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Holocene Variability of the AMOC as derived from $^{231}Pa/^{230}Th$

L. Gerber[1*], J. Lippold[1], F. Süfke[1], O. Valk[1], M. Ehnis[1], S. Tautenhahn[1], L. Max[2], C. M. Chiessi[3], M. Regelous[4], S. Szidat[5,6], F. Pöppelmeier[6,7]

*Corresponding author: lukas.gerber@geow.uni-heidelberg.de

Introduction

We analyze the AMOC (Atlantic Meridional Overturning Circulation) variability throughout the Holocene based on several marine sediment cores from the western North Atlantic in high temporal resolution (multi-centennial), by utilizing the $^{231}Pa/^{230}Th$ proxy. This proxy indicates bottom water advection strength and has been previously applied mainly to older time periods [1-4]. Here we aim for better connecting the paleo-circulation $^{231}Pa/^{230}Th$-based records of the last deglacial with high resolution Holocene paleo-data.

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

Both ^{231}Pa and ^{230}Th are homogeneously produced by decay of U in the water column. With ^{231}Pa being less particle reactive than ^{230}Th, ^{231}Pa is preferentially advected by the AMOC (Fig. 1).

- Low $^{231}Pa/^{230}Th$: higher ^{231}Pa export → stronger AMOC
- High $^{231}Pa/^{230}Th$: lower ^{231}Pa export → weaker AMOC

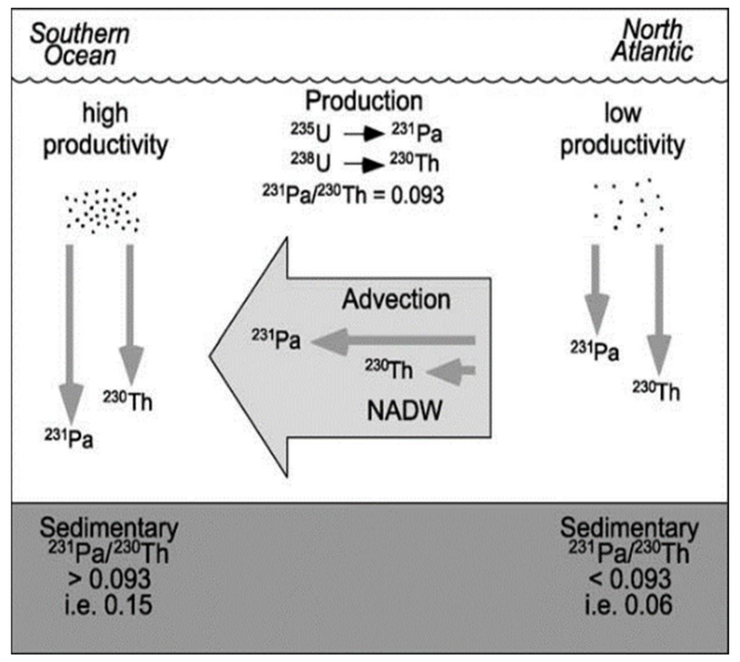

Fig. 1: Schematic representation of the $^{231}Pa/^{230}Th$ proxy in the Atlantic Ocean [5]. NADW= North Atlantic Deep Water.

