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

This paper presents a high-resolution record of source contributions to embedded dust within the EPICA Dome C (EDC) ice core, specifically focused across the time interval of 33.7-2.9 kyr BP. The authors apply a statistical model previously developed by Vanderstraeten et al., 2023 to a large dataset of discrete rare earth elemental (REE) concentrations of ice core dust from EDC as reported in Gabrielli et al., 2010. The previously published dataset contains nearly 300 sections of ice from EDC which have been acid leached using 1% HNO3 and individually characterized for REE concentrations. Subsequently, the model in Vanderstraeten et al., 2023 includes a database of REE concentrations for a variety of samples from potential sources within the Southern Hemisphere. After making the EDC leached REE data comparable to total REE concentration using element-specific enrichment factors, the authors then modeled various combinations of sources that would result in the most closely matched data for each ice core dust sample. In this way, source contributions are effectively unmixed from the dust.

The authors show that before 14.5 kyr BP high-latitude PSAs (Patagonia + New Zealand) dominate the EDC ice core dust record and are stable. After 14.5 kyr BP, there is more heterogeneity in PSA contributions with periods of greater low-latitude PSA contributions (Australia, South Africa, and Puna-Altiplano Plateau). These changes are attributed to both hydrological changes in Patagonia and its corresponding shelf exposure as well as regional source dynamics at low-latitude sources. Candidly, I found the latter to be a bit hard to follow in its current organization. Lastly, when compared with EDML, the EDC record's PSA contributions over time are broadly similar with subtle differences owing to their geographic positioning. Overall, I enjoyed reading and learning more about this statistical application, and I find it very clever and interesting; however, I have some comments on clarity and the inherent limitations in the methods that I believe merit additional discussion in the paper after which I believe it would have my full support. I hope the following suggestions can help improve the manuscript:

We would like to warmly thank Austin Carter for the time and effort he dedicated to this review. In what follows, we did our best to accommodate his remarks and comments.

Q1: L17: The authors frequently refer to their record as "continuous." However, it is my understanding that the EDC REE dataset from Gabrielli et al., 2010 used for this study is not continuous. Instead, these measurements were on discrete sections of ice. If this is correct, then I do not think it's valid to describe the paper's results as continuous, and this should be edited for clarity.

A1: We agree with the reviewer and modify the text accordingly.

Q2: L34-52: The opening paragraph of the introduction parallels that of the opening paragraph of Vanderstraeten et al., 2023 very closely with regard to sentence structure and reference order etc. While I recognize the parallel logic between the papers, it would be nice to differentiate this manuscript's introductory paragraph a bit.

A2: We rewrote the introduction focusing more on the advances made in Vanderstraeten et al., 2023 in terms of dust provenancing and the relevance of studying EDC ice core. We believe that this new introduction is distinct enough from our previous work. Here is the new introduction:

"Antarctic ice cores preserve long-range atmospheric dust at high temporal resolution and provide a unique window into past changes in continental aridity, atmospheric circulation, and Earth system feedbacks during major climate transitions (Lambert et al., 2008; Grousset and Biscaye, 2005). Variations in dust flux and composition recorded in these archives have been central to our understanding of glacial–interglacial climate dynamics, particularly through the role of mineral dust in Southern Ocean iron fertilization and its impact on

atmospheric CO_2 concentrations (Martínez-García et al., 2014; Lambert et al., 2015, 2021). However, translating Antarctic dust records into quantitative constraints on past climate processes requires robust reconstructions of dust provenance and an understanding of how source-specific emissions respond to climatic and geomorphological change.

Geochemical fingerprinting of dust and sediments from Potential Source Area (PSA) upwind of Antarctica has therefore been a central component of dust provenance studies. Southern South America (SSA), Southern Africa (SAF), Australia (AUS), New Zealand (NZ), and ice-free regions of Antarctica have been identified as the dominant Southern Hemisphere PSAs (e.g., Grousset and Biscaye, 2005; Delmonte et al., 2010; Gili et al., 2017). While radiogenic isotope systems such as Sr–Nd and Pb have been widely used to trace dust sources, their application is limited by the relatively large sample masses required, which restricts temporal resolution—particularly at remote, high-elevation sites such as EPICA Dome C (EDC), where dust fluxes are low and decrease by up to a factor of ~25 from glacial to interglacial conditions (Delmonte et al., 2008; Delmonte et al., 2017). In addition, overlapping isotopic signatures among PSAs and the effects of dust mixing during transport complicate quantitative source ap-portionment (Gaiero et al., 2004; Delmonte et al., 2020).

