Response to Reviewer #1

We thank the referee for reviewing the manuscript again and for giving further instructive comments.

As suggested, we kept the discussion of Sec. 3.6 and slightly extended it to make it clear that with the current data set the question of a volcanic trigger of DO cooling events is still inconclusive. Here we specifically mention all 3 remaining issues identified by the reviewer as to why the analysis on the cooling events is limited at present, including new references to papers suggested by the reviewer that highlight the large impact that extra-tropical eruptions (not considered in our paper) can have on the climate.

A side note regarding these new references that consider the climate impact of NH extra-tropical eruptions:
In accordance to the mechanism we propose with our ocean model simulations, a large NH cooling (as suggested by these references) does not lead to a weakening of the AMOC (shutdown of AMOC = transition to a stadial) but instead a strengthening (e.g. van Dijk et al 2022). Thus, it is not clear whether such eruptions are good candidates for a stadial onset trigger. But of course we cannot say at this point that our hypothesized mechanism is the correct one.

We further removed the reference to DO coolings from the abstract, and give a more careful interpretation of our analysis in the Discussion/Conclusion section, where a mention of the cooling events has been removed in one of the two relevant passages, and the other passage has been appropriately caveated, as suggested.

Response to Reviewer #2

We thank the reviewer for reviewing our revised manuscript and for the useful suggestion to more clearly highlight limitations of our approach.

1.) Following the suggestion by the referee to make the main limitations of the study more prominent, we added the following to the Discussion/Conclusion Section (slightly modified from the Referee suggestion):

“As a result, while the SVE20 bipolar volcanic catalogue certainly undercounts the true number of bipolar volcanic events of arbitrary strength, we argue that it captures a sufficiently large portion of the strongest events most relevant to triggering climate change. While our analysis only considers bipolar volcanic eruptions that have been identified in the glacial sections of the ice cores used, volcanic events restricted to either the northern or southern hemisphere may likewise contribute to abrupt climate change. However, uncertainty in assessing their latitude and magnitude precludes us from evaluating them here.”

And the following to the abstract:

"While we argue that the bipolar catalogue used here covers a sufficiently large portion of the eruptions with the strongest global climate impact, volcanic events restricted to either the northern or southern hemisphere may likewise contribute to abrupt climate change."

2.) Regarding the minor comment that we are severely undercounting bipolar eruptions:

We do not claim that there can be only up to 2 times more bipolar eruptions (of any size) in the record, or that 1-in-500 years is our estimate of the return period of all bipolar eruptions that would have any discernible signature in the ice cores at both poles. 500 years is simply the return period we find in the SVE20 data, which we argue is a data set with eruptions above a certain threshold in magnitude. We then find that the characteristic magnitude of these eruptions is indeed consistent with the largest eruptions of the last 2,500 years (roughly Tambora-sized) of the same return period (and not of all bipolar eruptions of any size), meaning the catalogue is likely relatively complete. Based on the unipolar deposition magnitude (LIN22 data), we then further find that there could only be up to 2 times the number of bipolar eruptions of this characteristic magnitude (sulfate deposition) during the investigated time period, assuming there would be no local eruptions with large but only unipolar sulfate deposition.

We already stated in the relevant parts of the manuscript that we are trying to constrain the number of missing bipolar eruptions of the same characteristic (large) magnitude, and that only eruptions of this characteristic magnitude are relevant to our statistical analysis. In the revised manuscript, we made this more explicit in several places. To make it more clear, we added the following to Sec. 3.2:

"Further, the numbers given here, i.e., the return period of 500 years as well as the estimate of eruptions potentially missing from the SVE20 data set, do not refer to bipolar eruptions of any size, but to bipolar eruptions of the characteristic (large) size of the bipolar eruptions in the SVE20 data. The former are indeed known to occur much more frequently (Sigl et al 2022)."

The previous version of the manuscript did acknowledge that there are 80 eruptions in the last 2500 years based on Sigl et al. 2015. Actually, we do not claim anywhere in the manuscript that this time period "is too short for strong conclusions". I assume this was a reference to some of our previous author responses in relation to the Rougier et al. data.
Certainly, a data set of the last 2,500 years is not suitable to give statistically robust results for eruptions with return periods on the same order of magnitude, nor is it applicable directly to the study of DO events. However, the recurrence time for bipolar eruptions (of any size) is indeed well-constrained, yielding roughly 31 years, consistent with the newer data covering the entire Holocene.
We agree of course that it is good to include the newer data, and now include the new estimate of 35 years from the extended record by Sigl et al 2022.

We further added the following clarification in Sec. 2.4:

"By saying the data set is relatively complete, we mean that it covers a sufficiently large portion of the bipolar eruptions above a certain threshold in magnitude, which corresponds to eruptions with return periods of 1 in 500 years and larger. In contrast, we do not mean that it represents a complete catalogue of all bipolar eruptions of any size that could be detectable in more highly resolved and better synchronized ice core records, such as during the Holocene (Sigl et al 2022)."

3.) As suggested, we added 2 panels with time series segments of the two instances to Fig. 1.