Disentangling the effects of particles and circulation on $^{231}Pa/^{230}Th$ during Heinrich Stadials

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Introduction

The Bermuda Rise (Fig. 1) has become a prominent site for the investigation of past changes in ocean circulation strength by the $^{231}Pa/^{230}Th$ proxy *[1-4]*. However, scavenging effects also have been made partly responsible for the archived $^{231}Pa/^{230}Th$. Especially during Heinrich Stadials high dust fluxes are mirrored by the sedimentary Ti/Ca ratio and in $^{231}Pa/^{230}Th$. Furthermore, during Heinrich Stadials sedimentary $^{231}Pa/^{230}Th$ sometimes exceeds the production ratio and therefore indicating a scavenging signal biasing the circulation signal.

In this study we examine the influence of dust input into the North Atlantic with sedimentary Ti/Ca as well as $^{231}Pa/^{230}Th$ during the last glacial period. We aim for disentangling if high $^{231}Pa/^{230}Th$ ratios are indeed indicative of a reduced AMOC or if dust (or dust induced particle fluxes) may cause effective scavenging of both radionuclides possibly overprinting the initial circulation signal.

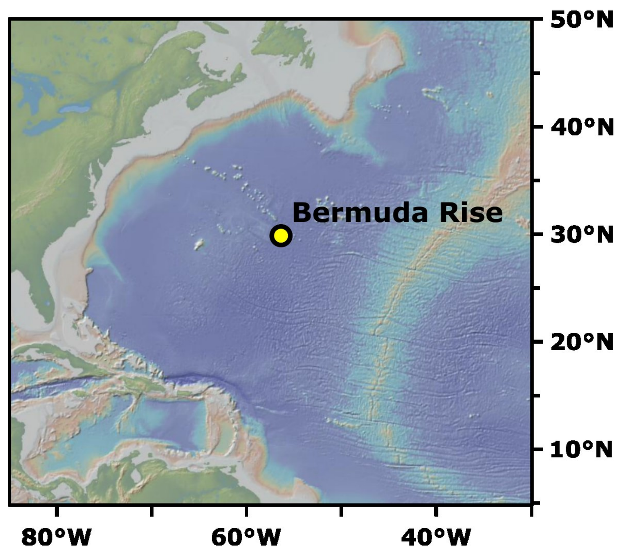

Fig. 1: Overview map of the NW Atlantic. The Bermuda Rise (with cores: OCE326-GGC5 [1], ODP 1063 [2], KNR191-CDH19 [4]) is indicated by the yellow circle.