Rare Earth Element patterns (i.e., the concentrations of the lanthanide series) offer a promising complementary approach to overcome these limitations. Because the full lanthanide series captures multi-dimensional geochemical information, REE patterns provide greater discriminatory power than elemental ratios alone, while requiring substantially smaller sample sizes and thus enabling higher temporal resolution. Previous applications of REE measurements in Antarctic ice cores achieved multi-decadal resolution but were limited in their ability to quantitatively resolve mixed dust sources (e.g., Gabrielli et al., 2010; Wegner et al., 2012). Recently, Vanderstraeten et al., (2023) introduced a novel statistical apportionment framework based on REE pattern fitting, producing the first quantitative, decadal- to centennial-scale reconstruction of dust provenance at EPICA Dronning Maud Land (EDML) across the Last Glacial–Interglacial Transition (LGIT).

That study revealed pronounced and time-dependent changes in dust source contributions to East Antarctica. During the Last Glacial Maximum, dust reaching EDML was dominated by high-latitude sources, particularly Patagonia and New Zealand, consistent with enhanced glaciogenic sediment production, expanded continental shelves, and strong Southern Westerly Winds. During deglaciation and the early Holocene, contributions from lower-latitude PSAs such as Southern Africa, Australia, and the Puna–Altiplano Plateau increased as high-latitude dust emissions declined. Beyond documenting changing provenance, Vanderstraeten et al., (2023) suggested that distinct physical mechanisms controlled dust delivery at distinct stages of the LGIT. During Heinrich Stadial 1, reductions in dust flux occurred without major provenance changes pointing to en-hanced atmospheric wet scavenging as the main driver of dust flux reduction. In contrast, the shift from high-to- low latitude sources after ~14.5 kyr BP likely reflects geomorphological thresholds in Patagonia. These include sea-level rise and the submergence of continental shelf, as well as and a major hydrological reorganization of Patagonian rivers (Delmonte et al., 2017; Davies et al., 2020; Thorndycraft et al., 2019). Together, these processes would have reduced the volume of sediment available to aeolian deflation (Vanderstraeten et al., 2023; Delmonte et al. 2017).

While EDML provides a sensitive record of dust provenance changes in the Atlantic sector of East Antarctica, it remains unclear to what extent these source shifts are representative of the broader East Antarctic Plateau. EPICA Dome C, located further inland and at higher elevation, receives lower dust fluxes and integrates longer atmospheric transport pathways, making it particularly sensitive to changes in large-scale circulation and dust residence time. EDC has played a central role in reconstructions of Southern Hemisphere dust variability and climate coupling, yet quantitative, high-resolution provenance across the LGIT remain limited at this site due to analytical challenges associated with low dust concentrations. Here, we apply the REE-based statistical provenance framework developed for EDML to the EPICA Dome C dust dataset of Gabrielli et al., (2010).Our study aims at (1) establishing a quantitative record of dust provenance in EDC throughout the LGIT and particularly during the Holocene, (2) confronting and validating the EDC results from our REE pattern-based model against Sr-Nd isotopic data published in the literature, (3) examining shifts in dust provenance at EDC in relation to regional climatic changes and (4) contrasting this new EDC provenance with the coeval record in EDML in the Atlantic sector of the Antarctic continent to assess spatial variability of dust deposition across East Antarctica during the LGIT."

Q3: L69: It would be useful to elaborate or define what is meant by "REE patterns" here.

