Clim. Past Discuss., 9, C3459–C3479, 2014
www.clim-past-discuss.net/9/C3459/2014/

Interactive comment on "Centennial-scale shifts in the position of the Southern Hemisphere westerly wind belt over the past millennium" *by* B. G. Koffman et al.

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Received and published: 17 February 2014

Author Comment

Koffman et al., "Centennial-scale shifts in the position of the Southern Hemisphere westerly wind belt over the past millennium"

February 17, 2014

We thank the reviewers for their well-informed, thoughtful, and thorough comments, which have helped us to clarify and improve the paper. We particularly value the reviewers' suggestions of additional plots and datasets to include in our analysis. We

have revised the manuscript in accordance with their suggestions, and have responded to specific comments point-by-point (see below).

Anonymous Referee #1 Received and published: 21 October 2013 In their paper entitled "Centennial-scale shifts in the position of the Southern Hemisphere westerly wind belt over the past millennium", Koffman and co-authors address an important aspect of the climate system, and potentially the carbon cycle, that is the reconstruction of the location and intensity of the Southern Hemisphere westerly winds. The authors have analyzed different dust particle related parameters from the West Antarctic Ice Sheet (WAIS) Divide deep ice core over the last ca. 2400 years. This archive allows working with an incredibly high resolution (sub-annual) and a precise age model (+/- 1 yr) based on annual layer counting, and provides invaluable records for paleoclimate reconstruction in the Southern Hemisphere high latitudes. The study presents new, valuable data, the data are discussed in details, the methods (although I'm not from the "ice core community"), results and their interpretations are convincing, and the manuscript is well-written. I have only a few remarks and suggestions (mainly) for the authors. I strongly recommend this study to be published in Climate of the Past after some revisions.

In my opinion, four points (randomly numbered) still need to be developed in this study (these are addressed throughout the review):

(1) The time-interval covering the last 150-200 years provides an opportunity to "calibrate" the coarse particle percentage (CPP) data. In my opinion, a figure (including e.g. the CPP, SAM, SH dust stack, NAMI, records, see below) and a short section discussing this time-interval would add an interesting side to the study presented here and would give a robust frame to the CPP as proxy for SWW variability.

AC: We have added a new figure and a short section (Section 4.5) discussing the past 150 years, as suggested.

(2) A discussion on the potential relationship between the SWW variability as recon-

structed from the CPP record and changes in solar activity from 10Be and 14C records would be interesting as this link has been suggested by modeling studies (Warma et al., 2011, Clim. Past 7, 339-347; Warma et al., 2012, GRL 39, L20704) and proxy data comparison (see e.g. Kilian and Lamy, 2012, Quaternary Science Reviews 53, 1-23).

AC: We have added a new section focused specifically on this topic (4.7.2) and have included the TSI reconstruction of Steinhilber et al (2009) in our figure of paleoclimate records (now Figure 7).

(3) As the authors mention it (P. 3131, lines 14-16), it is still impossible to differentiate between shifts and changes in the intensity of the SWW in the past. As the proxy used in this study (CPP) cannot differentiate between these two mechanisms as well, the authors should always mention both possibilities, i.e. either "weakening and/or equatorward shift of the SWW", or "strengthening and/or poleward shift of the SWW", what is not always the case throughout the manuscript, as well as on Figure 9. The literature suggest that in the present day the SH storm track activity related to the SWW is persistent over the year in both intensity and location. Strongest activity is found in austral autumn and activity is extending over broader latitudes in austral winter, but it is always close to 50_S (Trenberth, 1991, Journal of the Atmospheric Sciences 48, 2159-2178). Garreaud et al. (2009, Palaeogeography, Palaeoclimatology, Palaeoecology 281, 180-195) wrote: "In particular, over the southern tip of South America and the adjacent south Pacific, the westerlies are strongest during austral summer, peaking between 45_ and 55_S. During the austral winter, the jet stream moves into subtropical latitudes (its axis is at about 30_S) and the low-level westerlies expand equatorward but weaken, particularly at â′Lij50_S." So my impression is that the SWW are shifting poleward AND strengthen, while they are expanding equatorward AND weaken (see also Varma et al., 2012, GRL 39, L20704), but this may be valid only for the present day southeast Pacific region. The authors could mention this general pattern of the SWW in e.g. Section 3.

