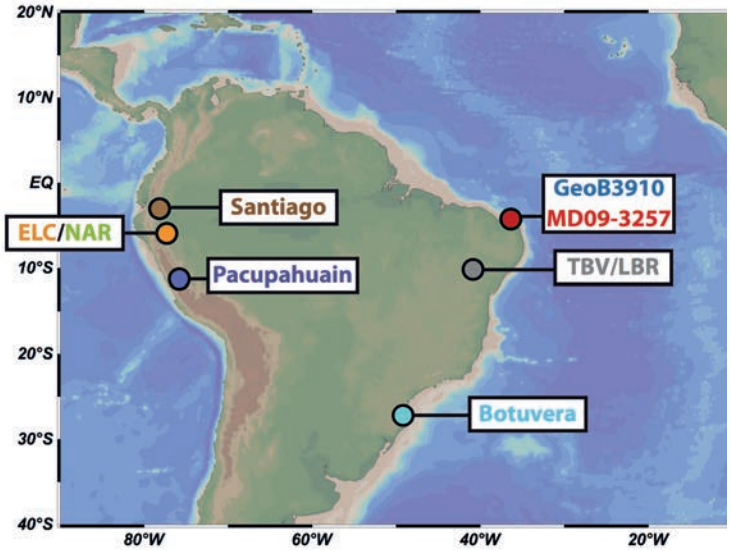
Marine cores **MD09-3257/GeoB3910** and **MD09-3256Q**:

- changes in NADW or Atlantic Meridional Circulation (AMOC) upper cell [*Burckel et al.*, 2015; 2016],

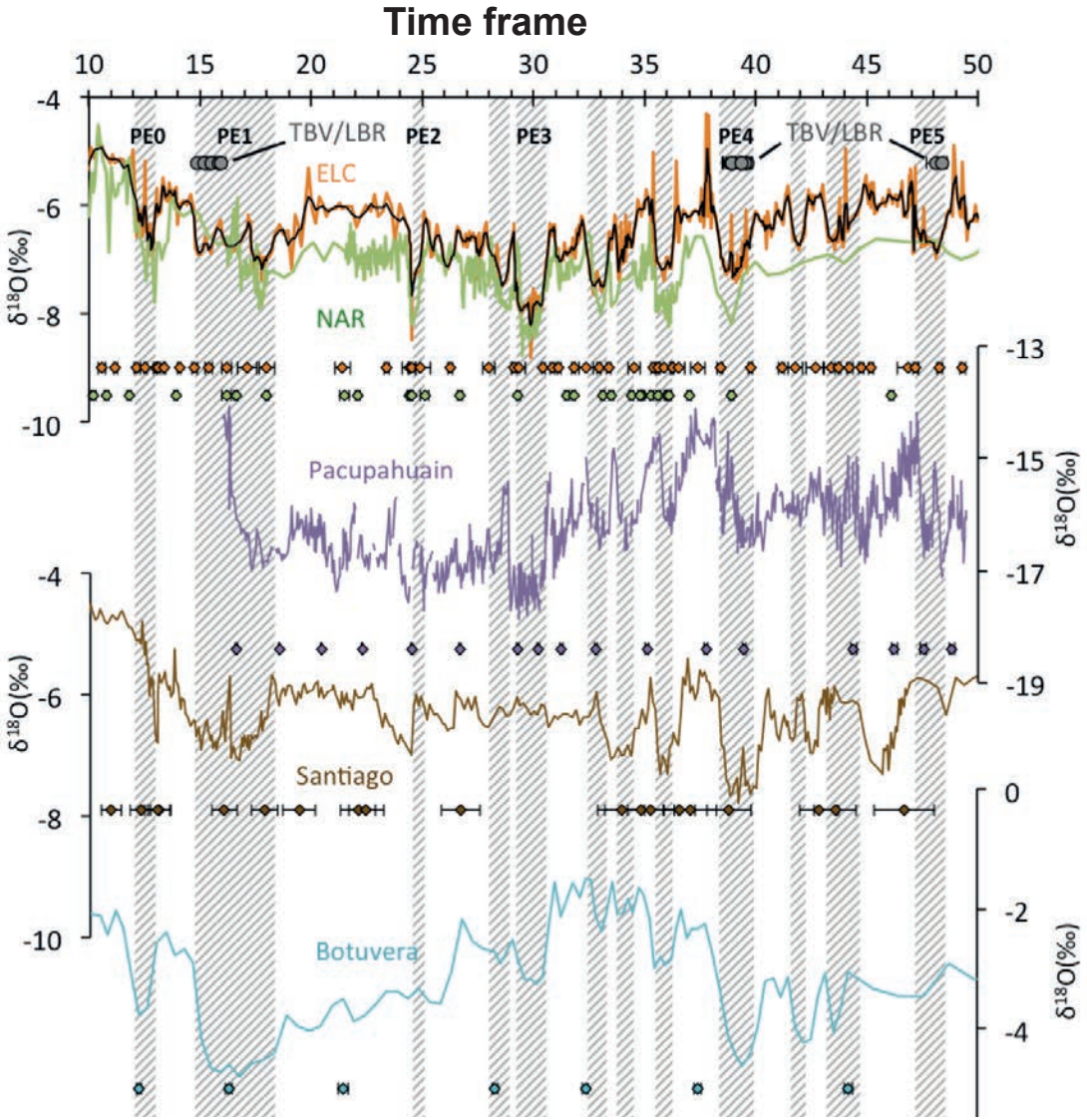
- changes in runoff [*Jaeschke et al.*, 2007]

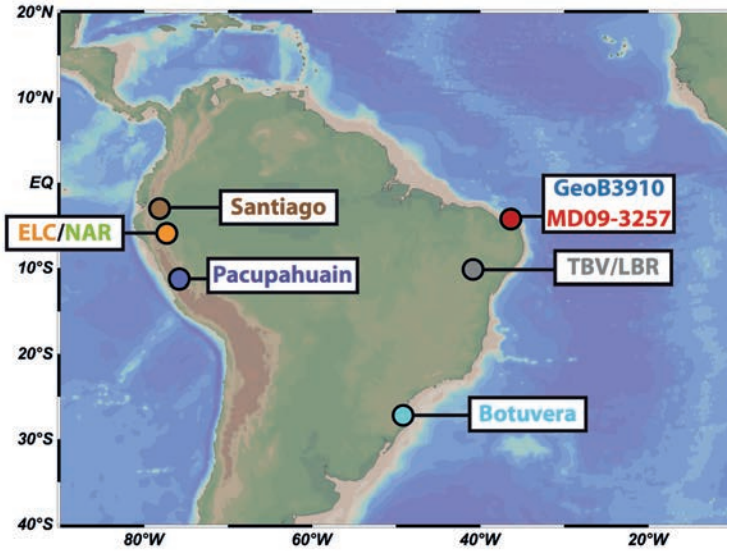






- El Condor (ELC) and Diamante (NAR) [*Cheng et al*., 2013]
- Toca da Boa Vista (TBV)/ Lapa dos Brejoes (LBR) speleothem and travertine growth intervals [*Wang et al*., 2004]
- Pacupahuain [*Kanner et al.*, 2012]
- Santiago [*Mosblech et al.*, 2012]
- Botuvera [*Wang et al*., 2007]





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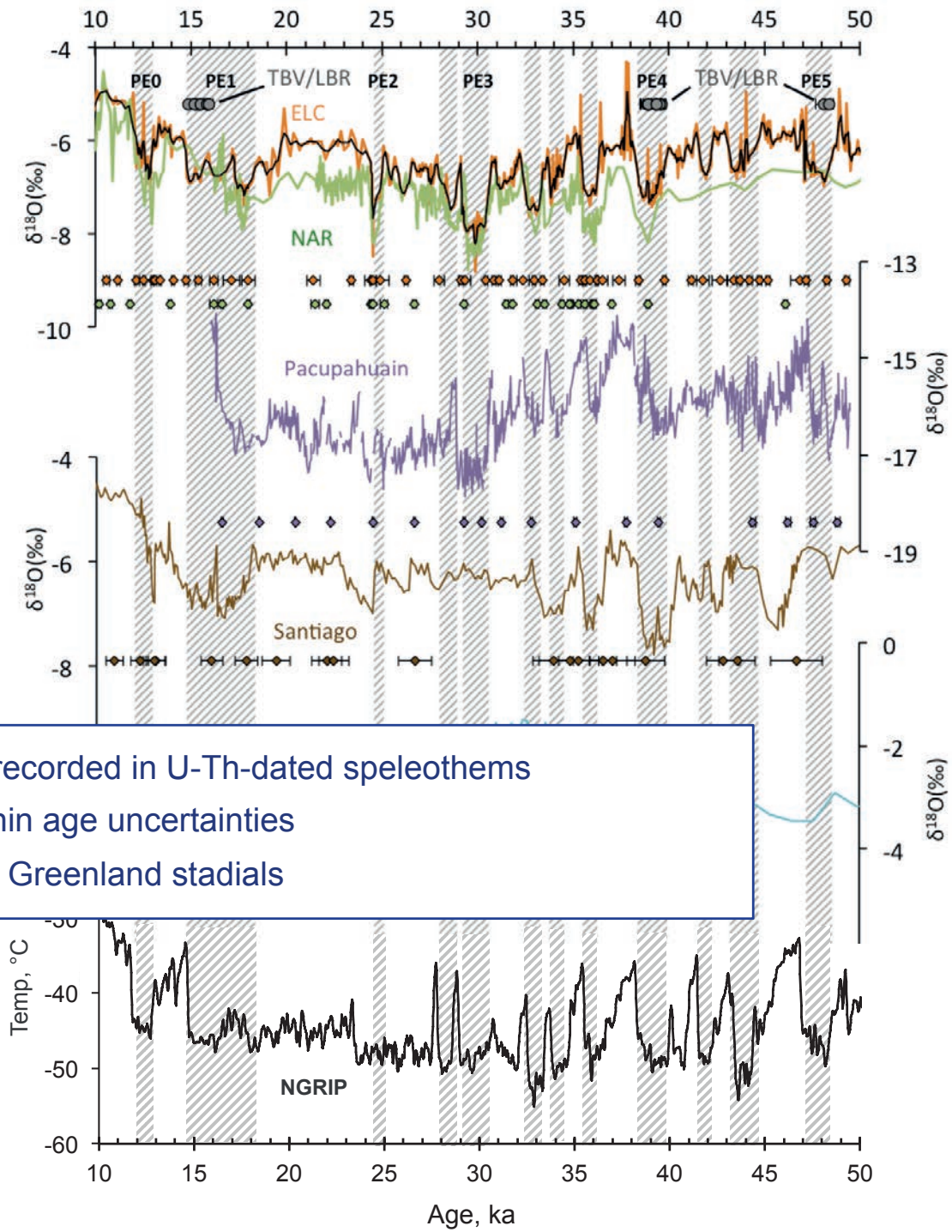
- NGRIP temperature [*Kindler et al.*, 2014]