A3: We agree and made the appropriate changes in the text in lines. Added text in lines 56: "i.e., the concentrations of the lanthanoid series"

Q4: L121-124: The first limitation when applying the DEPOT statistical model lies in the ability to compare acid-leached REE concentration data with other REE concentration data from PSAs. There is a possibility for preferential leaching of LREE (La, Ce, Pr, Nd) during a 1% HNO3 leach as shown in Gabrielli et al., 2010. Hence the need to apply enrichment factors to translate data from acid-leached to its potential total concentration form, which I think is handled well in the manuscript. However, the readers are left to assume that all of the PSA data are in total REE concentration form. Can you confirm this? Or are enrichment factors also applied to these data in their respective studies? I think some added clarity and its importance for direct comparisons would be valuable and would strengthen the paper's methods.

A4: We thank the reviewer for this comment. We confirm that all the REE patterns from the PSA database were measured after full digestion, as total REE concentration. The correction factor (*cf*) are used solely to convert the REE concentration measured in EDC dust after partial dissolution into total REE concentration. Those "*cf*" values were measured in Gabrielli *et al.,* (2010).

Q5: L129: While I recognize the term Dust Sources (DS) was previously adopted in Vanderstraeten et al., 2023, I do think it can be slightly misleading. From my understanding, these are not unique sources, rather these are individual samples of dust, loess, sediment, and/or soil that make up a Potential Source Area (PSA). The text would benefit from some clarity on that and additional descriptions here. The confusion is made clear when we take Patagonia, for example. The authors describe 39 Dust Sources that make up the Patagonia PSA. To me this implies, 39 unique regions, but I only count 19 markers on Fig. S2 for Patagonia. This is likely because multiple samples come from similar sites, which therefore would not necessarily be a different dust source.

A5: We thank the reviewer for pointing out a potential source of confusion regarding the terminology "Dust Sources (DS)". Our intention is to retain the terminology introduced in Vanderstraeten *et al.*, (2023) for consistency with the existing database; however, we acknowledge that the term "Dust Source" may be misleading without clarification. DS refer to individual aeolian dust (or sediment/soil) samples collected within a given PSA, and do not systematically represent distinct or independent geographic source regions. This is the case for example, for DS from Bahia Blanca (39°S), Puerto Madryn (42.7°S), Trelew (43.15°S) and Puerto San Julian (49°S) which represent aeolian dust samples collected at the same site during different seasons in 1997, 1998 and 1999 (see Gaiero *et al.,* 2004; Gili *et al.,* 2017 - for details). Although the composition of those sample is broadly similar across seasons, including multiple sample allows us to cover the regional variability of dust composition transported through those areas (predominately via westerly winds). To clarify this point, we modified:

- the description of the sample in Table S1 to clear specify the season and year when needed ;

- the section 2 in lines 130 by adding the following text:

"Following Vanderstraeten et al., (2023), "Dust Sources" (DS) refer to individual samples collected within a given PSA. Multiple DS may originate from the same sampling location when samples were collected during different seasons (see Table S1)."

Gaiero, D. M., Depetris, P. J., Probst, J.-L., Bidart, S. M., and Leleyter, L.: The signature of river- and wind-borne materials exported from Patagonia to the southern latitudes: a view from REEs and implications for paleoclimatic interpretations, Earth and Planetary Science Letters, 219, 357–376, https://doi.org/10.1016/S0012-821X(03)00686-1, 2004.

Gili, S., Gaiero, D. M., Goldstein, S. L., Chemale, F., Jweda, J., Kaplan, M. R., Becchio, R. A., and Koester, E.: Glacial/interglacial changes of Southern Hemisphere wind circulation from the geochemistry of South American dust, Earth and Planetary Science Letters, 469, 98–109, https://doi.org/10.1016/j.epsl.2017.04.007, 2017.

Q6: L127-133: The second and most important limitation in this approach is related to the quantity of data in the PSA database. Because the goal is to compare all samples in the PSA database individually to the ice core samples, PSAs that have a greater quantity of REE concentrations might have a bias. Perhaps this is less of an issue after taking the median of each PSA-specific PDF, but it is hard to know without seeing an example. I made a pie chart showing the distribution of the PSAs below. Australia makes up nearly half of the database, which I'm concerned that the % contributions might be biased heavily as a result.

