Climate of the Past Discussions

Clim. Past Discuss., author comment AC1
https://doi.org/10.5194/cp-2021-88-AC1, 2021

Reply on RC1

Dieter R. Tetzner et al.

Author comment on "Regional validation of the use of diatoms in ice cores from the Antarctic Peninsula as a Southern Hemisphere westerly wind proxy" by Dieter R. Tetzner et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-88-AC1, 2021

Dear Editor,

We appreciate all the comments and suggestions made by the anonymous reviewer #1 and thank for her/his time and consideration. Please find to follow a list of all points raised and our responses to each item.

Reviewers comment #1

Whilst the SO is the principal source of marine diatom to this region, which is the argument allowing to rule out completely contributions from exposed sediments? Marine diatoms can be windblown to coastal sites and can be remobilized easily by winds. This does not imply that the amount of diatoms is necessarily related to the amount of dust since different dust sources can have a very different abundance of microfossils.

Response:

In **Tetzner et al. (2021)**, we present a detailed study of the diatom diversity found in the ice cores presented in this manuscript. The diatom records from these ice cores included marine and non-marine diatoms. These diatoms were identified to come primarily from the SO. This primary source is supported by airmass backward trajectories showing that airmasses reaching ice core sites only interact with sea level in the Northern Antarctic Zone of the SO (including the Polar front and the Permanently Open Ocean Zone) (**Thomas and Bracegirdle, 2015; Allen et al., 2020**). Despite this primary source, we cannot rule out secondary sources. Secondary sources could potentially include modern fresh/brackish-water bodies and exposed diatom-bearing sediments. We involuntarily missed including in this manuscript details about the regional diatom diversity and potential sources (other than the primary marine source). We agree with the reviewer that we cannot rule out contributions either from exposed sediments or from modern non-marine waterbodies.

To address this comment, we have modified the manuscript removing references to diatoms as exclusively marine (**e.g. Line 60, Line 74**). Additionally, we have included further details about the diatom diversity of these ice cores (**Lines 128-130 and Table A1**) and outlined potential sources of diatoms in the Antarctic region (**Lines 65-66**).

References

Allen, C. S., Thomas, E. R., Blagbrough, H., Tetzner, D. R., Warren, R. A., Ludlow, E. C., and Bracegirdle, T. J.: Preliminary Evidence for the Role Played by South Westerly Wind Strength on the Marine Diatom Content of an Antarctic Peninsula Ice Core (1980–2010), Geosciences, 10, 87, https://doi.org/10.3390/geosciences10030087, 2020

Tetzner, D. R., Thomas, E. R., and Allen, C. S.: Marine diatoms in ice cores from the Antarctic Peninsula and Ellsworth Land, Antarctica; species diversity and regional variability, The Cryosphere Discussions, 1–32, https://doi.org/10.5194/tc-2021-160, 2021.

Thomas, E. R. and Bracegirdle, T. J.: Precipitation pathways for five new ice core sites in Ellsworth Land, West Antarctica, Clim Dyn, 44, 2067–2078, https://doi.org/10.1007/s00382-014-2213-6, 2015.

Reviewers comment #2

Why the abundance of freshwater or brackish-water diatoms is not taken into account?

It seems completely neglected but it can be very useful. Are sponge spicules or other

microfossils also present in the samples? Is it possible to show the two diatom abundance records (marine and nonmarine/brackish)? Also, which species of diatoms are you looking at? Imagine that not all readers switch

between the two papers in order to understand what you are effectively counting.

Response:

The diatom abundance presented in this manuscript includes all marine and fresh/brackish-water diatoms found on each ice core. We agree the non-marine component of the assemblage could hold valuable information. However, as reported in the review of **Tetzner et al. (2021**) (https://doi.org/10.5194/tc-2021-160-AC1), insufficient image resolution prevented us from unequivocally differentiating between marine and non-marine species in four "cosmopolitan" genus. These limitations prevented us from accurately quantify the non-marine proportion of diatoms on each ice core site. Despite this, if it was assumed that all the diatoms classified in the cosmopolitan groups were non-marine, the main diatom assemblage at each ice core site would still be prevalently conformed by marine diatoms (>58%). Sponge spicules were not identified in our samples. Our samples occasionally presented low numbers of chrysophyte stomatocytes.

