Clim. Past Discuss.,
https://doi.org/10.5194/cp-2018-60-RC3, 2018
© Author(s) 2018. This work is distributed under
the Creative Commons Attribution 4.0 License.

Climate of the Past Discussions



# *Interactive comment on* "The role of elevated atmospheric $CO_2$ and increased fire in Arctic amplification of temperature during the Early to mid-Pliocene" *by* Tamara Fletcher et al.

**D. Royer (Referee)**

droyer@wesleyan.edu

Received and published: 15 July 2018

Fletcher and colleagues present a Pliocene high arctic record of CO2, temperature, plant species composition, and inferred fire frequency. They then explore how these components may be interconnected. The study summarizes an impressive amount of data. My expertise lies with paleo-CO2 reconstruction and so my review will focus on there.

1. CO2 reconstruction.

-Ben Fletcher developed a process-based model for paleo-CO2 reconstruction based



Printer-friendly version

Discussion paper

on the $\delta$13C of liverworts. I'm surprised that the authors have not tried to incorporate/modify this method for their own study. It's not even mentioned! Instead, the authors rely on a present-day empirical-based model, which is likely to be inferior to a process-based model. To give just one example, the authors note the problem of growth rates with other paleo-CO2 methods (p. 15, line 10). But growth rate is a key uncertainty with the authors' method, and something that is acknowledged and (partially) addressed in the Fletcher model. This is a key deficiency with the current manuscript.

Fletcher, B. J., Beerling, D. J., Royer, D. L., and Brentnall, S. J., 2005, Fossil brophytes as recorders of ancient CO2 levels: Experimental evidence and a Cretaceous case study: Global Biogeochemical Cycles, v. 19, p. GB3012, doi:3010.1029/2005GB002495.

Fletcher, B. J., Brentnall, S. J., Quick, W. P., and Beerling, D. J., 2006, BRYOCARB: A process-based model of thallose liverwort carbon isotope fractionation in response to CO2, O2, light and temperature: Geochimica et Cosmochimica Acta, v. 70, p. 5676-5691.

-Using leaf $\delta$13C to reconstruct air $\delta$13C is problematic because many factorsâĂŤfor example water stressâĂŤcan affect leaf $\delta$13C. The authors are assuming no change in water stress (and other factors that could affect leaf $\delta$13C) between the present-day and Pliocene. Given what is said in section 4.3, this assumption is tenuous.

Diefendorf, A. F., Mueller, K. E., Wing, S. L., Koch, P. L., and Freeman, K. H., 2010, Global patterns in leaf 13C discrimination and implications for studies of past and future climate: Proceedings of the National Academy of Sciences, USA, v. 107, p. 5738-5743.

Kohn, M. J., 2010, Carbon isotope compositions of terrestrial C3 plants as indicators of (paleo)ecology and (paleo)climate: Proceedings of the National Academy of Sciences, USA, v. 107, p. 19691-19695.

-The empirical transfer function (Figure 3) maxes out at 360 ppm. The authors use the function to reconstruct ~450 ppm. This is a problem with extrapolation.

-The empirical transfer function is based on a mix of species. Some of the scatter is likely due to "vital effects". This needs to be acknowledged. The best transfer function would be one based on the same species (or genus) as the fossil material.

-The authors have underestimated the uncertainty associated with their paleo-CO2 reconstructions. As best as I can tell, their stated uncertainty (1ïĄş = 35 ppm) is the confidence interval from Figure 3 (dashed lines). A confidence interval says how confident one is in the regression. But if one wishes to infer the y-axis value from a new single data point (as is being done here), the prediction interval is appropriate. And the prediction interval is wider than the confidence interval. In addition, the authors have not propagated uncertainty associated with the measurement(s) of leaf $\delta$13C at each level; the authors are assuming no error. Beerling et al. (2009) lays out a solid strategy for propagating uncertainty with these kind of empirical functions.

Beerling, D. J., Fox, A., and Anderson, C. W., 2009, Quantitative uncertainty analyses of ancient atmospheric CO2 estimates from fossil leaves: American Journal of Science, v. 309, p. 775-787.

-The authors deal with the confounding factor of water stress in the Discussion, but this section should move to the Introduction. Otherwise, the informed reader will be wondering why the authors haven't dealt with the issue while they are reading the Intro, Methods, and Results.

2. CO2 compilation.

-The B/Ca estimates should be excluded as they are not reliable.

Allen, K. A., and Hönisch, B., 2012, The planktic foraminiferal B/Ca proxy for seawater carbonate chemistry: a critical evaluation: Earth and Planetary Science Letters, v. 345–348, p. 203-211.

-It looks like some Pliocene estimates have been missed. See Foster et al. (2017) for compilation and citations.

Badger, M. P. S., Schmidt, D. N., Mackensen, A., and Pancost, R. D., 2013b, High-resolution alkenone palaeobarometry indicates relatively stable pCO2 during the Pliocene (3.3–2.8âĂĽMa): Philosophical Transactions of the Royal Society A, v. 371, 20130094.