AC: The reviewer makes a valid point, in that a single record cannot distinguish be-

tween a latitudinal shift and a change in strength of the SWW. And we agree that modern observations indicate that SWW seasonal variability includes both strength and position changes. However, as we discuss in Section 4.6.4, by using records spanning the latitudinal range of the westerlies' influence, we believe we can differentiate between changes in strength and changes in position on decadal to centennial timescales. For example, where the GeoB-3313 Fe record (Lamy et al., 2001) indicates a southward shift and/or weakening of the SWW at the same time as our CPP record indicates a southward shift and/or strengthening, we can infer that the core of the westerlies shifted southward, thereby diminishing precipitation in the Chilean mid-latitudes while enhancing cyclone activity and the deposition of coarse particles at the WAIS Divide site. Thus, we prefer to keep our language consistent with this interpretation.

(4) While the CPP data do show an increase during the MCA, suggesting a poleward shift and/or a strengthening of the SWW, there is no real signal during the LIA (one would expect a decrease in the CPP) in comparison to the period before the MCA (I mean here 1950-950 yrs BP). The CPP data alone do not give any clue about changes in the SWW during the LIA. Is the proxy mainly sensitive to changes in the southern side/boarder of the SWW during warm periods, but not during cold periods, when the poleward side of the SWW weakens and the equatorward one broadens? Is there a threshold mechanism, which explains that a CPP decrease related to a wind weakening cannot be recorded ? Or were the climatic conditions during the LIA similar to the ones before the MCA ? Could you comment on this issue?

AC: Yes, we believe the CPP record indicates times of increased SWW strength and/or southerly position, and that it is not as sensitive to northward shifts. It seems plausible that there is a threshold mechanism, as the reviewer suggests. We have added several sentences addressing this question in Section 4.6.

Title: I suggest to change the title into "Centennial-scale variability of the Southern Hemisphere westerly wind belt over the past two millennia" as (1) it is impossible yet to differentiate between changes in the position and in the strength of the SH westerly winds and (2) because the data covers the time-interval -50 to 2350 years BP, i.e. 2400 years.

AC: We have changed the title as suggested, and also have added " in the eastern Pacific" to further specify the focus of the paper.

Abstract: At the end of the abstract you may add a sentence about the last ca. 150 years [e.g. mentioning the CPP increase over the last ca. 40 years in consistence with observations that the SWW have been shifting southward and intensifying during this period (Thompson and Salomon, 2002, Science 296, 895-899)].

AC: Good suggestion; we have done this.

Please mention that B.C.E. = Before the Common Era and C.E. = Common Era.

AC: Done.

Introduction: P. 3128, line 15: You may add a reference here.

AC: Done.

P. 3131, lines 8-9: This is not really the case : : : No records from other ice cores are appearing on the figures. This is what is missing a bit in my opinion. See below.

AC: While we do not include dust time series data from other sites, we do make quantitative comparisons to dust measurements from around Antarctica, including both flux and particle size distribution (Sections 4.1 and 4.2). Given the focus of this paper on interpreting the observed dust particle size changes at WAIS Divide, we prefer to stay focused on comparisons with other SWW-influenced proxy records, rather than Antarctic dust concentration or flux records. We plan to address questions about larger-scale dust deposition changes in future work.

Methods: As I'm not so familiar with the methods applied to ice cores, I can't properly comment on the validity of the methods used in the present study.

Results: I think it may be useful to present the data with log scales. This would allow visualizing better the variability in the range of low values, which is hampered by 2-3 high peaks (Figure 2).

