Response to “Review CP-2019-88 Honegger et al.”

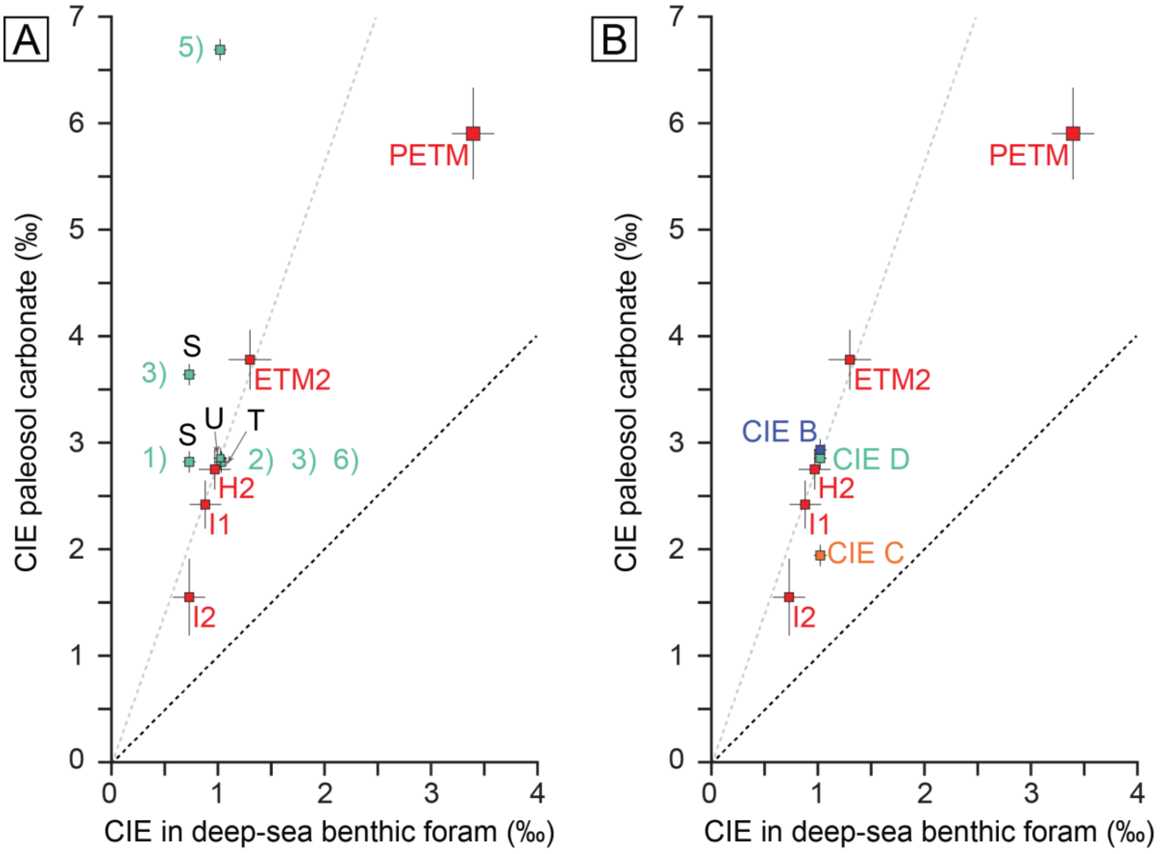
Louis Honegger et al.

In this response, the original comments are in black and responses by the authors to the reviews are written in blue. Changes in the manuscript are written in red.

We thank the reviewer for his work on and appreciation of our study. We greatly value his expertise and views on our study because his work provided some of the motivation for the research questions we are currently pursuing. We answer below point by point to each item raised.

> The only concern is the scaling of the U labeled hyperthermal in the deep sea and the CIE D in the carbonate nodules of the Chiriveta record. How do the events labeled B and C plot in Figure S2? However, the overall pattern in the carbon isotope records of marine and the Chiriveta record match well reinforcing the age model preferred.

Below, please find the modified figure incorporating in inset B, CIE B, C and D plotted regarding the CIE amplitude in soil nodules and in deep-sea into what is now Figure S3 (previously Fig. S2). CIE C is off trend, but both CIE D and B plot in the trend of I1, I2, H2 and ETM2. We favor CIE D as correlative to hyperthermal U because it is the only CIE in our record with a magnitude larger than 2 standard deviation.



The section 5.4 Preservation potential of hyperthermals in continental sections is informing but a bit out of context. It is clear to the community that higher sedimentation rates allow a more detail insight. This section, if kept in the manuscript, also needs to discuss that sedimentation is not uniform (steady) in terrestrial records but highly dynamic (50m away from the section things will look very different, see Bighorn Basin Project results where outcrops studies and drill cores allow a 3D view).

