The Cryosphere Discussions

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Reply on RC1

Dieter R. Tetzner et al.

Author comment on "Regional variability of diatoms in ice cores from the Antarctic Peninsula and Ellsworth Land, Antarctica" by Dieter R. Tetzner et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-160-AC1, 2021

Dear Editor,

We appreciate all the comments and suggestions made by Prof. V. Jones and thank for her time and consideration. Please find to follow a list of all points raised and our responses to each item.

Reviewers comment #1

The presence of non-marine diatoms needs some further discussion throughout the paper.

Firstly, in the introduction. Here there needs to be more of an acknowledgement that diatoms are also abundant and diverse in lakes, streams and wet habitats (e.g. soils) in terrestrial environments of Antarctica as well as growing on ice e.g. in cryoconite holes (Verleyen et al 2021, Noga et al 2020, Cavacini 2001, Van de Vijver & Beyens 1998). Thus there are additional sources of diatoms which either can grow *in situ* or be blown onto the ice which need to be taken into consideration. The authors mention some of these sources later in the paper, but they need to be referred to in the introduction.

Response:

Additional information about other environments where diatoms can be found was added in the Introduction as suggested (Introduction – 1st paragraph).

Reviewers comment #2

Diatoms in cryoconites aren't mentioned at all, are these environments present in their sampled locations? could they contribute an additional source?

Response:

Cryoconite holes are common in Alpine and Artic glaciers. However, in Antarctica, cryoconite holes have been comparatively rare, with most of them located in the McMurdo Dry Valleys (**Fountain et al., 2004**), some in the Dronning Maud Land Coast, East Antarctica (**Weisleitner et al., 2020 and references therein**) and just one report of cryoconite holes from the northern AP, in the South Sandwich Islands (**Buda et al., 2020**). Unlike cryoconite holes in Alpine and Artic Glaciers, Antarctic cryoconite holes are mostly perennially ice-lidded due to low air temperatures year-round, so it is unlikely that they are a prevalent source of diatoms to the ice core records presented in this study. We have addressed this comment by acknowledging cryoconite holes as potential source of diatoms (Introduction – 1st paragraph) and by describing the scarcity of cryoconite holes (and other non-marine water bodies) in this region and their limitations to become a common source of diatoms to our ice core sites (Discussion – Section 5.1 – 1st paragraph).

References:

Buda, J., Łokas, E., Pietryka, M., Richter, D., Magowski, W., Iakovenko, N. S., ... & Zawierucha, K. (2020). Biotope and biocenosis of cryoconite hole ecosystems on Ecology Glacier in the maritime Antarctic. Science of the Total Environment, 724, 138112.

Fountain, A. G., Tranter, M., Nylen, T. H., Lewis, K. J., & Mueller, D. R. (2004). Evolution of cryoconite holes and their contribution to meltwater runoff from glaciers in the McMurdo Dry Valleys, Antarctica. Journal of Glaciology, 50(168), 35-45.

Weisleitner, K., Perras, A. K., Unterberger, S. H., Moissl-Eichinger, C., Andersen, D. T., & Sattler, B. (2020). Cryoconite hole location in East-Antarctic Untersee Oasis shapes physical and biological diversity. Frontiers in Microbiology, 11, 1165.

Reviewers comment #3

Secondly, the 'broad ecological affinities' of the *Cyclotella* group (L300) needs a bit more unpacking. Many of these species are associated with freshwaters; the *Cyclotella* group as defined here may be considered to have a broad affinity but within it specific taxa have much narrower niches. By grouping together in this way information has been lost. Given the authors' comments about good preservation (e.g L179) it would have been useful to know (perhaps in the methods) the constraints on greater taxonomic resolution. Why was it not possible to identify diatoms to species level? If species had been determined then these could be more confidently assigned to aerial, freshwater, brackish or marine categories – diatom species are pretty faithful, especially in terms of salinity. *Cyclotella* is an important component at ice cores JUR and SKBL so there needs to be a bit more discussion of the possible genera and species found in the ice cores and where these are found in present day communities. The same point applies to the *Navicula* and *Achnanthes* groups (Table 3) as species from these groups/genera can be found in aerial or freshwater habitats as well as marine ones.