Study sites

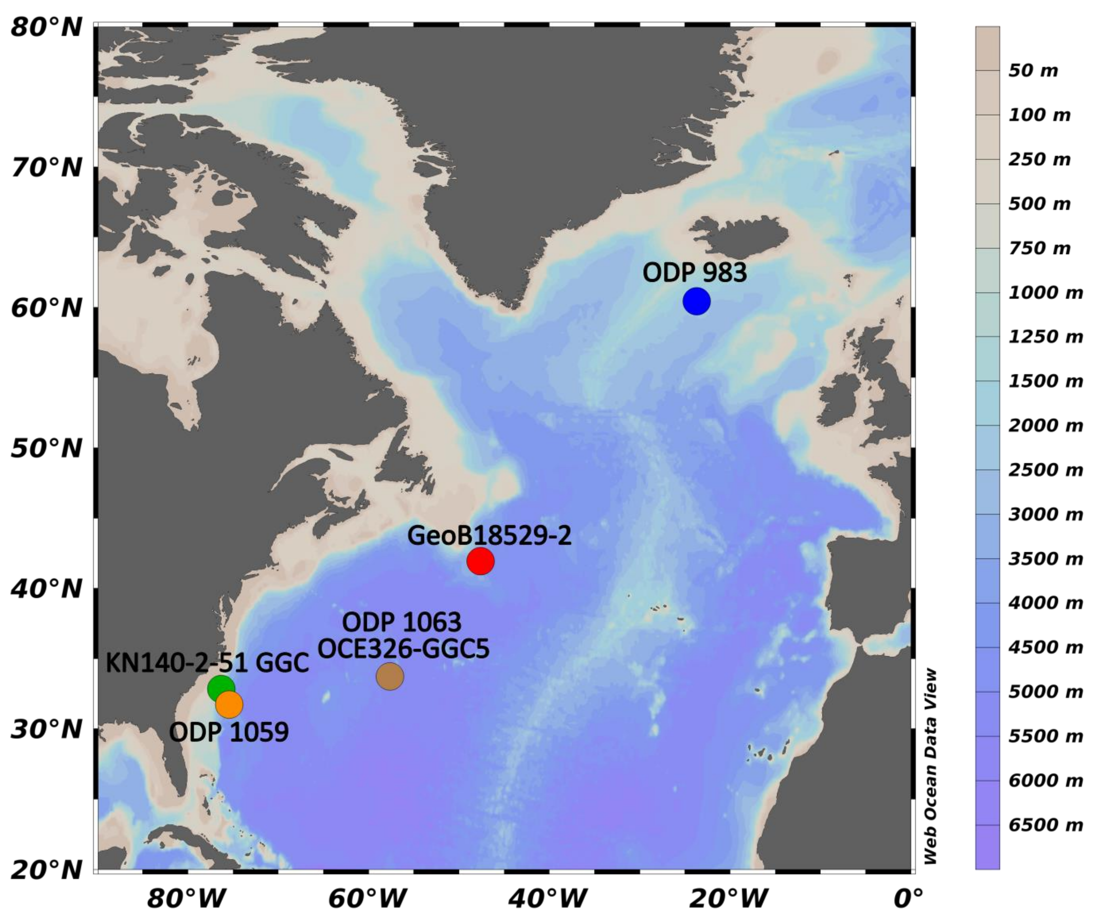

Fig. 2: Core locations.

Results

Here, we present five high resolution Holocene $^{231}Pa/^{230}Th$ records (Fig. 3a) covering the western North Atlantic (Fig. 2), including two new records from this study, two extended data sets from [7] and [8], and [6]. Additionally, biogenic Opal (bOpal) content of the respective cores was measured, to evaluate the influence of varying particle fluxes on Pa.

$^{231}Pa/^{230}Th$ and bOpal show no correlation, suggesting that the effect of varying particle fluxes only plays a subordinate role. The absolute $^{231}Pa/^{230}Th$ ratios vary between the core locations, inner-profile variations are more subdued for the last 10 ka. The most northern and shallowest core, ODP 983, shows increasing $^{231}Pa/^{230}Th$ ratios at the end of the Younger Dryas and the beginning of the Holocene, while the other cores show decreasing ratios (Fig. 3a).

A GAM (generalized additive model) was fitted through the mean-Holocene normalized $^{231}Pa/^{230}Th$ profiles of this study (Fig. 3a). Overall, this fit shows a low variability with deviations from the Holocene mean of about ± 5%.
However, two small peaks of higher normalized $^{231}Pa/^{230}Th$ can be observed in this fit, coinciding with the 8.2 and 4.2 events.

