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Interactive Comment

Interactive comment on “Were last glacial climate events simultaneous between Greenland and western Europe?” *by* M. Blaauw et al.

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Les Echets, a reference terrestrial site near Lyons, France has long been known in palynological circles as having furnished one of the first long records, extending to the end of the penultimate glacial (de Beaulieu Reille, 1984). A recently obtained new core has provided an opportunity to re-examine the sequence using a variety of palaeoenvironmental techniques and applying an extensive dating programme on the Middle and Late Pleniglacial sections (Wohlfarth et al., 2008). This has revealed the presence of a series of oscillations in local environmental conditions, which appear to be related to the millennial-scale variability recorded in North Atlantic marine sequences and Greenland ice cores. In the current MS, Blaauw et al. use a Baysian approach to construct a detailed age model based on 46 AMS radiocarbon dates and 21 IRSL dates. Two ra-

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Interactive Discussion
Discussion Paper

diocarbon calibration (comparison) approaches (Hughen06 and Fairbanks05) are used in parallel, providing two alternative solutions. This allows a comparison of the timing of oscillations in lake productivity with that of changes in d18Oice in the NGRIP ice core (Andersen et al., 2006). Blaauw et al. do this by calculating the statistical probability that both records reacted simultaneously within certain time windows, taking into account their chronological uncertainties. What emerges is that the relative timing of most events differs by many centuries (or even millennia), which is then interpreted as reflecting real offsets between the timing of climate changes in Greenland and France. Blaauw et al. go on to argue that as the Les Echets age model represents one of the best independent chronologies for this interval, the prevailing assumption of synchroneity between changes in terrestrial ecosystems in southern Europe and atmospheric changes over Greenland is no longer tenable. The implication is that the "tuning" of terrestrial records to Greenland chronologies is unsound and should be avoided.

The authors are aware, however, that a problem with this reasoning is that joint pollen and palaeoceanographical analyses from the same samples in marine cores in the Iberian margin (e.g. Sanchez Goni et al., 2000, 2002; Roucoux et al., 2001, 2005) have already demonstrated stratigraphical synchroneity (within the 200-year sampling resolution) between millennial-scale changes in Iberian terrestrial ecosystems and ocean surface properties. Anticipating criticism on this issue, Blaauw et al. point out that synchroneity between North Atlantic marine and Greenland ice core archives has not been demonstrated and therefore the tuning to Greenland chronologies remains unsupported. Thus in the best Popperian (and Wunschian) traditions, the authors go on to call into question the entire edifice on coupled atmosphere-ocean millennial-scale changes constructed for the North Atlantic.

While questioning the prevailing paradigm is healthy, it is worth remembering how this paradigm emerged in the first place. Following the publication of the evidence for abrupt events records in Greenland ice core records and North Atlantic sequences, Shackleton called for an international effort to understand the "rules of the new game". This entailed radiocarbon dating of Heinrich events and especially interstadials (where the effects of changes in marine reservoir ages would be limited) in the younger part of the record in order to establish, within the constraints of the method and calibration issues, some understanding of the extent of synchroneity between the marine and ice core events. In addition, climatostratigraphy played a central part and this is important to explain in detail. In a seminal paper, Shackleton et al. (2000) showed that the oxygen isotopic record of planktic foraminifera of the last glacial in core MD95-2042 in the south Portuguese margin matched the Greenland d18Oice record with remarkable fidelity. The similarity between the two curves was not confined to the presence of the same number of events, but extended to the shape of each event. Moreover, transitions marking the onset and end of interstadials were very abrupt in both the marine and ice core records, resembling a "square wave" form. The important point is that the shape of events contains information about the phase relationship between regions and the climatic transmission mechanisms. Thus, the abrupt transitions (abrupt jumps between consecutive samples 200 years apart) of interstadials in the marine sequence suggests that the polar front must have migrated extremely rapidly, leading to sudden changes in North Atlantic surface waters. It is vital to appreciate that if larger lags were involved then the shape of the curve would be different, as for example in Antarctica where interstadials have a "triangular" form, a reflection of a physical mechanism of heat piracy from north to south. The similarities with Greenland, replicated in several North Atlantic records and the western Mediterranean (Alboran Sea) , support the notion of synchroneity (within 200 years) and provide the theoretical foundation for alignment to ice core chronologies. By extension, this provides a chronology for vegetational changes recorded in the same marine sequences (e.g. Iberian margin), which may eventually be transferred to terrestrial sequences. Thus for example, Tzedakis et al. (2004) suggested that that the largest reductions in arboreal values at the Ioannina record, W. Greece, should correlate with arboreal pollen minima in the Alboran Sea pollen records, which are synchronous with Heinrich events. Identification of such prominent events was thus used to refine the age model by phase-locking the