To address this comment, we have included, in the method section, a sentence specifying the diatom abundance accounts for all marine, non-marine diatoms and indistinctive diatom fragments found on each ice core (**Lines 127-128**). We have added a table (**Appendix A – Table A1**) detailing which species are present on each ice core and their correspondent proportion of the main diatom assemblage, as reported in **Tetzner et al. (2021)**. We have also modified the manuscript removing all references to marine diatoms and replacing them for "diatoms" (**e.g. Line 60, Line 74**).

References

Tetzner, D. R., Thomas, E. R., and Allen, C. S.: Marine diatoms in ice cores from the Antarctic Peninsula and Ellsworth Land, Antarctica; species diversity and regional variability, The Cryosphere Discussions, 1–32, https://doi.org/10.5194/tc-2021-160, 2021.

Reviewers comment #3

Are the marine species identified in the cores comparable to marine species which are found in typical Sirius formation?

Response:

The main diatom assemblage identified in the Antarctic Peninsula (AP) and Ellsworth Land (EL) ice cores was comprised of *Fragilariopsis cylindrus, Shionodiscus gracilis, Fragilariopsis curta, Fragilariopsis pseudonana, Cyclotella* gp*., Navicula* gp*., Nitzschia* gp*., Pseudonitzschia* spp., and *Achnanthes* gp.. Of them, only *Nitzschia* spp. was identified in the Sirius formation (**Harwood, 1983; Harwood, 1986; McKay et al., 2008**). Diatoms classified as *Nitzschia* spp. are scarcely present in the AP and EL ice cores. They were only identified in the SKBL ice core and accounted for 6% of the main diatom assemblage at that site **(Tetzner et al., 2021)**. The lack of common diatoms evidence a weak relationship between the marine species found in the Sirius group and the ones found in the AP and EL ice cores. In turn, the main diatom assemblage in ice cores from the AP and EL region closely resembles the main diatom assemblage reported by **Budgeon et al. (2012)** in fresh snow samples obtained near Casey Station, which included *F. cylindrus, S. gracilis, F. curta, F. pseudonana, Cyclotella* gp*., Navicula* gp*., Nitzschia* gp*.*

To address this comment, we have added a Table (**Appendix A - Table A1**) outlining the main diatom assemblage at each ice core site.

References

Budgeon, A. L., Roberts, D., Gasparon, M., and Adams, N.: Direct evidence of aeolian deposition of marine diatoms to an ice sheet, Antarctic Science, 24, 527–535, https://doi.org/10.1017/S0954102012000235, 2012

Harwood, D. M. (1983). Diatoms from the Sirius Formation, Transantarctic Mountains. Antarctic Journal of the United States, 18(5), 98-100.

Harwood, D. M. (1986). Recycled siliceous microfossils from the Sirius Formation. Antarctic Journal of the United States, 21(5), 101-103.

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.

Tetzner, D. R., Thomas, E. R., and Allen, C. S.: Marine diatoms in ice cores from the Antarctic Peninsula and Ellsworth Land, Antarctica; species diversity and regional variability, The Cryosphere Discussions, 1–32, https://doi.org/10.5194/tc-2021-160, 2021.

Reviewers comment #4

In the introductions, lines 66-67, you cite as references for the sentence "Once in the atmosphere, they can be transported by winds over long distances" the papers from Gayley, 1989 and McKay et al., 2008 [I have no access to the 3rd publication cited]. Both papers consider diatoms as associated mainly with deflation of dry sediments. So, please provide references clearly indicating sea spray as the primary source for long-range transported marine diatoms.

Response:

Revised as suggested. We modified the previous references and added new ones that support sea sprays as the source for long-range transported marine diatoms (**Lines 68-69**).

Reviewers comment #5

In your statistical analysis, The diatom abundance (n*a-1) is a sort of annual depositional flux of diatoms (number of specimens per year) that already takes into account the snow accumulation rate, since it is calculated over an entire year. For the chemical parameters, conversely, you use average concentrations per year (I see "ppb" in your figure!??), not fluxes..(?). So if concentrations are used instead of depositional fluxes, how can you get free from the snow accumulation rate for chemicals? All data must be transformed into fluxes otherwise the comparison of chemical/dust records among different sites has no sense.

