Climate of the Past Discussions

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Reply on RC2

Giulia Sinnl et al.

Author comment on "A multi-ice-core, annual-layer-counted Greenland ice-core chronology for the last 3800 years: GICC21" by Giulia Sinnl et al., Clim. Past Discuss., https://doi.org/10.5194/cp-2021-155-AC3, 2022

Dear Anonymous Referee #2,

Thank you for your positive and comprehensive review of our manuscript. We hope to have improved our manuscript by addressing your concerns.

As we replied to An.Ref.#1, the construction of the GICC21 timescale has been a long work and we are glad to see our efforts recognized. The new uncertainty formula is the result of long discussions in our group and we are satisfied to see that all Referees agreed on its validity.

We agree that the manuscript ended up being quite long, however GICC21 needs thorough explaining and documentation. In response to your comment and to those by An.Ref.#1 and An.Ref.#3 we have concluded that the manuscript will gain more readability by shortening some parts, in order to refocus the manuscript around the GICC21 timescale, i.e. we intend to cut out the discussion of volcanic cooling and Mediterranean volcanic events (sections 5.2 and 5.3, Appendix A and B, and the relevant parts of abstract and conclusion). However, we feel encouraged to continue our future work on these topics thanks to your positive evaluation of the sections we now intend to remove.

Regarding your primary questions/concerns:

- ‘The first is about the improved match to IntCal.’ It was not our intention to send the message that GICC21 was born as an independent check of IntCal, or to be forced in alignment with IntCal, and we apologize if our phrasing implied otherwise. This section is meant to be a discussion of what GICC21 can be used for in a broader sense, hence we think it is important to keep it and to rephrase it better. In the revised manuscript we have made sure to clarify that GICC21 is an independent result that applies for Greenland only. The comparison to IntCal is intended as to solidify the link between the Greenlandic climate and the broader Northern Hemisphere region.
- ‘The second question/concern is the underlying data.’ We understand your concern and we will make sure that in the revised manuscript we explain more clearly where data can be found. We emphasize that all data will be available to the reader on Pangaea, but as Pangaea currently has a rather long processing time, not all data sets may get a doi in time for inclusion in this manuscript. For NEEM and NorthGRIP CFA data, the Pangaea repository listed (https://doi.pangaea.de/10.1594/PANGAEA.935838) already

contains data of all the species we have used in our work (ECM, Na, Ca, NH^+_4, NO3), and the moratorium will be lifted as soon as the corresponding ESSD paper is published.

As for EastGRIP data, the ECM has since been made available at https://www.iceandclimate.nbi.ku.dk/data/. For the EastGRIP CFA, Erhardt will make a Pangaea repository, but preliminary data can be obtained by Erhardt.

The two other ice-cores (DYE-3 and GRIP), for which we only used ECM and isotopes, already have published ECM and decadal-resolution isotopes, and we will make sure to refer to those publications in the revised manuscript. As for the full-resolution isotopes from GRIP and DYE-3, they will be published separately by Rasmussen in a paper that makes data from GICC05 and GICC21 available. The files have already been submitted to Pangaea.

Authors who want to access data sets which are not published when this manuscript is published, will be able to get the datafiles from the author team (with preliminary metadata, as the metadata is subject to review by Pangea editors).

- 'The third question/concern is about the ammonium (or -ECM log transform) matches.'