Bermuda Rise Records vs NGRIP Dust

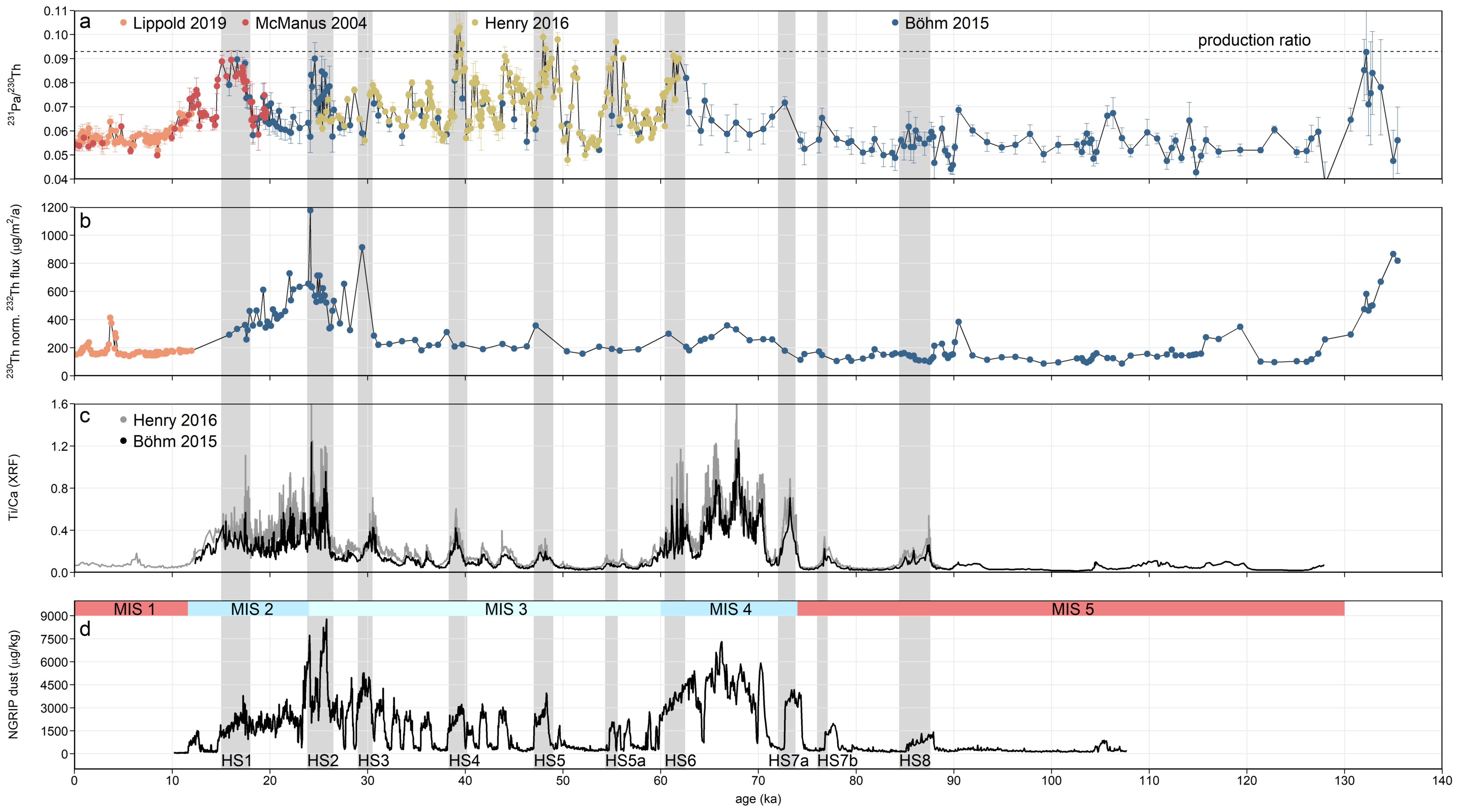

Fig. 2: (a) Sedimentary $^{231}Pa/^{230}Th$ of the Bermuda Rise site *[1-4]* **(b)** ^{230}Th normalized ^{232}Th flux as indicator for dust input into the ocean **(c)** Ti/Ca ratios of the Bermuda Rise Site *[2;4]* **(d)** Concentration of dust in the NGRIP ice core *[5]*.

