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Climate of the Past Discussions

Interactive comment on "Rare Earth Elements from an ice core in the Atlantic sector of Antarctica indicate a dust provenance change at the end of the last deglaciation" *by* A. Wegner et al.

Anonymous Referee #2

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Review

Wegner et al.: Rare Earth Elements from an ice core in the Atlantic sector of Antarctica indicate a dust provenance change at the end of the last deglaciation, Climate of the Past

General Comments

The authors provide a rare earth element (REE) data set from the Epica Dronning Maud Land (EDML) ice core as well as from a selection of potential dust source areas from the Southern Hemisphere. The focus of the paper is to use REE patterns measured in the EDML ice core as an indicator of the provenance of the dust reaching the

East Antarctic Ice Sheet by matching the REE signatures up with those of potential source areas. This is not the first study using REEs in Antarctic ice cores. The technique was first presented by Gabrielli et al (2006) and in a recent partner publication in QSR by Gabrielli et al. (2010).

A major problem of this study is the fact that REE concentrations in the Holocene ice are very low, close to the analytical blank levels, and therefore their interpretation is challenging (see details below). This is a very critical point that needs to be thoroughly addressed and critically discussed. In its present form the manuscript is not acceptable.

The two main conclusions are

i) Dust during glacials originates from South America.

ii) There is evidence for a change in dust provenance at the end of the last deglaciation.

Both conclusions have been drawn before for dust reaching the East Antarctic ice sheet. However, most of the information available to date is from EDC and Vostok where South America has been identified as the dominant dust source to East Antarctica during glacial period. This manuscript focuses on EDML, in the Atlantic sector of AA. As EDML is en route on the modeled and observed trajectories from the Southern American dust sources to the central East Antarctic ice sheet, the conclusion of this paper is not too surprising. It is, nonetheless, an interesting result, but needs to be better placed in the context of current knowledge.

A change for the East Antarctic dust provenance during the recent glacial-interglacial transition has been invoked before, largely based on observations at Dome C (including the authors' own work at EDC, Gabrielli et al., 2010), and a wide spectrum of geochemical and mineralogical proxies (Gabrielli et al., 2005; Siggaard-Andersen et al., 2007; Delmonte et al., 2007; Lanci et al., 2008; Marino et al., 2008, Gabrielli et al., 2010). There is also one study by Winckler and Fischer (2006) that invoked a change in the provenance of the dust from LGM conditions to the Holocene at the very same ice core

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location, EDML. The findings of the current study should be placed within the context of what is known about dust provenance and transport to East Antarctica and changes in dust provenance across the East Antarctic ice sheet. A more complete literature review (including, but not limited to the references listed here) needs to be added.

While the analytical technique of measuring REEs in ice cores has been introduced before (Gabrielli et al., 2006; Gabrielli et al., 2010), this is the first paper that shows detailed REE data for PSAs and fingerprinting of the sources. This seems to be the area where the paper could make a significant contribution, that is to critically examine the potential of the suggested REE fingerprinting technique and, eventually, to answer the key question: Where does the dust in the Holocene or latter part of the deglaciation originate? The paper touches upon these issues, but only lightly. The authors should further develop this line of evidence and critically evaluate to what extent REE patterns can be used to constrain dust provenance.

An obvious way of critically testing the REE tool would be to show how the REE results correlate with results of Sr and Nd isotopes (or other proxy systems analyzed on the same PSA samples, assuming that at least a subset of the samples has been analyzed for other proxies) and to critically look at similarities in these independent proxy sets to be used as dust provenance tools. Some of their proposed REE patterns show similarities for different types/regions that are hard to distinguish when discussing potential dust source changes (see more details below).

Using REE for dust provenance in ice may be an interesting approach but in my view the discussion of the results and their presentation needs a fair amount of clarification and revisions before publication. Specific comments are listed below.

