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Climate of the Past Discussions

Interactive comment on "Sensitivity of a leaf gas-exchange model for estimating paleoatmospheric CO_2 concentration" *by* Dana L. Royer et al.

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The authors present a sensitivity analysis of a mechanistic model (Franks model) to predict paleoatmospheric CO2. They explore several specific areas; the effect of gc(op)/gc(max), A0, temperature, photorespiration and leaf canopy position on the accuracy of CO2 estimates produced by the model. In doing so, the paper adds clarity, certainty or recommendations to the model for fossil application, all of which are important additions, especially as this model is being using in a growing number of research projects. Although the paper is an important contribution, it would benefit from clarity or expansion in certain areas: 1) Aims, methods and appendix: The aims and meth-

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ods section is hard to follow. This may be due to the fact the aims and rationale are mixed in with the methods. It is unclear from the text or appendix data whether all or a subset of the data is being used for each of the analysis performed. A summarised table in the methods section containing the information on the analysis being performed, data source and parameters used or tested would be beneficial (i.e. a summary of the methods in tabular format). Similarly, in the appendix, additional information on the origin of the data, sample number per species, which data points/values are measured vs estimated/assumed and a direct comparison of measured vs model estimated CO2 would greatly improve clarity.

2) Statistical analysis: Accuracy was evaluated by the degree of error rate. These claims can be strengthened by using statistical analysis. How well the model predicts CO2 could be assessed by whether or not the estimates are statistically significant different (or hopefully not) from measured CO2 values.

3) gc(op)/gc(max) and A0 (section 3.1): This section gives details about when both gc(op)/gc(max) and A0 values are either known or values from Franks et al. 2014 are used, but it would be nice to see these two parameters evaluated separately i.e. how much does gc(op)/gc(max) alone improve estimates and the same for A0. Does one contribute more than the other for improving error rates?

Additional comments: Line 86. Sensitivity saturates for some but not all taxa. See Haworth et al 2011. Line 93. A Nearest living relative or equivalent approach also get around the issue of extinct taxa. Line 156. Alternative approaches for fossils have been suggested such as estimating fossil A0 using scaling relationships between vein distance and assimilation rate however they are not discussed here (EG Montanez et al., 2016). Introduction – general comment. Critical published assessments of the Franks model are not cited (eg McElwain et al. 2016) yet they raise issues associated with parametrization of A0 and the insensitivity of CO2 estimates to variation in gamma star values which are both important discussion points in this manuscript in lines 454 -456 and 497-499. Paragraph 201-217: A some information is missing here:

chamber model/make, duration plants were grown in the chamber, light levels. What were measured vs set chamber conditions for temperature, light and CO2 (i.e. similar to how humidity is reported) Lines 232: Stomatal density/stomatal measurements and leaf stable carbon isotopes were performed on the same leaves. Clarify how this was partitioned, e.g. was the leaf divided into 2 or was a whole punch used for carbon isotopes, etc.? Lines 235: As Milligan et al is in review, I suggest adding more detail here on how δ13Ca of chamber CO2 was calculated. δ13Ca values of supplemented CO2 can be very negative and can vary between cylinders, unless the CO2 gas has a specific δ13Ca. What is the capacity of these cylinder, in L? Figure 1: Does this need to be on a log scale? 1000 or 2000ppm are not very high values and the log scale visually skews data and error bars. A difference plot between measured and estimates plotted on a non-log scale would improve this figure. Line 351: Please provide supporting data for this statement in tabular form. What are the error rates of other proxies? Line 355: Might be helpful to report standard deviation of CO2 estimates, here and throughout the text. Line 411 to 413. Reporting of the difference between estimated and measured CO2 here is incomplete. Only means of all species investigated are provided rather than species-based diffeences or errors. For some species the error is substantial whereas other taxa show very small errors. Line 454 to 456. This supports the findings of McElwain et al 2016 Paleo 3 but it is not cited. “This compensation point (ΓâĄŐ in Eq. (2) is temperature, species and O2 dependent (Ethier and Livingston, 2004) but Franks et al. (2014) account only for the temperature dependency in the new paleo-CO2 proxy model. Allowing ΓâĄŐ to vary in response to prevailing paleoatmospheric O2 concentration [O2] (ΓâĄŐ = 1.78 $\times$ [O2]), which is known to have varied widely (10% to 30%) through the Phanerozoic (Bergman et al., 2004; Belcher and McElwain, 2008; Berner, 2009),would increase the precision of paleo-CO2 estimates but only fractionally.”

Lines 500 to 506. A number of papers have suggested methods of estimating A0 to improve the accuracy of CO2 estimates using the Franks model but they are not discussed. This section would provide a good opportunity to discuss the proposed

ideas and solutions.

Section 3.4: Have any values for δ13Ca been measured or are all calculated for this section? Is there any data set (from the literature or otherwise) this could be compared to? i.e. a dataset where known δ13Ca is compared to itself when calculated as per the manuscript? This would strengthen this section. If δ13Ca has only been calculated/inferred for this section without a comparison to measured δ13Ca I think claims on the effect of δ13Ca (or low canopy plants) on the model should be softened. Appendix: The authors used both known and general values for gc(op)/gc(max) and A0 to evaluate error rates but no measured values of either gc(op)/gc(max) or A0 are given in the appendix or text.

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