

Interactive comment on “CO₂ radiative forcing during the Holocene Thermal Maximum revealed by stomatal frequency of Iberian oak leaves” by I. García-Amorena et al.

Anonymous Referee #1

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General comments

This manuscript is a potentially important contribution to our understanding of how the global carbon cycle and climate system have interacted during the Holocene. However, the size and temporal resolution of the leaf dataset used to reconstruct past CO₂ levels and to infer carbon cycle dynamics are too limited to support the fairly controversial implications put forward. To seriously challenge the present view of long-term Holocene CO₂ evolution, which is based on high-resolution data from several independent ice cores, requires a more detailed record than the one presented here. The authors also need to provide a plausible explanation for the observed divergence in long-term CO₂

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trend from both ice-core records and an earlier stomata-based reconstruction spanning the same period. Although the discussion of the results is generally interesting and potentially of great importance, there are unfortunately too few data points in the presented record to seriously consider the suggested implications. Publication of the study is, however, feasible if less stress is put on the controversial implications of the presented CO₂ record.

The manuscript addresses relevant scientific questions that are within the scope of the journal. The approach taken is relatively novel. The method has been applied in a number of studies during the last two decades and is still under development. Conclusions reached are far-reaching and partly controversial but based on a limited dataset. Scientific methods and assumptions are valid and clearly outlined. Results are not fully sufficient (too few data points) to support some of the main interpretations and conclusions. The study is well placed in the context of previous studies in the field. The title fits well to the contents of the manuscript but then also reflects the conclusions that are based on the limited dataset. The abstract provides a concise and complete summary. The overall presentation is well structured and clear, but some details appear to be erroneously stated or need to be clarified. The language is generally good but needs some polishing. Mathematical formulas etc. are correctly defined and used. There is no major need for editing of the text. Some complementary information is required in Table 1. References are generally relevant and used in an appropriate way.

As described above, the major concern with this manuscript is the size and temporal resolution of the leaf dataset used to reconstruct past CO₂ levels and to infer carbon cycle dynamics. Another aspect that needs attention is the dating. Radiocarbon dating was performed on wood samples, but it is not clear how this wood stratigraphically relates to the leaf samples analysed. Was wood dated from exactly the same levels as the leaves used in all cases? The depth values given in Table 1 are very coarse (in metres), and in one case a sampling interval of 5 m is stated! What does this imply? Was wood sampled and dated (and leaves analysed?) from this large interval? Also,

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how thick were the leaf horizons sampled? Do the horizons represent instantaneous deposition events or continuous leaf accumulation during decades or centuries? This is relevant information to be able to judge the time resolution of the data. Moreover, the CO₂ reconstruction presented here is based on a composite of samples from several cores and sites. This means that the stratigraphical control of samples is lower than in other (ice-core and stomata-based) studies based on single cores. Finally, it is argued that the CO₂ increase recorded by ice cores after ca 7000 cal BP cannot be explained by oceanic processes since it would require substantial ocean warming, which has not been recorded by climate proxies. The same was already concluded by Indermühle et al. (1999), who also claimed that the CO₂ increase was caused by release from the terrestrial biosphere based on carbon isotope data. This important conclusion by Indermühle et al. (1999) is not mentioned in the manuscript. More importantly, ocean surface cooling at high northern latitudes during the mid- to late Holocene does not imply that CO₂ concentrations must have decreased, as argued by the authors; this atmosphere-ocean carbon flux may have been counteracted by terrestrial processes (as suggested by Indermühle et al., 1999) or a concomitant oceanic warming in the southern hemisphere.

Specific comments.

3945, 12: Orbital variations are believed to control long-term (multi-millennial) climate change, but not abrupt climate change. 3945, 25: The Holocene minimum is centred on 7000 cal BP rather than 8000 cal BP. 3946, 9: The Holocene stomata-based record was presented by Rundgren and Beerling (1999), not by Rundgren and Björck (2003). Not only some features of this record are in agreement with ice-core records, in fact the major trends are in agreement. 3946, 12: The data coverage in the record by Rundgren and Beerling (1999) may be relatively low, but it is clearly higher (17 data points 9000-5000 cal BP) than in the record presented in the present manuscript (6 data points 10000-5000 cal BP)! 3947, 17: What is the stratigraphical relation between dated wood and analysed leaves (see above)? 3948, 6: How thick were these horizons

