

## ***Interactive comment on “Response of biological productivity to North Atlantic marine front migration during the Holocene” by David J. Harning et al.***

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Received and published: 21 October 2020

Harning et al. present an interesting and comprehensive study of the Mid-Late Holocene paleoceanography on the North Icelandic Shelf. They use a broad spectrum of micropaleontological and biogeochemical proxies seasoned with a sound statistical treatment. The major drawback of the manuscript is that some of the proxies were analyzed only in one core, which precludes a full comparison between the two records. It is also a pity that the records do not cover the entire Holocene. However, the study will certainly be of interest both for the researchers interested in the paleoceanographic/paleoclimatic history of Iceland and as a validation/comparison of the

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proxies used. It also has some implications for the Icelandic economy. Therefore I find the MS suitable for publication in *Climate of the Past* after minor revisions according to general, specific and technical comments listed below. I am looking forward to the authors' response and further discussion.

Best regards, Maciej Telesiński

General comments

**Abstract:** The abstract is not very clear, especially for a reader unfamiliar with NIS. I suggest using terms like 'westward/eastward migration of the front' etc. 'the AF stabilized on the NIS' doesn't say much.

**The regime shift analysis:** Even though the regime shift analysis certainly has a sound statistical basis, it is not convincing for me. First of all, the number and timing of shifts are generally different in both records so they do not bring much to the discussion. You attempt to group them (vertical bars in Figs. 3 & 4) but it is not convincing either as the intervals are different for different sets of proxies (Fig. 3 vs. 4) and they do not agree with the boundaries between the intervals defined in the discussion. Even regime shifts within the same proxy (%N. pachyderma and %T. quinqueloba) do not agree.

**The timing of major oceanographic shifts (and the discussed intervals) is unclear.** The abstract and conclusions give 6.1 and 3.8 ka (lines 18-19 and 428-429), the introduction – 6.4 and 3.5 ka (line 54) and the discussion – 6.3 and 3.4 ka (lines 293 and 321). Please give consistent ages. Also, the naming of the 3 intervals is unclear. Are they identical with 'early MidH', 'late MidH' and 'LateH'?

If you write 'Middle/Late Holocene' (with capital letters) it implies that you use the formal subdivision of the Holocene. You should refer to Walker et al. 2019 JQS and use the ages given there as the boundaries. Otherwise use 'middle/late Holocene'.

**Discussion:** The discussion is filled with references to changes in individual proxies which is largely a repetition of the Results section and make the discussion hard to

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follow. Please try to generalize the information from individual proxies and describe rather changes in environmental parameters and the implications for the oceanographic evolution.

#### Specific comments

37-40: Please rephrase. First, you write that the fronts separate AtlW and PW and then there appears another water mass between them. This might be confusing.

79: It is unclear what does 'it' refer to. Sea ice, I presume? Please rephrase.

88-89 and elsewhere: It is already stated in the previous sentence that these are 'marine sediment' cores so it is unnecessary to repeat it here and elsewhere.

106-112 and 132-144: The information on HBI III and IV is partly a repetition. Please rephrase.

152 and elsewhere: The '(s)' is unnecessary. As *N. pachyderma* and *N. incompta* are two different species it is obvious that by *N. pachyderma* you mean the left-coiling specimens.

161: Which technique was used for which reconstruction? Please specify.

184: Why are the results described in a different order than they are shown in Fig. 2? This is slightly confusing. Please reorder either the description or the figure.

194-196: This sentence is strangely formulated, suggesting that the IP25 and HBI III records show similar patterns. The similarity between the HBI III records in both cores is not evident, at least not in the figure with equal vertical scales. Please rephrase.

210: As the value of  $T_{25} = 1$  seems to be an important threshold (line 142), the relation of the data to this value should also be described here.

236-237: I would rather say that *C. neoteretis* shows maximum abundances in the Late Holocene or the late Middle Holocene (after 5 ka).

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254-256 and 258-263: Consider moving these sentences to the discussion.

265: The paragraph lacks the discussion on *N. iridea* and HBI IV which are grouped in the same AF cluster.

271-291: As you dedicate a considerable part of the discussion to *N. iridea*, consider adding the reference to its original description (Heron-Allen & Earland, 1932).

279: Please explain why the species' abundance is underestimated using dry analyses.

299: How can the percentage of *T. quinqueloba* document low surface diatom productivity? Please rephrase.