Response:

The reason to combine all diatoms identified as *Cyclotella* into a single *Cyclotella* group was due to the wide variety of diatom frustules with recognisable *Cyclotella*-like features but unidentified to species level due to insufficient image resolution, partial obscurance, or absence of diagnostic features. Filters were analysed for the presence of diatoms using an SEM equipped with an automated stage that acquires a grid of pictures with a dynamic focusing interpolation. The automated system images the filters in an efficient and optimized way. However, it does not permit zooming-in and re-focusing on individual diatoms to get a higher-definition image to differentiate subtle differences in the ornamentation. We circulated the best images of the most common *Cyclotella*-types to several colleagues in the polar diatom community and received only one suggested identification and several comments on being unable to resolve diagnostic features. Whilst we can't be sure of the source of these taxa, we can be confident that they are not sourced from the sea ice zone or open ocean south of the Polar Front, where these morphologies have not been recorded in either water column or sediment samples. Because of these limitations, we decided to group all *Cyclotella*-type morphologies into one group (The same applies to *Navicula* gp. and *Achnanthes* gp). We acknowledge a detailed classification of diatom species would yield additional information to better understand the diatom record preserved in ice cores and is something that we intend to explore and resolve in future work.

To address this comment, we have added further information on the constraints of our classification in the method section (Methods – Section 3.2 - 6th paragraph) and amended our description of the Antarctic marine taxa as 'prevalent' within the diatom assemblage rather than 'dominant' (across the whole manuscript).

Reviewers comment #4

The fact that marine diatoms consist of just over half (58%) of the assemblages (L307, Table 3) at the 4 sites means you do have to spend a bit of time thinking about diatoms from non-marine environments too. It is misleading to say in terms of marine components that (L330) they are – 'almost exclusively dominated' or (L341) there are 'minor contributions' from exposed sediments and freshwater and brackish. Stating (L380) that ice cores from this region are uniquely situated to record marine transported diatoms over emphasises this importance of the marine diatoms.

Perhaps this is a missed opportunity? it's not binary i.e., an ice core could provide useful environmental interpretations from both marine and terrestrial sources if those sources can be well separated which they should be if high enough taxonomic resolution is employed. For example, questions re. extent of terrestrial sources could also be explored.

Response:

We absolutely concur that the non-marine taxa offer the potential for greater environmental understanding and intend to explore this in subsequent work. However, a previous study has already pointed out the numerous limitations to identify the source(s) for non-marine diatoms in Antarctic snow air and snow samples (**McKay et al., 2008**). Since considerable time investment would be needed (manually locating and re-imaging individual specimens, undertaking several taxonomic investigations, etc.) with no certainty that definitive source region(s) could be identified, we consider this to be beyond the scope of this work.

As reported in our results section, at least 58% of the classified diatoms from each site were exclusively marine. These correspond to all the unambiguous classifications. The remaining fraction, the ambiguous group, comprised specimens identified as benthic, brackish and/or freshwater (some could also be marine e.g. *Navicula*) and diatoms that were, at best classified to genus level (excluding exclusively marine genus).

The broad ecological affinities of these groups prevented us from establishing a clear origin for the "non-exclusively marine" fraction of the assemblage. We acknowledge there is a possibility that the whole "non-exclusively marine" fraction of the assemblage could be entirely comprised by non-marine diatoms. To address this comment, we have modified the discussion section, accounting for the potential inputs from non-marine sources (Discussion – Section 5.1 – 1st paragraph).

As previously mentioned in Response #3, we acknowledge a detailed classification of diatom species that comprise our diatom groups would contribute valuable information to better identify their sources and intend to complete this as part of future research. In the manuscript we have added a clear statement of our intention to focus on the significance of the Antarctic marine taxa contribution to the assemblage in this study and acknowledge the similar potential in identifying the remaining taxa and their source regions. (Discussion – Section 5.1 – 1st paragraph).

