Climate of the Past Discussions

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Reply on RC2

Heidi E. O'Hora et al.

Author comment on "Clumped-isotope-derived climate trends leading up to the end-Cretaceous mass extinction in northwestern Europe" by Heidi E. O'Hora et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-104-AC4, 2022

We are sorry to hear about your health struggles and appreciate you getting around to our review in the end.

Q: what are the true effects of this warming? It is very short, basically a blip with a duration of no more than 100kyr, because the samples at ~66.3 Ma are indistinguishable from background. In fact, it is possible it is much shorter than 100kyr because of the limits of the sampling resolution here. However, what I see in the data is a longer-term _cooling_ from 66.37 to 66.07 Ma. In fact, this is the most significant secular signal in the data – what does this mean? It's of the right timescale to be the predicted pCO_2/temperature decrease due to continental weathering following the emplacement of the Deccan traps (e.g., Desert et al 2001, 2003). I think the authors should highlight this!

A: We appreciate this suggestion and will mention of silicate weathering feedbacks and timescales, with some of the citations you mention. However, the secular trend you picked up on does not hold up so well with the addition of a few additional samples analysed recently as part of this revision. In particular, in the Meerssen Member we previously only had one sample which was particularly cold and set a lot of the cooling trend you described. Now we have a second sample from that horizon which is closer to the "baseline" temperature of ~20C, so the sustained cooling trend has largely disappeared. It remains the case, however, that the clear warming shortly after the Deccan Traps onset is gone after ~100kyr or less, and this finding has only become stronger with the addition of more data points.

Q: There are always questions of timescale, so just so it's clear (and I probably missed it), but has the ejecta horizon/dust/Ir level etc. been positively identified in these N. European sections?

A: While an ejecta blanket was not preserved in the very shallow marine setting (i.e above fair weather wave base) of the type-Maastrichtian region, the K-Pg boundary is positively

identified (see Smit & Brinkhuis 1996; Vellekoop et al. 2020, https://doi.org/10.1111/pala.12462). The typical planktonic foraminiferal 'disaster' assemblage (Smit & Zachariasse 1996), the presence of the earliest Paleocene dinocyst marker taxon Senoniasphaera inornata (see Brinkhuis & Schiøler 1996; Herngreen et al. 1998) and 87Sr/86Sr analyses of well-preserved foraminifera from the clay layers of the Geulhemmerberg underground galleries (Vonhof & Smit 1996) have all demonstrated that the K-Pg boundary occurs at the base of uning IVf-7 of the Meerssen Member, at the base of a sequence of shell hashes and clay layers.

Q: Can we be certain that the horizons identified as coincident with the initial phase of volcanism are indeed correctly correlated? Bulk C-isotope data (Line 191) does not instill a lot of confidence…

A: The identification of the Deccan Traps interval is not only based on bulk d13C data. As highlighted in Vellekoop et al. 2022 (Newsletters on Stratigraphy), the age model for this succession is based on a combination of biostratigraphic markers (ammonites, belemnites, dinocyst) and the isotope record. Moreover, the presence of the acme of the dinocyst marker taxon Palynodium grallator, a marker for the LMWE (Vellekoop et al,. 2019, https://doi.org/10.5194/bg-16-4201-2019) in the type-Maastrichtian record (Schioler et al., 1997) is clear evidence for this phase of Deccan Traps volcanism.

Q: If I were to be critical of one point of this paper, it is the confidence with which the correlation is made between marine sections in Europe and the terrestrial record of Deccan volcanism that relies mostly on radiometric ages from India. This should be expanded upon and the tie points made more explicit (is the age model published?).

A: We do not completely follow the argumentation of the reviewer here. Radiometric dating places the large outpouring phases of the Thakaurvadi to Puladpur lava deposits in the time interval between 66.3 and 66.05 Ma (e.g. Schoene et al. 2019, Science). At this point, it is well established that the Late Maastrichtian Warming Event is related to these Deccan outpouring phases, for example also highlighted in the recent paper by Nava et al. in PNAS (https://doi.org/10.1073/pnas.2007797118). Hence, no direct correlation with any terrestrial records in India is required. The age-model for type Maastrichtian (based on a combination of biostratigraphy and chemostratigraphy described above) clearly indicates that the Nekum & Meerssen members fall within the LMWE interval. There is even a specific marker for this warming event present in these records. We hope any concerns considering the age model of the type-Maastrichtian record are waylayed by the publication of the new age model for this section by Vellekoop et al (2022).

To be more transparent about the uncertainty in our age estimates and correlation, we have added uncertainty in the age model as a horizontal error bar in Figure 5 (Temp vs. Age), as well as uncertainty in the onset of Deccan volcanism (grey shading). The onset of Deccan volcanism here is pinpointed as the oldest date coming from Deccan lavas (Sprain et al., 2019).

Q: Can you add the timing (duration?) of Deccan volcanism to Fig. 5? I need some frame of reference for where I should be looking for the increase in

temperature. The line at 66.4 is helpful but what is the duration?

A: We have thickened the bar showing the onset, now with error. This point is defined by the oldest dated volcanic rock from India (Sprain et al 2019). In terms of when to expect warming…CO2 driven warming does not happen instantaneously, and the CO2 addition would be expected to continue (perhaps nonlinearly) throughout the full period of eruptions, which extend well past the KPB.

Q: It may just be my general skepticism of absolute sea level estimates in ancient rocks, but can the authors expand upon the goals of the sea level reconstruction here? To what end?

A: This is a sea level reconstruction from another paper (Schioler 1997). We put it here as a possible explanation for our co-evolving temperature and d18Osw records. We propose that changes in sea level correlate with our study site experiencing differing water masses due to the paleogeography.