Response:

The diatom abundance parameter presented corresponds to the number of diatoms identified in an ice core annual layer. The reviewer is right pointing out this parameter is a sort of annual depositional flux. However, this parameter does not account for the snow accumulation rate. For example if the number of diatoms deposited throughout the year in an ice core site is 65, the diatom abundance will be 65 (diatoms * y^{-1}), regardless if the snow accumulation was 1 or 5 meters of water equivalent. We did not account for the snow accumulation to avoid incorporating the variability of it into the diatom abundance parameter. If incorporated, spatial correlations could have been biased by the correlation between the wind speed and precipitation parameters from the reanalysis. The same applies to the other records presented in this work.

The use of the flux parameter has proved very useful in Antarctic continental sites, where the snow accumulation presents a low interannual variability. Unlike Antarctic continental sites, snow accumulation in the southern Antarctic Peninsula presents a high interannual variability (**Thomas et al., 2017**) and it is very episodic, with some events accounting for the largest proportion of the annual snow accumulation (**Turner et al., 2019**). Presenting the data as fluxes in this region incorporates the large interannual variability of snow accumulation, variability in the frequency and magnitude of high snow deposition events. This, in turn, creates a signal which does not necessarily represent the deposition of chemicals or particles on top of the ice sheet. For example, a year with high inputs of ions but low accumulation could end up being represented by the flux parameter with the same magnitude as a year with low inputs of chemicals but high accumulation.

Taking into account the reviewers comment, we decided to recalculate Table S1 for the flux parameter (Table 1, attached). Table 1 show roughly the same results already reported in Table S1 (but with different magnitudes). Thus, evidencing the flux parameter does not change considerably the nature of the results presented in our manuscript. Based on these results, we decided to keep presenting the concentration parameter as it represents the raw temporal variability of ions and particles, preventing the incorporation of the variability from secondary parameters (snow accumulation).

Our approach is supported by the results obtained from the recent “CLIVASH2k-ice core chemistry” initiative, which gathered Na^+ and SO_4^{2-} data (concentrations and fluxes) from over 100 across Antarctica (**Thomas et al., in prep**). Data collected for this initiative show that the flux parameter in the Antarctic Peninsula leads to comparatively weaker and inconsistent spatial correlations with environmental parameters. Thus, suggesting the flux parameter in the Antarctic Peninsula region is biased by the high snow accumulation interannual variability.

References

Thomas, E. R., Van Wessem, J. M., Roberts, J., Isaksson, E., Schlosser, E., Fudge, T. J., ... & Ekaykin, A. A. (2017). Regional Antarctic snow accumulation over the past 1000 years. Climate of the Past, 13(11), 1491-1513.

Turner, J., Phillips, T., Thamban, M., Rahaman, W., Marshall, G. J., Wille, J. D., ... & Lachlan□Cope, T. (2019). The dominant role of extreme precipitation events in Antarctic snowfall variability. Geophysical Research Letters, 46(6), 3502-3511.

Reviewers comment #6

When looking at figure 2, one can observe that JUR and SKBL nicely show similar diatom abundance variability that is quite obvious given the location of the two sites and their common sensitivity to open ocean species. The SHIC core instead shows a different pattern of variability since it is sensitive to sea ice taxa. These are conclusions from the companion paper Tetzner 2021a. So, I think it is not well clear in this work what is novel and what is part of the conclusions drawn in the companion paper.

Response:

Figure 2 presents this data to show the reader the interannual variability of the diatom abundance at each ice core site. Despite this data was presented in **Tetzner et al. (2021)**, we decided to include it in Figure 2 for the reader to link the interannual variability of the diatom abundance to the values presented in Table B1 and Table S1 (calculations which were not presented in Tetzner et al. 2021).

To address this comment, we have specified in the method section that diatom abundance records were previously presented in **Tetzner et al. (2021)** (**Line 120**) and we specified in Figure 2 caption that the data presented in panel (a) was already presented in **Tetzner et al. (2021)** (**Lines 171-172**).