AC: The question of whether to plot on a log or linear scale is certainly worth considering. Following the reviewer's recommendation, we plotted the data in Figure 2 on a logarithmic y-axis (see attached figure). While this approach does show the variability in the low range of values more clearly, it diminishes the appearance of overall variability. In particular, plotting on a log scale de-emphasizes the changes in coarse particle percentage, which form the basis of our interpretation. Thus, we prefer to keep the datasets in Figure 2 on a linear scale.

AC: Figure caption for attached figure: as for Figure 2 except dust datasets are plotted on logarithmic scales.

P. 3135, line 18: If you are referring to other ice core records, I can't see these in the figures : : :

AC: We are referring to the WAIS Divide dust flux, shown in Figure 2. We added a reference to the figure here to clarify our intent.

Discussion: P. 3142, line 18: Put a reference to Figure 2 here. It is difficult to quickly find these peaks on Figure 2 because of the low increment of the X axis. I would suggest doubling its increment. And I would also suggest broadening/stretching the graphic (X axis). Furthermore, I cannot really see an increase in flux without a parallel increase in CPP between 1850 and 2002 C.E. from Figure 2. I rather see an increase in all parameters starting around 1900 C.E. and a sharp increase over the last 10-20 years, except in CPP. Could you be more precise here ? This is important, in my opinion, concerning a potential CPP increase over the last 50 years, which may be related to the strengthening of the SH westerly winds over the last few decades (Thompson and Solomon, 2002).

AC: We quadrupled the X increment of Figure 2 and broadened the graphic. We also added a new figure, which shows changes over the past 150 years in greater detail, including in the CPP, NAMI and SAM indices. We removed lines 15-25, as this paragraph was overly generalized. We will address recent changes in dust concentration and flux in future work.

P. 3142, line 19: It is not clear what “the dust source strength” signifies.

AC: We have removed this paragraph, as it was overly generalized and speculative.

P. 3145, lines 7-9: Put a reference to a figure here. In fact, it is very difficult to see this increase on any figure. Indeed, this is an important point in order to constrain and validate the CPP as proxy for wind variability. It would be great to see a plot here. I suggest adding a figure containing the CPP record and the NAMI record from Dixon et al. (2012), maybe together with the SAM and SH dust stack records, i.e. a plot of the last ca. 150-200 years (see Fig. 3 in Dixon et al, 2012).

AC: We have included an additional plot as suggested, and discussed the past 150 years in detail in a new section (4.5).

P. 3145, lines 21-22: Please, add the time intervals of the MCA (950-1350 C.E.) and the LIA (1400-1850 C.E.) here.

AC: We have removed this sentence and focused the paper more on the timing of observed changes than on links to NH climate anomalies. We still refer to the MCA and LIA, but have de-emphasized them in our interpretation.

P. 3145, line 26: Refer to a figure here. P. 3145, lines 26-27: Again: please show this in a plot !

AC: We have added a new figure and a section (4.5) discussing changes in the SAM, CPP, and NAMI proxies during the past 150 years.

P. 3148, lines 1-17: This discussion is not well placed in my opinion. I would suggest

moving this paragraph to the end of Section 4.3., for example.

AC: We agree with the reviewer’s suggestion, and have moved this paragraph to Section 4.3.

P. 3146, lines 10-29 + P. 3147, lines 1-8: I would recommend to have a look at the paper by Kilian and Lamy (2012, Quaternary Science Reviews 53, 1-23) in order to mention some more evidences on climate changes during the MCA and LIA in southernmost South America (e.g. glacier advances).

AC: We appreciate the reviewer’s recommendation, and have changed the text to include some of the datasets discussed in Kilian and Lamy (2012).

