Clim. Past Discuss., 8, C3614–C3622, 2013
www.clim-past-discuss.net/8/C3614/2013/

Climate of the Past Discussions

Interactive comment on "An optimized multi-proxy, multi-site Antarctic ice and gas orbital chronology (AICC2012): 120–800 ka" *by* L. Bazin et al.

L. Bazin et al.

lucie.bazin@lsce.ipsl.fr

Received and published: 6 April 2013

"Using this approach, it has become rather clear that one should not use a constant lag of d18Oatm behind precession, because indeed the cave deviations from precession are not at all constant over time. Note that this conclusion is not very sensitive to systematic errors in the cave chronologies, such as errors in the decay constants of U and Th, for example, because it derives from differences in duration and intensity of the d18O deviations, rather than their absolute ages per se. I believe it is possible to now falsify, with high confidence, the null hypothesis that the lag of d18Oatm behind precession is a constant. The underlying physics behind this conclusion are probably that large differences existed among precession maxima in the amount of meltwater input to the N. Atlantic (Cheng et al., 2010), depending on how much excess ice was being

destroyed at the time. For example, strongly nonlinear responses of the cryosphererknown as Terminations, consistently seem to cause a longer lag of d18Oatm behind precession than non-Terminations."

=> We agree and we have pointed out in the main text that the phase lag between δ18Oatm and precession is not constant through time. The matching was performed manually, associating the mid-slopes of both signals (extrema in the case of Vostok). The non-constant lag error is embedded in the uncertainty of the δ18Oatm-deduced ages, estimated to be 6 ka (see main text p.5967 and p.5976).

"There is perhaps a philosophical issue that could be useful to examine in this context. Many of our community have argued that it is premature to use information from the cave records in constructing ice core chronologies, because it has not yet been satisfactorily demonstrated that events seen in both types of archives are in fact synchronous. Yet it also would seem suboptimal to intentionally blind ourselves to the rich cornucopia of new information coming from speleothems. Other communities have made somewhat different choices than ours, for example, the radiocarbon community. They have decided to adopt the cave chronologies (Southon et al., 2010) in the new version of INTCAL for the time periods beyond the era of dendrochronology."

=> The integration of speleothem-deduced ages was an important subject of discussion within the "EDC4 team" during the building of AICC2012. It was decided to first produce a chronology independent from other archives. Second, we would then compare it to the other archives, especially with a compilation of speleothem data. Such a comparison will permit to estimate the added value of these archives and how to best include them in Datice for a next chronology.

"Another important source of information that could assist the authors in their AICC2012 quest is the Dome F ice core. I found it surprising that they did not strive to incorporate more of the excellent constraints from this ice core. My subjective judgment is that the true uncertainties of many of these tie points are smaller than those of the constraints used in AICC2012. A cynic might be forgiven for calling this the European Ice Core Chronology rather than the Antarctic Ice Core Chronology, as the latter has a kind of global implication to it."

=> The integration of the Dome F ice core was discussed in the team discussion and with Dome F scientists who are part of the "EDC4 team". The AICC2012 chronology is constructed using only published data (or soon to be published in the case of EDML-NGRIP synchronization by layer counting). So in order to include a new ice core in Datice, we need published records like methane to synchronize with the other cores. In agreement with Dome F scientists, when more data will be published for the Dome F ice core (CH4 especially), it will be included in Datice, and will be of important value to improve the Antarctic chronology.

"Another potential source of tie points is radiometrically dated tephra. There is one at 135 ka +- 0.9 ka in the Mt Moulton "horizontal ice core" record that lies at the inflection point in dD, which marks the onset of the Termination in many Antarctic records. Unlike the Chinese cave records, these markers are all within-continent and so the synchroneity assumption is more robust. I would urge the authors to use this one and others like it. Nelia Dunbar and Bill MacIntosh at New Mexico Tech, and Trevor Popp at CIC, are the contact people."

=> Concerning the Mt Moulton "horizontal ice core", this was discussed within the "EDC4 team". We used one radiometric age coming from this core (the Mt Moulton eruption, recorded in EDC, with an age of 93.2 ka). We agree that this is an important archive offering several radiometric ages from tephras. In order to use them in Datice, we have decided that the tephras have to be recognised in one of our different cores. A tephra is observed in EDC with an older age (1796.3m/141ka EDC3), its composition seems to indicate an origin from the Mont Melbourne and not the Mount Moulton area (Narcisi et al., 2006, Dunbar et al., 2008). We discussed this point with B. Narcisi at the beginning of the construction of the AICC2012 chronology. She indicated that no visible tephra that could be correlated with the Mt Moulton 135 ka tephra was present

at EDC. It possibly occurs as an invisible layer; in order to search it, new analyses are needed to identify microscopic tephra particles. Moreover, it appears difficult to judge if the chronostratigraphic position of the tephra at Mt Moulton and at Vostok corresponds. This is why this age marker was not used in the construction of AICC2012.