A6: We thank the reviewer for raising this point regarding the unequal number of samples among PSAs. We explicitly tested the sensitivity of our results to the size of the PSA-specific REE database. For Australia, model results were first obtained using 51 REE pattern (mostly from Darling Basin and Lake Eyre) and were then recomputed after adding additional regions (e.g., Murray Basin; Marx and Kamber, 2010), for a total of 107 REE patterns. This more than twofold increase in the number of Dust Sources did not lead to any significant change in the inferred Australian contribution.

A similar sensitivity test was performed for New Zealand, where model outputs based first only on 6 REE patterns (Marx *et al.,* 2005) were compared with results obtained after adding 19 additional patterns from Koffman *et al.,* (2021). Despite this fourfold increase in the number of samples, the inferred New Zealand contribution remained essentially unchanged. These tests indicate that our approach is not strongly biased by the number of samples per PSA, but rather by the distinctiveness and variability of the regional REE signatures. Once the characteristic range of a PSA is adequately captured in the database, adding further samples within this range has a limited impact.

Q7: Additionally, based on Pb isotopic data for both EDC ice core dust and PSAs, Gili et al., 2016 argues against significant glacial and interglacial Australian contributions to the EDC dust record, yet this paper's finding suggests otherwise. If there is no bias in <u>the</u> DEPOT model, then the findings showing large influences from Australia are interesting and worth discussing further in that regard. While I agree with L366-355, importantly this study's findings with respect to Australia are not fully consistent with those in Gili et al., 2016.

A7: As discussed in A6, we are confident that our algorithm is not biaised by the large number of dust sources representing AUS. Regarding Gili *et al.,* (2016) (Fig. 3), it should be noted that the isotopic Pb domains defined for the various PSA are heavily overlapping with one another (more so than in Sr-Nd systems), preventing in our view, any solid quantification or appreciation of the contribution of AUS. More recent studies by de Deccker *et al.,* (2019, 2020) have re-evaluated the role of AUS as a dust source during modern and Late Quaternary times showing that Australian dust likely reached certain sectors of Antarctica, such as Taldice and Taylor Glacier, predominantly during interglacial periods. Modelling studies (Albani *et al.,* 2012; Krinner *et al.,* 2010; Li *et al.,* 2008) also showed that AUS modern dust prevails over the Pacific SO and towards western coastal regions of Antarctica. Looking at ensembles of air-mass back-trajectories, Neff and Bertler, (2015) have demonstrated that modern dust from Australia can reach EDC. We agree that the discussion regarding the Australian contribution to Antarctica which has been largely debated in the literature, probably merits further discussion in the present paper.

We added this text in lines 401-417: "*Although Gili et al., (2016) dismissed AUS as a major Antarctic dust source, later studies re-evaluated its role, suggesting Australian dust reached TALDICE and Taylor Glacier mainly during interglacials (de Deckker et al., 2019, 2020). Modeling and back-trajectory analyses further indicate that modern Australian dust dominates over the Pacific Southern Ocean and western Antarctic coasts and can reach EDC (Albani et al., 2012; Krinner et al., 2010; Li et al., 2008; Neff and Bertler, 2015).*"

Albani, S., Delmonte, B., Maggi, V., Baroni, C., Petit, J.-R., Stenni, B., Mazzola, C., and Frezzotti, M.: Interpreting last glacial to Holocene dust changes at Talos Dome (East Antarctica): implications for atmospheric variations from regional to hemispheric scales, Clim. Past, 8, 741–750, https://doi.org/10.5194/cp-8-741-2012, 2012.

De Deckker, P.: An evaluation of Australia as a major source of dust, Earth-Science Reviews, 194, 536–567, https://doi.org/10.1016/j.earscirev.2019.01.008, 2019.

De Deckker, P.: Airborne dust traffic from Australia in modern and Late Quaternary times, Global and Planetary Change, 184, 103056, https://doi.org/10.1016/j.gloplacha.2019.103056, 2020.

Krinner, G., Petit, J.-R., and Delmonte, B.: Altitude of atmospheric tracer transport towards Antarctica inpresent and glacial climate, Quaternary Science Reviews, 29, 274–284, https://doi.org/10.1016/j.quascirev.2009.06.020, 2010.