Time frame

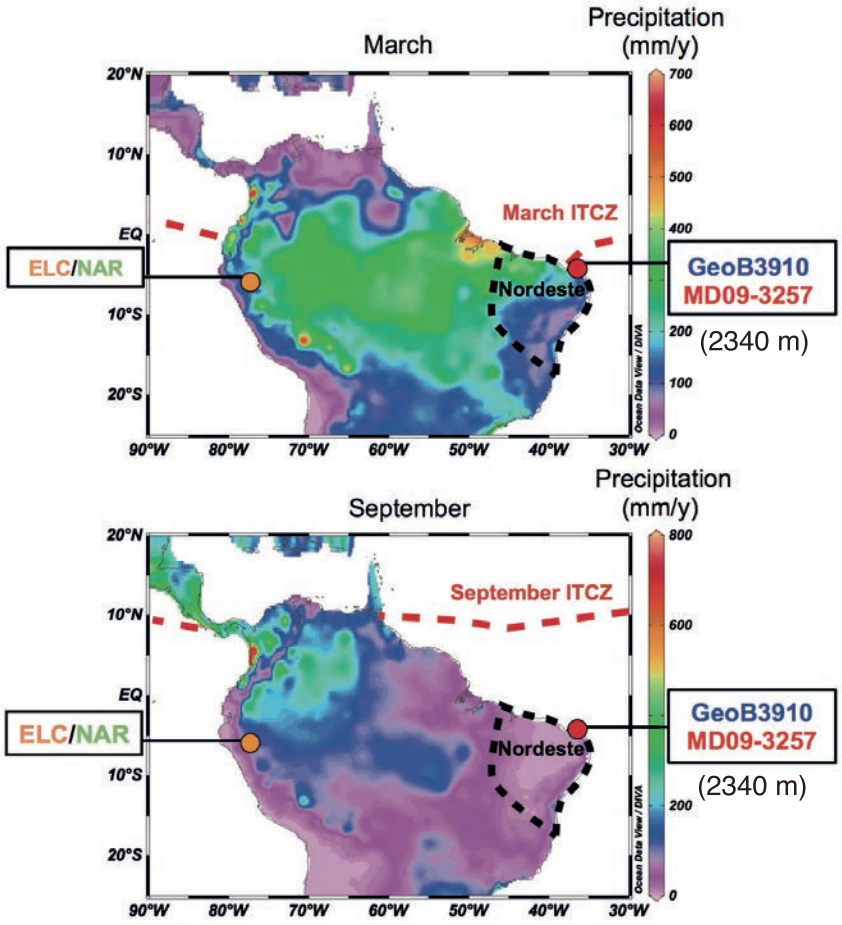


Precipitation events recorded in U-Th-dated speleothems

- Synchronous within age uncertainties
- take place during Greenland stadials

Precipitation events

• interpreted as **southward shifts of the ITCZ** [*Wang et al*., 2004; …; *Arz et al*., 1998; …]



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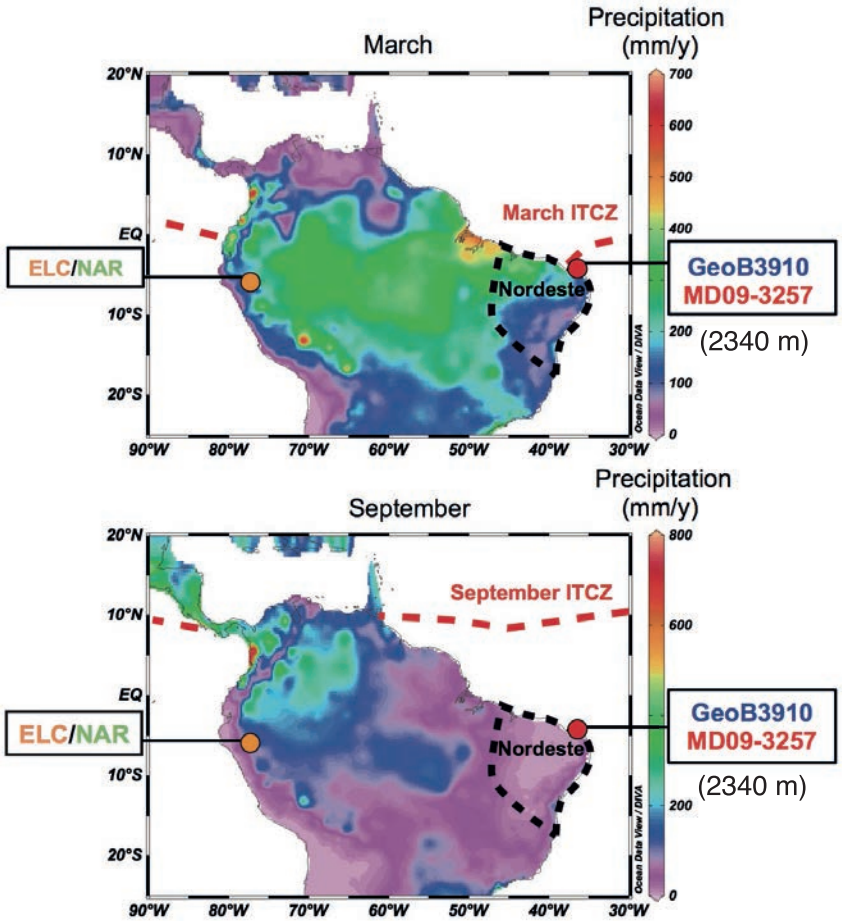

