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Biogeosciences Discussions

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Interactive Comment

Interactive comment on "CO_2 radiative forcing during the Holocene Thermal Maximum revealed by stomatal frequency of Iberian oak leaves" *by* I. García-Amorena et al.

I. García-Amorena et al.

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General comments

The main objection of both anonymous referees is that the low density of our observed CO2 values is not enough to argue about the CO2 trends during the mid- to late Holocene. We agree that no continuous curve can be deduced from our data set, and thus interpret trends only. Changes in the manuscript have been carried out to account for the lack of continuity of our observations. Nonetheless, we are confident, that the CO2 values reconstructed, reflect ambient CO2 during the time of growth, since stomatal frequency is permanently fixed during the life-time of the leaves and resistant to digenesis during fossilisation. The low data density does not introduce significant

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long term smoothing. In addition, the Iberian CO2 record fits well with independent results from stomatal frequency studies carried out on leaf material from Denmark (in preparation by Wagner-Cremer et al.).

Our single estimates are well calibrated (see Biogeoscience Discuss. 5, S2043-S2045, 2008) and diverge from the CO2 values as deduced from Antarcic ice-cores. The data set here presented support successive CO2 fluctuations during the Holocene that allow comparison with other existing CO2 reconstructions. However, as the main argument of the manuscript is the connection to the Holocene Thermal Maximum -in contrast to referees #2 comment-, suggestion of referee #1 is welcomed and less stress is put forward on the divergences observed between Atlantic ice-cores and stomatal CO2 reconstructions.

In the other hand, although suggested by both referees, we think that further than the given explanation of the complex climate system functioning for the observed divergence between the stomata and ice core records, is far out of the scope of this manuscript (see comment to referee #1).

Thanking for the referees input to improve the quality of the manuscript, less relevant comments are answered below.

Comments to referee #1:

Discussion about CO2 sources and sinks responsible for the observed atmospheric CO2 changes are complex. Examples can be found in the controversial hypotheses put forward to explain the observed CO2 records during the Holocene: While Indermühle et al. (1999) claimed that release from the terrestrial biosphere caused the Holocene CO2 increase, Kouwenberg et al. (2005) concluded that although changes in the terrestrial biosphere are likely to have played a role in shortterm carbon cycle dynamics, the amount of carbon needed to cause a shift of 50 ppmv would far exceed the size of potential carbon sources and sinks in the terrestrial biosphere. Yet, it has not been proved -as suggested by referee #1- that the observed cooling for the northeast Atlantic

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and Mediterranean (Marchal et al., 2002) is counteracted by a Southern Hemisphere ocean warming during the Holocene. Available SST records from the S-Atlantic and SW-Pacific provide evidence for a Holocene Climatic Minimum with below average SSTs after ˜6000 BP(e.g.: Weaver et al., 1998;Schneider et al., 1995).

Dating was performed by conventional radiocarbon analyses on wood samples taken from the same layers (and same depth) than the analysed leaves. Were no wood was available (PR6/18 and Ab), rather than estimate ages from depths, AMS radiocarbon analyses were performed directly on the leaves to secure the accuracy of the chronology. This is corrected in the manuscript as no mention to the AMS dating was previously made.

As indicated in the revised manuscript, the Villaviciosa and Pravia sites are incisions filled by fluvial-marine Holocene sediments, which complex sedimentology makes difficult to extrapolate ages from depths. The Meron site is formed by a punctual and well dated peat / clay deposit. As radiocarbon dating of each sample, depths data and the thickness of the horizons are irrelevant for the study. Therefore, depths have been removed from table 1, and indication of the material and the radiocarbon method utilised (conventional and AMS) are indicated instead.

Specific comments to referee #1:

BGD 5, 3946, 2008, line 12: We are not arguing that orbital variations are responsible of abrupt climate changes.

3946, line 25: Minimum values below 259 ppmv are reached in the Dome C ice core CO2 record from 8017 to 6713 yrs BP (Monnin et al., 2004), and below 261 ppmv from 7883 to 8147 yrs BP in the Taylor Dome CO2 record (Indermühle et al., 1999).

