Clim. Past Discuss., 8, C3623–C3634, 2013
www.clim-past-discuss.net/8/C3623/2013/

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.

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Received and published: 6 April 2013

"They arbitrarily gave 4 ka as the uncertainty associated with O2/N2 age markers for both Vostok and EDC cores. As the reasoning for this, they only refer to Landais et al. (2012) who only showed the limitation of EDC O2/N2 record (300-800 ka) due to poor data quality and/or possibly different target curve than the local summer solstice insolation at EDC. There is no evidence to justify the (approximately) doubling of Vostok O2/N2 age marker errors (down to âĹij400 ka). Regarding the Vostok record, its O2/N2 chronology is very close to the O2/N2 chronology of Dome Fuji (Kawamura et al., 2007; Suwa and Bender, 2008; difference is within 1 ka), strongly suggesting small uncertainty associated with those age markers. The Vostok and Dome Fuji chronology can also be compared with Chinese speleothem records for terminations (Cheng et al.,

2009; Barker et al., 2011), and the differences are within 2 ka. The subjective increase of O2/N2 marker error might be one reason for the rather consistent chronologies between those based purely on O2/N2, air content or d18Oatm (Fig. 4)."

=> The quality of δO2/N2 is the same for Vostok and Dome C (Suwa et Bender 2008, storage $\sim$10 years at -20°C leading to a large gas loss correction plus many outliers leading to a too low resolution over some periods, cf Figure 1). These are the reasons why we believe that using 4 ka for the δO2/N2 uncertainty is safer at Vostok. We have made the test of running Datice with Vostok δO2/N2 age markers with 2 ka uncertainties instead of 4 ka. Using such low uncertainty for δO2/N2 markers, we observe a difference of less than 1 ka in general with the original AICC2012 age scale, hence within the produced uncertainty (Figure 2). Still, in the case of age markers with 2 ka uncertainties, the chronology error calculated by Datice is smaller than 2 ka over the last 400ka (Figure 2). This small uncertainty results from the relatively high density of tie-points. We believe that such a small uncertainty back to 400 ka is not realistic.

An additional argument for a larger uncertainty for δO2/N2 comes from the direct comparison of the δD and δO2/N2 data from Vostok and Dome F on their δO2/N2 deduced chronologies (Kawamura et al., 2007, Suwa et Bender 2008) around the last interglacial period (Figure 1). First, it can be seen that the two δO2/N2 records present over some periods disputable attribution of the ages of tie-points for δO2/N2 maxima or minima.: (1) the resolution of the Vostok δO2/N2 record is sometimes low with some noisy features (100-110 ka ; 125-135 ka) ; (2) the δO2/N2 minimum on the Dome F record between 130 and 140 ka is not clear to capture also because of a bit of noise in the record. Second, we observe differences greater than 2 ka between the two chronologies. It thus appears unreasonable to consider an uncertainty of 2 ka for δO2/N2 age markers of Vostok.

Moreover, in order to answer to the last part of the comment, we made the same coherency test between the different orbital chronologies in the case of a 2 ka uncertainty for Vostok δO2/N2 age markers (Figure 3) as in our paper (Figure 4 in the paper). It appears that even with this uncertainty, the orbital chronologies are consistent. The increase of the δO2/N2 markers uncertainty isn't a reason for this coherency.

"The authors increased the d18Oatm data resolution for selected periods and derive age markers around MIS 11. However, the d18Oatm record in this time interval has no similarity to precession curve. More generally, d18Oatm has variable lags relative to precession as evidenced by recent papers (e.g. Kawamura et al., 2007; Cheng et al., 2009), and it also has 100 ka periodicity. Precession influences the d18Oatm through climatic and environmental changes. This manuscript states that d18Oatm and O2/N2 to be within a same category as the tools of orbital tuning (P.5966) and different from climatic records like methane, but it is simply not true. As discussed later in the manuscript, d18Oatm is heavily influenced by climate and should be categorized in the same group as methane and other climatic records. Air content is intermediate between d18Oatm and O2/N2, because it is influenced by local insolation but also by climate (pressure, temperature). The current manuscript might give readers a wrong impression that all three records are equal as dating tools."

