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Climate of the Past Discussions

Interactive comment on "A 250 year periodicity in Southern Hemisphere westerly winds over the last 2600 years" *by* C. Turney et al.

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General comments

The manuscript presents data from a 2600-year peat core with 30-yr resolution from a site on the Falkland Islands (51.7°S, 57.8°W). The pollen assemblage and charcoal records from the core are used to draw the following main conclusions:

1. That there was stronger westerly wind strength over the Falkland Islands between 2000 and 1000 years ago;
2. That there is a significant 250-yr periodicity in southern hemisphere westerly wind strength over the past 2600 years;

3. That this 250-yr periodicity strongly suggests solar forcing plays a significant role in modulating the strength of the southern hemisphere westerlies.

Records of southern hemisphere westerly wind strength and position have been much sought after. The pollen and charcoal data presented here are a new and very important contribution to this effort and will be of high interest to the palaeoclimate community. I feel that findings (1) and (2) above are sufficiently well supported by the results (although see below for some clarifications that are needed). However conclusion (3) is not sufficiently well supported and should either be removed or backed up by substantial additional work and evidence. The conclusion that solar forcing modulates southern hemisphere westerlies rests primarily on the similarity of the 250-yr period in the charcoal data and the to the 200–230-yr period of the solar De Vries cycle. Without cross-spectral analysis of the coherence between the charcoal record and the solar activity records and without a plausible mechanism the proposed solar-climate link is speculation only. Furthermore, alternative explanations for the periodicity (such as centennial-scale internal variability in the climate system) are not explored.

Overall the manuscript presents important and original work. If revisions can address the major points below (most importantly the point on the implied solar forcing), then I think the paper would be an excellent contribution to Climate of the Past.

Specific comments

1. The manuscript reports a (visual) correspondence between peaks in *Nothofagus* pollen (exotic to the Falklands and therefore originating from South America) and peaks in charcoal counts. The wind-blown *Nothofagus* pollen is interpreted as a proxy for westerly wind strength and the charcoal counts are interpreted as proxy for local fire frequency and by extension local temperature/dryness: the authors

interpretation is that stronger winds drive warmer and drier conditions, leading to more fire and charcoal. Some clarification is needed here on the following points.

- The interpretation receives some support from the ERA-Interim data shown in Fig. 4 and it is important that this is included. However it should be noted that the ERA-Interim data spans 34 years and the extent to which the pattern in Fig. 4 can inform on the centennial scale dynamics involved in the observed pollen and charcoal peaks is at least open to question.
- A quantitative assessment demonstrating significant coherence between the *Nothofagus* and characoal data would give more confidence in the proposed link between these two and in the later use of the charcoal data directly as a proxy for wind strength.
- Other exotic pollen types in the core (*Podocarp*, *Ephedra fragilis* and *Anacardium-type*) are presumably also wind-blown to the Falklands but do not show any correspondence with *Nothofagus*. There is missing some explanation of why the peaks in *Nothofagus* should be related to wind strength while the peaks in pollen from the other species are not. Perhaps this is obvious to someone more familiar with pollen records, but it was not clear to me.

2. Between pp2165 and 2166 the major step is taken of using the charcoal data directly as a wind strength proxy. This step needs to be stated explicitly and some additional text/reasoning included on why for example charcoal is used rather than e.g. the *Nothofagus* pollen data and why the < 50 μm charcoal rather than the > 50 μm. This goes to a general point of the paper being well written but sometimes too brief; there is room for more detailed explanation in the Climate of the Past format.

3. The presence of a 233–244 year periodicity in the charcoal data is supported by the multi-taper and single-spectrum analyses. I accept that this is close to

the period of the solar de Vries cycle (200-230 years). The problem I have is that the similar periodicity is not adequate to justify the 'strong suggestion that solar forcing plays a significant role in modulating southern hemisphere westerly wind strength (pp2168 line 6-7)'; these phenomena could also be completely independent. To support the claimed link (or as a test of the hypothesis that southern hemisphere wind strength is solar modulated) I would suggest a cross-spectral analysis between the charcoal data and one or more reputable solar reconstructions [e.g. Steinhilber et al 2012]. As it stands the reader does not know if the peaks are supposed to align with high or low solar activity, which would be a straightforward thing to check in order to see if the data is consistent with the Varma et al., [2011] hypothesis.

