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Interactive comment on "Interpolation methods for Antarctic ice-core timescales: application to Byrd, Siple Dome and Law Dome ice cores" *by* T. J. Fudge et al.

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General Remarks

This paper uses the opportunity provided by the annually resolved WAIS Divide (WDC06A-7) timescale to test the performance of three interpolation schemes on the fidelity of the timescale between eleven tie points. The authors confirm the unsurprising, and previously established (Waddington et al., 2003) result that linear interpolation of ages between ties leads to biases, and errors which are larger than more sophisticated methods with higher-order, smooth interpolants. The paper is able to quantify the relative performance of the various methods using the WDC06A-7 timescale, and also

presents some discussion and analysis around the implications of interpolations used for Byrd, Siple Dome and Law Dome deglacial records. As a methodological paper this makes a valuable contribution, highlighting an important issue for constructing ice core chronologies. It also highlights the need to consider interpolation errors when interpreting features in records. The paper does contain some small errors which require fixing and one or two analytical questions which arise. More importantly there are several instances where the interpretations made or language employed might be misleading to the reader, especially around the definition of when an interpolation method is linear or not, and the application of WAIS specific values to other records. I would recommend this paper is suitable for publication once these matters have been addressed.

Comments and corrections

Overall remark on the characterisation of 'linear interpolation'

A key point made by this paper is that linear interpolation of ages between tie points should be avoided and I agree. This paper mis-characterises the Law Dome timescale methodology as being a "variation of linear interpolation" (p67 line 20), although later (p80, line 3) acknowledges that it incorporates a Dansgaard-Johnsen flow relation. It should be clarified in the earlier instance (p67) that the method used is intrinsically non-linear (accounting as it does for flow thinning), but shares some of the biases and problems associated with simple linear interpolation because it has constant accumulation steps between tie points.

It is true that the non-linear effect of flow thinning becomes small over short intervals or toward the bed, and that the 'stepped' accumulation leads to a stepped annual layer thickness as seen in Figure 7E. While this leads to the same type of errors seen in simple linear interpolation (with 'flat steps') it can also be seen in figure 7E that the annual layer thickness of the original Law Dome scale and the ALT scale are close across several tie intervals (see, e.g. 14.8-16.2 ky) and certainly generate smaller magnitude biases than 'flat steps' (without thinning) would do. This is also relevant when applying the WAIS-derived uncertainty-rate accumulation to Law Dome (see below).

Other points

P66 line 9 "...abrupt changes in inferred duration [of depth intervals] at tie points..."

P67 line 17 "Two common approaches [have been used]..." suits the tense of following sentence better.

P67 lines 20 and following "variations of linear interpolation were used"... As noted above, some clarification would be appropriate re Law Dome.

P77 line 13 "... and a carbon dioxide record measured in a single core..." should read ..."and carbon dioxide records measured from individual cores" Since the Pedro et al study used two CO2 records, not one

P77 line 28 "...result in ages biased 200 yr too old [at WAIS] for linear interpolation" This is not a general result

P78 lines 2-5 This comparison between the Pedro et al CO2 lag and the 200-yr WAIS interpolation bias implies that the lag reported in Pedro may be too large by a similar amount. This implication is not founded and overlooks the following:

1) The 200 year bias is a WAIS-specific value and not the correct value for the cores used in the Pedro stack. That is for Byrd, Law Dome, EDML, Taldice or Siple Dome. The interpolation bias estimates for Byrd (30 years) and Law Dome (150 years) are smaller than WAIS, while EDML and Taldice use the Bayesian technique which this paper (P79, lines1-4) suggests is unbiased.

2) Taking Siple Dome, which has the largest potential interpolation bias (older 240 years) as an indicator, one would expect that removing it from the Pedro lag calculation would make the stack younger and therefore reduce the lag. In fact, removal (done by Pedro et al in jackknifing tests) of Siple increases the lag by 55 years. This is a powerful indicator that simple expectations in the presence of multiple interacting factors (like the

fact that both the CO2 and temperature timescales suffer bias) can be misleading.

3) The Pedro et al results are computed with a Monte Carlo style sensitivity in which the timespan of comparison was truncated over a 1200yr range of ages from 18.2ky-19.4ky. The results therefore include a substantial portion of the interval of greatest putative bias (Fig 7E) without displaying any inconsistency. Further, this method is likely to have captured in the distribution of lags an allowance for bias variations in this interval.

As an additional point, the lag estimate in Pedro et al is -56 to 381 years, not 0-400 years.

A suggested rephrasing of this section which addresses this might read: "Understanding the potential interpolation biases in ice core timescales is important when comparing phase relationships between records. For example, the study of Pedro et al., compared a composite temperature proxy with two CO2 records and identified a lead of Antarctic temperature with respect to carbon dioxide of -56 to 381 years. It might be expected that interpolation biases in the temperature proxy, when removed would lead to a reduced lag, however jackknife sensitivity tests in Pedro et al, suggest that the effect is likely to be small in this case".

P80 line 23 19.5 kyr not 19.1 kyr

P80 line 24 19.5ky not 19.2 kyr

P80 line 25 ...over 500 yr.... this raises an interesting point about figure 7E which I don't understand. If I'm correct, the quasi-parabolic age difference curves in Figure 7A, C, E are integrations of the difference between the ALT and original timescales from start to finish of the interval. ALT starts a typical interval at higher layer thickness than the original, so as discussed in the manuscript, the errors start accumulating with the original scales running 'old' relative to ALT. When the point is reached where ALT crosses through original, the scales run instantaneously at the same rate, and we see the maximum in the 'parabola'. Why then, does the maximum near 17.7ky in figure 7E not appear to align with the crossover?

P81 Section 4.2 This specific example is in some respects of limited value as it is an example built on the comparison of a timescale developed according to the arbitrary assumption of "smoothness" with a separate timescale built on the assumption that accumulation rate over the interval is constant. While the rest of the paper makes the case that the ALT method is generally superior to the abrupt jumps, and I have no quibble with that as a general principle, it is hard to claim that the ALT timescale is preferable to other methods for a given interval in a specific record. Indeed, the authors are careful to avoid this claim (p81 line 17).

Putting this aside, if there is to be this discussion, it is not clear that the rate of accumulating uncertainty can be validly transferred from WAIS to Law Dome as they do here. They use the value of 31 yr per hundred yr, which for WAIS, never minding that it is an entirely different site, was based on using the square-stepped annual layer relationship of a naive linear interpolation without flow correction. Since the Law Dome interpolation includes flow thinning, as seen in the 'sloping' steps of Figure 7E, it might be expected that uncertainty would accumulate more slowly – at the very least, the author assumption is not demonstrated: viz that 31yr per hundred is sensible.

P84 line 3 –J and m symbols should be bold

Table 4 The values and row headings are not correctly placed: the Ice age values and depths are transposed

The Ice Age values have been computed from publicly available depth age data and are generally correct with a couple of typos. I do wonder at the rounding of the ages to the nearest 100 years, as this could affect the calculation of accumulated bias over the intervals – this is probably a small effect, and not critical.

Typos: "12.8" kyr age should be 14.8; "12"kyr age should be 21, and units on the rows

would be good (kyr and m).

Interactive comment on Clim. Past Discuss., 10, 65, 2014.