=> We agree that δ18Oatm has a variable lag with precession parameter (see answer to the comment of J. Severinghaus and main text p.5967 and 5976). Over MIS 11, we agree that the EDC δ18Oatm record cannot easily be aligned with the precession curve (already illustrated in the original work of Dreyfus et al., 2007). The same is true for EDC δO2/N2 record over MIS 11 despite the very good quality of measurements performed over this period (ice stored at -50°C). Figure 4 illustrates why no obvious correspondence between the δO2/N2 curve and the local insolation can be performed (Landais et al.,2012). In the EDC3 chronology construction, several δ18Oatm tie-points proposed by Dreyfus et al., 2007 are disputable (see figure 5). As a consequence, we have decided to improve the chronology by (1) increasing the δ18Oatm resolution over MIS 11 to detect unambiguous tie-points and (2) to reduce the δ18Oatm and δO2/N2 tie-points proposed in AICC2012 to those that unambiguously show a clear correspondence between insolation curves / precession and δO2/N2 / δ18Oatm. As a

consequence, no age marker was derived for some mid-slopes δ18Oatm or δO2/N2. In the future it will be possible to implement δ18Oatm constrains as age difference markers, which will be more appropriate for this kind of orbitally-tuned proxy, thanks to current improvements of Datice (Lemieux-Dudon et al., in prep).

"The resulting chronology AICC2012 is not compared with other chronologies than EDC3. For 400-800 ka, there is no other choice so it is fine. However, for the younger part, detailed discussion on accuracy of AICC2012 is limited to MIS5.5 despite the existence of other published chronologies. They estimate the uncertainty of AICC2012 to be small: less than 2 ka for the last glacial and around 2.5 ka for the previous two glacial cycles (MIS 6-9), which are excellent if true. But the error for AICC2012 might be underestimated. For example the AICC2012 uncertainty around MIS 5.3 is estimated to be âĹij1.5 ka (read by eyes from Fig. 6) but Veres et al. give the possibility that AICC2012 may be off by 2 ka (by comparison with U-Th speleothem age). It is stated in the text that interglacial duration is not very much altered in AICC2012 from EDC3. But if the age around MIS 5.3 (D/O 23-25) is off by 2 ka and MIS 5.5 is accurate, the duration from MIS 5.5 to 5.3 is in error by 2 ka which is about 10 % of the duration (not small at all). What can be said from this is the agreement between AICC2012 and EDC3 does not help evaluating the estimated uncertainty of AICC2012. Other published chronologies should be compared with AICC2012 and discussed in terms of uncertainty of AICC2012, with appropriate graphs (as it was done for comparing EDC3 with other chronologies, Fig 2-5 of Parrenin et al., 2007): Vostok (and Dome Fuji) O2/N2 chronology, and EDC correlated with U-Th speleothem chronology assuming bipolar seesaw (Barker et al., 2011, a few authors of Bazin et al. also authored Barker et al. paper)."

The Datice methodology permits to calculate directly the uncertainty of the final chronology by combining the uncertainties of the background chronology and all data markers (stratigraphic, absolute and orbital, see SOM and answer to Referee comment 3 of the discussion). The error was slightly underestimated (see Review 3), but this will be corrected in the revised paper. As a result, the uncertainty of the new chronology is not at all estimated by the comparison with EDC3. This comparison only permits to identify periods of significant changes over the last 800 ka and explain their origin. We agree that the explanation of the origin of the uncertainty calculation was not sufficiently described in the previous version and comments from reviewer 3 helped us to improve this aspect of the manuscript in the revised version.

When comparing AICC2012 chronology of Vostok with the chronology of Suwa et Bender 2008, they are very close (3.5 ka max difference within the last glacial period due to the numerous stratigraphic links with other cores, otherwise less than 2ka difference over the last 360 ka, figure 6), which is consistent as we used the same age markers but with an enlarged uncertainty. As our chronology appears to agree with the one of Suwa et Bender 2008 for Vostok, it should be consistent with the Dome F dO2/N2 age scale (Figure 6). This is mainly the case, within 2ka, except for the last glacial inception (up to 5-6ka difference with Dome F, and only 1.5 ka difference with Suwa et Bender 2008). This offset might come from the link between δO2/N2 and δD records that are not really identical during MIS 5 (Figure 1) at Dome F and Vostok.