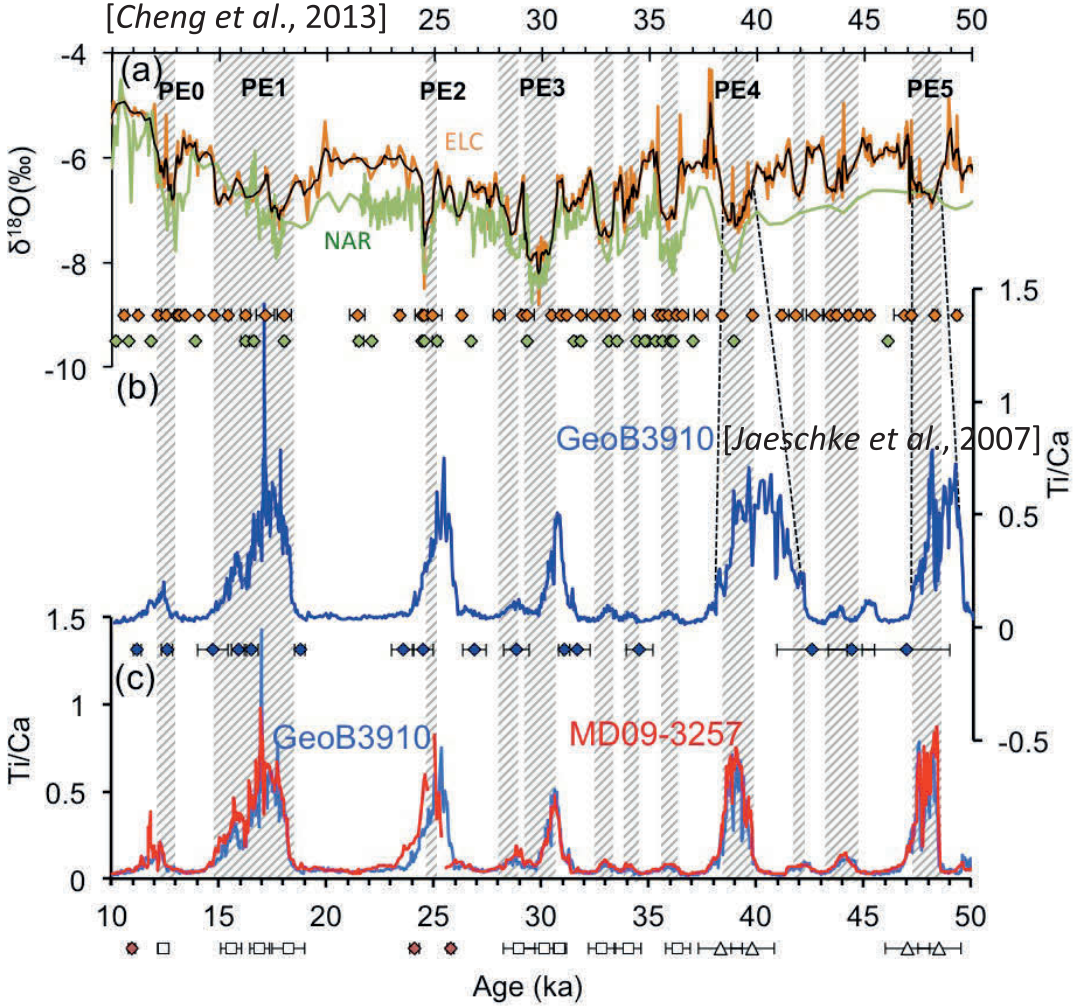

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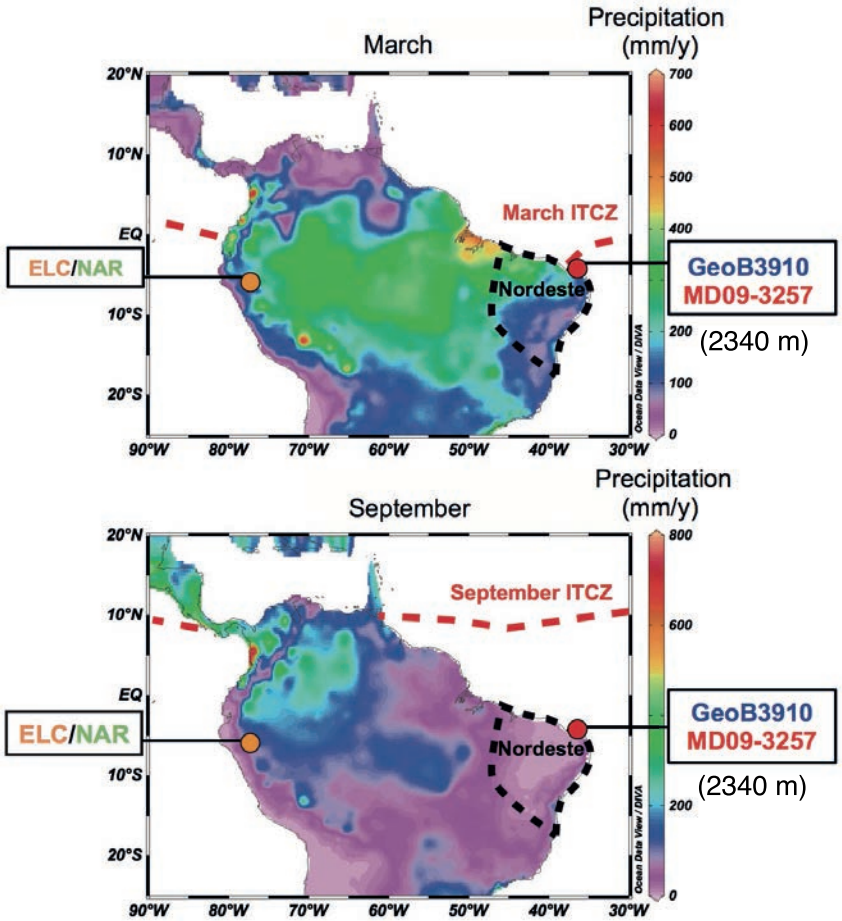
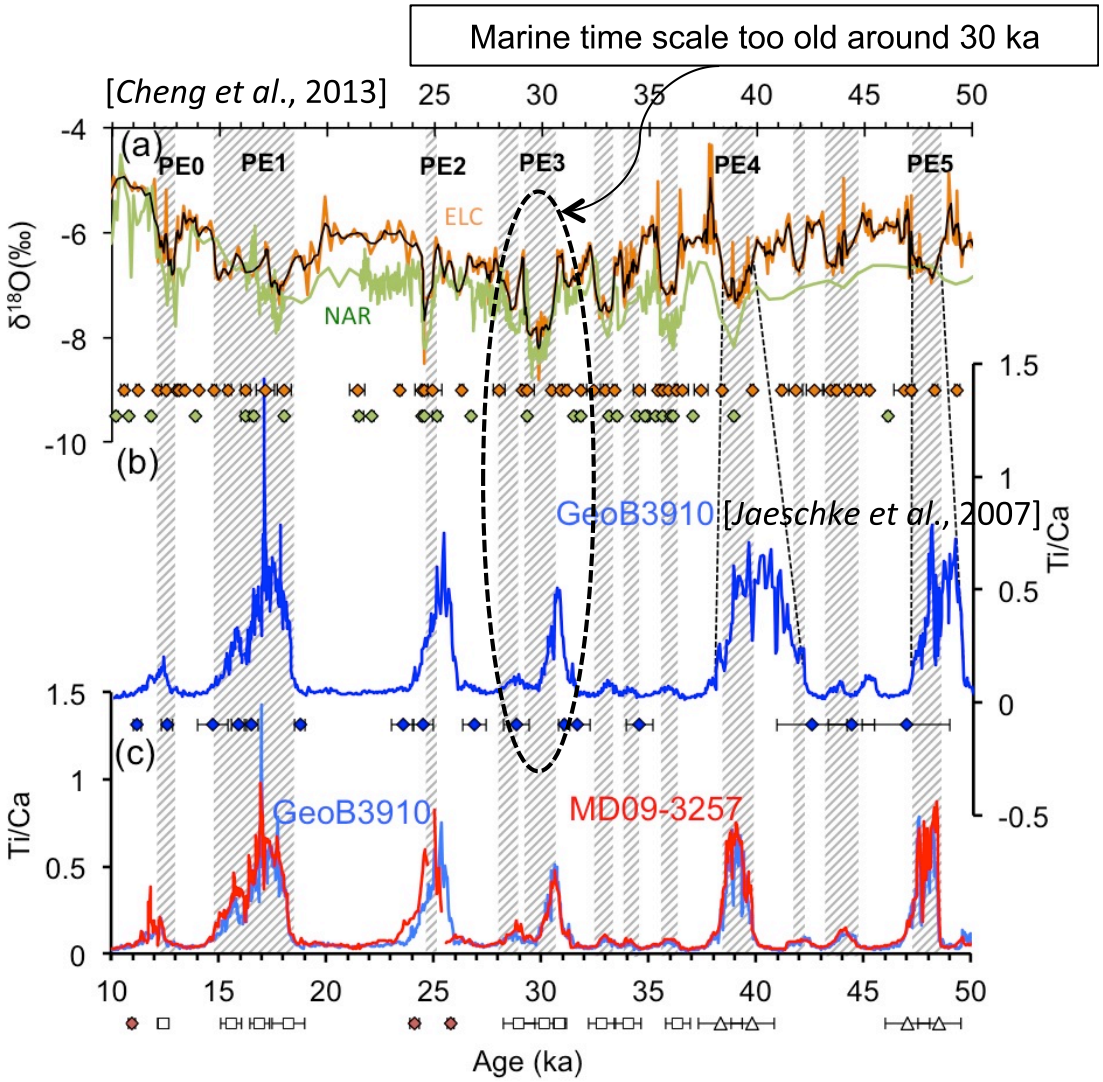
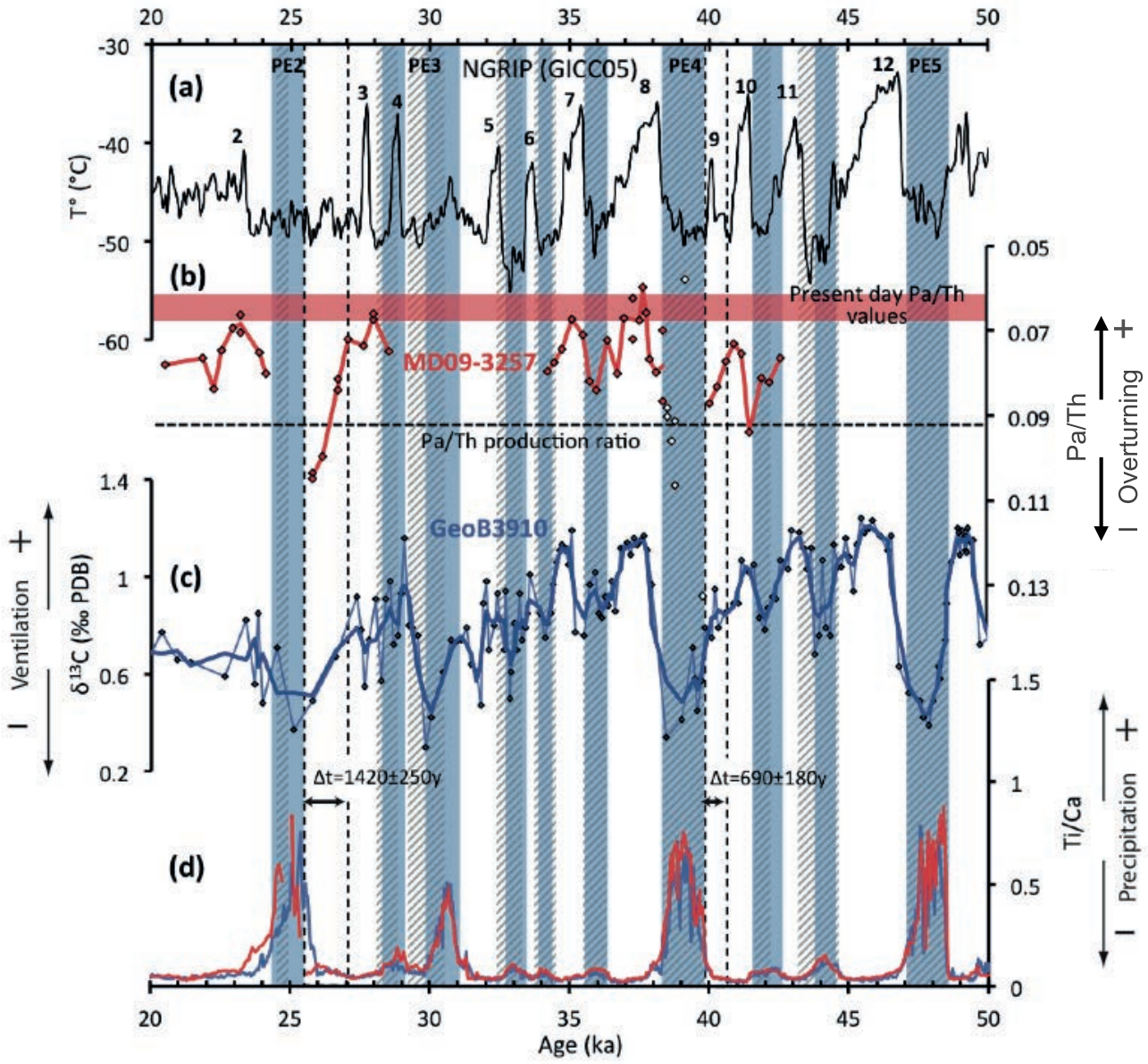




