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Interactive Comment

Interactive comment on "A 60 000 year Greenland stratigraphic ice core chronology" *by* K. K. Andersen et al.

K. K. Andersen et al.

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Comments given by reviewer are shown in *italic*.

A new ice core chronology in the palaeoclimatologist community is of first importance as it often becomes the reference for a lot of archives where climatic events are well marked and where the absolute dating is difficult to obtain. It is also of first importance for the archives where absolute dating is available like on speleothems and where we can check the coherence of independent chronologies. Another key point in this study is that it concerns a period beyond the 14C method in which the timing of climatic events is still debatable.

The comparison with absolute dated records, speleothems and magnetic field events fits well which give confidence in this new chronology. I have however raised some

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Interactive Discussion

Discussion Paper

important points about the counting method and the comparison with speleothems that could be more discussed in the paper.

p. 1239 : while in fig. 2 the annual layer counting appears relatively easy to perform (stadial preceding GI14), it is much less trivial in fig. 1 which is however within GI14 itself: when the grey scale curve displays a small peak compared to its neighbour, then it is reasonable to count 1/2 +- 1/2 as seen at about 2343.3 m; but other examples of uncertain annual layers are not so obvious: for example near 2343.6m a layer is marked as uncertain despite the fact that the grey scale curve shows, at this place, a pronounced peak; similarly, at 2343.5, the peak is as high as the former one but is also marked as uncertain. The information given by the Conductivity and the Sodium seems, here, not very useful as individual annual layers do not appear clearly. A more detailed recall of the counting method would be useful in order to be more convincing.

The visual stratigraphy (and the ECM) appears to be the most accurate measurement for layer counting, but we observe that several double peaks in these records are counted a single year (i.e. 2343.25; 2343.27; 2343.4); this might result in an underestimation of the ages. This should be discussed more.

In figure 1, the annual layer counting is mostly based on Sodium and conductivity, because we know that both the visual stratigraphy and the ECM profiles tend to show multiple peaks within an annual layer during milder climatic periods (Andersen et al., 2006, section 3). We now state this in the figure caption. However, as discussed in the comment to Eric Wolff, the assignment of individual marks can always be debated.

The counting method is very carefully discussed in Rasmussen et al., 2006, and Andersen et al., 2006, and we make reference to those papers in the methods section. The applied data set is the same (but extended) and the annual layer thicknesses are very comparable to those of Andersen et al., 2006, so the counting method is also the same.

p. 1240 and fig.3: because the former NGRIP ss09sea chronology has been widely *used, it seems important to show the difference with GICC05 on a time scale and not only on fig.4 graph. Then, we will be able to observe that the difference between both NGRIP chronologies becomes noticeable before and after GIS8, and that for the GIS12 onset, which is among the most important events of this period and which has been recorded in many archives, the new GICC05 chronology is about 500 years younger.*

We presented an isotope profile comparison figure for the 10-42 kyr interval in Svensson et al., 2006 (Figure 1), but we find that Figure 4 in the present manuscript actually gives a much more detailed picture of the difference between the time scales, because a 500 yr difference is hardly visible in a low-resolution figure such as Figure 3.

p. 1241 : Comparison with cave records - It seems important to be a little bit more cautious when comparing Greenland ice core and speleothem records: are we sure that Greenland d18O changes and speleothem proxy are synchronous ? Is the Asian monsoon intensity, recorded in the Hulu Cave speleothems, perfectly synchronized with the temperature changes in Greenland ? All these questions have a sense in regard to the bipolar seesaw mechanism that is observed between South and North ice records and where offsets of more than 1ka can be observed for glacial events (Barbante et al., 2006) (EPICA community members). The shape of the transitions can be very different between the Greenland records and speleothem ones depending on its geographical location and of the mechanism that drives the isotopic composition of the calcite 8211; it is not obvious to find accurate tied points to correlate in both records. For example, if you look at the last deglaciation in Borneo you will observe a smooth and regular trend that began earlier than the abrupt NGRIP Bølling-Allerød transition and that displays neither the B?lling-Aller?d cooling trend nor the Younger-Dryas event. All this raises the complexity of the relationship between the North Atlantic and Pacific climates (Partin et al., 2007)). See also the different pattern during the Last Deglaciation between Greenland and stalagmites from France and North Africa (Genty et al., 2006).

We basically agree about this concern. However, to first order the Hulu Cave profile resembles that of the Greenland isotope records quite well - much more than that of the

Antarctic isotope profiles. We, therefore, agree with the authors of the Hulu Cave profile that that record mainly reflects a NH signature, which justifies the direct comparison to Greenland. Concerning the synchronization of the records we agree that we cannot know about the exact phasing, in particular due to the low resolution of the Hulu cave record, but we think that the long term comparison is reasonable as long as we do not get into discussion of individual events.

There is also circumstantial evidence based on the NGRIP dust/calcium record. The main dust sources for NGRIP are Asian deserts. The dust signal in NGRIP is modulated by the dust source strength, which in turn is related to the monsoon systems that impact the Hulu cave record. Within the resolution of the cave record, the NGRIP dust and d18O records are changing synchronously over DO events (Röthlisberger et al., in prep), therefore it is justified to match the NGRIP and the Hulu cave record. This argument, however, does not necessarily apply to cave records from other regions that are not linked to the Asian monsoon.

A new, high-resolution d18O profile of the Hulu Cave record has been presented at meetings. This record looks more similar to the Greenland records than the published d18O profile which has lower resolution. The new profile, therefore, suggests a rather close relationship between the Greenland and Chinese records, but since it is not yet published we do not apply it. Furthermore, we are also waiting for a new high-resolution absolute dating of the Hulu Cave.

We have modified the text to more clearly state that the comparison between Greenland and the Cave records is made under the assumption that the records are synchronous at the onsets of the DO events.

It is interesting to note that the Villars cave record which is the closest to Greenland and which is the longest one in a single stalagmite (31-82 ka), fits very well with this new chronology, better than the Hulu record for the GI12 period, which corresponds to among the most pronounced climatic changes in Europe during MIS3. A second *stalagmite from Villars had confirmed the chronology and the isotopic changes of this period (i.e. the GIS12 onset is at 46.6 ka ś 0.5; (Genty et al., 2005)), this should be addressed and, despite the more confused shape of the Villars isotopic records between GIS9 and GIS11, the GI12 onset is clear, well dated on very fast growing stalagmites, this looks like another confirmation of this new NGRIP chronology (keeping in mind that the isotopic records, d13C, d18O of speleothem and d18O of ice core, are synchronous in the error margins). It is true also that for this key period the Hulu Cave is constrained by less dated points and that its growth rate is much smaller.*

We now refer to the Villars Cave dating of the onset of the GI-12 event and note the excellent agreement between the two records at this point.

In Fig. 6, it would be useful to add, as for the Hulu record, the U-Th dated points for the Kleegruben Cave record so we can have an idea of the possible accordion effect. For this later record, you should discuss more in detail why there is such a discrepancy with the GICC05 chronology for the GI12 transition : more than 1ka (> than the estimated errors) and of the same order as observed with the Socotra record for GI11 onset. This makes the warming in the speleothem record occur during a very cold period in NGRIP.

The Kleegruben U-Th points are now included in Figure 6 as it is done for the Hulu record, and we comment somewhat more directly on the disagreements towards the ends of the cave record.

Comparison with cosmogenic records and tephra horizons bring complementary pieces that support this chronology. The conclusion could be amended in light of the above comments. This is a very nice work of first importance for all palaeoclimatologists.

The conclusion has been significantly updated.

Detailed comments : p. 1237 : Eemian, sensu stricto should be used for the vegetation changes, OIS 5e may be better here;

The "Eemian" has been widely used for ice cores when referring to MIS 5e. We now mention both.

p. 1239 : It is not clear what the difference is between ECM and conductivity records

It is now stated that ECM is obtained from the solid ice whereas the CFA conductivity record is obtained from melt water.

Figures 1 and 2 : units are missing for ECM and Visual stratigraphy

Arbitrary units, now stated.

p. 1240 :". . . 1.5cm thick. . . "; ". . . 2.5 cm thick.."

Ok.

p. 1242 : the two Hulu Cave stalagmites that concern this period (MSL and MSD) are about 40 and 45 cm long, not two meters.

Text modified.

Interactive comment on Clim. Past Discuss., 3, 1235, 2007.