P. 3146, line 26: The records from Moy et al. (2008) may not be the most representative and may contain some bias (see discussion in Lamy et al., 2010). In fact other record from these latitudes (south of 50_S) suggest humid conditions in southernmost Patagonia during the MCA, and relatively dry conditions during the LIA [see Schimpf et al., 2011, QSR 30, 443-459; Waldmann et al., 2010, Journal of Quaternary Sciences 25, 1063-1075; and for a “review” see Kilian and Lamy (2012)] in agreement with your record. I would recommend showing one of these records instead of the Moy et al. record on Figure 8.

AC: We have removed the Moy data from the figure and discussion, and added the Schimpf record, as suggested.

P. 3149, lines 13-14: You may here shortly mention the potential mechanistic link(s) between ENSO and SWW variability.

AC: We have revised the organization of the Discussion section and added a new subsection (4.7.3) explicitly addressing the mechanistic link between ENSO and the SWW, as suggested.

P. 3150, lines 3 & 4: Why is the _18O record from the WDC ice core (WAIS Divide Project Members, 2013, Nature, doi:10.1038/nature12376) not shown and discussed here ? I thought it would be a reference record of air temperature changes in West Antarctica. In my opinion, this record should appear on Figures 8 & 10.

AC: We have added the recently published WAIS Divide isotope record and removed the lower-resolution temperature records included previously.

P. 3150, lines 7-9: Showing this record on Figure 8 is not necessary, as the proxy is not that much straightforward.

AC: We have removed this record from the figure.

A major issue, which is missing in Section 4.5, is the potential role of solar variability on SWW variability. Warma et al. (2011, Clim. Past 7, 339-347; 2012, GRL 39, L20704) have shown the impact of solar forcing on the SWW using data and modeling outputs. Based on these results, the authors suggest that periods of lower solar activity caused equatorward shift of the SWW, which get weaker on their poleward side. During high solar activity, the SWW shift poleward. A discussion on this mechanism is missing here and I would strongly recommend plotting on Figures 8 and 10 the 10Be record from Steinhilber et al. (2012, PNAS 109, 5967–5971) or Steinhilber et al. (2009, GRL 36, 10.1029/2009GL040142) as proxy for solar activity.

AC: We have added a new section focused specifically on this topic (4.7.2) and have included the TSI reconstruction of Steinhilber et al (2009) in our figure of paleoclimate records (now Figure 7).

P. 3151, lines 17-19: You cannot exclude a poleward shift + strengthening, as well as an equatorward shift + weakening. Please be more precise here.

AC: We argue that we can, in fact, discriminate between strength changes and latitudinal shifts, as we discuss in Section 4.6.4. The mid-latitude records indicate weakening and/or southward movement at the same times that the CPP suggests strengthening and/or southward movement. Conversely, decreased CPP occurs at times when precipitation proxies from the mid-latitudes indicate enhanced SWW influence, caused

by a northward shift and/or strengthening of the SWW. The changes we describe are consistent with shifts in the position of the wind belt.

Conclusions: Should be updated for the few modifications.

AC: Duly modified.

Figures: Fig. 1: Latitude and longitude coordinates are missing on both maps. Please indicate where the Amundsen–Bellingshausen Sea region is located.

AC: We have added lat/long coordinates and place names to both maps.

Fig. 2: I suggest plotting the data on log scales (as well for the CPP records on Figures 8 and 10 ?). It would be helpful for the reader to broaden/stretch the graphic and to increase (double) the increment of the X axis.

AC: See above. We prefer to keep these datasets plotted linearly. We have broadened the graphic and increased the x-increment (x4), as suggested.

Figs. 6 & 7: These two figures could be merged into one figure only.

AC: Done. We combined figures 6 and 7 and added a spatial correlation map for the CPP and meridional wind speed, as requested by the second reviewer.

Fig. 8: I recommend removing the records from Hall et al. (2010) and Moy et al. (2008), and add a 10Be record, the _18O record from the WDC ice core and e.g. the Y content or the _18O stalagmite records from Schimpf et al. (2011).

AC: We have followed the reviewer's recommendations.