Li, F., Ginoux, P., and Ramaswamy, V.: Distribution, transport, and deposition of mineral dust in the Southern Ocean and Antarctica: Contribution of major sources, J. Geophys. Res., 113, 2007JD009190, https://doi.org/10.1029/2007JD009190, 2008.

Neff, P.D., and Bertler, N.A.N.: Trajectory modeling of modern dust transport to the Southern Ocean and Antarctica. JGR Atmospheres 120, 9303–9322, https://doi.org/10.1002/2015JD023304, 2015.

Q8: Similarly, I believe the Antarctic PSA might be discounted too easily and quickly despite it being argued as a plausible contributor during the Holocene at EDC in Gabrielli et al. 2010 from which the REE dataset originates. Additionally, Delmonte et al., 2013 highlights how the measured EDC ice core dust for the Holocene are geochemically similar in Sr-Nd isotope composition to Antarctic PSAs. However, the PSA database contains only 5 samples from the McMurdo Dry Valleys to represent the Antarctic continent (though only 4 are reported in Table S2). Because there are so few available samples, it seems inherently less likely that there will be enough trends to compare to and, thus, less likely they will make up a significant portion of the EDC ice core dust in the statistical model. Part of this issue may also be a result of limited measured Antarctic PSAs for REE concentrations within the literature. Some added caution here would be valuable and perhaps the inclusion of dust size might be useful as well.

A8: We thank the reviewer for this thoughtful comment and agree that the potential contribution of Antarctica deserves careful consideration, although ice-free regions represent only ~2% of the modern Antarctic surface. Among these regions, the McMurdo area is the largest, the closest to EDC (~1700 km), and includes the active McMurdo Volcanic Group along West Antarctic Rift System. It therefore represents the most relevant Antarctic dust source region for our study. Other coastal ice-free areas (e.g., Bunger Hills, Vestfold Hills, Larsemann Hills) are smaller, more distant from EDC (>2000 km), and, to the best of our knowledge, are not yet been geochemically characterized in terms of REE.

The McMurdo Dry Valleys (Miers, Victoria, Alatna, and Taylor) have a complex geological and depositional history (Diaz et al., 2020). Low-elevation valleys (i.e, Miers and Victoria) were submerged during the LGM, whereas higher-elevation valleys (i.e., Alatna and Taylor) have remained ice-free since the Miocene and have accumulated substantial atmospheric material from distal sources, especially during glacial periods where dust loading were 25 times higher than during interglacials. As a result, dust emitted from Alatna and Taylor valley displays REE signatures strongly influenced by deposition from Australia, Patagonia, New Zealand (Diaz *et al.,* 2020). Including these valleys therefore introduces the risk of conflating distal and local Antarctic signals, potentially leading to an overestimation of the Antarctic contribution. For this reason, we focused on Miers and Victoria valleys, which became exposed in the late Pleistocene, when Antarctic dust inputs were proportionally more relevant to investigate (as they potentially represent a larger fraction of total deposition to EAP).

To better represent the variability of these two valleys, we expanded the Antarctic PSA dataset by adding 32 individual geochemical patterns from Diaz *et al.,* (2020), replacing the four valley-averaged patterns previously used. This substantially improves the representation of McMurdo sources in the DEEPOT dust source database. We re-ran the provenance model for EDC using this expanded dataset, and the results are now presented in Fig. 1 of the revised manuscript. After those improvements, the Antarctic signal increase - especially in the Holocene which is in line with the

deglaciation timing of those valley - but overall it remains secondary and does not modify the trends of the other PSA. These new simulations confirm that, our provenance patterns are robust, supporting the internal consistency of the model.

To adjust our isotopic calculations to include Antarctic dust source, we used the Sr-Nd isotopic data from Blakowski *et al.,* (2016). More precisely, we have selected the Sr-Nd values of the fine fractions (<5 microns) from regolith and glacial drift rocks or sediments recommended by Blakowski *et al*., (2016) as the most representative of the McMurdo Dry Valley. Figure 2 (and new Figure S5) and its caption have been modified accordingly.