We also amended the text to better acknowledge the contribution of "non- marine" taxa.

Reference

McKay, R. M., Barrett, P. J., Harper, M. A., & Hannah, M. J. (2008). Atmospheric transport and concentration of diatoms in surficial and glacial sediments of the Allan Hills, Transantarctic Mountains. Palaeogeography, Palaeoclimatology, Palaeoecology, 260(1-2), 168-183.

Reviewers comment #5

In sections 2.1 2.2 and 2.3 current conditions in terms of oceanographic, climate and sea ice are detailed but there is no mention of what is happening on the land...if we accept that there is, or at least could be, a terrestrial signal in the ice cores then a brief discussion of recent terrestrial changes would be justified.

Response:

We added a paragraph in section 2 ("Regional Settings") presenting a brief review of recent terrestrial changes in the region.

Reviewers comment #6

In Table 2 high proportions of diatoms are 'unclassified' e.g. in JUR 544 diatoms out of 1149 (i.e. *c.* 50%) but also high at other sites (e.g. SHIC *c*. 25%), I assume these are the (L157) "unidentified (obscured, undiagnostic or indistinct)" diatoms. With so many in this category (I acknowledge when doing diatom analysis allocating some diatoms to this category is inevitable, but in my experience, these would be unusually high proportions) there needs to be a bit more detail as to why and whether this has any consequences. For example, if they are obscured then by what? What is meant by undiagnostic? And indistinct? Most diatoms can be identified to species level (or if not identified with confidence to a described species at least put into separate taxonomic units) so is this an issue with the technique, for example the use of SEM rather than light microscope? Some comments would be useful. What I am worried about here is some sort of systematic bias, for example if some genera are more undiagnostic than others due to being say harder to identify.

Response:

The high proportion of "obscured & undiagnostic" diatoms is due to the large amount of

other insoluble particles & diatom fragments present in ice cores. The insoluble particulate matter greatly outnumbers the diatoms (roughly 100:1 ratio) and frequently obscure part of the diatom remains (**See Figure 1 to Figure 6 - Supplement**). The large number of fragmented diatoms in snow and ice core samples has been widely documented, with fragments sometimes even exceeding the number of whole diatom frustules present in the sample (**Burckle et al., 1988; Budgeon et al., 2012; Delmonte et al., 2017; Allen et al., 2020; Tetzner et al., 2021**). This characteristic feature highlights how diatom records preserved in ice cores differ from the diatom records preserved in other archives (marine cores, lake sediments, etc). Since many diatom fragments do not retain diagnostic features, it is generally not possible to classify them (**See Figure 1 to Figure 6 - Supplement**). It is also important to note that there was no partiality in fragmentation nor concealment, based on the ratios of pennate to centric fragments and the varied morphologies of partially covered frustules. Therefore, it is unlikely that "obscured & undiagnostic" diatoms are causing a systematic bias.

We have added a detailed explanation of the above to better communicate the constraints encountered in analysing the diatoms from these AP/EL ice cores (Methods – Section 3.2 - 6th paragraph).

Reviewers comment #7

The percentage diatom assemblage data presented in Figures (2 -4) are "normalised" to the main species (i.e. recalculated to 100%) but when you have varying amounts of unidentified species it makes it difficult to compare between sites. Ideally, you need to look at the whole assemblage if not then there is an assumption that all the unidentified diatoms are a random subsample (not biased) of the assemblage? Is that a reasonable assumption?

I assume that as with light microscopy fragments are counted e.g. a fragment of a raphid diatom central area is usually distinct enough to assign to a genus if not a species. But if fragments form part of the 'indistinct' category then there is a need to square this with the pristine nature (ornamentation and chains are mentioned L409) of the diatoms. Again, this could be covered with more detail on what constitutes the 'unclassified' portion.