3947, lines 9-13: Correct. Rundgren and Beerling (1999) presented the Holocene stomata record discussed in the manuscript. The argued discrepancies in amplitude and magnitude between CO2 reconstructions from Njulla (leaves) and Dome C (ice-

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core) can be observed in Rundgren and Beerling (1999) and Monnin et al. (2004) raw data [high variability of the Njulla raw data and lower data coverage for the first half of the Holocene (17 points of the 115 data given)]. Our manuscript focuses in the Holocene Thermal Maximum which coincides with the lower represented part of the Njulla record, that shows ˜100 ppmv variability. Compared to this data, the Northern Iberian record shows less variability and, although is based on fewer data, clear trends. Please, see BGD 5, S2043-S2045, 2008 for discussion about the reliability of the reconstruction.

3951, lines 24-25: This sentence has been removed, as we agree that long term trends are poorly represented with our data set.

3952, lines 18-20: Taylor Dome records show a clear CO2 minimum at 7883-8147 yrs BP (Indermühle et al., 1999). A trend to higher CO2 values from 8017 years BP towards the present can be observed in the Dome C data set (Monnin et al., 2004). References have been added.

3952, lines 21-24: Reference has been modified to make clear that we base on Kouwenberg et al (2005) to consider ocean properties as major constituent to atmospheric CO2 changes.

3953, lines 3-4: W/m2 data have been corrected (-0.18W/m2 and +0.2W/m2 substitutes -0.06 and +0.06 respectively). There are no other radiative data given in the text. Temperature data (oC) given in the text are correct. The scale given in figure 3 for the Northern Hemisphere CO2 forcing [oC] has been corrected.

3954, line 16: As stated in the manuscript, we refer to Kaufman et al. (2004) to assert that broadly speaking, early Holocene warmth was driven by earth’s orbital variations. This is addressed in the revised manuscript for clarification.

3954, line 25: Relative non-variability has been addressed in the revised manuscript to make clear that there is no Holocene stability in the ice core CO2 records.

Table 1. In the Universal Transverse Mercator coordinate system, the Earth is divided into zones. These are needed to be given to indicate a specific location.

Table 1. As already mentioned, depths date are not relevant for the work. Samples were taken in the Pravia site by collecting block sediment extracted from road works with a 2 m diameter Œ 5 to 1 m length corer. Higher accuracy for depths is not available.

Technical corrections have been taken into account in the revised manuscript.

Comments to referee #2:

As stated above, the main argument of the paper is the connection to the Holocene Thermal Maximum rather than divergences between ice-cores and stomatal CO2 reconstructions. Therefore, although Antarctic ice-cores records are utilised to compare with our results, less stress is put on such differences in the revised manuscript.

According to the general comments given above, despite the scarcity of the data, four observations from ˜9500 yrs BP to ˜6000 yrs BP, one for ˜5860 yrs BP and four from ˜5800 yrs BP to ˜1100 yrs BP, show increasing CO2 values for the first half of the Holocene, high CO2 values for the Mid Holocene (7000-5000 cal yr BP), and a CO2 drawdown for the last half of the Holocene. We agree to the reviewer #2 comments that our record does not show continuous CO2 records for the Holocene, and that the CO2 decline starts at about 6000 yrs BP rather than at 5000 yrs BP. In view of that, manuscript has been revised.

Based on our records, we can stress that the first part of the data set is comparable to the Antarctic CO2 records, whereas a divergence is observed from the later part of the Holocene. The fact that CO2 base level from stomata records is higher than ice core data, in our opinion, does not question the reliability of the normalised stomatal CO2 reconstructions (see Biogeoscience Discuss. 5, S2043-S2045, 2008).

The sudden increase of CO2 captured by our reconstruction from 4110 to 3950 cal yr BP, is not only observed in our data set. Large scale variations during the Holocene, including ˜4000 cal yr BP shift, is observed in a wide variety of Holocene records [e.g. thermohaline circulation, ice core proxies; pollen based temperature reconstructions (Arz et al., 2001; Meese et al., 1994; Bond et al., 1997; Davis et al., 2003; Mayewski et al., 2004)]. Although ocean circulation and terrestrial biosphere have been suggested as the most probable drivers of observed CO2 changes (BGD 5, 3952, 2008, lines 13-14), as stated above, explanation for this is out of the scope of this manuscript.

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