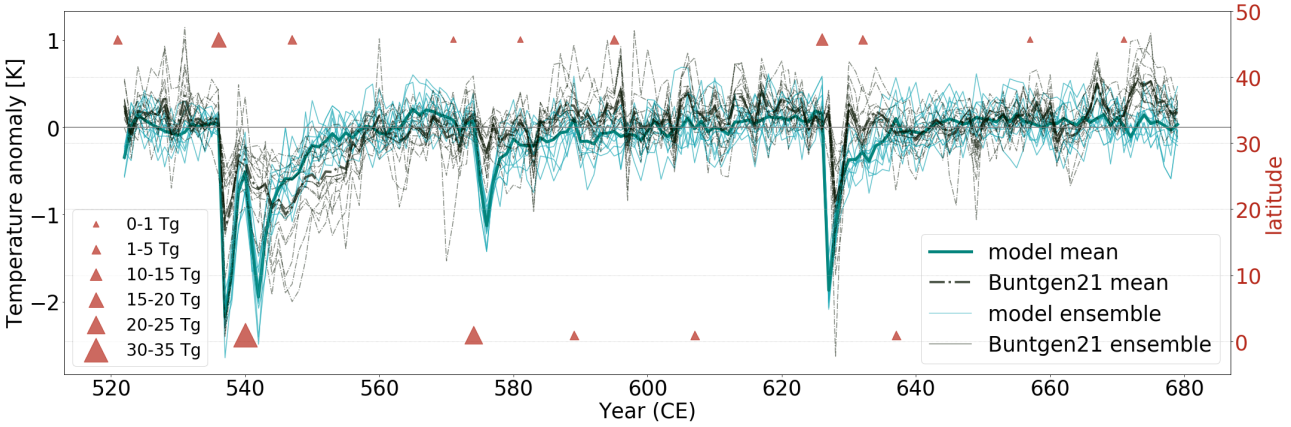
Dear editor and reviewers, thank you for the detailed review of the paper. We have compiled a point by point response going through all comments of the four reviews. Our comments are given in blue and bold text.

General reply:
We have considerably revised the manuscript by rewriting the abstract, introduction and summary and conclusion, as well as separating the discussion from the result section. We updated the references in the introduction and discussion. As suggested, we now use the Büntgen et al. (2021) tree-ring reconstruction ensemble for the model - tree-ring comparison (see figure below) and have rewritten the comparison section accordingly, focusing on the Northern Hemisphere temperature anomaly.



Reviewer 4:

My review of submission cp-2021-49 by van Dijk and co-authors focuses on the paleoclimate part of the paper and not on the models, as the latter are not my field of expertise. In their contribution, the authors seek to answer the question whether long-lasting cooling occurred over the Northern Hemisphere following a cluster of large 6th and 7th century eruptions which occurred in 536, 540, 574 and 626 CE according to sulfur deposits in bipolar ice cores. The authors do so by comparing proxies (mostly tree-ring reconstructions) with model output.

Thank you for your constructive comments. We have taken your comments into account in the revised manuscript, as further answered above in the general comments and in detail below.

The idea of the paper is nice, but I have a few major comments that shall be addressed by the authors in a revised version:

1. The title is misleading, no proxy record has hitherto posited that the 6th century eruptions would have been at the origin of a long-lasting hemispheric cooling. Instead, a study based on data from the Alps and Altai (by Buntgen and colleagues, 2016) has just pointed to marked cooling at these two sites. Other tree-ring records do not suggest a comparable cooling. Speaking of hemispheric cooling is thus an overstatement and should be changed.

We have discussed this comment thoroughly and would like to stay with the given title.

The main scope of the paper is to study the volcanic response with this model set-up and volcanic forcing, not on the tree-rings. For us, the title underlines the aim of our study. In the introduction, the long lasting cooling from tree-ring records and other proxies that have provided evidence for volcanic eruptions in the same period as the long lasting cooling from the tree-rings, act as a motivation. Together they lead to our question: Whether a series of volcanic eruptions induced a multidecadal to centennial cooling in the mid 6th to 7th century. The point that the Alps and Altai are not representative for the entire Northern Hemisphere is fair and we have thus altered the aim of the paper accordingly.

2. Along the same line, starting from line 32ff the authors state that cooling might have exceeded that of the LIA and focus on two site chronologies that were presented in 2016. While the authors rightly present the results of this study, and add the reply provided by Helama and colleagues from 2017, they ignore a vast body of proxy studies that have been published on the topic and where the chronologies cover many sites of the NH. By focusing only on the LALIA study, they ignore a large body of spatial and temporal reconstructions covering the period of interest. The authors should therefore present a more balanced assessment of the existing data by including e.g., Schneider et al. (2015, ERL), NTREND (spatial and temporal; Wilson et al., 2016 QSR ; Anchukaitis et al., 2017 QSR), Guillet et al. (2017 NGEO) or the most recent TRW-based paper from the tree-ring community published lately by Buntgen et al (2021) in NCOMM.