In the revised manuscript we have added more explanation about the NH^+_4 matches and the log-inverted ECM (pseudo-NH^+_4). We believe that matching of NH^+_4 is useful for our construction method. We do not use NH^+_4-matching (including matching NH^+_4 peaks to ECM dips) for matching up the cores in the first place, but we use it as a way of matching ice-core data across sections that don't have any clear volcanic signals. NH^+_4 has showed high potential for ice-core matching from the beginning of our work, as opposed to Na and Ca, who show very low agreement across ice cores since they are more strongly influenced by local climate. That said, by no means we believe NH^+_4 to be better than volcanic matching and the use of ammonium spikes as a matching tool is secondary and dependent on the coherence of the volcanic match. Moreover, we have made use of patterns of ammonium matches, rather than of single peaks, in order to tie the ice cores together. This is because we believe that by matching NH4 patterns we can obtain better results than just by interpolation between eruptions. As for the pseudo-NH^+_4, we will reconsider the nomenclature in order not to imply a closer correlation with NH^+_4 than there actually is. The agreement with ammonium can be seen visually and can possibly be quantified by a statistical test of correlation, which we aim at providing in the Supplementary Information of the revised manuscript.

Our reply to your specific comments:

>>L69 – add sulfate, black carbon, as well as electrical conductivity measurements, and insoluble particles (i.e. dust). This seems too focused on water isotopes.

Reply: Thank you for the remark, we will do that.

>>L69 – change "heavy" to something that does not imply weight, like "significant"

Reply: We will.

>>Section 1.3 – The first paragraph focuses on sulfate for volcanic event identification, then the second paragraph switches to acidity. I think you are likely referring to ECM rather than a direct measure of acidity. Please add more discussion around how the sulfate (and sulfur), ECM, and acidity measurements are interrelated and used together.

Reply: We will make sure to add more information on the matter.

>>L98 – I understand what you are going for with a volcanic event being recorded differently as various sites, but GRIP and DYE-3 are both about the same distance from an Alaska volcano. Seems like Iceland might be a better example.

Reply: Clausen et al. (1997) explicitly talk about the Katmai eruption (Alaska) of 1912 CE being recorded in GRIP but not in DYE-3, which we also observed. That is why we cited Alaska as an example. We will rephrase the sentence to remove the argument of distance from the source, limiting ourselves to the meteorological factors that can alter the shape of the eruption signals across the ice sheet.

>>L105 – There is no reference for the matching of ammonium records among cores. As indicated above, this portion of the timescale development needs to be better supported. I'm not aware of this being widely used before. If it has been, please add a paragraph with references here. If it has not, please dedicate a section of the paper to the ammonium matches.

Reply: Ammonium events are excellently described by Legrand et al. (2016) as peaks that significantly exceed the background levels, and the importance of NH^+_4 for reconstructing past forest fire activity is well documented in their review. We were not the first to use NH^+_4 for ice core matching, since Legrand et al. also provide a match of NH^+_4 across NEEM and Summit for the recent 2 centuries, admitting that "peak to peak comparison is rarely perfect". However, they note that similar events happen within 1-2 years, which is explained as being caused by timescale inaccuracies. Furthermore, they provide clear indication that the ice-core peaks occurred within dating uncertainties of record-years of Canadian forest burning.

In conclusion, we agree with your criticism of our explanation being insufficient and we will add more details about why NH^+_4-matching is a reliable addition to the volcanic matching and that is has to be considered a secondary tool.

>>L107 – add a reference to Taylor et al., 1996: Biomass burning recorded in the GISP2 ice core: a record from eastern Canada?, The Holocene unless there is an even earlier reference for the ECM/ammonium/biomass burning relationship

Reply: Thank you, we will add this reference.

>>L130 – This paragraph provides a nice description.

Reply: Thank you.

>>L157 – "bias in the counting process" should be changed to "bias in the interpretation process". The counting has never been the issue – the identification of annual layers is the issue. If you can identify each year, the counting is easy

Reply: We agree on this distinction. We will make the change.

>>L182 – "includes all available data from Greenland deep ice cores" is not true – GISP2 is excluded. An explanation for why GISP2 is excluded, despite having publicly available data that allows annual layer identification, should be added. There should also be a transfer function for GISP2 to GICC21.

