Clim. Past Discuss., 6, C1074–C1088, 2010
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Climate of the Past Discussions

Interactive comment on "Sub-millennial climate variability during MIS 11 revealed by high resolution EPICA Dome C isotopic data – a comparison with the Holocene" *by* K. Pol et al.

C. Lemmen (Referee)

carsten.lemmen@hzg.de

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1 Summary

The authors discuss a new high-resolution deuterium data set obtained from the EPICA Dome C ice core. On this record, they analyse long-term trends, non-stationary variability, and spectral features in the marine isotopic stage 11 interglacial, a 20-30 ka period roughly 400 ka before present. In their analysis they take into account the poorly know length of MIS 11 and uncertainties introduced by molecular diffusion. Consistently, the findings for MIS 11 are compared to MIS 1, the current 12 ka interglacial.

Their main finding is the apparent coupling of long-term (multi-millenial) to short-term variance at the onset of the cooling in both interglacials; this coupling is robust when tested against known uncertainties.

2 Evaluation

The content of the paper is a suitable contribution to the topics covered by Climate of the Past. The scientific question, i.e., the coupling of centennial to millennial climate modes is highly relevant for our understanding of the internal versus external dynamics of the climate system. The analysis presents well-established methods and an innovative approach to using the variability analysis. The new data set has not been published elsewhere. The analysis is presented clearly and straightforwardly, the conclusions are substantiated by the methodology and results presented. Reproducibility is given, once the dataset is published (see general comment below). References are appropriate and properly used. The structure of the paper is clear, with a very good abstract. The language is fluent, but could be improved, one issue with symbols remains (see technical details below). The length of the paper is appropriate, the figures are appropriate, but could possibly be reduced (see below). One weakness of the current manuscript is the conclusion section, also the title could be adjusted when the conclusion has been rewritten. Another weakness is the technical quality of the figures which must be improved substantially.

Based on my evaluation, I recommend that the paper is accepted for publication in Climate of the Past with major revisions according to my comments below.

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3 General remarks

3.1 Dataset publication

I recommend to follow the lower-resolution data set (Jouzel 2008) publication method, where the data was archived on PANGAEA (http://www.pangaea.de/) with assignment of the digital object identifier (http://doi.pangaea.de/10.1594/PANGAEA.683655. Once the DOI is assigned, it should be referenced in this manuscript.

3.2 Time axis

To facilitate accessibility of your conclusions to interdisciplinary readers, you should consider reversing the time scale with old age on the left increasing towards younger age to the right (descending ka BP). Although this is not the standard display for scientist working on palaeodata, it will make your results better understandable to the modeling community which Clim. Past addresses, too. Moreover, throughout the text, your discussion is time-forward, starting with older ages, again pointing to a time-forward x-axis as a more natural approach.

3.3 Figure quality

Although this is "just" a technical issue, the figures are not suitable for publication as is. Bitmaps are inappropriate for this type of display, please choose a vector format for figures 1 and 2. Figure 3 could be shown as a bitmap, but the quality is vary poor due to the use of a spectral compression method (wavelet jpeg?) which leads to artifacts; incidentally, these artifacts are exactly those, that you tried to avoid in your scientific analysis by padding your data for the wavelet analysis ....

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I would appreciate if you could adjust all texts (figure titles, axis labels, and tickmarks, labels on figure) to the font used by CP (Times 11pt), and increased the tickmark font size somewhat.

Figure 1a: please use grey (and adjust in caption and text) instead of red to enable b/w printing. Add y axis label

Figure 1b: I don't find this figure necessary, no added value, the findings can be stated without this figure.

Figure 2: it is hard to see that panels a,b,c,d refer to columns; please think of a better way to group the panels. Add information like 'detrended' within the figure (panel b), visually separate time axis (panels a,b,c) from variability axis (panel d)

Figure 3: I would like to see panels for EDC on the same x-axis or on an x-axis aligned by date. here, it seems that TEST2 is longer than TEST1, but it is, actually, shorter.

3.4 Holocene climate variability

Regarding the Holocene, I recommend you include a reference to our recently published manuscript Wirtz et al. (2010) on changing Holocene climate variability. Below, I point to information contained in this paper, which would be relevant for your discussion.

In Wirtz et al (2010) we identify 5.5 kyr BP as the change point in Holocene climate variability (fig 2), this information substantiates your analysis.

Among the 124 globally distributed proxies, two are deuterium measurements on Antarctica (Komsomolkaia, Masson 2000, and Vostok, Petit 1999). We detected cyclic periodicites in both records, both in the upper and in the lower Holocene (Fig 4). Variability increased from the lower to the upper Holocene, especially in the sub-millennial band (200-850 a), no increase in the millennial band (860-1800 a) could be detected.

