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Climate of the Past Discussions

Interactive comment on "Correlation of Greenland ice-core isotope profiles and the terrestrial record of the Alpine Rhine glacier for the period 32–15 ka" *by* M. G. G. De Jong et al.

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After thorough study of the report by Anonymous Reviewer # 1 (AR1) we offer the following general comments:

The objective of our paper is stratigraphy. By analyzing and comparing the patterns in two different climate proxies, we highlight the multiscale nature of the climate oscillations, i.e. stratigraphy, in the period 32-15 ka. This multiscale nature has been underexposed in the analysis and interpretation of, notably, the Greenland ice cores. This we consider the main message of our paper, together with the conclusion of synchroneity of the proxies. The correlation of the terrestrial record with the Greenland stratigraphy will contribute, we hope, to establishing a detailed reference section for an interval which is notoriously problematic in stratigraphy in Central Europe and beyond due to hiatuses in the profiles/proxies.

Climate dynamics as such are not the main topic of our study. Our focus is on the 'products' of the processes that control/drive climate and climate change. An in-depth discussion of the drivers of the climate oscillations – as interesting and important as it may be – we consider beyond the scope of this contribution. We have only briefly touched on this issue to sketch the broader framework for making the correlations.

The main method we apply is pattern analysis in combination with graphical correlation. With regard to the Greenland ice cores, we identify and correlate patterns in the unprocessed data (δ18O and [Ca2+]) with the help of MEM-based spectral trend attribute curves. Our work on the ice-core data is not a statistical analysis with focus on identifying driving mechanisms through decomposition and analysis of the spectral content of the data series.

Within the context of the above, we would like to comment on the major issues raised by AR1:

The signal-to-noise issue. Signal is usually considered to be the periodic component of a spectrum, noise the non-periodic information. After removal of noise the periodic component is analyzed, and 'cycles' may be linked to known or inferred periodic processes responsible for the signal. A better understanding of climate dynamics may result from such an approach. As said above, our major interest is not climate dynamics, but stratigraphy. Stratigraphy is the 'sum' of periodic and non-periodic processes. By removing noise we may lose valuable stratigraphic information. This explains why we do not apply a signal-to-noise analysis. Please refer also to the publication of Vaughan et al. (in print) for a discussion of the problems of spectral analysis of stratigraphic data.

The hypothesis of periodic fluctuations. Unlike AR1 states, the mathematical method

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we have applied does not assume periodic fluctuations. We quote from Section 3.1 of the manuscript: "MEM makes no a priori assumptions about the nature of patterns in the data; it makes use of the degree of departure of the data from randomness, which makes it appropriate to our attempts to extract information from data such wireline logs and ice core profiles." This is consistent with our approach of using the total spectral content, not just the periodic component. It also means that the oscillations as we interpret them are not necessarily periodic.

The sampling issue. We are fully aware of the potential sources of error and uncertainty in the data (imperfections in the ice-stratigraphic record itself; the coring process; the dating of the individual cores; the matching of the time scale between the cores). These have been described in the original papers on the time scale (which are referenced), and we follow the common practice – also of papers on statistical analysis of ice-core data series – of not reproducing these, unless deemed critical. More importantly from our point of view, our main method is pattern analysis & graphical correlation: we look for patterns in the original data, facilitated by graphical enhancements and the spectral trend curves. Patterns are compared between the ice cores. Essential in this approach is that each time we find more or less the same succession of features in data series, we consider that we are reducing the risk that they are random (although we do not try to quantify this). We look for correlatable temporal variations, taking into account that the patterns between ice cores may be different due to spatial variations (which may have many causes). In addition, rather than using one curve (i.e. δ18O) we have used two (δ18O and [Ca2+]) – which should further reduce error and/or uncertainty. In our presentation of the oscillations in the ice core data we have made a special effort to describe the lateral variability in the patterns. We consider this as a discussion of uncertainty.

It is generally accepted that climate changes are regional phenomena and that climate proxies such as isotopic profiles from different locations within a region can be expected to show similar, synchronous, patterns. Local factors, however, may lead to spatial variation in the profiles, thereby masking the temporal variation. Figures 3 and 4 show the ice core data in the depth domain; the thickness of the study sections is by and large the same in all cores. The depth-time relationship (GICC05 time scale) is almost linear in the cores over this interval (not shown in the publication). Generally speaking, factors as thinning and changes in accumulation are not likely to play a dominant role. These are the ‘sideboards’ to our correlation work.

The issue of the uncertainty discussion. After our first publication on Greenland ice cores (De Jong et al., Terra Nova, 21, 2009) colleagues have suggested that we explain our approach in more detail. This is why parts of our manuscripts are quite descriptive. We pay specific attention in the descriptions of the stratigraphic units to the lateral variation in the nature of the boundaries we identify and correlate. This is the generally accepted way of discussing uncertainty in graphical correlation. It also explains the nature of our figures 1 – 4. Figure 1 is part of the explanation of our method. Figure 2 presents an overview (synthesis) of our interpretations and of previous interpretations. Figures 3 and 4 present details: the unprocessed data, the spectral trend curves, and the interpretations. The latter figures are best displayed on A3 size (or larger); they are intended to provide the interested reader the opportunity to study (reconstruct) our interpretations in detail (including the uncertainties as presented in the text).

The issue of the discussion not being satisfying. The discussion, in Section 6.3 and throughout the manuscript, focuses on the stratigraphic aspects of our study, less on climate dynamics. We consider this to be in line with the nature and objective of our manuscript as outlined above. In Section 6.3 we have suggested links between our findings and causes of climate change as presented in the literature without trying to be all-encompassing. The multiscale nature of climate change seems to be underexposed in the debate on the causes of climate change – this is what we try to raise and highlight.

The issue of the figures. Please refer to our comments on the issue of uncertainty discussion.

We hope that AR1 is willing to reconsider his/her recommendation for rejection the manuscript, based on the comments we have offered to the criticism. We are convinced that our findings are founded on solid scientific grounds, contribute to a better understanding of the stratigraphy – climate development – of an interval which in many areas is not yet very well understood, and hence meet the qualifications for publication in Climate of the Paste.

Rereading our manuscript we still think that our wording and explanations clearly convey our 'message'. We are, however, very willing to make the necessary modifications, if deemed necessary for acceptance.

References: Vaughan, S., Bailey, R.J. and Smith, D.G., in print. Detecting cycles in stratigraphic data: spectral analysis in the presence of red noise. Paleoceanography.

Interactive comment on Clim. Past Discuss., 7, 4335, 2011.

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Interactive Discussion

Discussion Paper