Earlier Heinrich Stadials

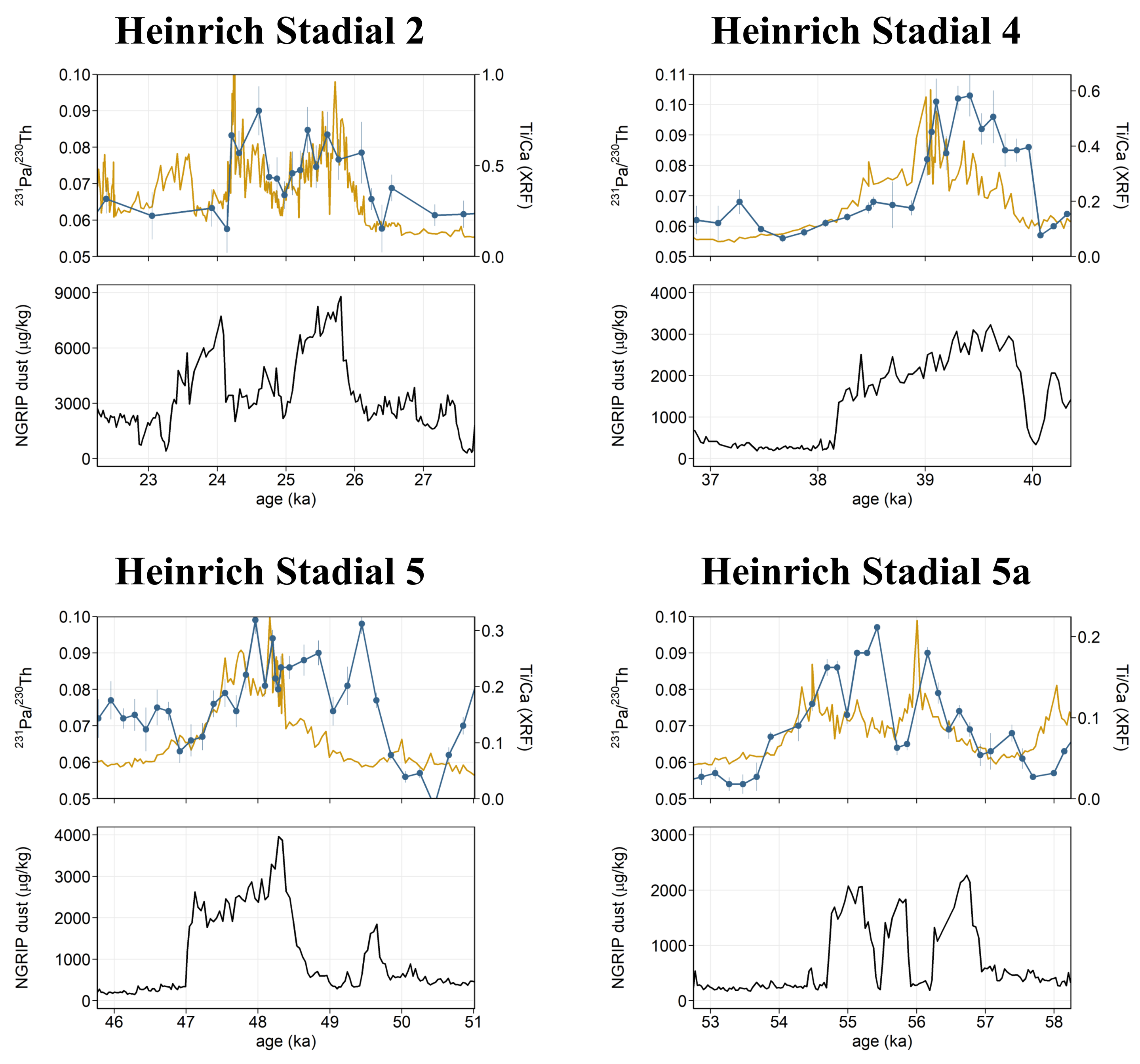

Fig. 3-6: Ti/Ca (yellow) *[2;4]* and $^{231}Pa/^{230}Th$ (blue) *[2;4]* of ODP 1063 compared to NGRIP dust *[5]* during selected Heinrich Stadials from the last Glacial period (MIS3).

- Increases and decreases in NGRIP dust occur abrupt, while sedimentary Ti/Ca reacts more slowly until peak values are reached (e.g. HS4, Fig. 4).
- $^{231}Pa/^{230}Th$ leads the Ti/Ca record from the very same sediment core before reaching peak values.
- Initial increases in $^{231}Pa/^{230}Th$ are in phase with increasing dust.
- Each Heinrich Stadial shows own characteristics in Ti/Ca, $^{231}Pa/^{230}Th$ and dust (Fig. 3-6).

Heinrich Stadial 1

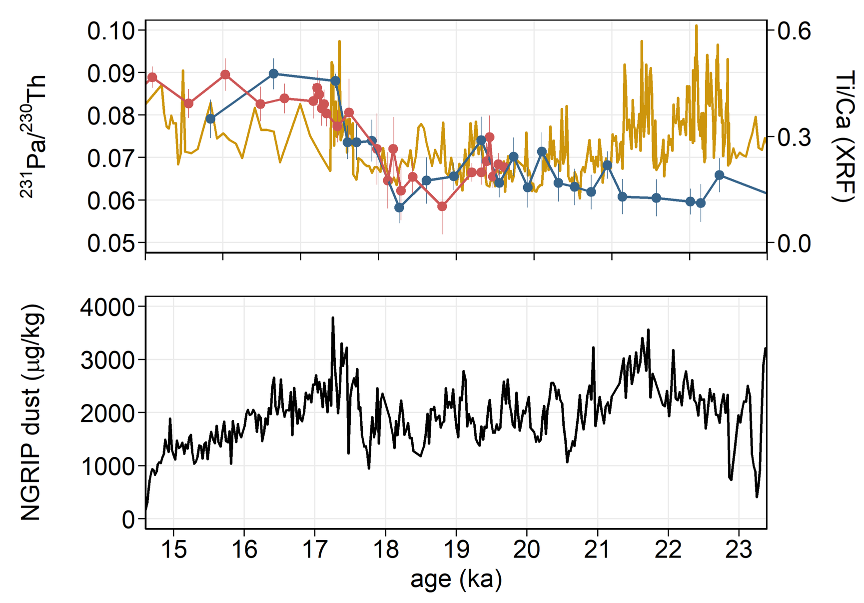

Fig. 8: Ti/Ca (yellow) *[2]* and $^{231}Pa/^{230}Th$ (red/blue) *[1;2]* of ODP 1063 compared to NGRIP dust *[5]* during Heinrich Stadial 1.