1. Timing of AMOC slowdown with respect to tropical rainfall events

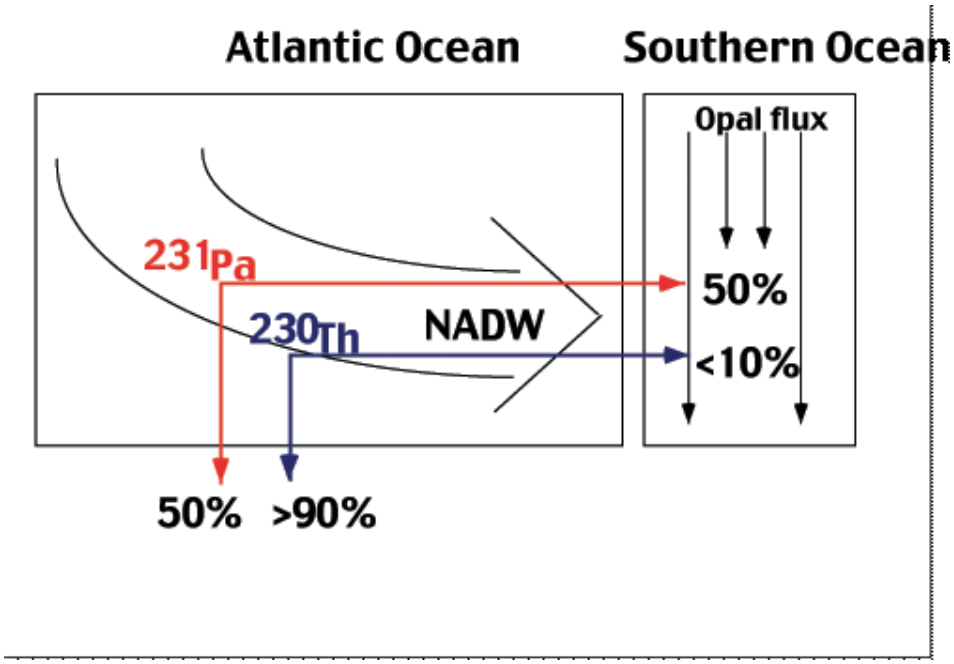


Pa/Th + *C. wuellerstorfi* $\delta^{13}C$:

longer bottom water residence times and lower ventilation **at 2400 m** depth in the western tropical Atl. during stadials

[*Burckel et al.*, GRL 2015]

Sedimentary $^{231}Pa/^{230}Th$: a proxy of water masses renewal rate



- **^{231}Pa** and **^{230}Th** produced by uranium radioactive decay
- if they had the same solubility --> **$^{231}Pa/^{230}Th = 0.093$** = production ratio [Yu et al., 1996]
- **Th** residence time < 30 years
- **Pa** residence time ≈ 200 years

⇨ North Atlantic sedimentary $^{231}Pa/^{230}Th$ ↗ when NADW slows down

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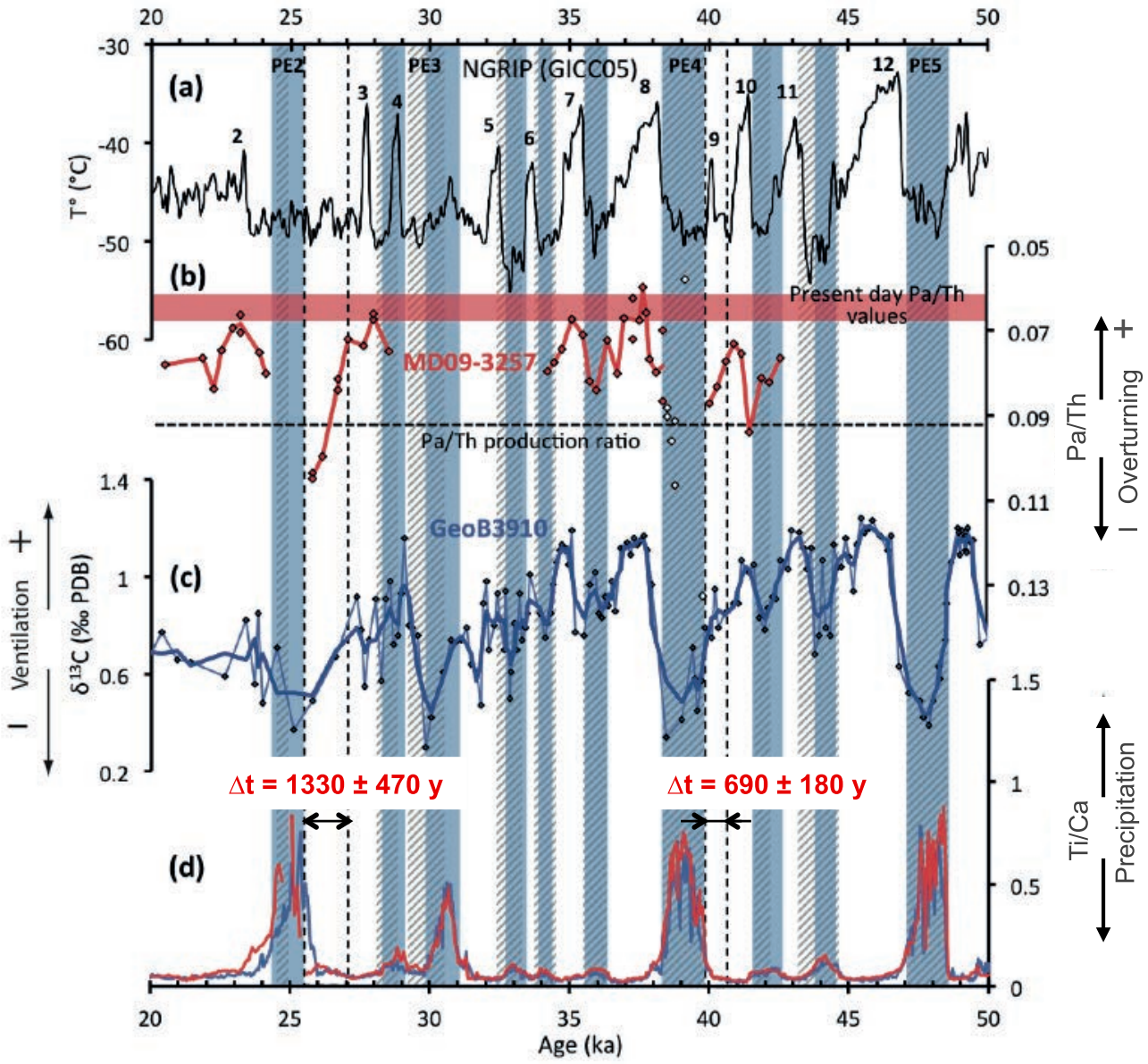

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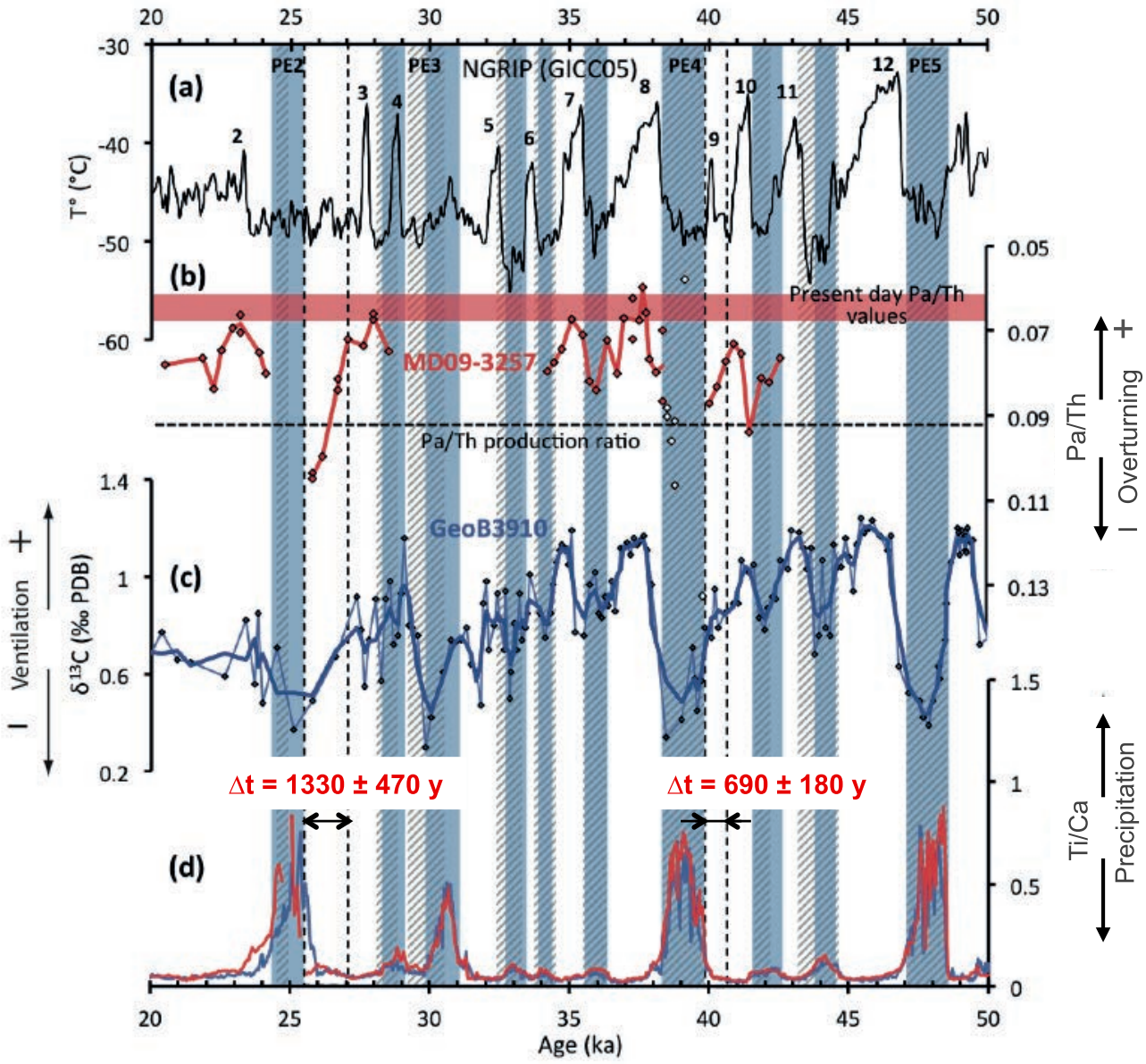