The time difference between the AICC2012 timescale and Dome F timescale is of the same amplitude as the later with the EDC3 timescale. To enhance the comparison, it would be very interesting to compare also the AICC2012 gas chronology with Dome F gas age scale using methane records when it will be published for Dome F.

We propose add the comparison AICC2012 with Suwa et Bender 2008 and Dome F chronologies in the SOM, as they cover the last 360 ka.

References:

Dreyfus, G. B., Parrenin, F., Lemieux-Dudon, B., Durand, G., Masson-Delmotte, V., Jouzel, J., Barnola, J.-M., Panno, L., Spahni, R., Tisserand, A., Siegenthaler, U., and Leuenberger, M.: Anomalous flow below 2700 m in the EPICA Dome C ice core detected using δ18O of atmospheric oxygen measurements, Clim. Past, 3, 341–353,

2007.

Kawamura, K., Parrenin, F., Lisiecki, L., Uemura, R., Vimeux, F., Severinghaus, J. P., Hut- terli, M. A., Nakazawa, T., Aoki, S., Jouzel, J., Raymo, M. E., Matsumoto, K., Nakata, H., Motoyama, H., Fujita, S., Goto-Azuma, K., Fujii, Y., and Watanabe, O.: Northern Hemisphere forcing of climatic cycles in Antarctica over the past 360 000 years, Nature, 448, 912–916, 2007.

Landais, A., Dreyfus, G., Capron, E., Pol, K., Loutre, M. F., Raynaud, D., Lipenkov, V. Y., Ar- naud, L., Masson-Delmotte, V., Paillard, D., Jouzel, J., and Leuenberger, M.: Towards orbital dating of the EPICA Dome C ice core using δO2/N2, Clim. Past, 8, 191–203, 2012.

Suwa, M. and Bender, M. L.: Chronology of the Vostok ice core constrained by O2/N2 ratios of occluded air, and its implication for the Vostok climate records, Quat. Sci. Rev., 27, 1093–1106, 2008.

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

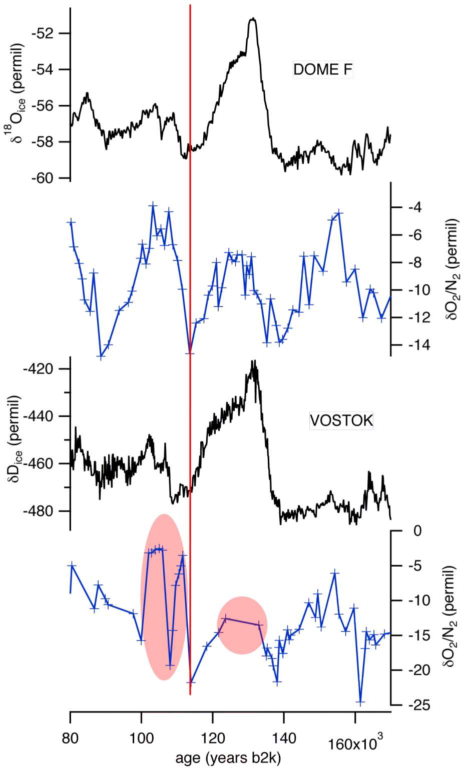

Fig. 1. Comparison of Dome F and Vostok δO2/N2 and water isotope records on their δO2/N2 deduced chronologies. The red zones mark the significant differences between Dome F and Vostok δO2/N2 records.