4. I agree that the wavelet analysis and bandpass filtering supports a relatively weaker amplitude of the 250yr periodicity during 0–1000 cal yr BP and stronger amplitude during 1000–2000 cal. yr BP. This is amplitude modulation is central to the argument that westerly wind strength decreased during the past 1000 years. This leaves me wondering why the Nothfagus representation does not itself show generally lower values during 0–1000 and higher values during 1000–2000 years. There is missing some explanation for why Nothfagus should correspond with charcoal and be representative of wind strength on the centennial scale but not correspond with charcoal and not be representative of wind strength on the millennial scale.

5. Internal variability in the ocean-atmosphere system offers a potential alternative explanation for the observed 200-250 year periodicity. The El Niño Southern Oscillation is an example of such internal variability (obviously with a much shorter period). Potential centennial scale oscillations in the southern high latitude climate system involving ocean–ice–atmosphere feedbacks have been proposed on the basis of modeling work and proxy data [e.g. Latif et al., 2013; Martin et al., 2013]. This work should be cited and the potential for internal variability to

explain the observed periodicity (or not) should be discussed.

Technical comments

- pp2160, line 9: wind strength, not 'air' strength. Also, either clarify what is meant by 'air flow' or stick with wind-strength throughout.
- pp2162, line 1: atmosphere-ocean-ice
- pp2161, line 1: clarify what is meant by the 'delivery of precipitation'.
- pp2161, line 2: 'ocean warming'.
- pp2161 line 12: Moreno et al [2014] should also be cited here. Their 3000-yr pollen record from southwest Patagonia (same latitude as Falklands) is also claimed to be influenced by the SAM and notably it also shows centennial-scale periodicity. It would be interesting to compare this record with the Falkland Is. data.
- pp2161, line 14: 'few provide a direct measure of past airflow'. Couldn't that criticism equally be made of the current manuscript? In the end the local charcoal count – not wind-blown pollen – is used to assess periodicity. This goes to the point further above clarifying the step made between the pollen data and the charcoal data as a wind-strength proxy.
- pp2163, line 26: likely.
- pp2165, line 14: 'with several periods of low fire frequency associated with implied weaker westerly wind flow'. I think it would be clearer to the reader what is implied here if this sentence were modified along lines of '.. associated with low *Nothofagus* counts, which we interpret as weaker westerly wind flow'.

- pp2165, line 16: I would suggest to add dashed lines to Fig 3 marking these peaks. Also state in the caption of Fig 3 what the shading represents and what the horizontal black lines represent.
- pp2165, line 16: Give the time span of the ERA Interim data which was used in the text.
- pp2165, line 26-27: I think it would be more reasonable to say the ERA Interim data supports the interpretation rather than the 'observations' (after all there are no temperature observations reported in the manuscript).
- pp2166, line 2: note that at the top of Fig 5 it says 90
- pp2166, line 10-15: Cosmogenic 10Be data from ice cores support a solar cycle of period 200-230 years (e.g. Wagner et al., 2001; Adolphi et al., 2015). These records should also be cited and the name of this cycle the 'solar de Vries cycle' should be given.
- pp2166 line 22: there is also potential for non-zonal changes in the westerlies e.g. consider the ideas on the 'split-jet' in Chiang et al., [2014]. The wavelet analysis is used to argue that the 200–250 yr periodicity is suppressed during the 0–1000 cal yr BP period. Is this conclusion supported if the MTM and SSA analyses are repeated with the data restricted to that interval?
- pp2167: Some more discussion here is warranted. How does the data compare with the 3000-year record from Moreno et al [2014] from southwest Patagonia? How does it compare with recent ice-core based SAM reconstruction of Abram et al., [2014]? If broad conclusions are to be drawn on southern hemisphere westerly winds then the internal consistency (or not) between such records should be addressed.
- An additional point for discussion is why should we see a 200-250 yr solar cycle in the data and not e.g. an 87-yr Gleissberg cycle? And why if the

cycle is solar forced would it be suppressed during the past 1000 years; I do not think that the de Vries cycle itself was suppressed as we have good evidence for several grand solar minima during this time.

- Check consistency: cal. yr BP and calendar years.
- Increase the font size on the y axis in Fig 2 and 3.
- Upon publication the authors should agree to make the pollen and charcoal data used in the manuscript available on a suitable paleoclimate database, e.g. NOAA WDC-Paleo.

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Data available at:

ftp://ftp.ncdc.noaa.gov/pub/data/paleo/climate_forcing/solar_variability/steinhilber2012.txt

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