Boxho et al. "Quantifying Southern Hemisphere dust sources during the Last Glacial-Interglacial Transition using rare earth elements in the EPICA Dome C ice core"

Reviewed by Austin Carter

The authors have done a nice job addressing most of the feedback I have provided in my initial review as well as the feedback from the other reviewer. The new introduction is very well written and frames the context for the paper nicely, and the discussion sections are also outlined better. Thank you for making these revisions. I believe this is an exciting manuscript that cleverly uses rare earth element concentrations and an unmixing algorithm to resolve dust provenance at EPICA Dome C (EDC) across the Last Glacial-Interglacial Transition. The authors show very clearly that dust sourced to the EDC during times older than ~14.5 kyr BP are dominated by stable high-latitude source regions, specifically and overwhelmingly from Patagonia with secondary input from New Zealand. The authors also show that for times younger than ~14.5 kyr BP there is a shift toward increased and erratic contributions of dust from low-latitude sources (Australia, South Africa, and the Puna Altiplano Plateau). The results from this work are interesting to me and will be of interest to others as well. My comments below are predominantly minor, but I have some more major comments with respect to Fig. 2 and Sr-Nd isotope compositions of dust. It is for this reason only I request major revisions, however, after these are addressed along with the minor corrections, I believe this work will be close to ready for publication.

Below are my suggestions, which I hope will improve the manuscript further:

L25: The authors appear to refer to New Zealand as a low-latitude source here but everywhere else refer to it as a high-latitude source, which should be revised.

L31: It might be clearer to say something like this: "This transition in dust sources to EDC is supported by our modeled Sr-Nd isotope compositions of dust, which also align with…"

L125: Perhaps clarify "our database" as "our provenance database" or something to that effect.

L177-178: It might help to clarify here that you are ranking in order from greatest to least contribution (i.e., Rank 1 to Rank 7). I think it's implied but would be useful to be explicit how you are ranking.

L262-264: If rounding to the third decimal place, then the 87Sr/86Sr ratios for the LGM should be ~0.709 (not ~0.708) based on Delmonte et al. (2004a). Please also add a reference to Delmonte et al. (2007) for the Holocene data. Importantly, it should be noted here that the isotope composition of dust for the LGM and Holocene at EDC are sparse (n=2 for each interval). Furthermore, the isotopic differences in LGM vs. Holocene dust at EDC are not very large and can be fully captured in your EDC model for the LGM alone. I think if using these data in your argument, it would be very important to be clear that while yes there is support for a shift in dust provenance, the data is sparse and the changes are subtle. Personally, I agree that this is a limitation that your high-resolution dataset is able to resolve better and makes much more powerful, so you could reiterate that point here or elsewhere.

L264-266: This sentence and corresponding references confuse me. To my knowledge, there are no Sr-Nd isotope data on ice core dust from the LGM at Vostok, so I'm not sure that a "shift" can be determined. Also, while there are two data points from the Holocene at Vostok, these come from Delmonte et al. (2007) and not either of the references listed. Please double check this.

L266-268: Do you mean larger variability in the Holocene compared to the LGM across all sites in East Antarctica? It would be helpful to clarify what is being compared.

L284-289: I think this is a fair point on the limitation of measured isotopic data. Alternatively, it might also be fair to mention the limitations of the modeled isotopic data. For example, these seem to hinge on accurately determining both the mean Sr and Nd concentration and isotope composition for each PSA, which inherently have wide ranges.

L288 + L470: I appreciate the wording change from "continuous" to "quasi-continuous." I think the word "continuous" to me was initially ambiguous because it was unclear if the measurements themselves were continuous (i.e., continuous flow analysis) or if the temporal resolution was essentially continuous. While the former is not true, the latter appears to be so as detailed nicely in L110–115. For added clarity, maybe somewhere in L110-115 it would be useful to mention that given the high temporal spacing the dataset therefore represents a near continuous record, but I leave that up to the authors' discretion.

L367-368: The second and third driver appear to be competing with each other a bit with one seeming to argue for shorter and the other longer residence times. The second driver is an important point but may be more related to dust flux than provenance. This is shown nicely in Fig. S2. If I am mistaken, it could be helpful to elaborate on why this second driver would result in increased variability of dust after 14.5 kyr BP.

L370-373 + L403-404: These two sentences seem to be at odds with each other. The former argues for a northward shift in moisture sources, whereas the latter hints at southward shift, unless I am misinterpreting the sentences.

Figure 1:

- In the caption, I would suggest mentioning LGIT something like "Evolution of dust PSA contributions to EDC ice core across the Last Glacial-Interglacial Transition between…"
- In addition, I recommend adding labels for MIS3, LGM, HS1, ACR, YD, Early and Middle Holocene. This does not need to be shaded bars like in Fig. 4 and 6, rather a semi-thick vertical black line at each time boundary would be helpful. I realize this will make the figure busier, but I do think it will guide the reader through your temporal discussion and really highlight changes within each timestep.
- It would also be helpful in the caption to elaborate a bit more on the ranking technique and to clarify that there is a total of seven PSAs with only six being shown, excluding CWA.

