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Climate
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Discussions

Interactive comment on "Anomalous flow below 2700 m in the EPICA Dome C ice core detected using δ^{18}O of atmospheric oxygen measurements" *by* G. B. Dreyfus et al.

G. B. Dreyfus et al.

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Responses to numbered Referee #2 comments:

1) It would be useful to independently match the del18O(atm) record to obliquity.

It is very difficult to match the $\delta^{18}O_{\mathrm{atm}}$ record directly to obliquity alone. Rather, we have re-run our algorithm using age-markers derived by matching to the Shackleton orbital tuning target (ShOTT; Shackleton, 2000). ShOTT has equal power in the 41 kyr and 23 kyr bands. For comparison, the insolation curve for June 21 65° N has an obliquity component with only 1/3rd the power of the 23 kyr precession component. We find that the mean difference between the resulting chronologies is 675 years (ShOTT tuned chronology minus precession tuned chronology) and ranges between –600 and

2600 years with a standard deviation of 636 years. This is well within the 6000 year uncertainty range.

To address this in the manuscript we have modified the following:

p. 7: The implications of this choice are assessed by independently tuning to ShOTT, which has equal power in the 41 kyr and 23 kyr bands.

p. 13 (added): We assess the influence of tuning exclusively to precession by repeating the above least-squares analysis using the same control points tied to ShOTT. The agescale correction agrees to within 2.6 kyr along the entire tuned section, with a mean difference of 0.6 kyr (ShOTT tuning older). Tuning $\delta^{18}O_{atm}$ to a record with a strong obliquity component does not significantly change the relative spectral power or peak frequency in the obliquity band.

c) 29 kyr peak As noted by the referee, there does appear to be a small peak at approximately 29 kyr in the spectral plot of $\delta^{18}O_{atm}$ on EDC3. This peak does not however appear to be significant according to the f-test using the multi-taper method. Since it is a minor side peak in the obliquity component, it does also appear in the ShOTT target. Interestingly, this peak disappears in the $\delta^{18}O_{atm}$ spectrum when considering only the interval spanning 400-800 ka (compared to the 300-800 ka shown in Figure 3). The spectral power in the obliquity band and around the eccentricity band (87 kyr) both are also reduced for this shorter interval. We note also that there is no evident 29 kyr peak in the Vostok record (0-406 ka, analyzed on the FGT1 timescale).

2) It would also be useful to map the EDC oxygen isotopic record directly into the Lisiecki Raymo marine 18O stack, since ice volume is still presumed to be a significant component of the 18O(atm) variability.

The effect of ice volume can most clearly be seen in the most strongly enriched $\delta^{18}O_{atm}$ data that tend to occur during glacial maxima. Direct comparison, however, is complicated by additional effects, such as the Dole effect on $\delta^{18}O_{atm}$, and temperature on

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the marine δ^{18}O. We do not know of an objective way to tune directly to the stack. We did attempt to match to the $\delta^{18}O_{sw}$ record reconstructed by Bintanja and others (2005). Significant differences in shape were still apparent. Since the goal for the EDC3 chronology was to be independent of the marine record, we opted to tune $\delta^{18}O_{atm}$ to insolation rather than marine records.

3) In Figure 3 it would be well worth showing the coherency spectra. Since the focus is on precession, the signal's amplitude modulation makes coherency a useful evaluation tool.

A panel showing coherency with respect to the precession parameter has been added to figure 3.

4) Another (somewhat) independent check could be derived from comparing the deuterium record to Southern Ocean sea-surface temperature (SST) time-series, as there are a number of Southern Hemisphere SST records, which cover the MIS 12-20 interval. These show, similarly to EDC, that sea-surface temperatures were low during MIS 12-15 compared to subsequent interglacial intervals.

The reviewer raises a good point that deserves further consideration in another paper. Here, we focus primarily on the chronological correction required as a result of the flow anomaly. In this respect, we have added a short paragraph comparing the timing and duration of events in the LR04 stack with the EDC deuterium record on the corrected chronology. The improved agreement compared to the previous agescale (EDC2) is encouraging given the very different tuning approaches and assumptions used in constructing the LR04 agescale and the EDC chronological correction.

Paragraph added p. 13: "Comparison of the δD record on the corrected chronology with the LR04 marine $\delta^{18}O_{benthic}$ stack (Lisiecki and Raymo, 2005) in Figure 1 gives us confidence in the proposed agescale correction. Whereas the timing of climatic transitions differed by up to 20 kyr for the EDC2 chronology, the two records agree to within $\pm$5 kyr for the corrected chronology. We note that the tuning method used

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for LR04 and for the chronological correction involve different assumptions and tuning targets: an orbitally forced ice volume model for LR04 and the precession parameter for EDC."

5) Finally, an independent stratigraphic tie-point to the marine record may exist in the EDC core in the form of the Brunhes-Matuyama magnetic reversal.

Again, this is beyond the scope of the current paper, but this is the subject of a manuscript in progress. The youngest 10Be peak spans 764-776 ka on the EDC3 chronology. This is in excellent agreement with the most recent radiometric dates from Singer et al. (2005) giving an age of 776 $\pm$2 ka.

References:

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