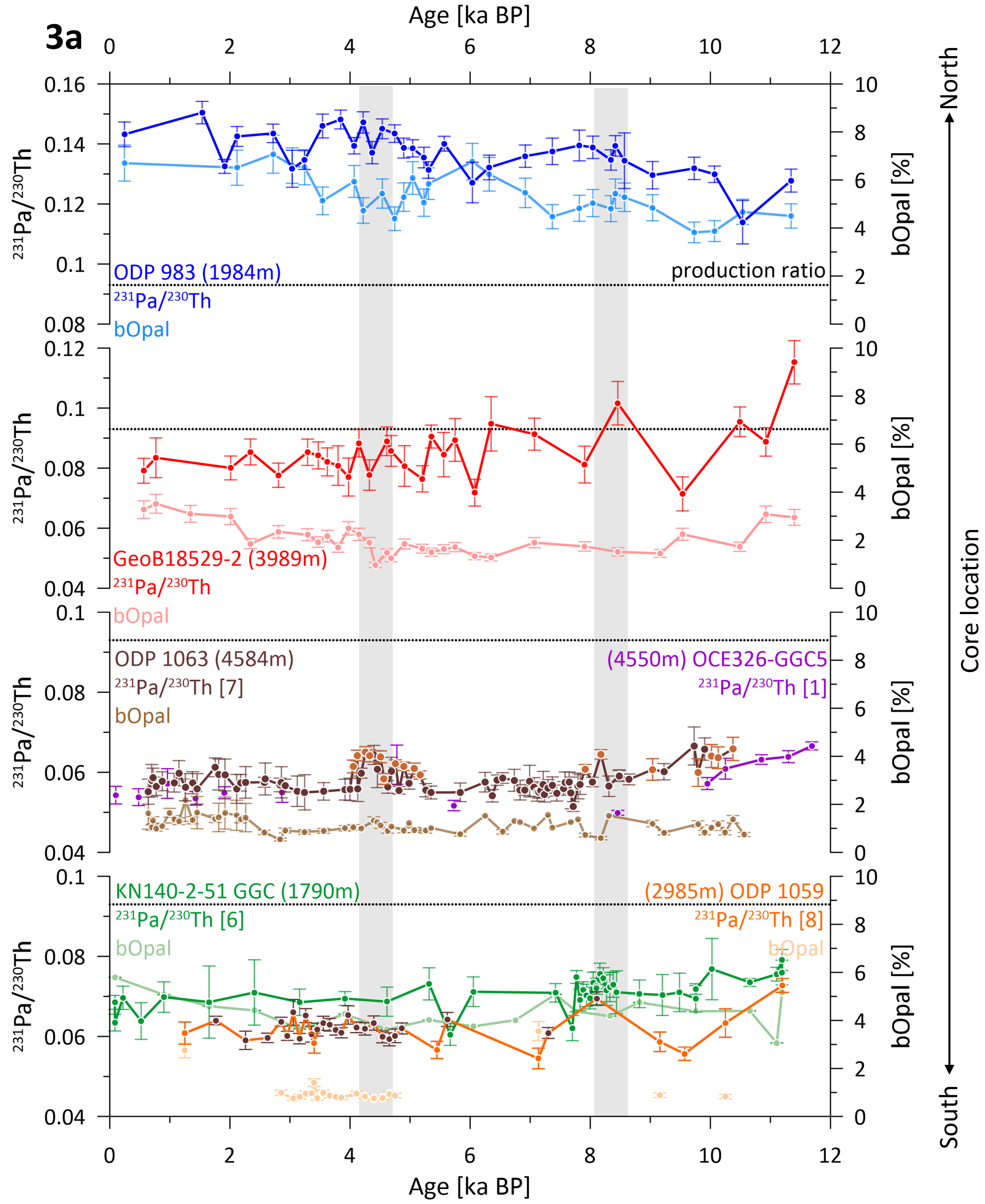

Fig. 3a: High resolution Holocene $^{231}Pa/^{230}Th$ records from the western North Atlantic, compared with its respective bOpal content. Different colored points in ODP 1063 and 1059 indicate new $^{231}Pa/^{230}Th$ data of this study. Highlighted in grey are the 8.2 and 4.2 events, while the black dotted line represents the constant $^{231}Pa/^{230}Th$ production ratio of 0.093 (Fig. 1).