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This finding tends to support your result that the 800 a cyclicity becomes dominant in the late Holocene. But note that also non-cyclic anomalies significantly increased from the lower to the upper Holocene in Antarctci records (see Fig 8).

In line with your discussion and with Debret et al (2007) we found cyclic variability in the lower but not in the upper Holocene in the solar proxies, thus a decrease in solar variability, especially in the submillennial band. This could have lead to an increase of internal variabilities instead of the solar-driven earlier part of the Holocene. To substantiate these conclusions, however, I believe we need to assess more finely which frequencies we are talking about and what we mean by millennial (Bond uses 1500 +/- 500), you use 960, I used (860-1800), and submillennial (you see 300-500, I analysed 200-850). Especially in the frequency domain 600 to 950 a, there seems to be a lack of studies, you could point to this lack in your outlook.

3.5 Reanalysis of your results

Referring to section 5.3, the sensitivity of the wavelet analysis to the uncertain duration of MIS 11, I did a quick calculation (see table below).

Age scale	Wavelet cycle (a)	duration (a)	compression	corrected cycle (a)
EDC	495	24	1	495
Test1	470	22.4	22.4/24.0	460
Test2	320	16.4	16.4/24	336
EDC	1395	24	1	1395
Test1	1330	22.4	22.4/24.0	1295
Test2	960	16.4	16.4/24	947
EDC	3360	24	1	3360
Test1	3220	22.4	22.4/24.0	3122
Test2	n/s	16.4	16.4/24	2282

This table shows in the last column the expected cyclicity with the assumption that the timeseries was compressed equally from the EDC age scale. All comparisons between your result and this expected value agree. In the light of this, there is no qualitative information gain from the wavelet analysis on the Test1 and Test2 age scales beyond corroborating the robustness of the approach. Therefore, the figures are not necessary for reaching your conclusions if you would include my analysis above.

I did a further analysis using the methodology from Wirtz et al. (2010) on the dataset by Jouzel (2008, this is the 55cm sampling of the same ice core EDC). For the Holocene focus period, at p=.95, I identify significant frequencies at 49, 85, 770, and 3500, but not at 100-300a as you do in the fine sampling data. Also note, that these periodicities are not significant at the critical p-level of p=.99 (according to Thomson 1990).

For MIS11 and the EDC time scale, I do find significant (at p=.99) frequencies at 330 and 490 (corresponding to your 495). For your convenience I attached figures of my analysis to this review.

3.6 Your conclusion and title

I do not see how you demonstrate the relevance of this new dataset for the comparison between MIS11 and MIS1. Was this type of analysis not possible with the older 55 cm sampling? If it was simply not done, you could redo your analysis with the Jouzel 2008 dataset and show how the new sampling improves the comparison between MIS11 and MIS1. From my quick analyis (see section above) it seems that you could have gotten these results also from the coarsely sampled core.

In your conclusion, I miss that the (at least to me) apparant and very interesting coupling between the different frequency scales is not highlighted enough, despite the uncertainty in the frequency analysis. You do get this result also from the variability analysis. In this light, I would like to see the title focus more on the coupling between

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the frequencies or on the onset of the cooling phase. Also, change isotopic to deuterium in title.

4 Specific remarks

P1783 L1: please use a different symbol for standard deviation (σ) here or use a different symbol for diffusion length (also σ in L14). One of these has to be renamed, otherwise readers are confused.

P1784 L 8ff: please motivate why you do not in general use a common time step of 50 years for both MIS 1 and 11

P1784 L 9: can you quantify the effect of the resampling on the signal? how regular/variable is the age vs depth model in the period of MIS 11, please state a number.

P1785 L20: explain why you do not test against a red noise background as I would expect for this type of record.

P1785 L22: what is the motivation to take p=.95? why not .99? According to Thomson (1990), a good p level would be $1 - 1/(1 - n)$, where $n \approx 700$ the number of samples in your focus period, i.e., $n = 0.998$. Are your spectral results significant at this level?

P1786 L1: explain Antarctic Isotope Maximum and give reference

P1786 L3: I see no plateau but a small decrease

P1786 L6: what do you mean by "calculated"?, a reference to figure 1b is missing here

P1786 L10f: depths are wrong, please correct by 100 m (i.e. 2640 to 2740)

P1786 L13: not published? please give pers. comm. or indicate whether you are doing this analysis yourselves.

P1787 L2ff: indicate focus period also in figure 1, possibly still show (but don't analyse)

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the period outside the focus in figure 2.