Response:

As previously mentioned (See response comment #6), the large number of "unclassified" species is due to the large number of obscured diatoms and undiagnostic diatom fragments, a characteristic feature in the diatom records preserved in ice cores. The recovery of specimens still articulated in short chains at the bottom of the ice cores evidence the diatoms we find in ice cores are not affected by mechanical fracturing after being deposited. This is also supported by lab experiments where diatom frustules have

withstood pressures equivalent to the ones exerted at the bottom of an icesheet (**Hamm et al., 2003**). Therefore, supporting diatoms are not fragmented within the ice. Since the "undiagnostic" fragments are not likely to be produced in the ice, then, we are able to assume that they constitute a random subsample which does not bias the "normalisation" of the diatom assemblage. We acknowledge there will always be a potential bias when defining the main diatom assemblage. However, the assumptions we have taken do not contribute to increase the bias. Since the "unclassified" category contributes 18 to 52% of the total annual diatom abundance, we agree this must be acknowledged in the manuscript.

To address this comment we have modified the manuscript, emphasising the presence of fragments (Discussion – Section 5.2 – 4th paragraph), including more details about the "unclassified" portion (Methods – Section 3.2 - 6th paragraph) and outlining some of the possible causes for diatom fragmentation before their deposition (Discussion – Section 5.2 – 4th paragraph).

Reference

Hamm, C. E., Merkel, R., Springer, O., Jurkojc, P., Maier, C., Prechtel, K., & Smetacek, V. (2003). Architecture and material properties of diatom shells provide effective mechanical protection. Nature, 421(6925), 841-843.

Reviewers comment #8

Fig 1 the locations of the ice cores aren't particularly clear – an inset would help here (like that of Figure 6..or just refer to that) and the caption needs to include the names of the ice cores. Locations such as Amundsen-Bellinghausen seas, Ellsworth Land need to be added.

Response:

We have modified Figure 1 and its caption as suggested. We acknowledge the locations of the ice cores in Figure 1 look close together. To address this comment we added a rectangle in Figure 1, directing the reader to Figure 6 to see the ice core locations from a closer perspective.

Reviewers comment #9

What is the justification of the decadal subsets? if these are ”to assess the consistency of the assemblage” (L160) there might be better ways to do that e.g. DCA axis scores to see if there are changes in ‘turnover’. Subsequently there is more emphasis on using the decadal data sets to examine changes in diatom concentration (number per L) between the 2 time periods (L404) and these are compared directly but the time intervals aren’t the same e.g. JUR is 1992-2001 and 2002-2012 whilst SHBL and SHIC are 1999-2008 and 2009-2019. So I am unclear as to the justification for these decadal means when all 3 cores show positive trends over the whole sampled period and section 2 doesn’t discuss climate/sea ice changes at these time intervals.

Response:

Our reason to analyse temporal changes in the assemblages and on the diatom concentration was to assess the consistency of the diatom record in response to recent environmental changes in the region. In particular, to determine if there were shorter-term shifts in the diatom concentrations caused by changes in certain diatom species or if there was a general shift in all diatom species that shape the main assemblage. We decided to assess this at a decadal timeframe to reduce the potential imprints of interannual variability. We did not discuss specific changes in climate/sea ice during the assessed decades because trends in both, wind strengthening and sea ice retreat, have been sustained over the last decades.

We acknowledge we did not specify that wind and sea ice trends have been sustained over time or refer to the different timing of the decadal subsets across the sites. To address this comment, we have modified the manuscript, specifying our reasons to analyse the dataset in decadal subsets (Methods – Section 3.2 – 6th paragraph), we have clarified that recent trends have been sustained over the last decades (Discussion – Section 5.2 – 5th paragraph) and we specified the timeframes considered when comparing recent changes in the diatom concentration (Discussion – Section 5.2 – 4th paragraph).

Reviewers comment #10

Line 267 S. gracilis (not gracilics)

Response:

Revised as suggested

Additional modifications:

Based on the reviewer's comments, we have decided to modify the title of the manuscript, acknowledging the records we present are not exclusively marine and to emphasise the spatial component.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2021-160/tc-2021-160-AC1-supplement.pdf