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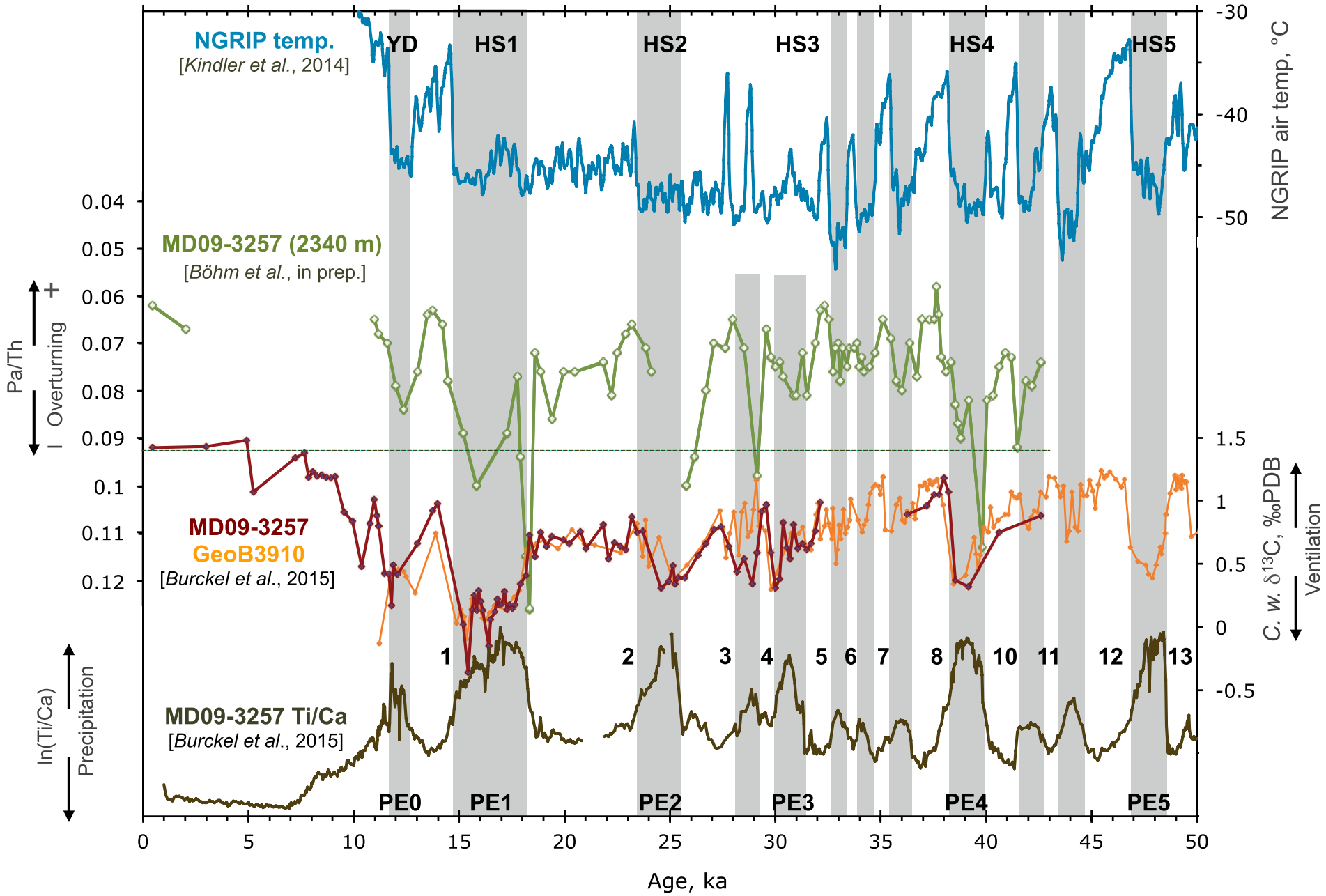
Pa/Th:

marked decreases in transport (~flow speed) of the water mass overlying the core site (**between ~1300 and 2300 m**) **prior** to **tropical precipitation events** associated with **Heinrich stadials.**

***Precise determination** of the **lead** in core MD09-3257.*

[*Burckel et al.*, GRL 2015]

2. AMOC slowdowns during Dansgaard-Oeschger stadials



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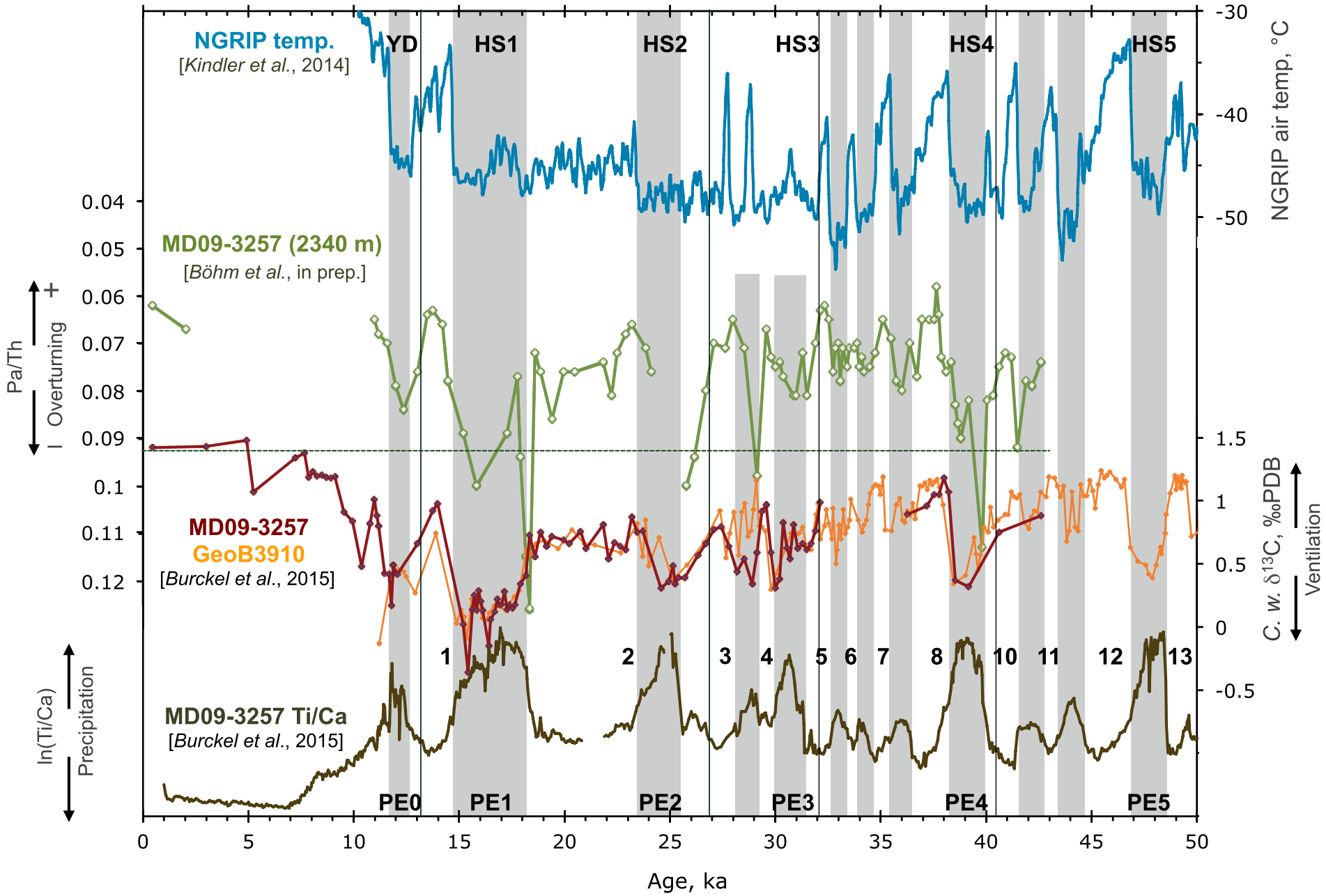
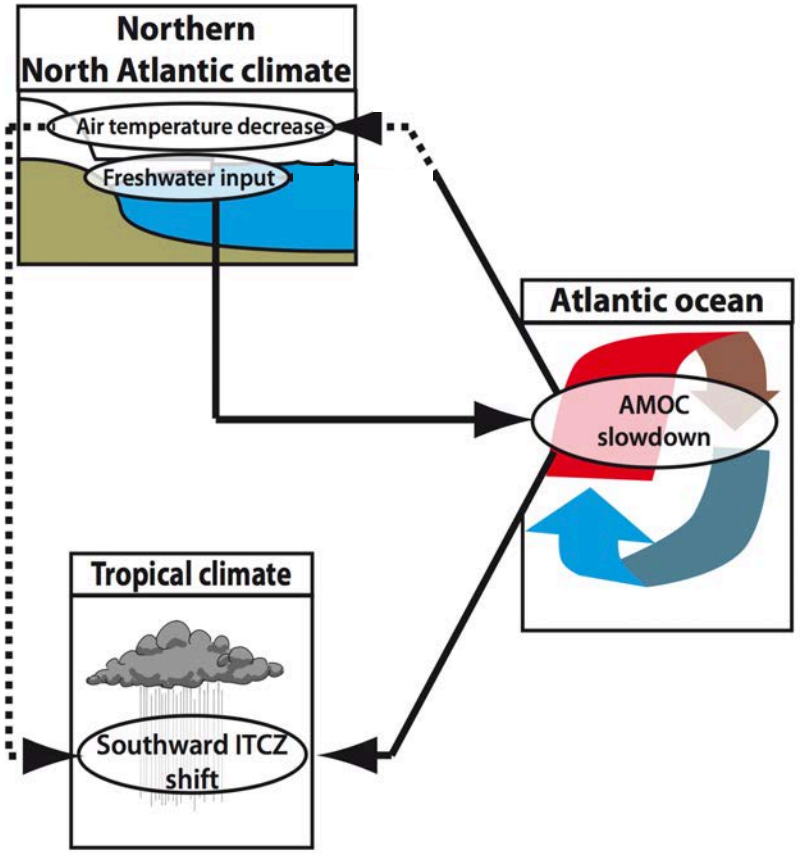