Specific Comments

Abstract

Needs some serious editorial input, e.g. the first sentence is irritating. Line 8: delete

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‘s’ in PSAs Line 10: delete ‘to be’ . . .

Introduction

Needs work, particularly between line 18 on page 603 and line 11 on page 905.

The introduction about dust, its relevance within the climate system and the relevance of establishing dust provenance is incomplete and confusing, so is the referencing.

General: References in introduction are poorly selected, among the many examples are Sun et al for the impact of dust aerosols on the radiation budget of the earth; or Sarthou et al., 2003 (a paper focusing on tropical/subtropical Atlantic) for limitation of productivity in the Southern Ocean, rather than original literature (in this case, Martin, 1990, Paleoceanography). References need to be revised and checked.

Lines 3 to 10 on page 605: introduction of state of the art of provenance information is limited, the context in which the new results from EDML are placed should be clearly presented, including a complete literature review (see comments on page 1).

Methods Section

The analytical methods for the ice core samples seem to follow closely the partner publication, Gabrielli et al., 2010. The description of the methodology should be much reduced and limited to the critical details where the method applied here differs from the Gabrielli et al. (2010) paper.

On the other hand, the novel contribution of this paper is the detailed data for the PSAs (some of the data may have already been shown in Gabrielli et al., 2010 and cited as Wegner, personal communication; this should be pointed out). As mentioned previously, the presentation of the PSA data and a critical evaluation of the data should be a major emphasis of this paper. In contrast to the ice core samples, the description of the digestion method used for the PSA samples is not very detailed and needs to be extended, including crucial information such as amounts of acid added and timing information for different acid digestion steps. Even more importantly, there is no

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information about yields/completeness of the digestion for the PSA method. General statements such as 'blanks were . . .analyzed regularly' (page 609, line 18/19) need to be expanded in a more specific way.

What are the results of duplicate measurements performed for the PSA samples, given that these analyses were not sample size-limited? The authors should indicate results of duplicate measurements for the PSA samples as REE measurements often indicate high errors in duplicate measurements because of their low concentrations and blank corrections.

Results and Discussion

1. The manuscript discusses the synchronous change in the LREE/REE ratios at EDML and EDC at about 15,000 yr BP. However, one of the first-order observations of the data, as presented in Figure 2, is that the glacial LREE/REE values differ significantly between the EDC and the EDML record, from .22 for EDML to .17 for EDC (values not given, eyeballed from Figure 2). In other words, while the timing of the change in the LREE/REE ratio may be coherent between EDC and EDML, the absolute values are not. What is the explanation for this significant difference, given the consensus that both ice core sites see the same Southern American dust source during glacial times? How can this difference be reconciled with the findings by Marino et al., 2009? Most importantly, what are the implications for the use of REE as provenance proxy?

2. Holocene ice core data:

The discussion of the low concentration Holocene data and related data quality/reproducibility questions is insufficient. As shown in Table 1, for most of the REE, the PB values are fairly high, compared to the mean Holocene concentration. The PB data seem too high for most elements to effectively interpret Holocene data. The ms evaluates the comparison of PB data to transition values (also shown in Table 1), but does not explicitely discuss the very low Holocene concentration data. On page 612, the authors state 'The full REE spectrum could not be evaluated for all samples, espe-

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cially in case of the lower concentrated Holocene samples. Thus, from the climatically warm period, postdating 15200yr BP, of 227 samples, 86 could be evaluated using the full REE spectrum'. What is the criterion for evaluating the Holocene data and how does this affect the results? To what extent, does this selection bias the results? What is the basis for claiming that the 'elimination' method is conservative? One can easily imagine scenarios where sample elimination to a certain degree will bias the data? How does this affect the significance of the higher variability of the Holocene data? How much of that variability could be due to artifacts/corrections/elimination scheme (during the Holocene, not the onset at 15,2000 yr BP)? It seems that the best way of effectively testing this would be to run duplicates. What are results for duplicate measurement ?