References

Tetzner, D. R., Thomas, E. R., and Allen, C. S.: Marine diatoms in ice cores from the Antarctic Peninsula and Ellsworth Land, Antarctica; species diversity and regional variability, The Cryosphere Discussions, 1–32, https://doi.org/10.5194/tc-2021-160, 2021.

Reviewers comment #7

The attribution of JUR and SKBL marine diatoms to the POOZ suggested by Tetzner (TC, 2021a) is interesting, but given the very coarse size of such marine diatoms, a mechanism for strong uplift and transport inland is required. So, is it possible that diatom abundance reflects not only wind strength *sensu stricto* but low-pressure systems generated in that POOZ area or passing through that area and then directed towards the Peninsula? Indeed wind strength around LP systems is generally higher, so it is just a different interpretation of this correlation.

Response:

The mechanism proposed by the reviewer is plausible and has been previously considered by the authors, but not mentioned in this manuscript. We did not propose this mechanism for uplift and transport because we did not present data that could directly support it (e.g. spatial correlation between diatom abundance and mean sea level pressure and/or 850 hPa height). We did not include a comparison between diatom abundance and mean sea level pressure because we wanted to focus our discussion in the relationship between wind strength and diatom abundance. We agree with the reviewer that our manuscript does not mention explicitly a mechanism for the uplift and transport of diatoms to inland sites. However, as mentioned by the reviewer, it is implicit that strong winds are intrinsically linked to low-pressure systems which actively uplift and delineate airmass transport pathways in this region.

Reviewers comment #8

The novel proxy for wind strength is interesting but different from proxies like Calcium and dust. It is not correct to say (330-333) that particles and calcium reflect wind strength as they have been always associated with the cumulative effect of different factors that are: the primary production at the source(s), the humidity/precipitation en route during atmospheric transport, the snow accumulation rate in Antarctica, ... Conversely, a proxy that is much more directly related to transport (including wind strength) is dust grain size. So it is not correct to say that these are traditional proxies for wind strength. Different proxies are related to different dynamics. Please change these considerations accordingly.

Response:

We agree with this comment. To address this comment, we have modified the manuscript accordingly. We now emphasise that major ions and dust have been traditionally used to interpret changes in atmospheric circulation in a broad sense, not restricted to wind strength (**e.g. Lines 72-73, Line 77**).

Reviewers comment #9

In general, it must be clarified to the reader that given the position of the sites, dust and Calcium are probably dominated by the effect of the local dust sources from marginal ice-free areas, that are not the same sources of marine diatoms but can provide diatoms through eolian reworking.

Response:

The main source of dust and calcium to this region has not been yet well established in the literature. It has been suggested that the main contributors of dust and calcium to this region could be (1) southern South America (SA) (mainly from the Patagonia region), (2) New Zealand/Australia, and (3) local Antarctic sources (**McConnell et al., 2007; Bory et al., 2010; Koffman and Kreutz, 2014; Neff and Bertler, 2015; Bullard et al., 2016**). The largest source of dust in Antarctica are the Transantarctic Mountains and the McMurdo Dry Valleys region (TAMS-MDV) (**Bullard et al., 2016**). Both, SA and the TAMS-MDV are located 1500-2000 km away from the ice core sites, highlighting both as potential contributors of dust and calcium. Small ice-free areas are scattered across the Antarctic Peninsula (AP). The sum of all these areas accounts for less than 3% of the total surface of the AP (**Siegert et al., 2019**). A small number of ice-free areas are located within a 100-km radius from the ice core sites (**see Figure 1 attached**). However, these areas are very small and not exposed to active weathering processes, preventing them from contributing considerable amounts of dust to the ice core sites.

Among the three ice core sites, SKBL is the more proximal to ice-free areas. Despite its proximity to ice-free areas, SKBL does not exhibit a considerably larger amount of dust compared to SHIC, which lacks of ice-free areas on its vicinities. Similar dust values at both sites suggest ice-free areas near JUR and SKBL do not play a major role supplying dust to the ice core sites. In light of this, we do not share this reviewers comment: “dust and calcium are probably dominated by the effect of the local dust sources from marginal ice-free areas”. We cannot rule out potential contributions of dust from local ice-free areas to ice core sites. However, we do not support local ice-free areas are the primary source of dust to these sites. Instead, we support a major proportion of dust and calcium to be originated from distal sources (>1000 km) with secondary contributions from neighbouring ice free areas, in line with the results obtained by **McConnell et al. (2007)** in the northern Antarctic Peninsula.