Mechanisms at play



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A southward shift of the ITCZ can be produced by:

- an AMOC slowdown [e.g. *Kageyama et al*. 2009, 2010, …]
- high northern latitudes cooling and ice sheet or sea ice cover expansion [*Chiang et al.*, 2003; …]

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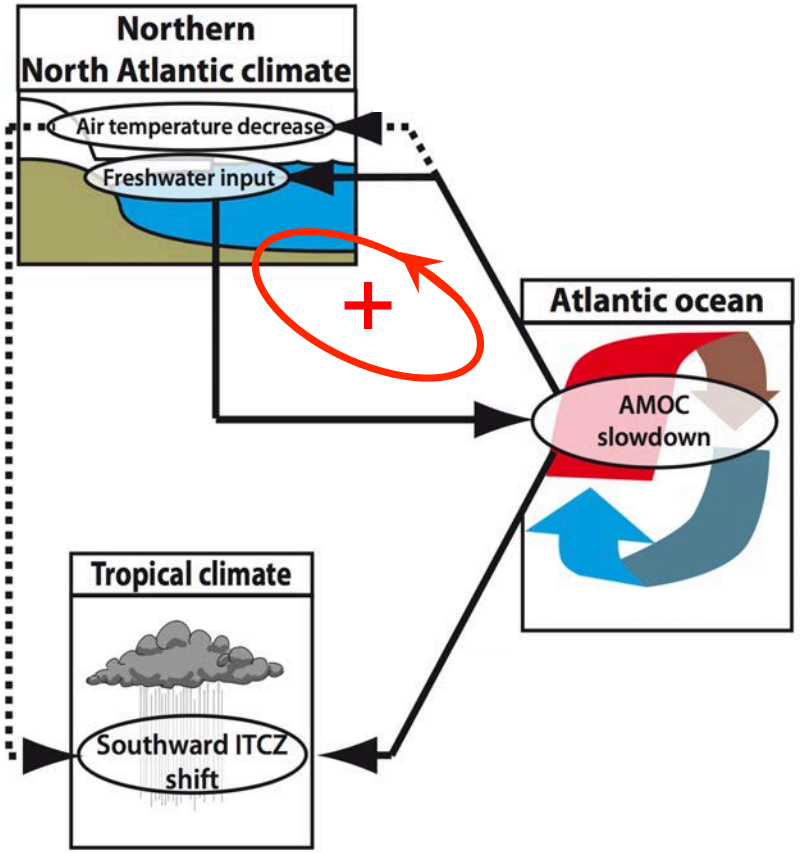

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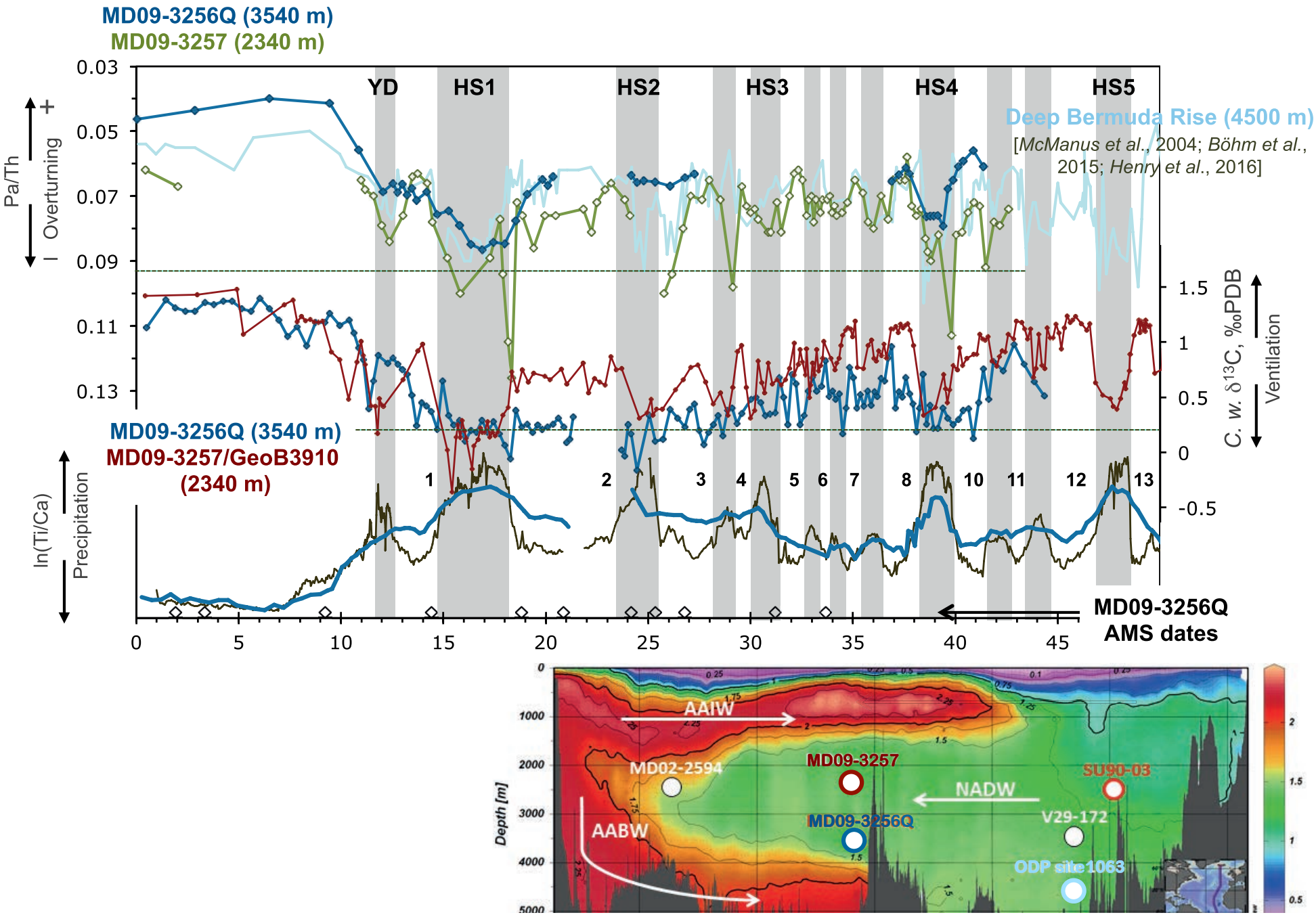
AMOC slowdown induces subsurface warming in the high northern latitudes [e.g. *Mignot et al*., 2007; *Alvarez-Solas et al.*, 2013]

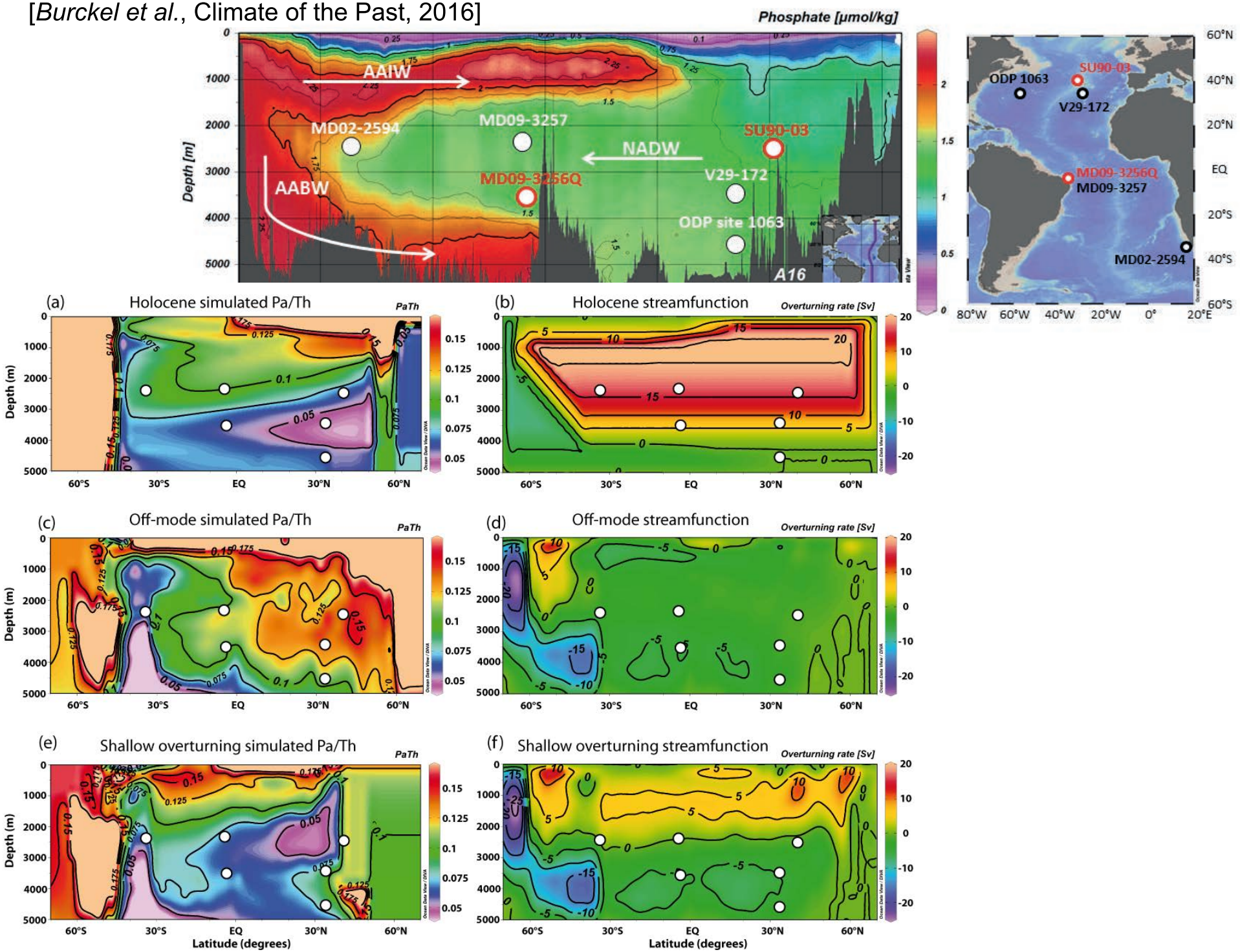
→ possible positive feedback that could explain the time lag and larger slowdown associated with IRD discharges: Heinrich, not D-O stadials.