Fig. 9: Repeat in the figure capture that PSD = particle size distribution.

AC: Done.

Fig. 10: As well as for Figure 8, you may add here the 10Be record, the _18O record from the WDC ice core and e.g. the Y content or the _18O stalagmite records from Schimpf et al. (2011), and also the TEX86 record from Shevenell et al. (2011). Why

the CPP data are not going back to 2350 yrs BP as in Fig. 2 ? Plot the complete record.

AC: We have extended the time period of the earlier figure (now Fig. 7) to 2350 years BP, and thus eliminated this second figure. We have included the 10Be, d18O, and stalagmite records, as suggested.

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Anonymous Referee #2 Received and published: 24 October 2013

Koffman and co-authors present a dust particle dataset from the West Antarctic Ice Sheet Divide ice core over the past 2400 yrs. Measured dust size changes are compared with zonal wind strength between 1979 and 2002 in an attempt to calibrate the dust record in terms of wind strength. The dust size is interpreted as reflecting Southern Hemisphere westerly wind strength and is subsequently compared with published datasets from the mid-latitude and tropical Pacific. The paper reads well and the datasets appear to have been obtained in a rigorous manner. However, I have several major comments below which should be addressed before the manuscript is published in its final form. In general I feel that more effort should be made to understand what the measured dust parameters actually represent before fitting the data with existing hypotheses about SWW shifts.

Major points: The authors argue convincingly that the relatively coarse size of the dust particles at WAIS suggests that dust sources are local, and are thought to be in Marie Byrd Land; P3140). Yet, in terms of the link between wind strength and CPP, there is little correlation between dust size and wind strength in the Marie Byrd Land region (Fig. 6). The authors should explain why this is the case. There is an arrow in their schematic (Fig. 9) suggesting the authors must have reason to think that winds were stronger in this region during periods of coarser CPP. One reason for that lack of correlation may be that the main winds in this region (and the arrow on the schematic) are onshore i.e. they are meridional as well as zonal. Therefore, the authors could

also analyse the correlation with meridional winds in this region. Until a mechanism linking CPP and SWW in the Marie Byrd Land region is shown, the interpretation of CPP remains speculative.

AC: As the reviewer points out and as we show in Section 3.2, winds in the central West Antarctic region are predominantly onshore (i.e., from the NE). Although we had not made the link between zonal and meridional circulation explicit in the text, we do observe that the CPP correlates with zonal winds in the middle latitudes and with meridional (onshore) winds in Marie Byrd Land. This is consistent with our interpretation that changes in the mid-latitude westerlies are translated to the WAIS Divide site via cyclonic systems, as summarized in Figure 9 – a dynamic that can also been seen on a synoptic scale in satellite imagery. We have added a figure that shows the spatial correlations between meridional wind speed and WAIS Divide CPP (Figure 6b), and have added a paragraph in Section 3.3 to describe the circulation patterns more thoroughly.

The timing of the increase in CPP seems not to fit so well with the northern hemisphere climate anomalies, the MCA and LIA. The maximum in CPP is at 1300 and seems to span between about 1200 and 1450, hence covering the boundary between both MCA and LIA periods. The authors should still compare their record to the northern hemisphere climate anomalies such as the MCA and LIA, but I do not think that the CPP peak at about 1300 CE should necessarily be attributed to the MCA as is stated in the abstract and conclusions. Similarly, the timing appears to be later than climate changes in other records that are shown in Fig. 8. If the control on all of the other records is simple shifts of the SWW as the authors argue in section 4.4, the mismatches in timing should be better justified than the explanation that is presently given (P3149, L8-9).

AC: The reviewer makes a good point. Upon further consideration, we have adjusted the language throughout the paper to de-emphasize links with Northern Hemisphere climate anomalies. The addition of several new datasets to Figure 7 (previously Fig. 8) provides evidence for a close link with the tropical Pacific, and we have shifted the focus of the discussion toward discussing this relationship. In addition, we explicitly address (Section 4.6.4) the apparent temporal offsets among records, which we expect are a function of their respective timescales. We have plotted the age control points, with uncertainty, for the Lamy et al. (2001) and Schimpf et al. (2011) records, to help make the point visually that the three records' timescales are not equally resolved.