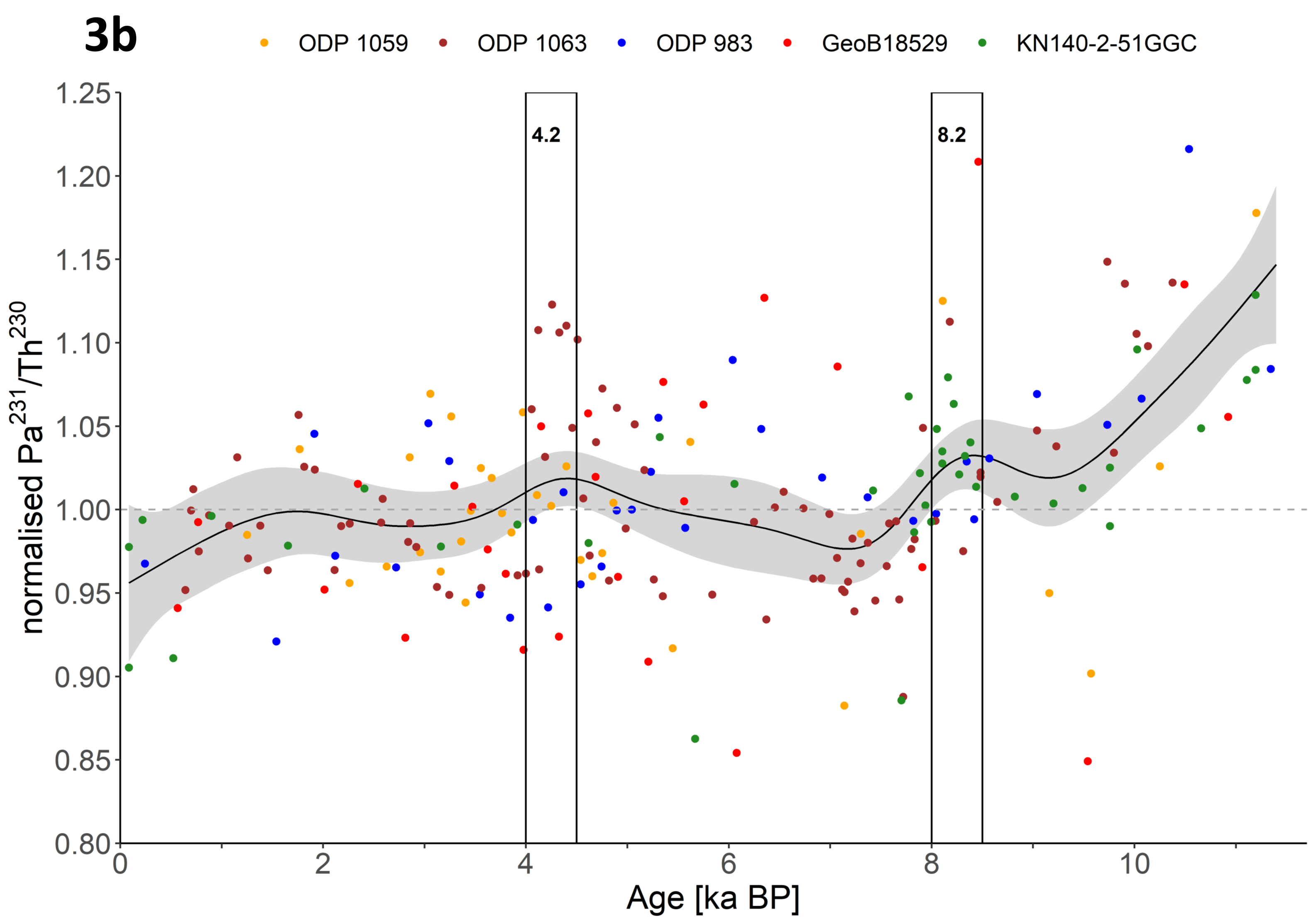

Fig. 3b: GAM fit of the mean-Holocene normalized $^{231}Pa/^{230}Th$ ratios. For the normalization the period form 9.5-0 ka BP was considered, so that possible deglacial effects are not taken into account. Error envelope represents the 95% confidence interval.

Conclusion

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

The absolute $^{231}Pa/^{230}Th$ ratios of the individual sites differ, because local $^{231}Pa/^{230}Th$ within one overturning cell is a function of e.g. traveling distance and water depth [9]. $^{231}Pa/^{230}Th$ of ODP 983 behaves inversely to the other sites, caused by the proximity to deep-water formation areas and higher particle fluxes at this latitude.

Holocene

Long-term trends or changes of the AMOC strength cannot be identified over the Holocene. However, smaller, short-term changes in individual records can be observed.

➢ **Low Holocene multi-centennial AMOC variability**

8.2 Event

4 of the 5 records show slightly increased $^{231}Pa/^{230}Th$ ratios for a short time period over the 8.2 event, suggesting a possible slowdown of the AMOC. Given the low amplitude and not sufficient temporal resolution, questions about the AMOC's response to a potential meltwater input during this event [10] still remain.

➢ **Possible AMOC slowdown over the 8.2 event**

4.2 Event

ODP 1063 shows higher $^{231}Pa/^{230}Th$ during the 4.2 event, while the other cores do not show this feature. These elevated ratios are accompanied with high lithogenic ^{232}Th fluxes and can therefore be explained by increased bottom scavenging of ^{231}Pa, probably caused by benthic storms [11], induced by the transfer of eddy kinetic energy from the surface to the deep ocean.

➢ **No significant AMOC changes over the 4.2 event**

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[1] Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany.
[2] MARUM Center of Marine Environmental Sciences, University of Bremen, Bremen, Germany.
[3] School of Arts, Science and Humanities, University of São Paulo, São Paulo, Brazil
[4] GeoZentrum Nordbayern, FAU Erlangen-Nürnberg, Erlangen, Germany.
[5] Department of Chemistry, Biochemistry and Pharmaceutical Sciences, University of Bern, Bern, Switzerland.
[6] Oeschger Center for Climate Change Research, University of Bern, Bern, Switzerland.
[7] Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland.