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Climate of the Past Discussions

Interactive comment on "Leads and lags between Antarctic temperature and carbon dioxide during the last deglaciation" *by* Léa Gest et al.

Anonymous Referee #2

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General remarks: This manuscript presents the phasing (lead/lag) between the isotopic records of several Antarctic ice cores (stacked into one record) and atmospheric CO2 concentration from the WAIS Divide ice core (WDC). Essentially, this updated a previous result by the same group by making more robust age controls. It is important for documenting the phasing between Antarctic temperature proxy and atmospheric CO2 concentration over glacial cycles for investigating the mechanisms of carbon cycle changes and their relation to the climate, and this manuscript could potentially contribute significantly as the most robust result.

However, I have a strong doubt about one of the resulting phasing, at the onset of the Holocene, as follows. I ask the authors to re-think the appropriateness of the employed method for obtaining meaningful phase information, if long-term trend is disturbed by

abrupt change around the end of the trend (as seen in CO2 at the Holocene onset).

I could understand that the method employed here produces the lag of CO2 by 400 yr "objectively", but visual inspection into Fig 2 actually shows different shapes of CO2 and ATS2 signals, questioning the applicability of the simple breakpoint detection by line fitting in the first place. As discussed by Marcott et al. and repeated in this manuscript, abrupt (centennial-scale or less) changes in atmospheric CO2 is important, and one of the major abrupt changes occurs at the onset of the Holocene (or the end of Termination). It seems inappropriate to detect the breakpoint here as the crossing point of the two lines fitted to the millennial-scale trends, ignoring the abrupt increase of CO2 at around 11500 kyBP (very close to the breakpoint in ATS2). No change in trend is actually found at the 11211 yrBP (there is no significant change in linear trend from $\sim$9000 to $\sim$11500 yrBP). The trend line through the second increase of CO2 over T1 goes near the lowest point in the earliest part around 13 ka and the highest point at around 11600 yrBP (just before abrupt rise), suggesting the overestimation of the slope detected for this long period due to the (automatic by method) inclusion of the abrupt CO2 rise and subsequent high values. Thus, I suspect that the 406-yr lag of CO2 is artifact by the method of fitting just two lines after 13 ka. The authors should consider if the method here for detecting the slope change is really appropriate, and if the statement in abstract that climate/carbon models should respect the phasing is reasonable, especially for the Holocene onset.

From this and specific comments below, I recommend the editor not to accept the manuscript in its current form. Thorough considerations on the method and results and another review round may be necessary.

Specific comments: L11. Proxy for temperature is recorded in ice (not the temperature itself).

L15. This time, it includes West Antarctic isotope record.

L16. stack of East. . .. <– Also West Antarctica.

L21. Add “for sites with much lower accumulation rates” after “firn modeling”.

L25. See general remarks.

L27. Future climate. . .. I suggest deleting this sentence (see above).

L34. Add Abe-Ouchi et al., 2013.

L55. The description of the firn structure and the relation to the age of air are somewhat awkward. Please describe the three zones (convective, diffusive and lock-in zones) and lock-in depth in clear and compact manners. Add references for firn air studies at Antarctic inland sites; e.g. Bender et al., 1994 (GRL), Battle et al., 1996 (Nature), Kawamura et al., 2006 (EPSL), Landais et al., 2006 (QSR), Severinghaus et al., 2006 (EPSL).

L67. I think ice age-gas age difference should not be called in different ways than traditionally used (age “shift” does not sound right for me but please check with English speakers if you really want to use it).

L70. nitrogen-15 should be replaced by “isotopic ratio of N2 in air (d15N)” (and use d15N for the rest).

L100. ATS and ATS2 in Fig. 1 should both use WDC2014 age scale and it is indeed implied to be the case, but it does not seem to be explained in text. Also, it may be better to place the comparison of ATS and ATS2 after explaining the age scale.

L102. Quantitatively, ... I see that the amplitude of the difference between ATS and ATS2 is less than 0.5 degC, but the average is not zero. Please discuss the reason for the offset between the two stacks.

L111. This reference should be Fudge, 2014 (the position in the reference list should be wrong).

L112. “after”. Actually, “before”?

L112. “Up to”. Please clarify the range of age (e.g. “9 - 11.4 ka”).

L.113. Here too, please clarify the range of age.

L.114. Why three times the S.D.? Please explain.

L.123. Why is the 20% reasonable? Please explain.

L.124. “after”. <– “before”?

L.161. (section 2.5 as a whole) This comparison is not used for the ATS2-CO2 phasing estimation. It should be clearly spelled out and the aim of this comparison should be described in introduction.

L.176. See general remarks.

L.182-. The argument here (phasing was in error in 2013 paper because of low CO2 data resolution for EDC) requires the comparison between CO2 records from WD and EDC cores on the same time scale (here the CH4 comparison indeed becomes relevant to the central discussion of this study).

L.205. Here the authors should remind the readers that the Antarctic air temperature should not directly drive the atmospheric CO2, but it is the Southern Ocean which is thought to be mainly responsible for the CO2 glacial-interglacial variations, so it is important to further investigate in Antarctic ice cores for potential source temperature signals (i.e. Tsite from d-excess; Cuffey and Vimeux, 2001; Uemura et al., 2012).

Figure 1. Please show all individual Antarctic ice core records for ATS2 on WDC chronology. Drawing method in this figure and other figures are different (it is line between points in fig 1, and it is staircase function for other figures). Why?

Checking of English by native speakers (in authors) would be useful.

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