"A broader concern I have with the approach of using background scenarios is transparency. It is difficult as a casual reader to truly assess the strength of each pinning point and how much the final solution relies upon it. I don't mean to suggest that communicating this information is an easy task: as our data sets get richer and the ice flow physics becomes more realistic, it is a necessary evil that complexity increases and transparency suffers. However I wonder if there are some ways that transparency could be increased, for some partial subset of critical points. Perhaps sensitivity tests, with removal of a critical point, could illuminate for the reader just how much is resting on one particular tie point. This was done for the 131 ka speleothem point, for example, and was very helpful. More of these kinds of sensitivity tests would be beneficial, I think, especially for the problems around MIS 12."

=>We follow the suggestion of J. Severinghaus and give below another example of the relative influence of background scenarios and age markers over MIS 12. Figure 1 shows a comparison of the background LIDIE (constructed from δ15N measurements on EDC over this depth interval) and output LIDIE using δ18Oatm and δO2/N2 constraints. Clearly, the implementation of some δ18Oatm markers creates spurious 10m variations of the LIDIE during a period of 12 ka within MIS12 and MIS 14. Such variations do not correspond to any changes in surface conditions and are thus not expected to happen. Moreover, no convective zone is observed at Dome C today. This is a good indication that at least during interglacial periods at Dome C, no convective zone should affect the relationship between δ15N and LIDIE. These are the two reasons why we raised doubts on the coherency of these age markers. Still, removing these age markers had no significant impact on the final chronology within the uncertainty range (figure 1 bottom).

For the background parameters, a comparison of the different LIDIE scenarios is already included in the SOM. Concerning the thinning function, we performed a test of the influence of a different thinning function as input for Vostok. The "test thinning function" is very simplified and obtained using "IceChronoModel" (F. Parrenin comm. Pers.). We can see that the thinning outputs with Datice tend to the same behaviour. The resulting chronology is not significantly changed with the "test thinning function" as input (Figure 2). For the accumulation rate, this is currently done for the paper of Lemieux-Dudon et al., in prep, testing different accumulations with age difference constraints compared to GICC05.

Finally, our answer to reviewer 3 provides a detailed explanation of the origin of the uncertainty (relative influence of background scenario and tie-point) that should also help the reader to follow the way Datice is working.

"It would also be useful to perform some sensitivity tests to show the reader how much influence ice physics has on the solutions. How are fundamental uncertainties in ice rheology incorporated into the cost function? This is not clear from the present text. It is well known that ice rheology depends on fabric, and fabric depends on the integrated history of deformation as well as impurity content. These issues become increasingly severe in the older half of the 800,000 year record, and I would welcome some analysis of them along with sensitivity tests."

=> An important part of the discussions within the "EDC4 team" was on how to implement the variances, how to parameterize them in order to consider ice physics. We agreed on the definitions proposed in the SOM, but we are aware of the necessity to improve the variance definitions. Comparing the previous variance definitions (constant for accumulation and LIDIE, and increasing as 1/T for thinning, Lemieux-Dudon et al., 2010) and the current one (AICC2012) showed us that it doesn't really impact on the chronology, but mainly the error values at the end.

We are currently working on the improvement of the thinning variance definition by

including a term function of microstructure and fabric orientation. As you well said, these parameters are dependant of deformation history and climatic conditions (impurity content/isotope). Departing from the data of Durand et al., 2007 for EDC and after treatment, this variance parameterization will be more realistic. It will be the subject of a future paper as well as other improvements.

Legends:

Figure 1: Top: influence of δ18Oatm markers on the LIDIE parameter at EDC around MIS 12. Red crosses mark position of the δ18Oatm age markers that are included (left) or not (right) in our sensitivity tests. Bottom: EDC δD record on the resulting ice chronologies: with δ18Oatm age markers (blue) and without these age markers (orange).

Figure 2: Thinning function tests on Vostok. Grey curves are background and blue curves are Datice results. a: thinning function as in AICC2012. b: "test thinning function". c: comparison of Datice outputs (AICC2012 in dark blue, "test thinning function" in light blue). d: comparison of the resulting chronologies.