The link between SWW speed and dust emission/transport to the WAIS Divide site is an important aspect of the story but it is only briefly mentioned in the discussion (P3144 L20-26). The mechanisms by which increased cyclogenesis causes an increased CPP should be explained more clearly here, in terms of this region and the WAIS dust record and should be included in the abstract. Also, if cyclones are important, the authors could test this by analysis of temperature indicators as suggested by Lubin et al 2008.

AC: One of the challenges to a more complete discussion of dust emission/transport to the WAIS Divide site is the fact that at present, no dust provenance data exist for any site in West Antarctica. Unlike the Dome C, Talos Dome, Berkner Island, and Vostok sites in East Antarctica, we do not yet have Pb, Sr, Nd or major/minor element geochemical data that can be used to constrain dust sources. For this reason, our discussion of dust sources and transport relies on grain size data coupled with known atmospheric circulation patterns. We suspect that the McMurdo Dry Valleys supply dust to WAIS Divide via cyclonic systems (as discussed in Section 4.1), but we cannot yet test this hypothesis. One of us (B.G.K.) is working currently with a group at Lamont-Doherty Earth Observatory to develop provenance datasets from West Antarctica that can be used to resolve some of these questions. Regarding the observation of Lubin et al. (2008) that mesoscale cyclone activity is associated with positive (primarily) winter temperature anomalies, we do not have adequately resolved long-term data to address this question. Lubin et al. (2008) were able to observe this relationship using daily-average temperature data, computed into monthly anomalies. Because the WAIS Divide oxygen isotope record is interpreted as an annual-mean surface air temperature record (WAIS Divide Project Members, 2013), synoptic-scale changes in sensible heat

flux would be masked by larger-scale temperature variability.

In the introduction there is a lengthy description of the SWW and their importance for global climate. However, considering that the manuscript aims to reconstruct changes in dust sources and dust transport pathways, very little information is presented on known Antarctic dust sources and on the mechanisms by which this dust is transported towards the ice core site. The introduction should be modified to focus more on Antarctic dust sources and transport pathways and less on the significance of the SWW.

AC: We see the reviewer's point, and recognize the challenge of describing and interpreting a 2400-year dust flux and size distribution record, while also comparing our record to a latitudinal range of paleoclimate reconstructions from the tropics and middle latitudes, and doing justice to all these topics. Given the primary focus of the paper on reconstructing past atmospheric circulation changes, we believe the introductory material on the westerlies is important. We chose to discuss dust sources and transport in Section 4.1, as this seemed the most relevant place to go into detail on these topics.

In the discussion there is a great deal of comparison with other records from South America. However, there is little comparison with downcore changes in dust from other high-resolution ice core records. I suggest to reduce the discussion of SWW records from South America but to add some plots and comparison with published ice core records (for e.g. those that are mentioned: Ruth et al, 2004; McConnell et al, 2007; Mosley-Thompson et al, 1990 or the cores using nssCa). This might help to assess the regional nature of dust deposition.

AC: We agree with the reviewer that a thorough discussion (with figures) of Antarctic ice core dust flux and concentration records may be warranted; however, given space considerations and the focus of this paper on interpreting the WAIS Divide dust size distribution record, we believe that a fair treatment of Antarctic dust flux and concentration records is beyond the scope of this paper. We are currently engaged in interpreting the WAIS Divide dust flux and concentration records, and expect to produce a second manuscript describing late Holocene dust deposition in Antarctica in greater detail.

Land-use changes are mentioned several times as a cause of the increase in dust flux over the last 150 yrs in the WAIS record and in other records (McConnell, et al 2007). The authors should address how land use might also be compromising the calibration of CPP and wind speed (between 1979 and 2002).