We agree with referee #1's comment that partially echoes similar comments from referee #2.

We will reorganize chapter 5.4 as follow:

Line 398:
"5.4 ***Possible implication for the*** *preservation potential of hyperthermals in continental deposits"*

Lines 399 to 406 were removed

Lines 406:
"Major events such as the PETM event have proven to be detectable in both marine and continental environments (e.g.; Abels et al., 2016; Koch et al., 1992), but the signal and preservation potential of smaller scale climatic events (e.g. hyperthermal events L to W in Lauretano et al., 2016), ***may be more difficult to detect*** *(Foreman and Straub, 2017****) because of the inherent highly dynamic nature of sedimentation in fluvial deposits****.* ***To address this issue in the present case study****, we calculated the compensation time scale (Tc)* ***of the Castissent Fm****."*

Lines 419 to 424 were removed

Line 424:
"Using an average sedimentation rate of 0.17 ***mm/yr and an average channel depth of 3.75m,*** *we obtained a mean Tc of 22,000 yrs****, which means that*** *hyperthermal events of 40 kyrs* ***duration (time-scale of hyperthermal U and preceding CIE) have the potential to*** *be recorded* ***despite fluvial system dynamics****."*

Line 427:
*"****Our estimate of preservation potential assumes steady sedimentation rates throughout the section. But, sedimentation in terrestrial records is not uniform (steady) but rather highly variable, resulting in spatial and temporal changes in facies and deposition rates ranging from < 0.1 to 1-2 mm/yr (Bowen et al., 2015; Kraus et al., 2015; Marriott and Wright, 1993). However, mean accumulation rates give a reasonable estimate approximating more realistic (i.e., variable) sedimentation rates as observed in the Bighorn Basin (Bowen et al., 2015).***
Additionally, we analyse the vertical movement of the nearby structures to evaluate their potential influence on disrupting deposition at Chiriveta during Castissent times. The Chiriveta section was deposited near or at the axis of the Tremp-Graus basin (Nijman, 1998), which is bounded by the Bóixols thrust in the north and the Montsec thrust in the south (Marzo et al., 1988). The Tremp-Graus basin is transported as a piggy-back basin on the

Montsec thrust emerging at the time approximatively 4 km south of the studied section (Nijman, 1998). In the basin axis, subsidence is the highest with rates of 0.1 to 0.29 mm/yr (this study and Marzo et al., (1988)). Taking into account a vertical movement rate of the Montsec thrust of 0.03 to 0.1 mm/yr during the Castissent time-interval (based on a horizontal displacement of 7 km, a period of activity lasting 26 Ma and a thrust dip between 6° and 20° (Clevis et al., 2004; Farrell et al., 1987; Nijman, 1998; Whitchurch et al., 2011), we estimate that the vertical displacement is no more than equal to sedimentation rates in the basin axis. This is consistent with the general absence of growth strata in the basin axis, although growth strata can indeed be observed closer to the Montsec (Nijman, 1998).
The rates of accumulation, distance to the main structures, and characteristic compensation time scale, together suggest that hyperthermal events of ca. 40 kys duration can be recorded in the Castissent Fm. These results confirm that, despite its highly dynamic nature, fluvial sedimentation may contain valuable record of high-frequency events, even in active tectonic contexts."

Lines 448 to 458 were removed

Abstract Line 23 – Hyperthermal cannot be "potential analogues, in the geological record, to the ongoing anthropogenic modification of global climate". Background conditions 50+ million years ago were much different. But the events can help to test the assumptions made by climate models and revise them for a better understanding of the climate system dynamics.

Thanks. Comparing the geological past with the current situation is often done, but we agree that the analogy has limitations and that the genuine value of investigating hyperthermals must be more clearly exposed. Inspire by the referee's wording of it, we thus propose to change this sentence in the abstract to:
*Line 24: "****Documenting*** *how the Earth system responded to rapid* ***climatic shifts during hyperthermals provides*** *fundamental* ***information to constrain climatic models.***"

Line 44-45: remove "towards icehouse conditions eventually reached later in the Cenozoic"

Removed.

Line 48: "Turner et al., 2014" change to Kirtland-Turner et al. 2014 in the entire text

Done

Line 51: "e.g., Westerhold et al., 2018"; add Lourens et al. 2005, Sexton et al. 2011, Kirtland-Turner et al. 2014, Lauretano et al. 2015, 2016. They published the records used.