(see above)? 3950, 12-15: Despite large variability, the record presented by Rundgren and Beerling (1999) also shows clear long-term Holocene trends, and these trends are based on more data points than the record presented here (see above). 3950, 23-25: Is it really possible to discuss long-term trends with only 9 data points? 3951: Is a CO₂ minimum really recorded in ice cores around 8.2 kyr? This is at least not supported by the references given. Temperature and CH₄ minima are, however, found in Greenland ice cores. 3951, 21-29: Indermühle et al. (1999) suggested that the long-term CO₂ increase was a result of terrestrial biospheric release, and this is supported by their d¹³C data. From the text, it sounds like they inferred an oceanic release, which is not the case (see above). 3952, 4: Is -0.06 W/m² really correct? It looks as it is -0.15 W/m² in Fig. 3. 3952, 5: Is +0.06 W/m² really correct? It looks as it is +0.2 W/m² in Fig. 3. 3952, 8: Is -0.05 W/m² really correct? It looks as it is -0.1 W/m² in Fig. 3. 3953, 16: It is agreed that climate is driven by orbital variations on multi-millennial timescales during the Quaternary, not in general (see above). 3953, 25: It is not correct to say that there is no variability in Holocene ice core CO₂ records. There are clear trends. 3954, 19: Is -0.05 W/m² really correct? It looks as it is -0.1 W/m² in Fig. 3 (see above). Table 1: Explain Zone. Depths given are imprecise (in metres). Does this mean that the samples span several decimetres (see above)? What is the stratigraphical resolution of the samples? This is relevant to the temporal resolution of the stomata data. One sample is stated to span 5 m (depth = 8-13 m). Is this really correct? If so, it has serious consequences for the temporal resolution?

Technical corrections

3945, 20: Perhaps add fully after yet? 1947, 6: It is not clear what is meant by cross section sampling. Sections crossing what? Do you just mean sampling in sections spanning in total 200 m? 1947, 7: collected in situ 1947, 13: Be consistent and use Holocene in stead of Flandrian here. Presumably, water table refers to sea level? 3947, 22: Replace dilute with disintegrate? Replace the with their. 1947, 24: Insert space between other and Quercus. 3947, 27: Replace silica with clay particles or fine minero-

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genic particles? 3948, 3: After rinsing for 5 min, samples were; 3948, 6: Replace of with from? 3948, 23: Is this the altitudinal range of the sites studied (not clear)? 3948, 27: IPCC (2001) is not found in the reference list. Replace radios with ratio. 3949, 1: Replace to with on. 3949, 6: Replace records with represents. 3949, 7: Replace compliments with complements. End sentence by older Holocene sediments at Merón and Pravia. 3949, 19: Replace at with in. Remove steady; the rise occurs from one sample to the next, so it cannot be regarded as a steady rise. 3949, 20: Replace From this date with Subsequently? 3949, 27: Insert A before 0.15. 3950, 1: Replace observed in this figure with inferred. 3950, 14: What is a successive trend? 3951, 13: Insert the before terrestrial. 3951, 15: Turn around: increase in CO₂ common to both records. 3951, 17: Change lead to led (or resulted in). 3951, 21: Remove the? 3951, 22: Replace constituent to with determinants of? Replace continuing with subsequent? 3952, 7: Replace in with into. 3952, 15: Replace shades with shaded. 3952, 18: Insert globally relevant after between. 3952, 20: Replace to with of? 3952, 21-24: Summer temperature anomalies can hardly be sensitive to temperature changes! You probably mean that the proxies mentioned are sensitive to temperature changes. 3952, 26: Replace deviation with deviations. Remove a. 3953, 13: Replace suggest with suggests. 3953, 25: Do you mean disregarded rather than disseminated? 3954, 1-2: End sentence with forcing of the climate system on millennial timescales during the Holocene. 3954, 3: Replace it can be with it is. Remove the. 3954, 11: Change to shows a comparable trend of. 3954, 16: Replace profiles with records. Insert cores after ice. 3954, 18: Replace back with down? 3954, 23: Replace orbital with orbitally. 3958, 25-27. Remove this reference (see above). Table 1: Replace Beta code with Lab. no. (Beta-XXXXX)? Replace CO₂ with Reconstructed CO₂ mixing ratio. Fig. 1: Replace Meron with Merón. Fig. 2: SI tic marks are at 1.5 % increments. Better to use 1 % increments. Add comma after SI in parenthesis. Replace layers with leaves? Remove based on stomatal counts.

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