Clim. Past Discuss., 9, C2352–C2358, 2013
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# *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.

**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.

(2) A discussion on the potential relationship between the SWW variability as reconstructed 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).

(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 âĹij50°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.

(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 ?

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.

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)].

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

Introduction:

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

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.

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).

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

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,



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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 Salomon, 2002).

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

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).

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.

P. 3145, line 26: Refer to a figure here.

P. 3145, lines 26-27: Again: please show this in a plot !

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.

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).

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



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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.

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

P. 3150, lines 3 & 4: Why is the $\delta$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.

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

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.

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

Conclusions:

Should be updated for the few modifications.

Figures:



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

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.

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

Fig. 8: I recommend removing the records from Hall et al. (2010) and Moy et al. (2008), and add a 10Be record, the $\delta$18O record from the WDC ice core and e.g. the Y content or the $\delta$18O stalagmite records from Schimpf et al. (2011).

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

Fig. 10: As well as for Figure 8, you may add here the 10Be record, the $\delta$18O record from the WDC ice core and e.g. the Y content or the $\delta$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.

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Interactive comment on Clim. Past Discuss., 9, 3125, 2013.