Modified

Line 52: "Early Thermal Maximum (ETM) 2, H2, I1, I2, and ETM3/X events"– correct to Eocene Thermal Maximum. Change the wording of the sentence to clarify the nomenclature (ETM is only for 1, 2, 3; H1 H2 etc. are from Cramer et al. 2003 revised by Lauretano: : :, Sexton et al. 2011 suggested the relative to magnetochron scheme, see Westerhold et al.). In Figure 1 the text refers to this, please streamline the manuscript text accordingly.

*The sentence was modified accordingly: "**Eocene** Thermal Maximum (ETM) 2 **and 3**, H2, I1 and I2 events.*
Figure 1 was modified with the naming schemes of Cramer et al., (2003), Lauretano et al., (2016) and Westerhold et al., (2017).
The last sentence of chapter 2 was modified to:

*Line 140: "…this period was marked by 4 hyperthermals labelled S**/C22rH3**, T**/C22rH4**, U**/C22rH5** and V**/C22nH1** (**Cramer et al., 2003**; Lauretano et al., 2016; Westerhold et al., 2017)."*

Line 54: "In the stratigraphic record, these events are primarily characterized by important negative carbon isotope excursions (NCIEs)" – rephrase!, they are characterized by a paired negative excursion in carbon and oxygen isotope data; do not use NCIE throughout as it confuses with the commonly used CIE (Carbon Isotope Excursion) abbreviation for the e.g. PETM.

The sentence will be rephrased as suggested and all NCIE in the text will be modified to "CIE".

Line 150: please specify the target material of the X-ray tubes (Mo, Rh?).

The target material of the X-ray tubes is Cu. This information was added in chapter 3.3 Majors and trace element composition.
*Line 179: "…using a PANalytical PW2400 XRF spectrometer **with copper tube (Cu)** at the University of Lausanne…"*

Line 180: provide tie-points to ODP 1263 as a table in the supplement and add the age to your data tables of isotope as well as XRF results.

Tie-points have been added in the new Table S3. Age have been added in the Table S2

One important thing would be to show images of the soil nodules from the Chiriveta record in the supplement.

Images of the soil nodules have been added as well as an image of the iron oxides nodules mentioned at line 374 (Figure S1).

Several typographical corrections, sentence reformulations and minor precisions have as well been implemented in this second version of the manuscript. Below are listed the majors ones.

Line 250:

A sub-chapter ***5.1.1 Identifying the CIE*** *was added.*

Line 251:

*"In continental successions, the carbon isotope composition of pedogenic carbonate nodules—which consists of calcareous concretions between 1 mm and 4 cm diameter formed in situ in the floodplain—****have been shown to be sensitive to environmental conditions during their formation (e.g., Millière et al., 2011a, 2011b), and are therefore a promising tool to track how environments respond to carbon cycle perturbation*** ~~*have been proven to reflect global δ13C variations (Abels et al., 2016; Koch et al., 1992; Schmitz and Pujalte, 2003), and may therefore be considered, sometimes together with the oxygen isotope composition (δ18O), as reliable proxy for environmental condition occurring during their formation (e.g., Millière et al., 2011a, 2011b).*~~ *The carbon isotope composition of the soil carbonate nodules depend on the δ13C value of the* ***atmospheric CO2 and*** *soil CO2, which in turn is a function of the δ13C of the atmospheric CO2 ,****and*** *the overlying plants, as well as* ***the*** *soil respiration* ***flux and the partial pressure of atmospheric CO2*** *(Abels et al., 2012; Bowen et al., 2004; Caves et al., 2016; Cerling, 1984). "*

Line 267:

"…nodules, ***which*** *is consistent with* ***a large compilation of data from eastern Eurasia (Caves Rugenstein and Chamberlain, 2018)****"*

Line 302:

"…varies between 0.1-0.29 mm/y, ***consistent with sedimentation rates reported for other Eocene floodplain successions (Kraus and Aslan, 1993)****."*

Line 307:

A sub-chapter ***5.1.2 Mechanisms causing the CIE*** *was added.*

Line 319:

*"****A release of 500 to 1500 Gt of carbon in the form of methane would imply a marine CIE of 0.8 to 2.3‰ or 0.3 to 0.9‰ if the carbon origin is dissolved organic carbon (DOC) (Sexton et al., 2011). The latter seems more plausible regarding the observed amplitude of ~1‰ measured in the marine record for hyperthermal U (Westerhold et al., 2017) and the supposed origin linked to the oxygenation of deep-marine DOC of post-PETM hyperthermals (Sexton et al., 2011). A global shift of -1‰ in δ13C can however not fully explain the 3‰ shift in δ13C observed in this study.*** *"*