

AC3: Response to editors' comments

Editor comments, [Author response](#), [Changed manuscript](#)

Response to Editor comments:

by Francesco Muschitiello

We thank the editor for the handling of our manuscript and the additional questions. The points raised could indeed be clarified to improve the text and the corresponding passages have been extended. However, we additionally wanted to address these points in more detail with this reply:

Editor

- 1) How effectively can 200 μm horizons integrate/capture annual events when SNR is only ~ 1 at that scale (i.e. when signal and noise are approximately equal at that scale)?

An SNR of 1 implies a maximum attainable correlation of ~ 0.71 :

$$r_{max} = \sqrt{\frac{SNR}{1 + SNR}}$$

In the typical proxy–climate context, this can already be considered relatively high.

The difference between this theoretical upper bound and realistically achievable correlations can be illustrated using modern varved sediments from the Santa Barbara Basin (SBB). Alfken et al. (2020) report correlations of ~ 0.6 between MSI-derived U_{37}^k and 0 - 30 m temperature data at quarterly resolution. At the same time, the exemplary varved sections show SNR values of $\sim 1.5 - 2$ at subannual resolution (Fig. 6A), corresponding to theoretical r_{max} values of ~ 0.82 .

Given the different sedimentological conditions in our samples and the lack of overlapping instrumental data for independent validation, we deliberately refrain from reporting correlations or making direct climate interpretations at annual timescales. Instead, this study represents an initial step toward validating the analytical workflow under optimal natural conditions (<1 mm sample spacing) and establishing a baseline estimate of shared signal relative to uncertainty for individual MSI series from a single core.

The short spatial correlation lengths identified in our variogram analysis (Fig. 4) are encouraging, as they suggest that spatially correlated noise, which could artificially inflate SNR estimates through shared non-climatic variability, does not strongly dominate the shared variance between adjacent slices. However, replication across larger spatial distances will be required before robust climate interpretations can be made at annual or subannual timescales.

We adjusted the text to clarify the intended use of SNR estimates in this study and emphasize that the current SNRs estimates can still contain correlated noise between replicates on top of the shared climatic information

Editor

2) Given that bioturbation creates spatial heterogeneity even in laminated sections, how much of the measured variability is climatically meaningful versus mixing artifacts?

Only variability shared between replicates increases SNR. In the absence of systematic sorting or self-organization processes affecting alkenones, bioturbation is expected to reduce SNR by mixing initially coherent signals rather than artificially enhancing them. Small-scale bioturbation, as described by Bernhard et al. (2003), would therefore tend to attenuate climatic variability through signal smoothing.

We find no evidence of partial large-fauna mixing or lateral burrowing in our sediment sections (see X-ray images in Fig. 2 and 6, Behl 1995), making it unlikely that mixing artifacts inflate the shared signal between replicates. Furthermore, the preservation of vertically distinct millimeter-scale laminae and the longer horizontal than vertical spatial correlation lengths in laminated sections (Fig. 4) indicate that sediment redistribution under low-oxygen conditions is limited and unlikely to remove interannual to multi-year signals.

The extent to which variability is climatically meaningful depends on the interaction between sedimentation rate, target timescale, and mixing intensity. In thoroughly mixed intervals (e.g., 10–15 cm in KC1B), aggregation does not increase SNR and variograms show no spatial differentiation, indicating that high-resolution sampling does not recover additional temporal structure. In contrast, laminated sections retain spatial structure consistent with preserved climatic variability.

The corresponding text passages have been improved in combination with comments by reviewer #2.

References

Behl, R. J.: Sedimentary Facies and Sedimentology of the Late Quaternary Santa Barbara Basin, Site 893, Proceedings of the Ocean Drilling Program, 146/2, 295–308, <https://doi.org/10.2973/odp.proc.sr.146-2.276.1995>, 1995.

Bernhard, J. M., Visscher, P. T., and Bowser, S. S.: Submillimeter life positions of bacteria, protists, and metazoans in laminated sediments of the Santa Barbara Basin, Limnology and Oceanography, 48, 813–828, <https://doi.org/10.4319/lo.2003.48.2.0813>, 2003.

Stastical proof, e.g.: <https://statproofbook.github.io/P/snr-rsq>

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