What is the initial trigger of the AMOC slowdown?

3. AMOC geometry and strength over the last 40 ky



[*Burckel et al.*, Climate of the Past, 2016]



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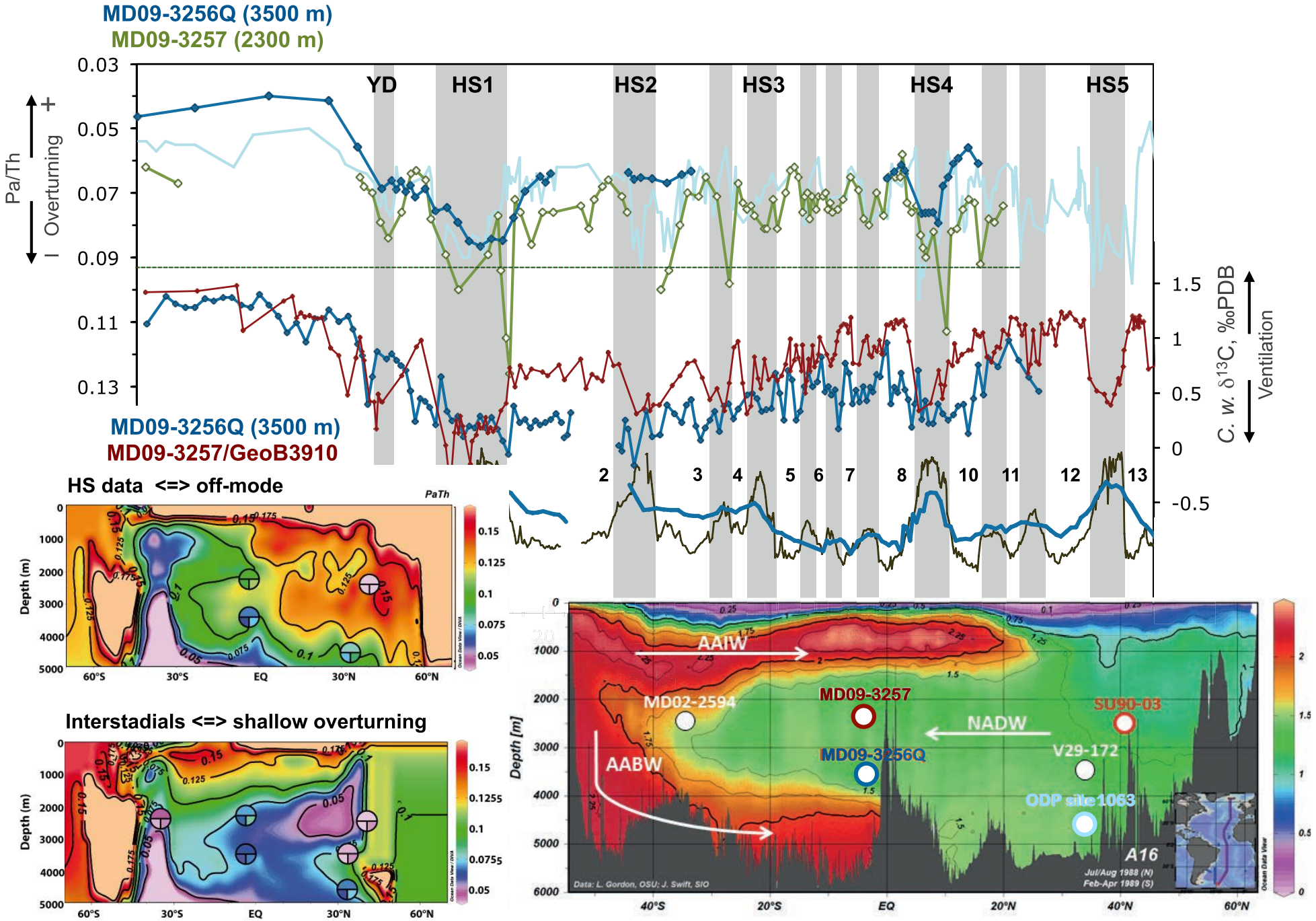
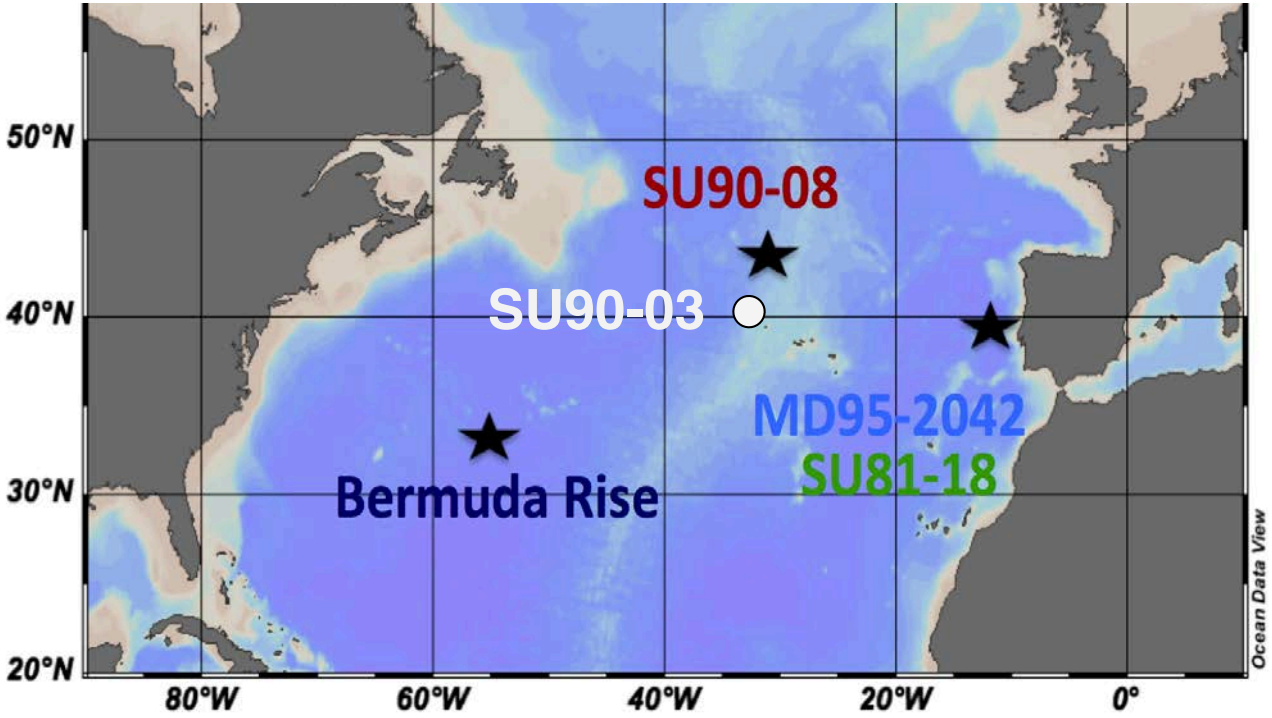
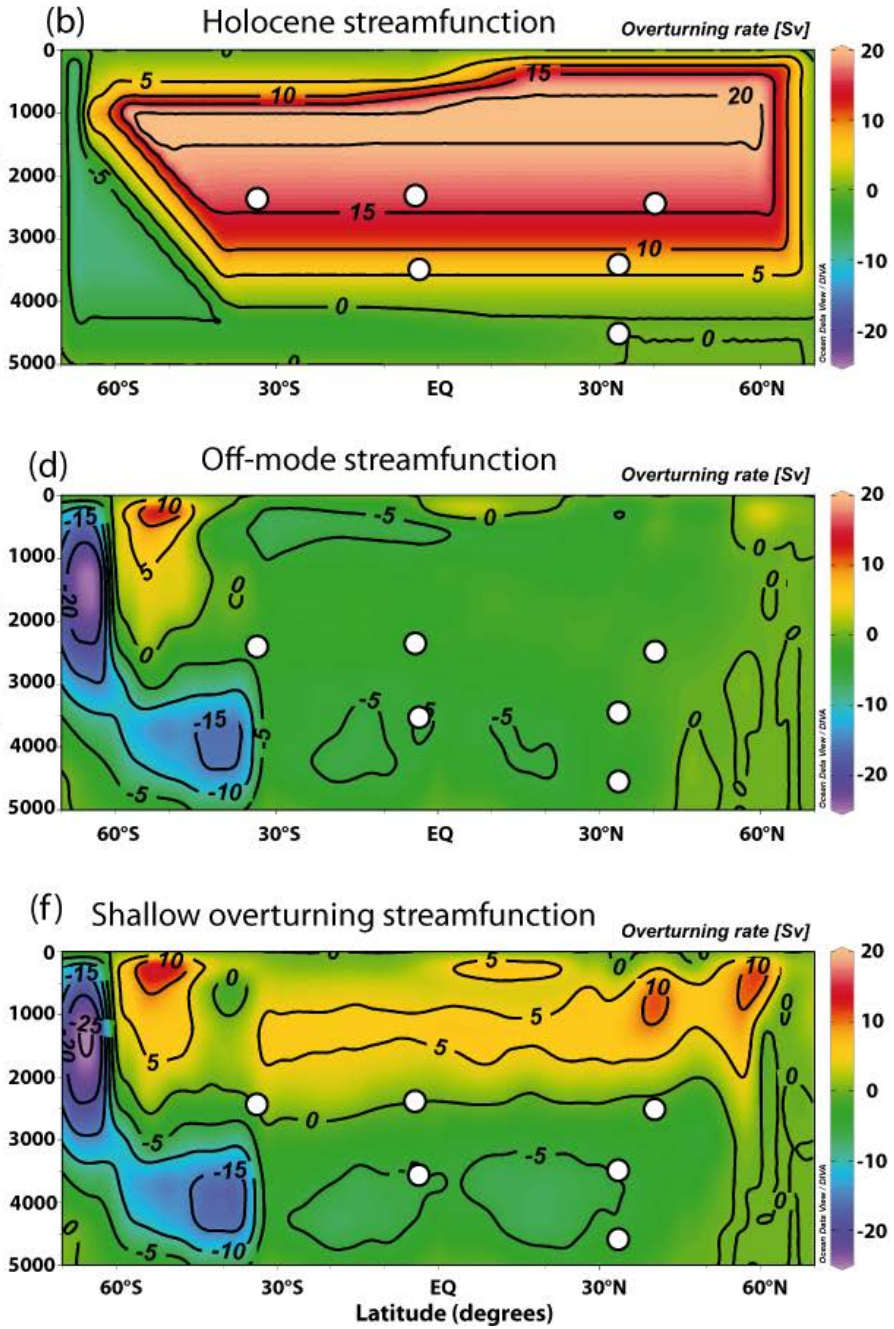