3. Similarly, the last paragraph on page 612 discusses identification of different types of patterns. How were these patterns selected? Is this done manually or is there a certain algorithm to identify these patterns? Type B, Type D and Glacial Type (or at least subsets of those) seem to be very similar.

4. Figure 3. The first order observation is that the post-glacial samples show much higher variability than the glacial samples. However, I don't see much of a difference in REE patterns from glacial to non glacial times. This seems to be especially true for EDML.

5. PSA data The PSA data is such as essential part of this study that much more information needs to be shared about the samples, their origin, collection method, etc.

What samples are they, soils, air filters, Aeolian deposits, moraine deposits? How representative are the PSA s of likely major sources of dust entrainment?

This is crucial information that should be provided together with the geographic information (which is listed in the supplement). Have any of these samples been used before and been analyzed for other geochemical proxies (Sr, Nd). Are they samples provided by some of the coauthors (Delmonte, De Deckker ?) This would be helpful in

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the direct comparison of the methods as suggested above.

6. PSA data The presentation of the key plot, Figure 7, and the accompanying text leaves room for improvement and clarity. The identification of the general area of Southern America as dominant source for dust transport to EDML seems to make a lot of sense, given the location of EDML and our knowledge of dust transport to Antarctica, and is not controversial.

The REE data are certainly consistent with this conclusion. However, the key question is to what extent do the REE data identify South America as a source? Or, in other words, if we didn't know the answer a priori, could we identify South America as the dominant glacial source.

The PSA fields are largely overlapping (as stated by the authors) and do not allow a good differentiation between the different dust sources. The glacial EDML points plot pretty much in the center of the overlapping fields (and the exact boundaries of those fields are debatable in the first place). Based on the REE data alone, it seems a challenge to unequivocally identify the dust source even for the glacial, let alone for the Holocene and transitional samples. This challenge is also reflected in the high correlation factors with at least three different sources in Figure 8.

Adding the bulk data from the literature appears to further blur the distribution, e.g.: the blue dots for Australian samples analyzed for the present study are distinctly different from the literature data. Why is that? Is this purely a grain size effect or some geographic effect as well? How representative is the selection of analyzed PSAs?

The text (page 615) discusses two options, i.e. with or without a correction for the lower recovery of a part of the REEs, while the figure only shows the data without the correction. Statements such as 'if taking into account the lower recovery of MREE and HREE, this spot moves slightly to the right. . .' are vague and need to be clarified.

In summary, it seems difficult to identify the dominant source based on the REE pat-

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terns - without any prior knowledge. The authors need to critically evaluate the potential of this method.

7. PSA data All data from South America are grouped, but the map in Figure 1 shows different subregions. Can you distinguish different patterns across South America, let's say between the Pampas, central and southern Patagonia or even the very southern tip (from the map in Figure 1 it looks like some of the samples are from Tierra del Fuego). No matter what the results are, this should be expanded on in the manuscript.

8. Ice Core data during the Holocene The authors seem to take the variability of the REE patterns during the Holocene (not the undisputable onset of the increased variability at 15,0000 BP but the variability during the Holocene) at face value and interpret them as representing input from different source areas. What is the likely switching (on and off) mechanism of the invoked 'reorganization in atmospheric circulation patterns'?

9. General The Holocene data suffer in their quality because the REE content is close to blank values or even detection limits. Given similar problems in the earlier study at EDC (Gabrielli et al., 2010), why can sample sizes for Holocene samples at EDML not be adjusted to analyze larger sample sizes which would still allow for high resolution time series?

10. Figure 7. Please include a legend in Figure 7 indicating the different source areas.

Editorial comments

The title appears to be long and convoluted.

I am not familiar with the abbreviation 'LGA' for last glacial age.

There are plenty of minor spelling and grammar errors through out the paper that need to be corrected.

Interactive comment on Clim. Past Discuss., 7, 601, 2011.