To address this comment, we have incorporated new information in the Introduction to emphasize that dust and calcium can be originated from both local and distal sources (**Line 48**). We have also outlined the various sources from where diatoms could have been removed to then become part of the ice core record (**Lines 65-66**). This new information was included for the reader to know that there are other, secondary, sources of diatoms which could potentially contribute to shape the diatom abundance parameter.

References

Bory, A., Wolff, E., Mulvaney, R., Jagoutz, E., Wegner, A., Ruth, U., & Elderfield, H. (2010). Multiple sources supply eolian mineral dust to the Atlantic sector of coastal Antarctica: Evidence from recent snow layers at the top of Berkner Island ice sheet. Earth and Planetary Science Letters, 291(1-4), 138-148.

Bullard, J. E., Baddock, M., Bradwell, T., Crusius, J., Darlington, E., Gaiero, D., ... & Thorsteinsson, T. (2016). High□latitude dust in the Earth system. Reviews of Geophysics, 54(2), 447-485.

Koffman, B. G., & Kreutz, K. J. (2014). Evidence that local dust sources supply low-elevation Antarctic regions. Past Global Changes Magazine, 22(2), 76-77.

McConnell, J. R., Aristarain, A. J., Banta, J. R., Edwards, P. R., & Simões, J. C. (2007). 20th-Century doubling in dust archived in an Antarctic Peninsula ice core parallels climate change and desertification in South America. Proceedings of the National Academy of Sciences, 104(14), 5743-5748.

Neff, P. D., & Bertler, N. A. (2015). Trajectory modeling of modern dust transport to the Southern Ocean and Antarctica. Journal of Geophysical Research: Atmospheres, 120(18), 9303-9322.

Siegert, M. J., Kingslake, J., Ross, N., Whitehouse, P. L., Woodward, J., Jamieson, S. S., ... & Sugden, D. E. (2019). Major ice sheet change in the Weddell Sea sector of West Antarctica over the last 5,000 years. Reviews of Geophysics, 57(4), 1197-1223.

Reviewers comment #10

Since dust deposited at JUR likely comes from proximal sources (and to a lesser extent from remote areas) I cannot find sense in the correlation between dust at JUR and wind strength 10m altitude around 40-45°S. Also, dust from remote continents must travel at high elevations in order to reach Antarctica. So, again I am not sure that all correlations that are shown in figure 3 make sense and are worth to be considered.

Response:

As previously stated (see response to reviewers comment #9):

"We do not support local ice-free areas are the primary source of dust to these sites. Instead, we support a major proportion of dust and calcium to be originated from distal sources with secondary contributions from neighbouring ice free areas"

Our statement is further supported by numerous previously published work. In particular, **Li et al. (2010)** demonstrated dust can be transported within ~4-5 days, in the low/mid troposphere, from South America to the Antarctic Peninsula and West Antarctica. Similarly, **Koffman et al. (2017)** demonstrated coarse ash from a volcanic eruption that occurred in South America (40°S) was effectively transported in the low/mid troposphere to the WAIS Divide ice core site (79.5°S) in West Antarctica within 7 days after the initial eruption. Additionally, several studies support airmasses from South American can take 5-10 days to reach the Antarctic Peninsula and Ellsworth Land (**Abram et al., 2010; Neff and Bertler, 2015; Thomas and Bracegirdle, 2015).** Altogether, these lines of evidence support the correlation between JUR dust and wind speed at 40-45°S is plausible.

References

Abram, N. J., Thomas, E. R., McConnell, J. R., Mulvaney, R., Bracegirdle, T. J., Sime, L. C., and Aristarain, A. J.: Ice core evidence for a 20th century decline of sea ice in the Bellingshausen Sea, Antarctica, Journal of Geophysical Research: Atmospheres, 115, https://doi.org/10.1029/2010JD014644, 2010.