3. AMOC geometry and strength over the last 40 ky

Lise Missiaen's poster:

New Pa/Th record from ~44°N, 3000 m in the North Atlantic





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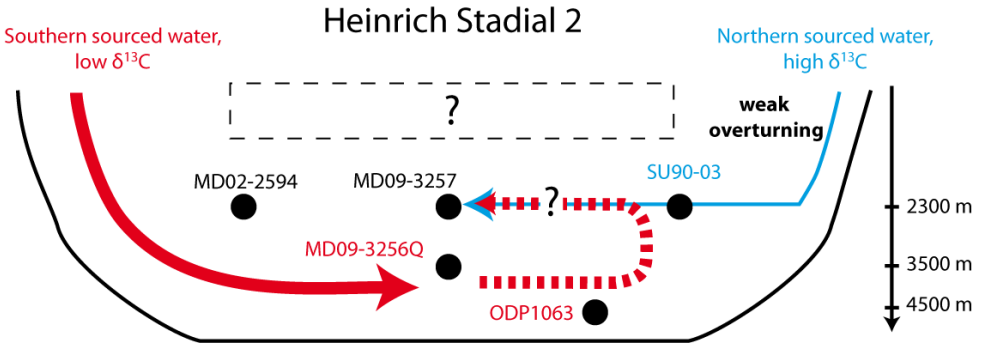
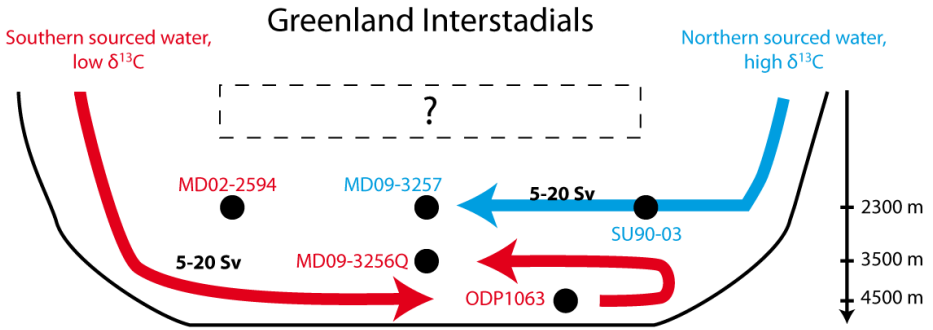




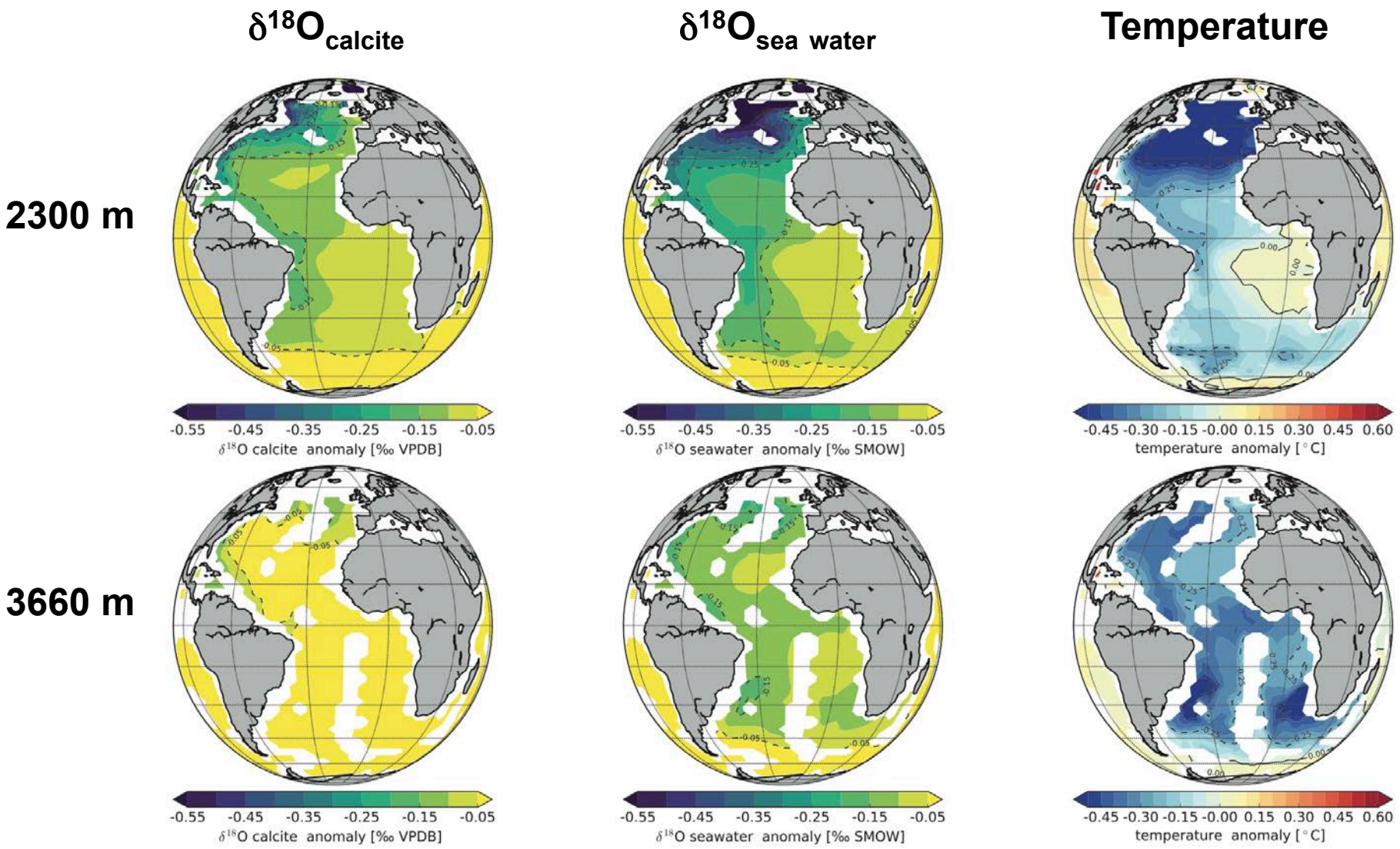
NB: at 4°S: modern NADW: 27 ± 7 Sv [*Lux et al.*, 2001]
modern AABW:~3 Sv [*Lux et al.*, 2001]

3. AMOC geometry and strength over the last 40 ky

Natalia Vazquez Riveiros' poster:

Glacial benthic $\delta^{13}C$ and $\delta^{18}O$ in the western tropical Atlantic during the last 45 ky

iLOVECLIM simulations



Conclusions

• Mid-depth equatorial core records **lower ventilation** (at ~2300 m) and **marked decreases** in **renewal rate** of the water mass overlying the core site (between ~1300 and 2300 m) **during all stadials.**

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• Mid-depth equatorial Pa/Th changed about 1000 y **before** the YD, HS2, HS3 and HS4.

*We suggest that a **positive feedback** linking AMOC slowdown and iceberg discharge is **triggered** when **AMOC slows beyond a certain threshold** → this would explain the difference between H and DO stadials.*

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• Combining Pa/Th and benthic $\delta^{13}C$ data from several water depths and latitudes with Pa/Th simulations shows:

=> HS data in best agreement with off-mode circulation

=> **Interstadial** data in best agreement with shallow overturning circulation;

transport of **northern-sourced** deep water likely **lower** than **modern NADW**;

transport of **southern-sourced** deep water likely **higher** than **modern AABW**