P1788 L3f: referring to P1787 L12, could the warmer temperatures in the Holocene be responsible for overall increased variability? I would like to see this discussed more.

P1788 L6: see comment on P1784 L 8ff

P1788 L7: add (not shown)

P1789 L1: change optimum (valued statement) to maximum (objective)

P1790 L7: The 2500 a cyclicity is outside the cone of influence. Is your interpretation valid despite this? Please add a statement.

P1791 L17: add reference: DF chronology (Kawamura 2007), expand DF to Dome Fuji

P1791 L27: the 1.5 permille drop is very difficult to see, can you better visualize this?

P1792 L14: In the light of the EDC multimillenial shift outside the cone of influence, and TEST1 no multimillenial shift, and TEST2 insignificant multimillenial frequency, you should qualify the robustness as applying only to the millenial and submillenial dynamics.

P1792 L19: system response to orbital forcing, add reference (Milankovitch 1941, or any other of the many)

P1797 L15: interest = relevance?

P1797 L19: what is “unexpected” about this. I would not expect any relationship between trend and variability pattern a priori.

P1800 L12: check status of submitted paper

P1801 L32: add information how to access this conference paper

P1809 figure caption Fig 2: remove The from The remarkable. Also it would help to point to this interesting additional information from the manuscript main text . I only

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found much of the relevant information I was looking for in these figure captions, and not in the main text: when you first mention figure 2, say, e.g., Fig 2, including details on significance testing.

P1810 Fig 3 caption. Which confidence levels are marked? You only talk about p=.95 in the text

5 Technical corrections

5.1 General corrections

I would recommend to reduce the number of hyphened words, such as de-trended (say detrended), pre-industrial (instead: preindustrial), re-sample to resample, possibly submillennial and multimillennial. The spell checker will disagree, but the words form an established terminology in palaeoscience already.

Please be aware, that the word 'however' cannot be used at the beginning of a sentence in the sense of 'on the other hand'; put it after the noun or verb and enclose it with commas. There are about 10-20 occurrences of this throughout the text.

Use correct prepositions, i.e., consist of, point to, on average,

Replace actual (meaning real) by recent (meaning current)

Be careful with the use of 'the', especially in conjunction with the Holocene.

Use a comma in constructions starting with: 'Nevertheless,' 'Thereafter,' Possibly around 20 occurrences of this in your rtext.

You make generous use of the construct 'thanks to' which I do not find appropriate for scientific writing. Due to, because of, derived from, based on... are possible alternatives and should be used instead.

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In the specific corrections below, I did not indicate every occurrence of the above general remarks.

5.2 Specific corrections

P1779 L23f: ‘consists’ replace with exists

P1779 L25f: ‘thousands of’ replace with thousand

P1780 L9: actual=recent?

P1780 L11: move position of however

P1780 L18: Nevertheless followed by comma

P1780 L19: add ‘MIS, which is’

P1780 L20: points to

P1780 L22: end of line add , however,

P1781 L2: along = during/within?

P1781 L9: remove obviously

P1782 L1f: reverse order: describes past interglacials at a lower temporal resolution

P1783 L27: delete ‘As already mentionened’

P1784 L27: ‘in the next’ where is the context?

P1785 L12: move however

P1785 L14: requested=necessary?

P1785 L19: modelling=simulation?

P1786 L9: on average

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P1786 L18: Thereafter,

P1786 L26: Thanks to = because of

P1787 L21ff: change 2 permille to 7 permille

P1787 L27: subtract from

P1787 L27: one can access to = one gains access to

P1788 L17: area=period, region?

P1789 L13: delete have

P1789 L14: focussed = focus?

P1789 L15: delete method

P1791 L20 :ranged=ranging

P1791 L 25: delete logically

P1791 L28: on average

P1793 L4: parallel=analogy?

P1793 L6: others=other

P1793 L6: 'for the MIS 11 period' or 'for MIS 11'

P1793 L11: the Holocene

P1794 L18: better: solar forcing of

P1794 L18: has been = was

P1794 L20: remove indeed

P1794 L26: North = northern?

P1794 L26: remove actually

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P1794 L26: highlights=highlight

P1795 L17: move however

P1796 L9: add apostrophe others'

P1795 L15: replace ellipses with e.g.

P1796 L2: add space after CO2

P1796 L4: given = within

P1796 L10: move however

P1796 L15: interest = relevance?