Reply: We will weaken our statement, also in view of the comments by Michael Sigl. The GISP2 ice core was not included in the timescale, that is true, and we will rectify this. However, including GISP2 in the timescale at this stage is not feasible because of the lengthy fine-tuning process. When planning the timescale construction, we noted that GISP2 ECM data is degrading in quality (many data gaps after 300 m) and that many ECM

peaks cannot be matched easily, hence we desisted from including it in our dataset. Since GISP2 is anyway very close to GRIP it would not have represented an important addition to the geographical coverage of GICC21. We will aim at matching GISP2 in the revised manuscript because we agree that this will complete our discussion of Greenlandic ice cores in the frame of a new chronology.

>>L335 – "major and minor" – I don't see any distinction in the ammonium matches in the remainder of the manuscript. I also think this is a suspect approach. Since there are lots of wiggles in the ammonium and ECM records, it seems like a lot of "matches" could just be of noise. Figures 2 and 3 do not convince me that the ammonium matches are anything more than non-unique wiggles that happen to fall at about the right age. As mentioned above, more analysis needs to be provided to support these matches.

Reply: the distinction between major and minor tie-points was removed from the manuscript in an earlier version. We will edit it out completely and apologize for the confusion. We will aim at making Fig 2 and Fig 3 more credible and expand on NH^{+}_{4}.

>>L480 – I don't understand why the uncertainty estimates are based on just 4 sections. The straticounter probabilities are available for all sections, as is the manually fine-tuned timescale. This process should be done for all of the timescale.

Reply: It was certainly possible to retrieve a continuous record of the uncertainty data, but we started by only analyzing the 4 test sections since we believed that 4 sections of 300 years (i.e. 1200 years in total) would be representative of the ~3000 years of the timescale before Samalas. Since your review, we have conducted a continuous analysis of the uncertainty and we will add it to the revised MS. As expected, it did not drastically alter the values we have proposed.

>>L485 – convolved not convoluted

Reply: Thank you, we will make this change.

>>L543 – Figure 6 – This figure is the most important in the paper. But it is hard to interpret, particularly the uncertainties. If the primary point of the paper is that a multi-core analysis yields a better timescale, then why plot each of the individual timescales, some of which don't really exist – i.e. is there really an independent EastGRIP timescale? I think you should make this into a two panel plot. The top panel should have a comparison of only published timescales – GICC05, NS1-2011 (this is the Sigl15 timescale, right?) GICC21, and GISP2 (an oldie but a goodie). This should allow the uncertainties to be better visible, but importantly, the GICC05 uncertainty should be plotted clearly. It is an important point that the GICC21 timescale is a revision that is outside the GICC05 timescale.

Then in a lower plot, you can make a plot that uses the individual timescales as you've done.

Reply: We will certainly evaluate if Fig.6 can be improved by dividing it into two panels. We kept the cores separate because they each react differently to the timescale revision, since both tie-points and layers were changed from GICC05. We will highlight the MCE boundaries and the GISP2 timescale will be included.

>>L615 – Of course GICC21 is in better alignment with IntCal; the disagreement, as pointed about by previous work, is why you went to all the effort to update GICC05 in the first place! I think you can rephrase this section to be clear you have developed an annual timescale that reconciles the previous offset within uncertainty. This is an important thing to do!

Reply: Thank you, we will rephrase this section.

>>L642 – I don't understand this paragraph. I think the main point of Figure 9b is that the purple (Be10 on GICC21) and the black (Be10 on Adolphi-Mueschler16) are very similar. But the main visual is the difference between the green (IntCal production) and the purple/black. The wording in the paragraph is hard to follow. Is the green important? Or could you just plot the purple and black?

Reply: We wanted to show that the wiggle-matching of GICC21 to IntCal (i.e. purple to green) is slightly better than the black-green one, especially in the last 300 years of our timescale. We will rephrase the section to explain this better.

>>L655 – How is the averaging done? Do you perform an initial average for the geographically similar cores, and average those together? I don't see this in Appendix B either.

Reply: This part will be removed. The data was averaged without considering geographical location.

Kind regards,

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