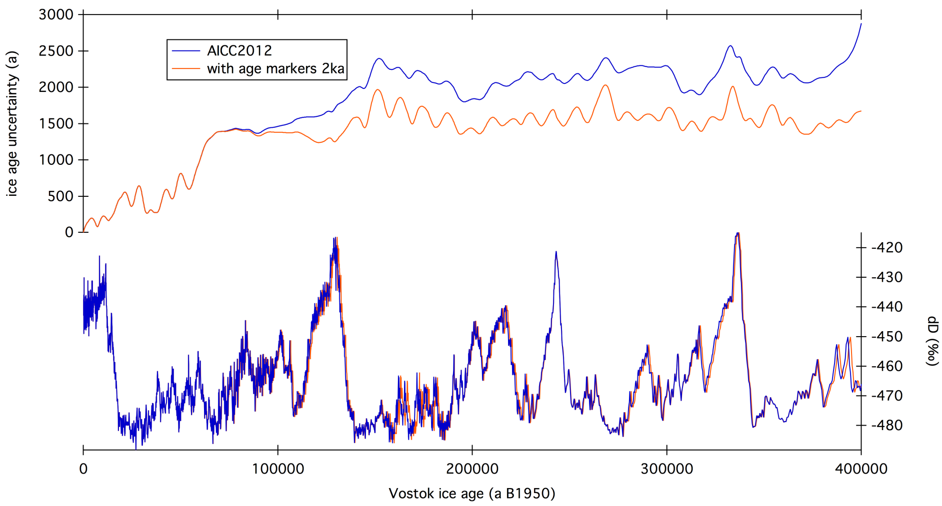

Fig. 2. Vostok chronology comparison of AICC2012 (blue) and Datice using 2ka uncertainty of δO2/N2 at Vostok (orange). Bottom: water isotope, top: ice age uncertainty calculated by Datice.

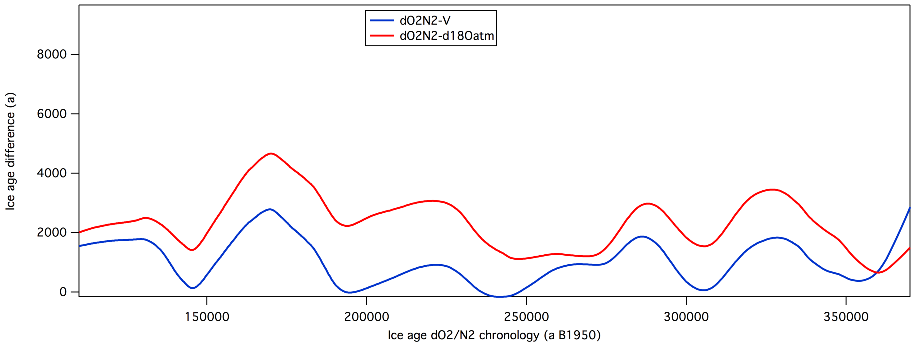

Fig. 3. Orbital chronology comparison in the case of a Vostok δO2/N2 age markers uncertainty of 2ka.

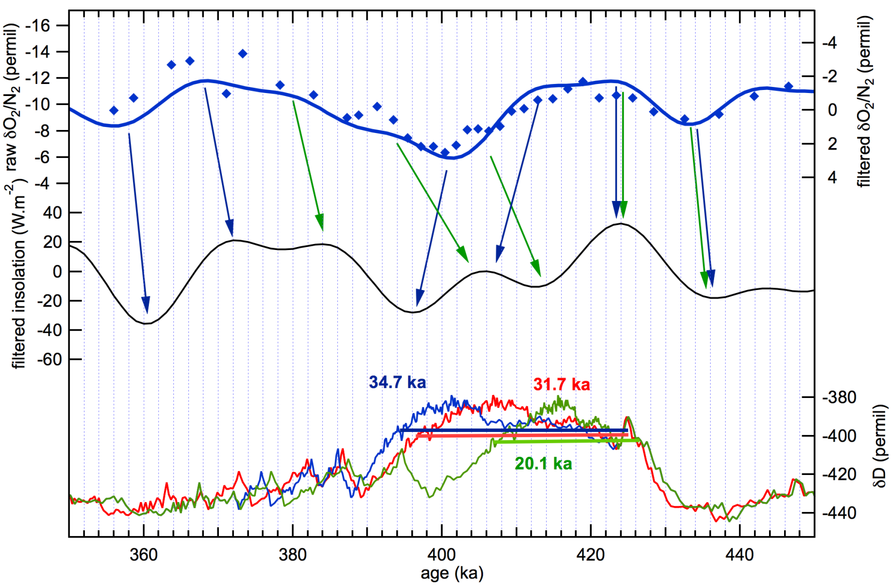

Fig. 4. Impact of δO2/N2 tuning on MIS 11 duration at EDC due to the lack of clear correspondence between δO2/N2 and local insolation curve.