Added text (lines 430-437) section 4.4: "*Local antarctic dust from the McMurdo dry valley is only detected after 13kyr BP which is consistent with the deglaciation timing of the low-elevation valleys included in the DS database (Diaz et al., 2020). In contrast, higher-elevation valleys in McMurdo regions have remained ice-free since the Miocene and have accumulated substantial atmospheric material from distal sources - especially during glacial periods. As a result, those areas display REE patterns are strongly influenced by deposition from Australia, Patagonia, New Zealand (Diaz et al., 2020). In order to avoid the risk of conflating distal and local Antarctic signals potentially leading to overestimation of the Antarctic contribution, we excluded those high-elevation areas from the DS database. Furthermore, dust transport from ice-free coastal areas to EDC have been shown very limited (Delmonte et al., 2013).*"

Q9: Along the same lines, Coppo et al., 2022 argues that the activation of S-CWA is a plausible dominant PSA to the East Antarctic Plateau during the LGM; however, this paper's findings suggest it is not a dominant contributor during any time across the LGIT. This is an interesting difference and may also be related to its limited quantity (n=5) in the PSA database. All of these above points, especially when in contrast to papers that are heavily cited in the text, central-western Argentina are worth noting/discussing further.

A9: We interpret the results of Coppo *et al.,* (2022) somewhat differently. While they highlight that the Sr–Nd isotopic composition of EAP dust during the LGM is almost identical to that of CWA, they also emphasize that this signal is not uniquely diagnostic and may reflect mixing ["*either from southern central-western Argentina or from a combination of Patagonia/Tierra del Fuego and southern Puna in the PAP. Our results favor this second scenario…*"]. For Holocene dust, Coppo *et al.,* (2022) report more dispersed isotopic signal, indicative of a more complex and variable source mixture, in which CWA may contribute mainly as part of a Patagonian–CWA end member. However, its relative contribution remains poorly constrained, and additional inputs from the Puna–Altiplano region and Australia are also proposed. Overall, the cautious interpretation of Coppo *et al.,* 2022 illustrates the limitations of relying solely on isotopic tracers for dust provenance.

In this context, we consider that our REE-based approach provides additional and more specific constraints on the contribution of CWA to EAP dust. Central-western Argentina displays distinctive REE patterns, notably characterized by negative Nd and Ho anomalies (Fig. S2 of [Vanderstraeten *et al.,* (2023)]), which would be expected to leave a clear imprint in the EDC record if CWA were a major contributor. The absence of such features and the consistently low modeled CWA contribution therefore suggest that CWA was not a dominant long-range dust source to EDC. CWA were also absent from our EDML provenance record which is the closest and directly down-wind from South Southern America sources.

Regarding the limited number of CWA dust source (DS) samples, we included all available <5 μm fine-fraction samples (n=5) reported by Gili et al., (2017), which, to the best of our knowledge, remains the only study providing REE data for fine-grained materials from CWA. Although the CWA dataset is limited, it currently represents the most comprehensive REE characterization of this region and cover with 3 REE patterns the South CWA.

To evaluate the sensitivity of our results to grain-size effects, we performed additional runs including REE data from the <63 μm fraction reported by Gili *et al.,* (2017), adding 5 REE patterns from CWA.

While this broader fraction is much less representative of long-range transported dust, its inclusion provides a useful test of model behavior for EDC and EDML ice core. These runs produced minor Holocene CWA contributions at EDC but no corresponding signal at EDML, despite EDML being geographically closer and directly downwind from South American dust sources. This spatial inconsistency, together with the well-established dominance of the <5 μm fraction in Antarctic ice core, supports our decision to restrict the provenance analysis to fine-fraction data in CWA. We therefore conclude that inclusion of coarser fractions does not provide a physically consistent or robust constraint on CWA contributions to Antarctic dust.