CPD

4, S629–S633, 2008

midpoint of post-Heinrich cold-to-warm pollen transitions to the Alboran Sea chronologies, which were ultimately aligned to the Greenland ice core chronologies. Tzedakis et al. (2004) noted that this procedure "precludes any assessment of relative leads and lags on centennial time scales, but this is a moot point because the rapidity of the changes are beyond the resolution of any geochronological". In suggesting that these sequences were directly "tuned" to Greenland chronologies, therefore, Blaauw et al. miss the entire point of stratigraphical cross-correlation through stepping stones.

Unfortunately, this may be symptomatic of a growing chasm between the geochronological and stratigraphical communities, where absolute dates and their statistical treatment are perceived as a more accurate approximation of reality than stratigraphical considerations. Incidentally, the term "tuning" is incorrectly used here, as in many other papers (including mine). With its Shackletonian musical overtones, tuning refers to adjusting a chronology to particular (Milankovitch) frequencies. A more appropriate term for the present purposes is "alignment" to a record and ultimately to a master chronology. Lurking in the background, of course, is the more derogatory term "wiggle-matching", sometimes used in geochronological salons to denote the uncritical stratigraphical synchronization of archives.

With the regard to Les Echets, a cursory look at the lake productivity record would immediately suggest that its shape/pattern is distinctly different from the Greenland d18Oice curve and therefore may not represent the best basis for comparisons (which brings to mind the notorious reply to the traveller asking directions for the way to Dublin: "if I were you, I wouldn't start from here..."). In other words, despite my 'wiggle-matching' tendencies, I would personally find it extremely difficult to align this record to Greenland. Perhaps other proxies from Les Echets when analysed at the appropriate resolution, might be better suited to the task, or then again might not, because of hidden stratigraphic disturbances.

This brings us to the age model itself. With 67 radiocarbon and IRSL dates, Blaauw et al. consider it one of the best available to-date. However, the 21 IRSL dates have uncertainties of 3000 to more than 9000 years, which raises some questions on their ability to contribute towards a precise evaluation of phase relationships between Les Echets and Greenland. Blaauw et al. suggest that most of the 46 radiocarbon dates fall within 1 standard deviation (sd) of the comparison ("calibration") curves of Hughen06 and Fairbanks05. However, closer examination reveals that 15 of them do not conform to that. Even within the better dated interval 26-40 ka, 10 dates are still not within 1 sd of the comparison curves. Finally, it is worth pointing out that one of the radiocarbon comparison curves (Hughen06) used in the age model is itself based on "tuning" the Cariaco record off Venezuela to the Hulu speleothem record in China. This appears to be somewhat inconsistent with main thrust of the paper to refrain from tuning.

In summary, the paper represents an important contribution in evaluating chronological uncertainties using state-of-the-art techniques. However, while the inferred chronological offsets between Les Echets and Greenland may be valid from a purely numerical view, they are far from representing the most parsimonious explanation and a long way from deconstructing the prevailing paradigm of North Atlantic millennial-scale variability. In view of this, I suggest that the paper needs to be revised substantially before publication. If the authors insist on questioning the correlation between North Atlantic sequences and Greenland ice cores, then I suggest they apply their method to those sequences, as Les Echets is not best 'placed' to test that.

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CPD

4, S629–S633, 2008

Interactive Comment