Thanks for your very good suggestion, which has motivated us to switch using the most recent TRW-based ensemble reconstruction from the tree-ring community (Büntgen et al, 2021). The introduction has been rewritten and updated with newer publications where necessary.

3. Chapter 2.2: It is not clear to the reader how the authors did the tree-ring analysis. They provide a long discussion on advantages of MXD over TRW data, but it is very unclear how the authors did the reconstructions and what they did with the data. How were the sites/data chosen? More details need to be provided here as it remains very unclear to the referee how the proxy series were developed.

Since the new tree-ring reconstruction ensemble from Büntgen et al. (2021) is used in the revised manuscript, we rewrote the methods for the tree-ring part. The data from Büntgen et al. (2021) is publicly available and we used them as published. We have clarified this in the methods section.

4. The same holds true for the NH approach: why did they not use the spatial reconstruction data from Anchukaitis et al. (2017) or Guillet et al. (2017)?

See the general explanation at the beginning of the comment replies. We now use the most recent tree-ring reconstruction ensemble from Büntgen et al. (2021).

5. Another major drawback is the restriction of the comparison of model with tree-ring data (lines 349ff) just between the Alps, Altai (both known for excessive cooling in tree-ring records) and Scandinavia. Why did the authors not rely on the full set of tree-ring reconstructions and include a comparison for Siberia, Central Asia and North America?

We have done a comparison for the sites for Siberia, Central Asia and North America as well, but both the model and tree-ring reconstructions showed such high variability that the volcanic signals were lost. We therefore chose only to show the sites for the Alps, Altai and Scandinavia. Since we are now using different tree-ring data, we decided to focus on the NH compilation and go more in detail here. The individual sites are added to the appendix and we added this information.

For the paper to become acceptable, the breadth of the proxy records needs to widened and the methods need to be described in much more detail.

The main scope of the paper is about the model simulations and the mechanism for a multidecadal volcanic induced cooling. New, published tree-ring data are used now and we described this data in the methods section, referring to the corresponding papers for the details. We have clarified these points in the revised manuscript.

Minor points:

6. Line 2-4 (Abstract): to which “multiple paleo proxies” are the authors referring to? This is a misleading statement as the proxy records pointing to massive and long lasting cooling are few. This needs remediation

The multiple paleoproxies, ice-core records, tree-rings and historical documents, are referring to both reconstructing the past climate and the date of the volcanic eruptions. We elaborate on

these in the introduction, and would like to leave it in the abstract as it is. The definition of a 'long lasting cooling' includes the decadal scale, which is what several of the proxies are showing as well. Thus, we would like to leave it in.

7. Line 12/13: "see" should be changed to "sea"

Thanks, corrected.

8. Lines 19-21: This needs some rephrasing, stating that the cooling was 20 years in the proxy records is somewhat an overstatement. The initial cooling was in fact there, but temperature recovered rather quickly to more normal conditions and reached "fully normal" after two decades. Some clarification would be good here.

Thanks, we have taken your comment into account when rewriting the abstract.

9. Line 30: what lines of evidence do you have to compare the 6th century cooling to the conditions that led to the LIA? I suggest that either references are provided or that this statement is removed.

Thanks for your suggestion. The introduction has been rewritten, and we have taken the reference to the LIA out of the sentence.

10. Line 152: How does peak cooling in models compare with proxies? How does the amplitude of cooling compare between the two data sets?

In this section, we show the results of the model and its indication. The comparison with the proxy data is made in a separate part of the section.

11. Line 155: what do you mean with background level for AOD? <0.1?

By background level we mean the 0 line in the AOD plot in figure 2. We have clarified this in the text.

'The AOD peaks after ~12 months and is back at 0 after 3-4 years (Fig. 2b).'

12. Line 376: the LALIA concept is based on records from two sites. The authors should go beyond these sites and analyze all data that exists in the NH. It is unclear why the study is limited to Alps, Altai and Fennoscandia

We chose these sites to touch upon the contrast between individual sites and a compilation for the entire NH. The other individual sites were hard to compare with, as the variability in both

data sets overwhelms the volcanic signal. We have now used the new Büntgen et al. (2021) TRW-based ensemble reconstruction data, and therefore focus on the NH in the main manuscript. The individual sites have been added to the supplementary material.

13. Line 386: use the data presented in the Buntgen et al. (2021) ensemble study instead

Thanks for the very good suggestion, we now used the new tree-ring reconstruction ensemble from Büntgen et al. (2021) instead.

References

Büntgen, U., Allen, K., Anchukaitis, K.J., Arseneault, D., Boucher, É., Bräuning, A., Chatterjee, S., Cherubini, P., Churakova, O.V., Corona, C. and Gennaretti, F., 2021. The influence of decision-making in tree ring-based climate reconstructions. ***Nature communications, 12*****(1), pp.1-10.**