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Climate of the Past Discussions

Interactive comment on "Mammal faunal response to the Paleogene hyperthermals ETM2 and H2" *by* A. E. Chew

M. Huber

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Dear Dr Chew,

Let me expand a bit on the previous point and try to answer your question. There are several points where your assumptions/estimates differ from the likely true value and these differences add up to a large final discrepancy. The key points are (a) the late Paleocene/early Eocene and PETM in the wyoming region were probably about 5C warmer than in your paper's interpretation; (b) these regional temperatures are associated with a warmer global mean than assumed; (c)the assumed equilibration time (300 years) is a factor of 5-10x too fast.

(a) is open to some debate–see lengthy back and forth in the Discussion of the

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Huber and Caballero 2011 article (http://www.clim-past-discuss.net/7/241/2011/cpd-7-241-2011-discussion.html). If you believe as I, and many others, do that the older calibrations/reconstructions were biased to too cold values, then temps that are 3-5C warmer than previously reported should be used. I don't think this is a huge issue, but it does change things a bit. If background latest paleocene/early Eocene temps in the wyoming region are in the 20C or higher range (see huber and caballero, 2011 table and also more recent data, included clumped isotope results–taken with grains of salt) and PETM temps were warmer than that, let's say 25°C in the region.

(b) is more clear and better constrained. Even to get temps in the region in the ball-park of 20C in wyoming requires a global mean temperature of ∼29.5C or let's say 15C warmer than preindustrial (Figure 3a in H&C 2011). This is not a particularly model dependent parameter (similar relationships could be found in Lunt et al., 2012 (doi:10.5194/cp-8-1717-2012, 2012). PETM global mean temperature would be 5C warmer than that (i.e. ∼35C). Even assuming ignoring transient behavior and using equilibrium climate sensitivity (i.e. allowing for all the possible warming to happen) of say 3C per doubling (a typical value) this would require 5 Doublings (8960 ppmv CO2) from preindustrial to get to the late Paleocene and 6 Doublings (16000ppmv CO2). That's way more carbon than the standard 5000GT–>2100ppmv CO2 typical arguments would allow.

So hopefully, by this point I hope it's clear that by my math (based on a lot of modeling and model-data comparison) the pre/post-PETM was 13+-2.6C (See Caballero and Huber, 2013) warmer than preindustrial and the PETM was therefore ∼16-20C warmer. My understanding is that the estimate in the paper in question is that the PETM global mean is 12C warmer than preindustrial. This is probably a better estimate of mid-to-late Eocene temperatures (Liu et al., 2009). One could certainly dispute these numbers, it would be an interesting exercise, but it is not clear to me what the basis for such an argument would be.

(c)is simply an easy to correct misunderstanding of the time scales of ocean equili-

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bration and the approach to surface temperature equilibrium in the modern climate change situation. One can not take the temperature trend from models of the next century and extrapolate them to final equilibrium. This ignores the physics of ocean heat uptake, which introduces lags of various time scales. The uppermost ocean warms rather quickly and hence there's a brief leap in temperatures in response to emissions (this leads to the strong trends that were used to extrapolate warm equilibrium temperatures). But, then the mixing with the deep ocean kicks and there is a long, slow , tedious approach to equilibrium with a much shallower slope. I refer to these two papers (http://journals.ametsoc.org/doi/pdf/10.1175/2008JCLI2596.1 http://journals.ametsoc.org/doi/pdf/10.1175/1520-0442(2004)017%3C0209%3ATSOCR%3E2.0.CO%3B2) for an idea of what that looks like. For a strong warming, 70% of the equilibrium value is approached only after >1500 years (but 40% of the warming occurs within ∼100 years). There is slop in those numbers due to sensitivity to ocean mixing rates and magnitude of imposed warming, but generally speaking a complete response to a large warming takes 2-5000 years.

Probably the most relevant prediction and closest in spirit to what has been covered in the Discussion is the results of Eby et al 2009 Figure 9 (top) http://journals.ametsoc.org/doi/pdf/10.1175/2008JCLI2554.1 . Pay attention to the dotted lines, which represent the A2-equivalent scenario. Choosing the largest imaginable release of ∼5000GtC, 7C of warming has happened by year 300 and 8C at peak in year ∼1-2000. The absolute value of these numbers will be a bit different depending on a model's value of climate sensitivity (the UVIC model used in the Eby study has a equilibrium climate sensitivity of 3.5 C per doubling, which is pretty high).

So, to sum up. Based on processes that are pretty well established, if we burn up all the readily available carbon for the next three hundred years (approximately how long it takes to burn that carbon) temperatures would still only be about 7C warmer than preindustrial. Only half the way to the early Eocene. Actually it would look a lot like the Miocene climatic optimum (Goldner et al., 2014, http://www.clim-

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past.net/10/523/2014/cp-10-523-2014.html), not the PETM. I'm choosing middle-of-the-road numbers here–there is some wiggle room.

How might my estimate be wrong? If my estimate of the Eocene global mean relative to today is off seriously. If climate sensitivity is at the really high end or is very sensitive to temperature itself. Or if there are surprises in the carbon system that inject an extra 5000GtC pulse in the near future. Or all three. To sketch that out a bit.... If the PETM were really only 12C warmer than today, if climate sensitivity were 4, and the total carbon burn was more like 7000 GtC then maybe we're in screaming range a match, but even then it would only be beyond 1000 years in the future (see Figure 9 in Eby again, for the pulse case). In other words, that's a lot of ifs. It may be better to back off that line of argument.

Interactive comment on Clim. Past Discuss., 11, 1371, 2015.