Bartoli, G., Hönisch, B., and Zeebe, R.E., 2011, Atmospheric CO2 decline during the Pliocene intensification of Northern Hemisphere glaciations: Paleoceanography, v. 26, PA4213, doi:10.1029/2010PA002055.

Foster, G. L., Royer, D. L., and Lunt, D. J., 2017, Future climate forcing potentially without precedent in the last 420 million years: Nature Communications, v. 8, p. 14845, doi:14810.11038/ncomms14845.

Martínez-Botí, M. A., Foster, G. L., Chalk, T. B., Rohling, E. J., Sexton, P. F., Lunt, D. J., Pancost, R. D., Badger, M. P. S., and Schmidt, D. N., 2015, Plio-Pleistocene climate sensitivity evaluated using high-resolution CO2 records: Nature, v. 518, p. 49-54.

Seki, O., Foster, G.L., Schmidt, D.N., Mackensen, A., Kawamura, K., and Pancost, R.D., 2010, Alkenone and boron-based Pliocene pCO2 records: Earth and Planetary Science Letters, v. 292, p. 201-211.

Stap, L. B., de Boer, B., Ziegler, M., Bintanja, R., Lourens, L. J., and van de Wal, R. S. W., 2016, CO2 over the past 5 million years: continuous simulation and new $\delta$11B-based proxy data: Earth and Planetary Science Letters, v. 439, p. 1-10.

Zhang, Y. G., Pagani, M., Liu, Z., Bohaty, S. M., and DeConto, R., 2013, A 40-million-year history of atmospheric CO2: Philosophical Transactions of the Royal Society A, v. 371, 20130096.

3. Temperature component.





CC BY

-The temperature record feels like a "third wheel" to the CO2 and fire records. In the discussion, other temperature records (often from the same site) are emphasized more than the record generated here.

4. Link between fire and climate.

-Quite a lot of space in the Discussion is devoted to how fire and climate are interconnected. And the bulk of this discussion centers on the literature. But, the record generated here shows no obvious link between fire and CO2 or temperature (Figure 4). As a result, there is a logical disconnect. For example, from the Introduction (p. 2, lines 30-31): "We propose that fire in arctic ecosystems may also be an important proximal mechanism for amplifying arctic surface temperatures during the Pliocene."

Minor comments:

p. 3, line 15: B/Ca (not "Boron")

p. 3, line 19: Foster et al. (2017, Nature Communications) is a more current reference

p. 3, line 24: what do you mean by "Although direct effects may be small"?

p. 4, lines 14-16: "The unit sampled spanned the 1 m remaining of Unit III as per Mitchell et al. (2016). The main sequence examined across the methods used in this study includes material above (Unit IV) and below (Unit II) Unit III, with a total sampled profile of 1.65 m." Parts of these sentences are confusing: 'unit' appears to have a different meaning as 'Unit'; what does '1 m remaining of Unit III' mean? (is most of the originally sampled material gone?); the first sentence implies that all of the data come from Unit III, but the second sentence says that some of Units II and IV are included too.

p. 6, line 31: "We also measured $\delta$13C of modern buckbean to constrain our estimates of pi / pa." More context is needed so that the reader can understand this statement. Why do the pi/pa estimates need to be 'constrained', and why do present-day measurements allow you to do this?





CC BY

p. 6, line 32: say that cellulose was measured (ditto in line 31).

p. 7, line 11: "paleosols"

p. 7, lines 30-32: Provide a citation for the transfer function. Is the combined error a one-sigma error? Two-sigma? Was quadrature used to calculate the combined error?

p. 8, line 19: "MAT"?

p. 9, lines 17-18: What is the difference between a maximum probability age and an optimized age?

p. 9, line 22: Unweighted mean age already stated.

p. 9, line 23: How was this uncertainty computed?

p. 9, lines 28-30: The first and second parts of this sentence are saying the same thing.

p. 9, lines 30-31: I don't understand why nonlinearity is expected because Figure 3 plots the log of carbon isotope discrimination (also, see next sentence in the manuscript).

p. 10, line 2: These "other processes" don't need to be nonlinear; the combined additive effect is nonlinear.

p. 10, lines 9-12: It is inappropriate to use the site-specific regression because the associated site-specific information is not available for the Pliocene samples.

p. 10, line 11: Is this the same model as in line 1?

p. 15, line 23: "over the Pliocene". Surely you don't mean the entire Pliocene?

p. 19, lines 30-31: "fire played an active role in. . .influencing the climate of the Arctic during the Pliocene." That's not what your data suggest (Figure 4).

Figure 3: Please add the theoretical regression (from equations 2 & 3). Add linear





CC BY

y-axis tick marks too. In the caption, say that the isotopic discrimination is based on cellulose (or an inferred cellulose value).

Figure 4: unit needed for x-axis.

Figure S2: Plots need axis labels

Figure S3: Axis and tick mark labels are too pixelated to read

---

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2018-60, 2018.





Printer-friendly version

Discussion paper