Figure 2: I really appreciate the updates made to this figure. Separating the LGM and Holocene into two panels makes this figure much more legible. Thank you for doing that. Below are additional corrections:

- It would be helpful if the references for the ice core and modern dust data were added in the figure caption both for the reader but also to get properly indexed.
- The caption for Fig. 2b mentions modern dust from Berkner Island and Holocene dust from Taylor Glacier and Talos Dome. I believe you are also including Holocene dust from Taylor Dome, so that should be stated as well. Additionally, Holocene EDC and Vostok data should be included on Fig. 2b and in Table S5, especially as they are referenced in L262-266 (Delmonte et al., 2007).
- Regarding the Taylor Dome data, it is important to note there are two types of isotopic data presented in Aarons et al., 2016. This includes data on both soluble and insoluble fractions (i.e., filtered ice and dust, respectively). The authors report both in Table S1 and in Fig. 2a and 2b when only the insoluble fractions are relevant to their comparisons. All soluble fractions need to be removed from Fig. 2 and Table S1 because these data are not of dust.
- Also, it appears that maybe two additional Taylor Glacier samples from Aarons et al. (2017) are missing from the compilation (sample ID P210 and P190) and should be included.
- After removing the Taylor Dome data that does not belong on Fig. 2, it becomes more clear that the modern dust from Berkner Island is unique when compared with Holocene ice core dust. All measured data on Panel b with ε_{Nd} values <-10 come from these samples, which to me highlights a source difference. This is further exemplified if modern dust from Dome A (Du et al., 2018) were included. To my knowledge, there are no published East Antarctic ice core dust records, which contain ε_{Nd} values <-10. The only ice core dust record that comes to mind, which contains very low ε_{Nd} values is Holocene data from Siple Dome (Koffman et al. 2021, 2023), but this is not an East Antarctic record, which I think the authors intend on focusing on these. Furthermore, all of these sites (Berkner Island, Siple Dome, and Dome A) highlight ice-free areas of East Antarctica as the most likely dust provenance. This is different from your modeled EDC Holocene data, which appear to be driven by contributions from Southern Africa. Because the manuscript does not focus on the modern and because the modern dust records are observationally different from East Antarctic ice core dust records, I think the inclusion of modern dust on Fig. 2b warrants further discussion. I understand the desire to include more data, but if the authors choose to include it, then it should probably be indicated with a different symbol to not be confused with data from the Middle or Early Holocene.
- Regarding PSA fields, it would be good in the caption to clarify where in Antarctica your Sr-Nd isotope compositions are representing (i.e., McMurdo Dry Valleys). It makes sense to me to have a PSA that represents just the Dry Valleys to match where the REE concentration data are coming from spatially. But it should be clear to the reader that, as drawn, the ANT PSA does not represent all ice-free areas of Antarctica, which can be quite diverse. For example, the McMurdo area is complicated because it contains material from the West Antarctic Rift System (WARS), which is reflected in the glacial drift samples from McMurdo Sound within Blakowski et al. (2014). These WARS data are less

radiogenic in $^{87}Sr/^{86}Sr$ (<0.710) and contain almost exclusively positive ε_{Nd} values, which are isotopically distinct from the Dry Valleys.

- The ANT isotopic data in the manuscript (Table S4) is listed as being sourced from Blakowski et al. (2014), Delmonte et al. (2004)b, and Diaz et al. (2020). To my knowledge, Diaz et al. (2020) does not present data on Sr-Nd isotope compositions. Please confirm the data sources.
- The legend in panel (b) appears slightly offset, but this is very minor. Also, for consistency with the rest of the manuscript, please use decimals instead of commas for the x-axis.
- Please also capitalize Old Dome C and Taylor Glacier in the caption.

Figure 3:

- The median lines appear to be missing for NZ and PAP on the Holocene plot. Is the median 0%? When looking at Figure 1, this would imply more than half of the contributions for the Holocene are 0% for both NZ and PAP, but that doesn't appear to be the case. Similarly, ANT appears to have appreciable contributions during the Holocene, yet on the box and whiskers plot, this seems reduced. Perhaps I'm missing something here.

Figure 4:

- Please reverse the direction of the y-axis for panel D so that wind intensity is consistent with panel C.
- In the caption, it would be good to add "(this study)" in the description of panel A.

Additional miscellaneous corrections

- L21: please change "Marine isotope 3" to "Marine Isotope Stage 3"
- L80: "as well as and" please omit "and"
- L198: Figure S3 should be Figure S2
- L252-255: Commas are probably best here instead of semicolons.
- L310: Consider revising "Based on Sr-Nd isotopes" to "Using the Sr-Nd isotope composition of dust,"
- L314: ~10,8% should be ~10.8%
- L338: Nd should be subscript
- L389 + L459: Please capitalize Dry Valleys
- L404: "Westly" should be "Westerly"
- L415: Please add the word "the" so that this line reads "during the Holocene" and also perhaps add references to Fig. 1 and 3 for the reader to refer to.
- L457: "Est" should be "East"
- In general, the use of dashes and en dashes are both used for ranges (e.g., L22-23). I recommend picking one or the other and being consistent.
- Author Contributions: N.M. and A.B. contributions are missing.
- Fig. S1: change DEPOT to DEEPOT and change Localization to Location
- Fig. S5: The caption should be revised. As written, it appears that much more data from many sites are plotted than actually are. Only Taylor Dome, Taylor Glacier, and Old

Dome C are being plotted as reported in Table S5. I would recommend being explicit about what's being shown for each site and period.

It appears that the authors addressed the comments from the other reviewer nicely as well. Perhaps a few lingering points include:

- The other reviewer was interested in a supplemental figure that shows the Sr-Nd isotope composition data used to construct the isotopic fields for each PSA. I think this would be a good addition. The authors should consider including this supplemental plot of just the PSA data for the curious reader.
- The other reviewer requested the use of decimals instead of commas on figures, which author response A48 suggests this was completed, although Fig. 2 and Fig. S5 remain as commas.