Added text in section 4.2 (line 305-316):
« Although CWA has been proposed as an important PSA in southern South America (Gili et al., 2017), it is notably absent from our EDC provenance record. A similar absence was observed in the EDML record (Vanderstraeten et al., 2023), despite this site being the closest to, and directly downwind of, SSA. The distinctive REE patterns of CWA, characterized by pronounced negative LREE and HREE anomalies, would be expected to produce a clear imprint if CWA were a major contributor to either ice core. The CWA "hypothesis" is based on isotopic evidence; however, the strong overlap between the isotopic signatures of CWA (εNd ≈ −4 to 0; $^{87}Sr/^{86}Sr$ ≈ 0.707–0.712; Gili et al., 2017) and those of Patagonia, the S-Puna, the Darling Basin, and southeastern Australia complicates the clear discrimination of these sources. Taken together, these lines of evidence suggest that CWA is unlikely to represent a major dust source in the EDC and EDML records. »

Q10: I agree with the principle of modeling Sr-Nd isotope compositions and comparing it to established data as a fidelity check for the DEPOT algorithm and thank the authors for exploring this; however, I have some concerns in the way this is currently presented in the manuscript. First, the measured Sr-Nd isotope compositions of samples are described as coming from dust in ice cores as reported in previous studies; however, the Iso Early Holocene category appears to consist predominantly of dust from modern snow pits on Berkner Island (not from ice cores; Bory et al., 2010). Furthermore, in the text Early Holocene is classified as 11.7-7.5 kyr BP, but these Berkner Island data do not represent that time interval. The dust described in Bory et al., 2010 span a two-year period from 2002-2003. Therefore, I do not think these are relevant and should be removed.

A10: We thank the reviewer for this careful observation and agree that the Berkner Island samples reported by Bory *et al.,* (2010) represent modern snow pit material (2002–2003) and therefore do not correspond to the Early Holocene time interval (11.7–7.5 kyr BP) as defined in our study. We acknowledge that was misleading and have changed to "Iso Holocene". It is important to note that this "Iso Holocene" dataset is not solely compose of Berkner Island dataset but also from Talos Dome, Taylor glacier and Taylor Dome that also showed a much wider variability than LGM data (Table S5).

We consider however the Berkner are important to keep as they currently represent one of the very few Sr-Nd isotopic measurements of East Antarctic atmospheric dust available to be directly comparable with our modeled results for low-dust conditions typical of Holocene. They therefore provide an important reference for evaluating the performance of the DEEPOT algorithm under modern-like climatic conditions. We have revised the caption and Figure 2 to clearly distinguish these data as modern reference samples.

We emphasize that this change improves the temporal consistency of the comparison without affecting the main conclusions of the Sr–Nd fidelity test.

Q11: Second, after removing the Berkner Island data, I would not necessarily agree that there is close agreement between the modeled EDC Sr-Nd isotope compositions and the literature measured Sr-Nd isotope compositions of dust from Dome C and Taylor Glacier. For East Antarctic sites during the Holocene, εNd values of ice core dust are generally below 0 but not lower than -10 and for 87Sr/86Sr range approximately between 0.707 and 0.715. While the modeled Holocene data do capture a wider range than the modeled LGM data (as expected), the modeled Holocene data appears to extend beyond what would be expected from measured ice core dust, which merits some explanation.

A11: We thank the reviewer for this careful assessment. To complement our A10 reply, it is important to add that some data points from the Taylor Dome reach -13.5 in εNd and 0.716 for $^{87}Sr/^{86}Sr$ values, i.e., highlighting that the isotopic measurements exhibits quite a large variability despite their scarcity (even when Berkner Island dataset is not considered). We believe that the wider range displayed by the modeled Holocene and LGM data primarily reflects the much higher temporal resolution of the REE-based record compared to the sparse isotopic dataset. The REE record provides "quasi-continuous" information, allowing the model to capture short-term variability and transient source-mixing events that are not resolved by the limited number of available isotope measurements. In contrast, Sr–Nd data are available for only a few discrete time intervals, which likely represent time-averaged conditions and may underestimate the full natural variability of dust sources. As a result, some modeled values extend beyond the currently documented isotopic range. Additional high-resolution Sr–Nd records would be required to more fully evaluate the modeled variability. Importantly, despite this broader spread, the modeled isotopic fields remain centered within the range of observed values, supporting the overall consistency of the DEEPOT results.