Koffman, B. G., Dowd, E. G., Osterberg, E. C., Ferris, D. G., Hartman, L. H., Wheatley, S. D., ... & Yates, M. (2017). Rapid transport of ash and sulfate from the 2011 Puyehue□Cordón Caulle (Chile) eruption to West Antarctica. Journal of Geophysical Research: Atmospheres, 122(16), 8908-8920.

Li, F., Ginoux, P., & Ramaswamy, V. (2010). Transport of Patagonian dust to Antarctica. Journal of Geophysical Research: Atmospheres, 115(D18).

Neff, P. D., & Bertler, N. A. (2015). Trajectory modeling of modern dust transport to the Southern Ocean and Antarctica. Journal of Geophysical Research: Atmospheres, 120(18), 9303-9322.

Thomas, E. R. and Bracegirdle, T. J.: Precipitation pathways for five new ice core sites in Ellsworth Land, West Antarctica, Clim Dyn, 44, 2067–2078, https://doi.org/10.1007/s00382-014-2213-6, 2015.

Reviewers comment #11

Line 78 - Are these really ice cores or firn cores?

Response:

SHIC and SKBL are firn cores. The top section of JUR included in this study also corresponds to firn (reaching a density of 700 kg m^{-3} at 36.9 meters deep). We modified the manuscript specifying this as suggested (**Lines 80-83**). To highlight the wide scope of our results we decided to treat firn cores and ice cores indistinctively. For practicalities, we have added a caveat specifying that the manuscript will use the term "ice cores" when referring to "firn cores" (**Line 84**).

Reviewers comment #12

Line 115: if microparticles are measured with an Abakus sensor, it is possible to get an idea of the degree of sorting of the dust, that is useful to constrain sources and transport distance?

Response:

We agree a detailed analysis of the particle size distribution and the variability of the finer/coarser fraction of dust can contribute to constrain sources and transport distances for dust. However, the aim of the research work presented here is to evaluate the potential for diatoms to reconstruct regional wind strength. The incorporation of other traditional wind and atmospheric circulation proxies was to validate the novel diatom proxy and to compare the performance of these proxies in the AP-EL regions. Based on the aims of this study, the incorporation of a detail study of the PSD and size subsets is beyond the scope of this work.

Reviewers comment #13

Line 120: Can small diatom fragments (that you discard from your counts) provide an idea of the degree of diatom reworking?

Response:

Diatom fragments discarded from our counts correspond to every fragment smaller than 5 microns in its longest axis. Unequivocally differentiating diatom fragments below 5 microns from other insoluble particles is already a major challenge, regardless of their degree of reworking. The difficulties of identifying diatom fragments of these sizes arise from the incapacity of diatom fragments of these sizes to retain features that will allow to identify their diatom origin. Thus, the discarded fraction will not provide a conclusive idea of the degree of diatom reworking.

Reviewers comment #14

Line 121: “Diatom abundance” means marine-only diatoms or really "all diatom valves"?

Response:

Please remit to our response to “reviewers comment #2”

Reviewers comment #15

Paragraph 3.1.2: The correlation between diatom abundance per year and wind strength

is interesting and is probably one of the key new messages of this work. However, figure 3 is too rich and the attention of the reader is not immediately captured by that. I also

wonder if many of these correlations make sense. I suggest splitting this figure in order to focus on the most interesting part of it while moving the remaining part to the

supplementary information.

For example, both JUR and SKBL show a correlation between diatom flux and wind

strength, while the correlations related to Calcium and dust that are found at one site are very different from the other, and in any case, they are difficult to understand. Is there a possible bias related to the use of average concentrations instead of depositional fluxes? Actually, in line 227 you mention that "No clear or consistent pattern was identified when comparing chemical proxies from different ice core sites" – and this is quite strange when JUR and SKBL are considered.

Response:

To address this comment, we followed the reviewers suggestion and modified figure 3 to focus on the spatial correlations between diatom abundance and environmental parameters, while moving the initially submitted figure to supplementary information.

Please also note the supplement to this comment:
https://cp.copernicus.org/preprints/cp-2021-88/cp-2021-88-AC1-supplement.pdf