Climate of the Past Discussions

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Review of "Stratigraphic templates for ice core records of the past 1.5 million years" by Eric Wolff et al.

Anonymous Referee #3

Referee comment on "Stratigraphic templates for ice core records of the past 1.5 Myr" by Eric W. Wolff et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2022-2-RC3, 2022

Review of "Stratigraphic templates for ice core records of the past 1.5 million years" by Eric Wolff et al.

Wolff et al. address the challenging problem of dating ancient ice from Antarctica with ages exceeding 800 ka BP – currently the oldest ice in the continuous ice core record. Such dating is challenging in particular when the ice is no longer in stratigraphic order. The authors suggest 4 ice core records (dD, dust, CH4 and 10Be) that may in theory allow for stratigraphic matching to independently-dated marine-sediment records (of benthic Mg/Ca, Iron, Atlantic SST and geomagnetic dipole, respectively).

The paper is well-written and easy to follow. The topic is suitable for Climate of the Past. I have a series of comments for the authors to consider, in particular for an improved discussion of the approach.

(1) I would ask the authors to provide a more in-depth comparison of the methods, including perhaps a ranking of the methods. There is currently no quantitative analysis of the four methods they propose – this could be remedied by adding a table with the correlation coefficients between the ice core record and the marine target record for each of the methods proposed.

Such a table could also include an assessment of how likely the physics that produce the correlation for the last 800kyr is to persist during 0.8 – 1.5 M also. Such an assessment is likely qualitative and somewhat subjective by necessity (e.g. "likely", "unlikely", "uncertain" etc).

A third entry into the table could for example be whether the method would allow for value-matching, or only the matching of sequences.

Combined, these elements would allow the reader to assess the relative usefulness of each method. The authors appear to give somewhat of a ranking of the four methods starting on line 366. The authors appear to favor the Dust-Fe matching over the dD-Mg/Ca matching – a choice that I agree with. This ranking is however never stated explicitly, or justified by the analyses.

(2) I have reservations about the dD to Mg/Ca matching. To me, one of the most exciting prospects of a 1.5 Ma ice core record would be to investigate the Antarctic dD climate record and its spectral properties. This possibility would be lost if it were wiggle-matched to the deep ocean temperature.

A surprising aspect of the 41-ka world is the absence of a precession (21 ka) signal in the benthic d18O. The hypothesis by Raymo et al. (2006), paper cited in the text, is that the NH and SH ice volume each responded to local precession forcing, yet this cancels out in the benthic d18O (and presumably also in benthic Mg/Ca) as the precession forcing is out of phase between the hemispheres. One of the key questions of a 1.5Ma ice core dD record is whether it has power in the precession band in the 41 ka world – the Raymo hypothesis requires that it does. If the dD record is wiggle matched to a benthic record, we would lose the ability to independently assess the differences in spectral content between such records – one of the key scientific objectives.

The authors suggest that the ODP 1123 benthic Mg/Ca resembles Antarctic dD so strongly because both are controlled by SH high-latitude SST. They follow the argument by Elderfield (2012) here (Lines 125-129). Antarctic dD also strongly resembles global benthic d18O (LR04), and it also strongly correlates with mean ocean temperature from ice cores (Shackleton et al., 2021; Fig. 3). I suspect that LR04 may actually give a better correlation to dD than ODP1123 Mg/Ca does (can you check/show?). Since bottom waters formed around Antarctica are at the freezing point, lowering Southern Ocean SST will not cool them further. It seems to me that global mean ocean temperature, the rate of bottom water formation, and circulation may all impact ODP1123 benthic Mg/Ca. ODP1123 certainly looks identical to LR04 (Elderfield 2012) in d18O, suggesting good connectedness to global ocean conditions.

For these reasons I would ask the authors to reconsider recommending wigglematching dD to ODP1123 as a dating strategy.

(3) could you elaborate on the temporal resolution needed to do the CH4 / planktic d18O matching, and whether this resolution is available in the planktic record (which is promised but unfortunately not shown). For example, planktic d18O misses a DO event around 778ka BP that is clear in the EDC CH4. Could there be DO events that are missed altogether by both records?

(4) if Raymo et al. (2006) is right, the MPT reflects a transition from terrestrial to marine terminating Antarctic ice sheets. If so, could we get local Antarctic dust sources to contribute to the ice core record? Could this impact the dust matching?

(5) line-by-line comments:

Line 40-44: acknowledge the Japanese and US ice core communities are also working on this in funded projects.

Line 65: other tuning targets are air content and d18O-O2.

Line 115: I think both cited studies suggest dD is a proxy for site temperature – they just disagree as to what the correct calibration is.

Line 128: The temperature of the deep waters formed around Antarctica is probably always close to the freezing point. Could it not reflect the volume of deepwater formation, for example, and the mixture with other deep water masses?

Line 131: You could add Shackleton 2021 here too (new MOT data from MIS 4). In that paper she explicitly plots the very strong correlation between MOT and ice core d18O, which strengthens your argument as you correctly note.

Figure 3: is it possible to also plot the comparison as a Mg/Ca vs. dD scatter plot? That way the reader can assess the correlation better.

Line 146: can you give the correlation coefficient for the comparison?

Line 177-180: I fully agree with this sentiment, but feel the same logic can (should?) be applied to ODP 1123. The Benthic temperature has an imprint of southern high-latitude SST, but also of global ocean temperature, volume of deep water formation, circulation, etc.

Line 203: How good is the match? Can you quantify, e.g. via a correlation coefficient?

Line 255: Perahaps note that DO 2 has no CH4 peak at all.

Line 268: Throughout what? Throughout the record? throughout the Pleistocene?

Line 269: can you give more details than "soon to be published". Is there a title and author list?

Line 317-318: This is unfortunate (though no fault of the authors). why is the full dataset from a 2013 publication not publicly available at this point? Can you provide more details?

Line 366: Here the authors appear to suggest a hierarchy with the dust matching being considered more accurate than the other methods. Is this really what you mean to imply?

Line 378: However, wouldn't the absolute values of the 10Be be challenging to use due to the accumulation uncertainty? Also, the VADM record is really variable, and certain 10Be values are not necessarily very unique.