AC: Our interpretation is that changes in the fine fraction of dust (around 2 um diameter) likely reflect changes in distant source regions, such as Australia. However, given that the mode particle size remains around 5-8 um throughout the record, we do not believe this far-traveled dust is affecting the CPP or its calibration with wind speed.

Minor points: Abstract, L4: mention the timescale under investigation

AC: Done.

P 3129, L27: 'regional temperature' – which regions?

AC: We clarified this sentence.

P3130 L1: replace glacial with glacier

AC: Done.

P3135 L10: mention Fig. 2e

AC: Done.

P3137, L3: 1680 to 1730 – this is labeled as 1670-1730 in the figure.

AC: We fixed this.

P3138, L10: why is 700 Pa shown rather than 850 Pa? Please justify

AC: We chose to use 700 hPa wind data rather than 850 hPa data because long-distance dust transport occurs primarily in the middle troposphere (3000-4000 m al-

titude; Krinner et al., 2010). Winds at 700 hPa roughly correspond to 2600 m ASL (Nicolas and Bromwich, 2011), and are consistently above the land surface in West Antarctica – unlike winds at 850 hPa. Thus we selected the pressure level most relevant to deposition of dust at the WAIS Divide site. We added a sentence to this section to explain our use of the 700 hPa wind field.

P3139, L23: 6-7000 km, should read 6000-7000 km

AC: Done.

P3140 L30-P3141 L4: Distal sources are suddenly mentioned. How much dust are they thought to contribute compared to local dust?

AC: At present, the relative balance of proximal and distal dust sources to West Antarctica can only be inferred from dust size data and atmospheric circulation patterns. As of yet, no dust provenance data exist for any site in West Antarctica. Unlike East Antarctica, where dust sources have been identified using Sr, Nd, and Pb isotopes (as well as rare earth elements and major element chemistry) for both glacial and interglacial periods, we have to infer likely sources using transport and size arguments. One of us (B.G.K.) is currently engaged in developing a dust provenance (Sr, Nd, Pb isotope) dataset for several sites in West Antarctica, which will help to unravel the source/transport story in future work. In the paragraph referenced by the reviewer, we thought it was important to include the current perspective from modeling studies, although the models are based on prescribed dust sources, and do not include any local (Antarctic) sites.

P3142 L18: refer to the correct figures (Fig. 2d and e) here and check that figures are always referred to throughout the manuscript. Check a to e is labeled on the figure.

AC: We thank the reviewer for finding these errors, and have fully checked the figure numbers and in-text figure references.

P3142 L19-25: The explanation here should be more detailed and specific to the WAIS core. Which glacier, which desertification and which dust source region are meant?

AC: We agree with the reviewer that the explanation of the dust concentration and flux time series should be more detailed. Considering the focus of this paper on interpreting the size distribution record, we have chosen to remove this short section, which was far too speculative. We plan to discuss long-term dust deposition changes, and to make comparisons to other Antarctic sites, in future work.

P3143, L28: Yes, it seems counterintuitive to me - I would have thought stronger winds would result in emission of coarser particles. Perhaps the reasons for this can be better explained here.

AC: Actually, the reviewer may be further surprised to learn that early wind-tunnel studies found the opposite relation: stronger winds were found to cause the emission of finer particles, presumably because of increased saltation and fragmenting of grains (See Kok, 2011, “Does the size distribution of mineral dust aerosols depend on the wind speed at emission?” Atmospheric Chemistry and Physics, and references therein). Jasper Kok has written two excellent papers discussing the physics of dust particle fragmentation, and we prefer to leave the theoretical explanation to these papers, as referenced in the text.

P3143 L8-9: Availability from a local source could also be caused by increased by local wind strength in the region of the local dust source

AC: True. We expect that local winds, whether in coastal Marie Byrd Land or in the McMurdo Sound region, are affected by the SWW via cyclonic storm systems (e.g., Lubin et al., 2008).