P1796 L20: repeated clarification of optimum/maximum, don't need reference here

6 References

- Jouzel, Jean; Masson-Delmotte, Valerie (2008): EPICA Dome C Ice Core 800KYr deuterium data and temperature estimates. doi:10.1594/PANGAEA.683655
- Masson, V., Vimeux, F., Jouzel, J., Morgan, V., Delmotte, M., et al., 2000. Holocene climate variability in Antarctica based on 11 ice- core isotopic records. Quat. Res. 54, 348–358.
- Milankovitch, Milutin (1998) [1941]. Canon of Insolation and the Ice Age Problem. Belgrade: Zavod za UdzÌĘbenike i Nastavna Sredstva.
- Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J.-M., et al., 1999. Climate and atmospheric history of the past 420, 000 years from the Vostok ice core, Antarctica. Nature 399, 429–436.

- Thomson, D., 1990. Time series analysis of Holocene climate data. Phil. Trans. R. Soc. London B 330 (1615), 601–616.
- Wirtz, K.W., G. Lohmann, K. Bernhardt and C. Lemmen (2010): Mid-Holocene regional reorganization of climate variability: Analyses of proxy data in the frequency domain, Palaeogeography, Palaeoclimatology, Palaeoecology Volume 298, Issues 3-4, Pages 189-200 http://dx.doi.org/10.1016/j.palaeo.2010.09.019

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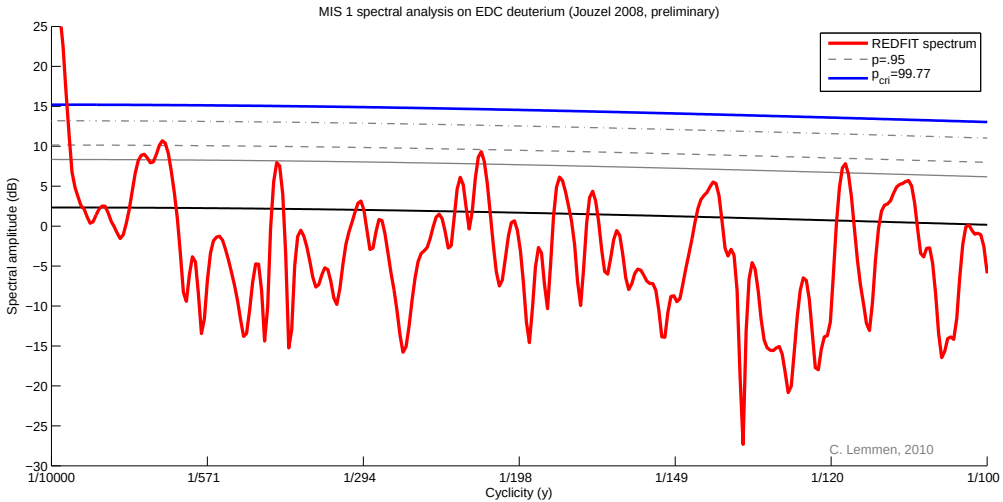

Fig. 1. Redfit analysis on EDC deuterium (Jouzel 2008) for MIS 1

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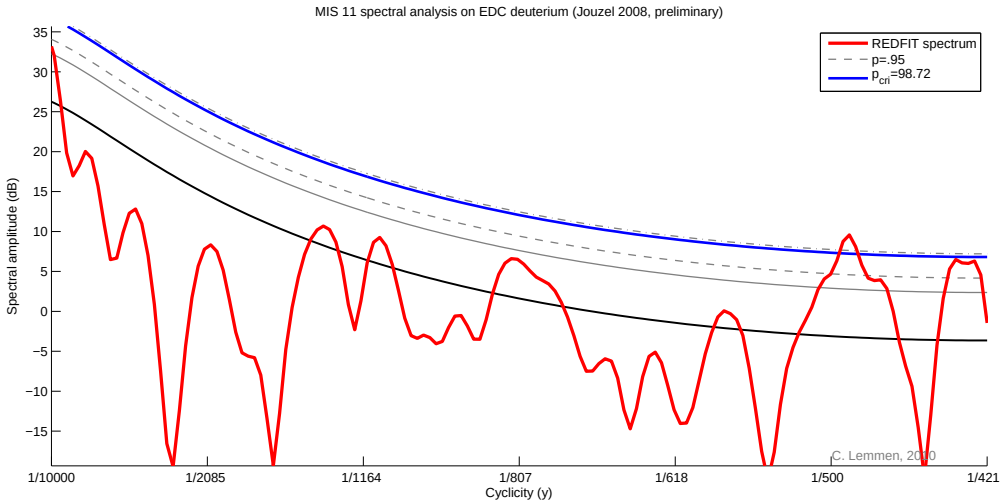

Fig. 2. Redfit analysis on EDC deuterium (Jouzel 2008) for MIS 1

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