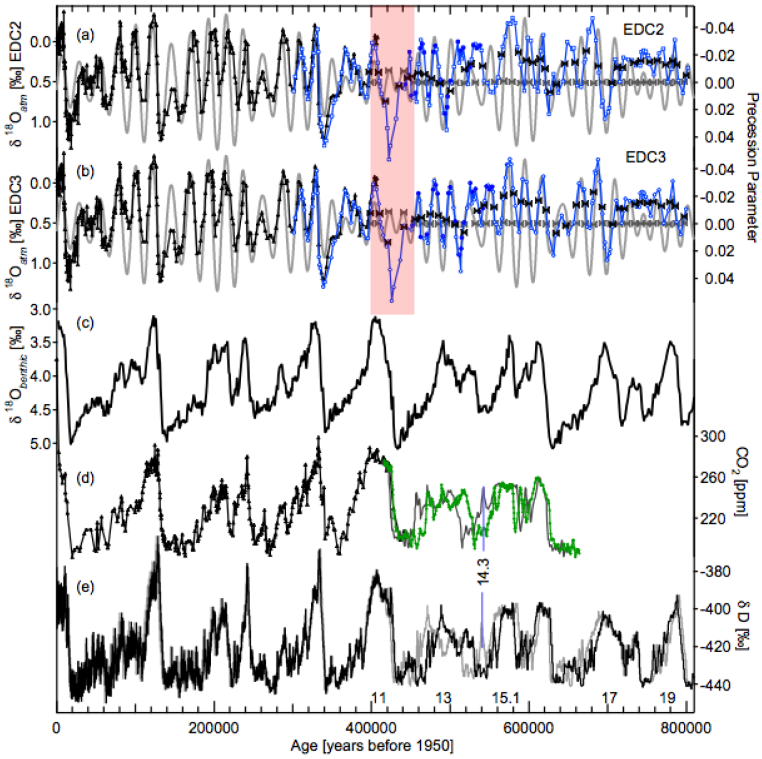

Fig. 5. Figure extracted from Dreyfus et al., 2007. The red box highlights the period were the orbital matching of δ18Oatm might be questionable.

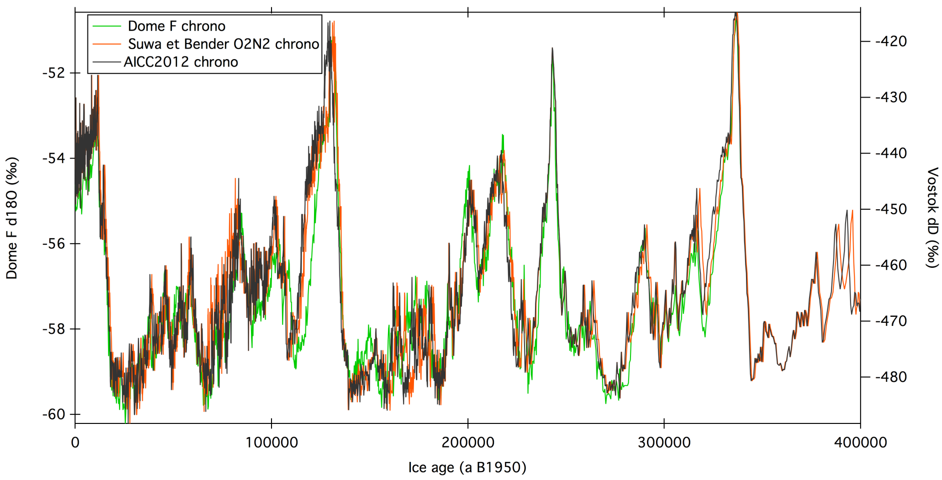

Fig. 6. Water isotopes of Dome F (green) and Vostok with different chronologies: Suwa et Bender 2008 (orange) and AICC2012 (black).