- During Heinrich Stadial 1 the strong correlation between $^{231}Pa/^{230}Th$ and dust input as seen from the earlier Heinrich Stadials is not observed.
- While NGRIP dust concentrations do not significantly increase from the LGM to Heinrich Stadial 1, $^{231}Pa/^{230}Th$ at the Bermuda Rise do.

$^{231}Pa/^{230}Th$ for the time period from LGM to Heinrich Stadial 1 records predominantly a circulation signal.

Ti/Ca as Dust Indicator

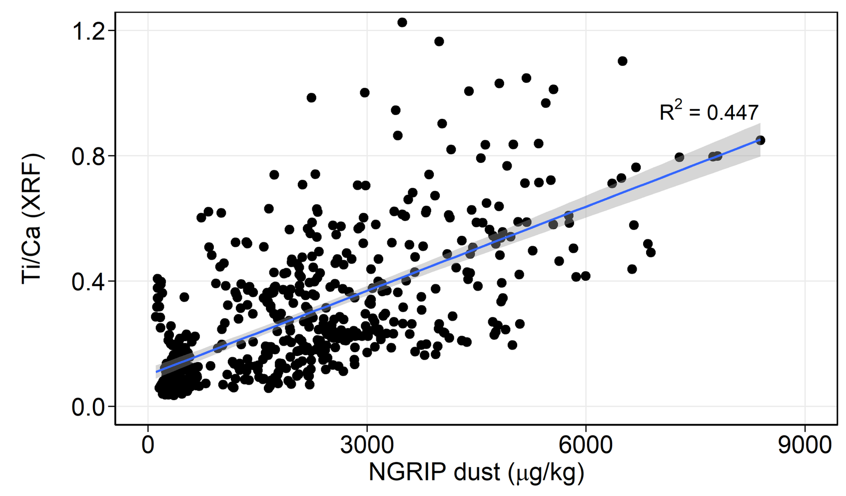

Fig. 7: Ti/Ca of ODP 1063 *[2]* compared to NGRIP dust *[5]*.

- Ti/Ca down-core record follows NGRIP dust concentrations (Fig. 2).
- Highest intensities in NGRIP dust are also seen as highest ratios in Ti/Ca (Fig. 2; MIS 4 and HS2).
- Positive correlation between sedimentary Ti/Ca and dust (Fig. 7).
- Quality of correlation is limited by the high variability of both records and potential age model offsets.

Ti/Ca can be used as a rough indicator for dust input into the NW Atlantic.

Dust-$^{231}Pa/^{230}Th$ feedback hypotheses

Scavenging by dust:
The high input of lithogenic material by dust works as an effective scavenger for radionuclides and increases sedimentary $^{231}Pa/^{230}Th$.

Dust as wind indicator:
High NGRIP dust concentrations are an indicator for strong winds. Stronger wind stress causes intense upper ocean mixing which can contribute to enhanced nepheloid layer occurrences, possibly acting as an effective scavenger for radionuclides *[6]*.

Iron fertilization:
High dust input into the ocean can stimulate primary production by iron fertilization *[7]*. High particle fluxes from the primary production (e.g. biogenic opal) can effectively scavenge ^{231}Pa *[8]*.

Detrital correction:
Calculating sedimentary $^{231}Pa/^{230}Th$ requires the correction for detrital $^{238}U/^{232}Th$. Variations of this ratio due to dust input may influence sedimentary $^{231}Pa/^{230}Th$.

References:
[1] McManus et al., Nature 428 (2004). [2] Böhm et al., Nature 517 (2015). [3] Lippold et al., Geophyiscal Research Letters 46 (2019). [4] Henry et al., Science 353 (2016). [5] Andersen et al., Nature 431 (2014). [6] Hayes et al., Deep-Sea Research II 116 (2015). [7] Lambert et al., Geophysical Research Letters 42 (2015). [8] Chase et al., Earth and Planetary Science Letters 204 (2002).

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