References:

Dunbar, N. W., McIntosh, W. C., and Esser, R. P.: Physical setting and tephrochronology of the summit caldera ice record at Mount Moulton, West Antarctica, Geol. Soc. Am. Bull., 120, 796–812, 2008.

G. Durand, F. Gillet-Chaulet, A. Svensson, O. Gagliardini, S. Kipfstuhl, J. Meyssonnier, F. Parrenin, P. Duval, and D. Dahl-Jensen. Change in ice rheology during climate variations – implications for ice flow modelling and dating of the EPICA Dome C core. Climate of the Past 3, 155-167, 2007.

Lemieux-Dudon, B., Blayo, E., Petit, J.-R., Waelbroeck, C., Svensson, A., Ritz, C., Barnola, J.- M., Narcisi, B. M., and Parrenin, F.: Consistent dating for Antarctic and Greenland ice cores, Quat. Sci. Rev., 29, 8–20, 2010.

Narcisi, B., Robert Petit, J., and Tiepolo, M.: A volcanic marker (92 ka) for dating deep east Antarctic ice cores, Quaternary Science Reviews, 25, 2682–2687, 2006.

Interactive comment on Clim. Past Discuss., 8, 5963, 2012.

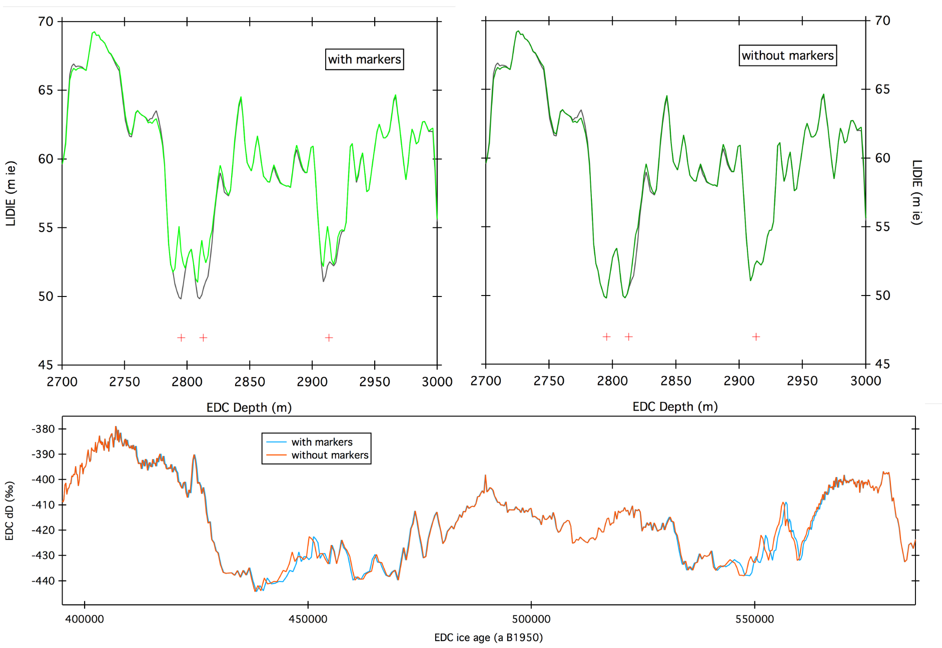

Fig. 1. see end of the text for complete figure 1 legend

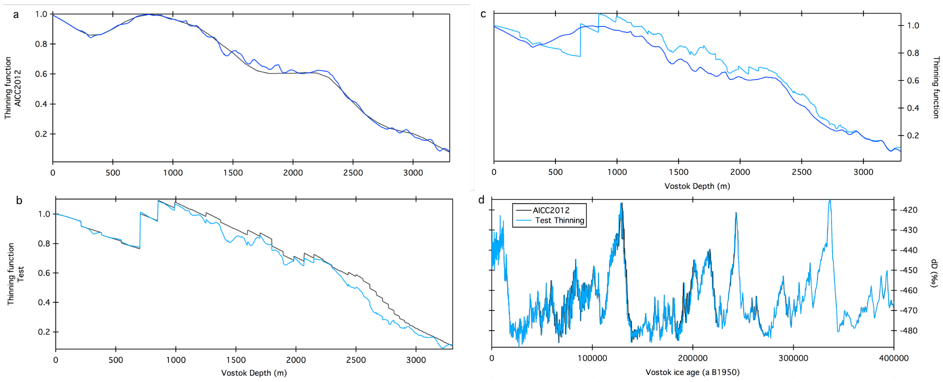

Fig. 2. see end of the text for complete figure 2 legend