Response to Referee #1

First we would like to thank the reviewer for the time invested to review our paper and constructive comments and suggestions. Comments that will lead to substantial modification of the manuscript are discussed below. As for the more specific minor corrections, they will be addressed in the revised version of the paper.

General comments

This is an interesting paper that adds to the debate on the problematic nature of apparent polar warmth during at least some intervals during the Mesozoic greenhouse. In this context, the data from Siberia are particularly valuable, particularly as a number of workers are insisting on the presence of substantial Jurassic and Cretaceous ice to explain sea-level changes and cold-climate phenomena such as glendonites in high-latitude sites. The fact remains, of course, that the present work offers only a snapshot of geological time, in the Toarcian case during a well-established hyperthermal, and extreme extrapolation to much of the Mesozoic would probably be unwise.

We agree with this statement. Obviously the data from lower Toarcian, specifically the TOAE cannot describe what occurred during colder Mesozoic intervals such as the late Pliensbachian, the Bajocian-Bathonian or the early Aptian. The main comparison was first made with the Early Eocene or the Cenomanian-Turonian transition, other well-established warm intervals, hence the comparison with climate models performed for such periods. Yet we also wanted to compare-it to the rest of the Mesozoïc to insert the early Toarcian within this climate history. The above comments suggest we must clarify the discussion in this sense. We propose to be more specific on the climate mode estimated for each interval used in this comparison, in order to better point the issue of polar warmth recorded during hyperthermal events, and the struggle of climate models to achieve such polar warmth.

Given the importance of the Arctic data, I think it would be preferable in parts of the text (e.g. Results and Discussion) to separate out the Pliensbachian and Toarcian data sets in separate subsections rather than running them together, which can become confusing to the reader.

We agree with this suggestion will address this issue for the revised manuscript.

In terms of fidelity of the paleotemperature records, much depends on the preservational state of the aragonitic fossils, and the authors have made some obvious moves to determine the integrity of their material. I must say, however, that, from the photographs, the Arctic specimens have a white 'powdery' look to them, which is typical for partly degraded aragonite.

Indeed, the fidelity of the record depends on the preservation of the fossil material. The superficial (optical) aspect of the shell can be dramatically altered by the mechanical crushing of the shell, which is common in such fine-grained sediments and clearly visible in SEM images for some samples. Besides, we did not find any evidence for mineralogical conversion in either the Raman spectra or the SEM observations.

As another test of alteration, strontium-isotope data would be useful, since the Toarcian global curve has particularly low values around the OAE interval and the presence of more

radiogenic $^{87}Sr/^{86}Sr$ ratios would be a fingerprint for alteration. Ideally, of course, there would be some accompanying TEX86 data, which should be obtainable given the relative lack of maturity of the sediments and at least a modest amount of organic material in the sediment.

Performing strontium isotope analysis on these samples would indeed provide interesting insights into their preservation state, provided the primary values have not been influenced by the presumably high freshwater input of radiogenic strontium in the first place. This is something we plan to do. However, for logistic reasons, we cannot perform such analysis in a near future (not before early 2022), so this is for-now out of the scope of our study. The same is true for TEX86; however, there is a slight chance that GDGTs are preserved here, and again, this looks instead as a task for further, dedicated study.

Specific comments

Line 244: can 'only a few degrees' be more specific? Estimates of the temperature drop across the thermocline from some localities during the Jurassic and Cretaceous, based on belemnite delta-18O values and TEX 86, come in at about 14°C (Mutterlose et al., Earth and Planetary Science Letters, 298, 286-298 and Jenkyns et al., Climate of the Past, 8, 215-226). So, presumably the bivalves were living in the mixed layer? As noted above, it would be useful to have some TEX86 values for the accompanying sediments.

From data derived in other Siberian sections, Dacryomya-Tancredia–dominated assemblages were common in relatively deep but near-shore environments (Shurygin, 2005). (Zakharov and Shurygin, 1978) referred Dacryomya to as eurybathic infaunal deposit feeder tolerant to low oxygen contents, which prefer environments with slow hydrodynamics. Position of natural habitat of these bivalves in relation to thermocline remains unclear. Dacryomya genus is one of the most common bivalve associated with the Toarcian OAE in fully marine facies around the World.

Figure 4, text figure explanation. Please explain what the different symbols mean and the shorthand for the zones. Should falciferum not now be serpentinum?

We will address the figure explanation, and detail the ammonite zone name. As for the question regarding ammonite zone, here the Siberian zonal succession is used, and it differs a little from the European zonation.

Fig 5, text-figure explanation is not comprehensive enough, making this diagram difficult to decipher. Make clear what grey bands signify. References should be given here, not in Supplementary data.

The caption will be clarified and references added in as suggested.

References:

Shurygin, B.N., 2005. Lower and Middle Jurassic Biogeography, Facies, and Stratigraphy in Siberia Based on Bivalve Mollusks. Geo, Novosibirsk.

Zakharov, V.A., Shurygin, B.N., 1978. Biogeography, facies and stratigraphy of the Middle Jurassic of Soviet Arctic (by bivalve molluscs). Transactions of the Institute of Geology and Geophysics, Siberian Branch of the Academy of Science of USSR 352, 1–206.