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Climate of the Past Discussions

Interactive comment on "Estimate of climate sensitivity from carbonate microfossils dated near the Eocene-Oligocene global cooling" *by* M. W. Asten

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Note: this comment was prepared jointly by Paul N. Pearson (Cardiff University), Gavin L. Foster (University of Southampton) and Bridget S. Wade (Leeds University).

We do not accept the validity of this estimate of equilibrium carbon dioxide climate sensitivity which was derived by Asten (in review) using our pCO2 reconstruction from boron isotopes across the Eocene-Oligocene transition (Pearson, Foster and Wade, 2009).

Estimating the long-term ('equilibrium') climate sensitivity to CO2 from geological data minimally requires making the assumption that CO2 is responsible for forcing the system and that all other significant factors can be regarded as feedbacks on that forcing. It also requires accurate and precisely correlated estimates of pCO2 and global mean surface temperature. This study fails to meet these criteria.

The geological record may provide some examples where large and abrupt natural releases of CO2 over short time intervals produced a transient climate response which permits us to estimate the climate sensitivity for that specific time in Earth history that is also relevant for the future. However the Eocene – Oligocene transition and its aftermath was anything but a simple transient perturbation: it was, instead, a highly complex interval of stepped change in the Earth system that involved the development of a continental-scale Antarctic ice sheet; major sea level drop by $\sim$50 m; reduction in the area of epicontinental seas and seaways; changes in local temperatures, seasonality and aridity; global carbon cycle perturbations; significant pulses of extinction at sea and on land; and the development of new biomes especially in high to mid-latitude terrestrial vegetation. Also possibly occurring through the same interval was a strengthening of current flow through the Tasman gateway that was opening between Australia and Antarctica which potentially affected global heat transport pathways. Most explanations for these complex events invoke some sort of threshold system response, perhaps triggered by CO2 decline and orbital parameters favouring ice growth in the south. But as events unfolded, many factors in addition to CO2 forcing likely influenced global temperatures especially through albedo-related effects. Some of the models predict a transient increase of CO2 after the ice sheet was formed. As discussed in our paper, our record is broadly in agreement with this state of current understanding although the timing of some features remain difficult to explain.

But even if we were to accept Asten's approach, the early Oligocene CO2 and temperature reconstructions are wholly inadequate for the task. Whilst we acknowledge the uncertainty in the boron based CO2 reconstruction is reduced when relative changes are examined, at 95% confidence (largely determined by the uncertainty of our boron isotope measurement) the difference in CO2 (delta-pCO2) between the rebound and the surrounding values (using the data tabulated in our Figure 1) is from as little as 77 to as much as 638 ppm. It is not entirely clear how the uncertainty in climate sensitivity was calculated by Asten, but much of his discussion is based only on the 'central estimates' of pCO2 quoted in our paper and a 66% uncertainty. However, given the full range of CO2 (and ignoring the small quoted additional uncertainty in temperature), we calculate climate sensitivity from 0.6 to 5 K per CO2 doubling by following the method of calculation used in the paper (equation 6; see table R1). This larger range clearly overlaps with the majority of those estimates quoted in Asten's Table 2 and importantly is too poorly constrained to support the conclusions made there. (We emphasize that we are not proposing these values as a serious estimate of climate sensitivity for the reasons explained above.)

The temperature reconstructions in the manuscript represent just two deep water sites that would have responded to the temperature of their high latitude source regions and the local seawater oxygen isotope compositions: it is a long way from this to estimate global average surface temperature. This shortcoming can be illustrated with an example from the Mid-Piacenzian Warm Period, a more recent and much better studied period than that discussed here (e.g. see http://geology.er.usgs.gov/eespteam/prism/prism_background.html). In our Figure 2 (from Robinson et al., 2011; doi:10.1016/j.palaeo.2011.01.004) are a number of independent estimates of deep water temperature (bullet points, change relative to modern) for the period 3-3.3 Ma. Global temperature change for this period (relative to modern) is well constrained at around +3.3 K. This estimate is based on a global database of sea-surface and terrestrial proxies (http://geology.er.usgs.gov/eespteam/prism/prism_background.html) and a combined data/model approach (to essentially fill in the gaps between the data). Only one of the reconstructions above shows the relationship assumed by Asten (ODP 552; deep ocean temperature change = global ocean temperature change) and the majority exhibit a much reduced change, and even change in the opposite sense (e.g. ODP 1092). Alternative methods to reconstruct bottom water temperature in the MPWP exist that rely on multiple stacked δ18O records, yet these also show deep ocean T change much less than global T change (e.g. Miller et al., 2012; 0.5 K vs. 3.3 K). A further consideration is that in Asten's paper, both the temperature and pCO2 reconstructions (especially the latter) are at very low resolution relative to the high frequency orbital climate variability of the early Oligocene, and their inter-correlation on those timescales is fundamentally uncertain. None of these data shortcomings are factored into the calculated errors.

In short, while the Eocene – Oligocene transition and its aftermath is an interesting period for studying CO2 and global change, the interval chosen is unusually complex and currently far too under-constrained to make a meaningful estimate of climate sensitivity.

Interactive comment on Clim. Past Discuss., 8, 4923, 2012.

Table R1. Recalculation of ‘Climate Sensitivity’ at 95% confidence

	ΔT_{global}	pCO_2 high	pCO_2 baseline	ΔpCO_2	CS[a]
Min CO_2 change	0.59	959	882	77	4.9
Mid CO_2 change	0.59	1132	775	358	1.1
Max CO_2 change	0.59	1305	667	638	0.6

[a] Climate sensitivity’ is the temperature change (K) for a doubling of CO_2, calculated here using equation 6 of Asten. This is just an exercise, not a serious estimate (see text).

Fig. 1.

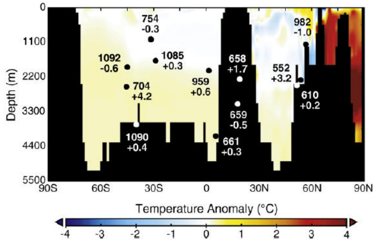

Figure 2: Modelled mean annual deep ocean temperature anomaly (Pliocene relative to modern) at 17 °W (coloured background) and PRISM3D proxy-based bottom water temperature anomaly (Pliocene relative to modern) in the Atlantic Ocean (bullet points). From Robinson et al., 2011, Bathymetric controls on Pliocene North Atlantic and Arctic sea surface temperature and deepwater production, *Palaeogeography, Palaeoclimatology, Palaeoecology*, **309** (1-2), 92-97)

Fig. 2.