314: From Fig. 4e, I would say it is rather  $\sim 6^{\circ}\text{C}$  than  $\sim 8^{\circ}\text{C}$ .

322-323: Please rephrase to, e.g., "At the beginning of this interval, planktic foraminifera indicate that NIIC Atlantic Water dominated the surface whereas benthic foraminifera show that Arctic Intermediate Water occupied the lower depths on the western NIS (Fig. 3)."

324: At 6.1 ka the *T. quinqueloba* abundance decreases (at least the LOESS-smoothed line).

334-335: The regime shifts have different timing for the two proxies (see the general comment on regime shifts).

354-355: This is contradictory to what is shown in Fig. 4f (the figure shows a decreasing influence of NIIC, i.e., a shift in surface water source). Please rephrase or change/remove the figure.

360-361: Please explain how the changes in AMOC strength influence the SST.

386-397: For the discussion of the warming over the last two millennia I suggest taking into consideration the shift in NAO (Olsen et al. 2012 NatGeo).

399-421: The section does not discuss the controls on the Holocene migration of the

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Arctic and Polar Fronts sufficiently. It rather gives an impression that all these state-of-the-art methods and the discussion are unnecessary if the frontal system is driven by insolation anyway. Furthermore, from Fig. 7 the fronts' migration does not seem to be progressive if the modern state is almost identical to that of the (late) Mid-Holocene (7b). Please expand the discussion in this section. Finally, the second paragraph could be a separate subsection (e.g., 'Future implications/predictions').

406: It is unclear what does 'its' refer to.

407-408: The ongoing warming is not driven by fossil fuels themselves, but by the burning of them. Please rephrase to, e.g., anthropogenic warming.

428: Can you really say that it stabilized if large variability both in HBI III and in %T. quinqueloba is observed over the 6.1-3.8 ka interval?

433-435: This conclusion is quite obvious just looking at the oceanographic setting of the NIS.

Fig. 7: What is the Early Holocene reconstruction based on if the presented records start in the early Middle Holocene? The diagrams should present the oceanographic conditions in intervals 8-6.3 ka, 6.3-3.4 ka and 3.4 ka – present (and perhaps 'present' based on modern oceanographic data for reference). See also the general comment on the timing of major oceanographic shifts.

Fig. S2: Please rephrase "GDGT-0/crenarchaeol values around and below 2 (grey dotted line) indicate minimal GDGT contributions from methanogenic archaea that may compromise TEX86L-based temperature inferences" to, e.g., "GDGT-0/crenarchaeol ratios around and below 2 indicate that the GDGT pool is not altered by methanogenic contributors"

Fig. S5: What is the blue vertical bar?

Technical corrections

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11-12: Shouldn't it be "the migration of frontal zones"?

164: results

178: select – is this word correct here?

239: was included?

271-291: *N. iridea* in italics.

294 and subsequent subsection titles: Change to "Northern distal Arctic Front (8 to 6.3 ka BP)" and so on.

329: Change 'to' to 'at site'.

377: Remove 'from'.

409: Not sure if this is the correct way of citing a website in CP (please refer to the guidelines for authors) and if citing the Icelandic Met Office homepage is the most relevant here. Are there no papers describing the last century's warming?

Fig.1. The colours of the sea ice edge lines are hardly visible.

Fig. 2: Please indicate the meaning of individual proxies (as in Fig. 3 – Arctic Front, growth rate etc.)

Fig. 2i-j: The value of T25 = 1 seems to be an important threshold (line 142) so I suggest marking it on the plots with a dashed horizontal line.

Figs. 2, 3, 4a, 6: Please add ages on the upper axis for easier reading of the plots. Marking the intervals as defined in the discussion (8-6.3, 6.3-3.4, 3.4-present or 'early MidH', 'late MidH', 'LateH') would also be helpful.

Fig. 4e: Giving exact ages of individual lines would be more informative than the colour coding used (see a similar example in Fig. 10 of Hald et al. 2007 QSR)

Fig. 5: Consider changing colours – red somehow does not fit with Polar Water. E.g.,

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blue – purple – green – red.

Fig. 6a: The regime shifts are not marked.

Fig. S4: *Globigerinita glutinata*, not *qlutinata*

Supporting Information Text S1 was not included in the Supplemental Material file and was therefore not reviewed.

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Interactive comment on *Clim. Past Discuss.*, <https://doi.org/10.5194/cp-2020-119>, 2020.