P3144 L19-25: CPP and PSD are both mentioned. Are the authors referring to two different parameters here or do they use them interchangeably in the sense that CPP is a measure of PSD? Either way, I think it's better to stick to one or the other in the text.

AC: We define the coarse particle percentage in section 3.1, and discuss in detail several measures of the dust particle size distribution (including the volume size distribution and its mode, or center). We consider the PSD to be a general term that refers to the statistical distribution of particles across a given diameter range, while the CPP is a specific numerical indicator of changes in the PSD. Ice core dust papers typically contain these terms and others, such as fine particle percentage (FPP) – and so we are not introducing new terms but simply using the established terminology in this field (See, for example, Delmonte et al, 2004, “Dust size evidence for opposite regional atmospheric circulation changes over east Antarctica during the last climatic transition,” Climate Dynamics).

P3146, L28: Fig 8c should be Fig. 8d

AC: We thank the reviewer for finding this error, and have updated our in-text figure references.

Figures: Figure 1 The colour of the symbols should be more distinct. Some symbols in S. America are hard to see. Consider making the WAIS symbol different from all the rest. Make sure that every region/place name that is described in the text is labeled on the figure (eg Marie Byrd Land, Victoria Land etc).

AC: We have revised Figure 1 as requested.

References: Delmonte, B., J. R. Petit, K. K. Andersen, I. Basile-Doelsch, V. Maggi, and V. Y. Lipenkov (2004), Dust size evidence for opposite regional atmospheric circulation changes over east Antarctica during the last climatic transition, Climate Dynamics, 23, 427-438, doi:10.1007/s00382-004-0450-9.

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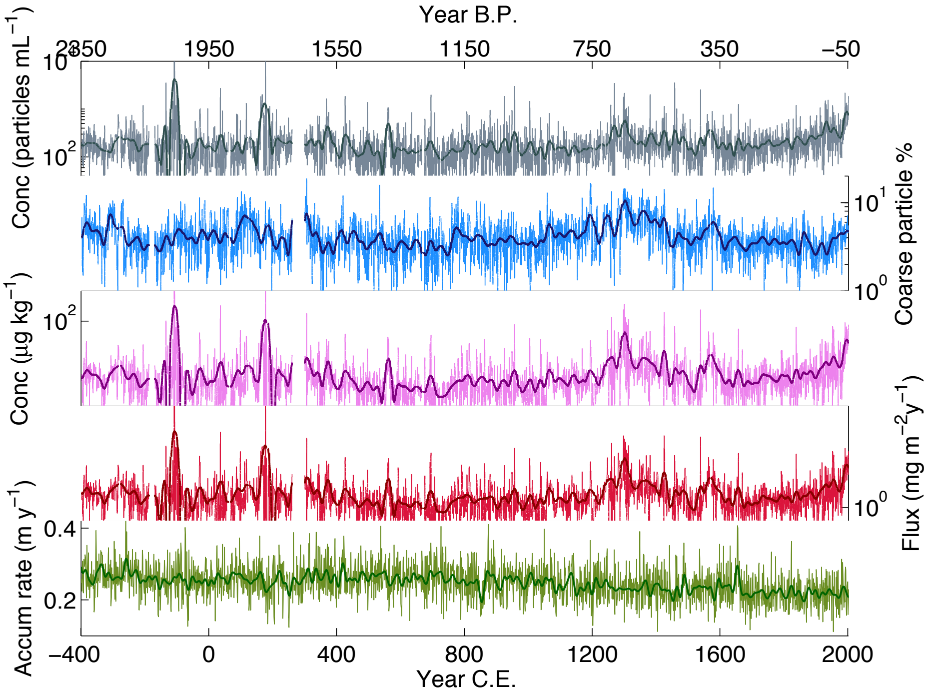

Fig. 1. Dust time series plots as in original Figure 2, except plotted on log scales.