We have added clarification in the revised manuscript (in section 4.1 in lines 282-286) to emphasize that the apparent mismatch partly reflects differences in temporal resolution and data availability, rather than a systematic bias in the model.

Added text in lines 261-273: "*The broader range of the modeled LGM and Holocene (relative to the measurements) primarily reflects the much higher temporal resolution of the REE-based record compared to the sparse isotopic dataset. The isotopic data, compiled from different sites and only available only for discrete time intervals likely represent time-averaged conditions and therefore underestimate the variability of dust sources. In contrast, the quasi-continuous REE record enables the model to resolve short-term variability and transient source-mixing events. Despite those limitations, our modeled isotopic compositions generally agree with those measured in EDC (and with other East Antarctic dust records) during both glacial and interglacial intervals supporting the robustness of our DEEPOT algorithm and reinforcing the interpretation that a distinctive shift in dust provenance occurred over the LGIT.*"

Q12: Similarly, the modeled LGM measurements span a wider range than would be expected for MIS 2 samples, which based on the literature should be tightly clustered around εNd of -1 or -2 and 87Sr/86Sr of ~709. Furthermore, when looking at the PSA % contributions during the LGM, all PSAs appear relatively stable and with a consistent mix of sources, I would expect a much tighter modeled cluster as a result. Why might be the modeled data result in these wider ranges?

A12: We thank the reviewer for this comment. As in **A11**, the broader range of modeled LGM isotopic values primarily reflects the contrast between the high temporal resolution of the REE-based modeling and the limited number of available Sr–Nd measurements for MIS 2. The isotopic data currently available for the LGM represent only a small number of discrete samples and likely reflect time-averaged conditions, resulting in a tightly clustered signature in the literature. In contrast, our model is constrained by tens of REE data points spanning the MIS3/LGM, allowing it to resolve shorter-term variations in source mixing.

Although the relative dust source contributions during the LGM appear comparatively stable over, they are not constant. As shown in Fig. 3, the Patagonian contribution varies between approximately 50% and 95% during this period. Given the strong contrast in Sr–Nd compositions between Patagonia and other PSA, even moderate changes in mixing proportions can lead to significant shifts in modeled isotopic values as illustrated in Fig. 2. This sensitivity, combined with the higher temporal resolution of our dataset, explains why the modeled LGM isotopic fields display a wider range than the currently available measurements. We have clarified this point in the revised manuscript.

Q13: Lastly, I think part of the difficulty in deciphering Figure 2 is that there are multiple goals rooted in several comparisons (i.e., comparing time interval changes, modeled vs. measured data, and PSAs).

Perhaps this could be split into multiple figures or panels. One could focus on directly comparing modeled vs. measured data and one on just comparing modeled data to PSAs.

A13: We agree with the reviewer. We have now separated this overly complex figure in several panels separating the different periods of time. Figure 2 now shows only LGM and Holocene while Figure S5 shows four panels illustrating end of MIS3, HS1, ACR and YD.

Q14: Section 4.3. This section is packed with useful information but does struggle a bit in its structure. The opening paragraph provides three processes to explain the variability across the Holocene. As a reader, I expected the subsequent paragraphs to be focused on a discussion of these processes in greater detail, but that was not necessarily the case. The next paragraph (L315-334) feels very results heavy and compares the record broadly to other papers. Then, the following paragraphs are subdivided into PSA-specific discussions, which are very detailed but also hyper-focused. I think this section would be greatly improved by a slight restructuring and including a broader discussion of the glacial-eustatic and hydrological feedbacks that connect the regional source dynamics.

A14: We agree with the reviewer on this point. Section 4.3 has now been divided into two sections: Section 4.3, which addresses the drivers of variability after 14.5 kyr BP, and Section 4.4, which focuses on regional responses to glacial–interglacial transitions. Glacial-eustatic and hydrological feedbacks are discussed in detail at the end of Section 4.5, following the EDML/EDC comparison that establishes a pan-Antarctic dust signal.