

Interactive comment on “Arctic Holocene proxy climate database – new approaches to assessing geochronological accuracy and encoding climate variables” by H. S. Sundqvist et al.

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We appreciate the positive and constructive comments by D. Fisher (Referee #1) and by anonymous Referee #2. Our detailed response to their comments follows.

Response to D. Fisher, Referee #1

1. Since this data set will become a “go-to” resource for Holocene work and be used by people not necessarily in the paleo-climate field, maybe it is an idea to have some sort of Wikipedia portal to this ms and to the data in WDC-paleo (NOAA). This is just a suggestion. It might need someone to write a short-ish Wiki article.

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- Yes, it true that data might be used by non paleo-specialists, and the suggestion to have some Wikipedia portal linked to them is good. We will take this suggestion into consideration and possibly write a Wiki article once the data are available on NOAA.

2. P5 In “procedures and protocols” is noted that the data base is very heterogeneous in resolution, age accuracy, climate sensitivity and signal/noise. Maybe there should be a statement that it is possible and useful to put such a wide range of paleo records together and what one should expect to get. There is a considerable literature on the subject. It is well worth using all such series together but the case should be alluded with a few references, (eg. Fisher D.A., 2002. High- resolution multiproxy climate records from ice cores, tree rings, corals and documentary sources using eigenvector techniques and maps: assessment of recovered signal and errors. HOLOCENE, 12,3 , pp323-340).

- In the introduction we say that the database can be used to describe spatio-temporal patterns of Holocene climate transitions. We will also add the following text to “procedures and protocols”: Temperature-sensitive series from different proxy types can also be combined to produce temperature reconstructions like in Fischer (2002) or temperature patterns like in Ljungqvist et al. (2012).

3. P9 The Database structure as presented in the supplementary material is in xls format. While it is openable with old versions of Excel, I think it also a good idea to also store a purely ascii or txt version of the database. There is no guarantee that Excel will always exist or support the stored xls version. Ascii will go into anything including Excel.

- In addition to the Excel format, the WDC for Paleoclimatology (NOAA) will translate the data files to text/ascii as part of their standard data-archival procedures.

4. P11 There is a discussion about there being some series that have been converted to proxy met variables, eg. Temperature. I noted in the Table 2 column about this having been done that neither Renland or Agassiz ice core O18 time

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series had been converted to temperatures. This is an error, see (Vinther B.M., Buchardt S.L., Clausen H.B., Dahl-Jensen D., Johnsen J., Fisher D.A., Koerner R.M., Raynaud D., Lipenkov V., Andersen K.K., Blunier T., Rasmussen S.O., Steffensen J.P. and A.M. Svensson. Holocene thinning of the Greenland ice sheet. *Nature*, doi:10.1038/nature08355.3d,2009).

- Currently, we report the raw d18O values from all ice core sites, including uplift-corrected d18O for Renland and we will add the uplift-corrected d18O from Agassiz as well. The temperature reconstruction using the uplift-corrected d18O records of Renland and Agassiz is a regional reconstruction and since the other records of the database are site reconstructions this is the reason why we have not included it.

5. Table 2 The Logan O18 record as being a measure of the Aleutian low. This should be replaced with El Nino. I wrote the paper referenced.

- Thank you for pointing this out. We will replace Aleutian low with El Nino.

6. P19 or Appendix A The discussion of "Glacier Ice" should make some specific reference to the time scales used for Greenland and Canadian ice cores. There has been a major effort to reconcile the time scales for all the Greenland ice core records. This has been done by various means and the reconciled chronology is called the GIC05 (Greenland Ice Core version 5) chronology. The major volcanic acid layer's ages from GIC05 are those that are deferred to by the Canadian ice core series. In particular all the Agassiz ice cores have been tied into this Greenland chronology. The paper covering this process and its result should be in the reference list, (Vinther, B.M., Clausen, H.B., Fisher, D.A., Koerner, R.M., Johnsen, S.J., Andersen, K.K., Dahl-Jensen, D., Rasmussen, S.O., Steffensen, J.P. and A.M. Svensson Synchronizing ice cores from the Renland and Agassiz ice caps to the Greenland ice core chronology. *Journal of Geophysical Research*, 113,D08115, doi:10.1029/2007JD009143,2008 :10 pages,2008)

- Thank you for pointing this out. We will add the following text and the reference at the

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end of section 5.2.3 (Glacier ice): In the recent decade a major effort has been made to reconcile the time scales for all the Greenland ice core records and the reconciled chronology is called the GIC05 (Greenland Ice Core version 5) chronology (Vinther et al. 2008). The Canadian ice core series, in particular the Agassiz ice cores, also use the major volcanic acid layer's ages from GIC05 are those that are deferred to by the Canadian ice core series.

Response to Anonymous Referee # 2

Major comments 1. For each calibrated variable, please provide somewhere in the metadata the reported size of the calibration error. This is hugely important for comparing to model output, a stated goal for this compilation. A one paragraph discussion in the text of generally how large these calibration errors are would also be useful.

- We agree that the size of the errors in the reconstruction is important and variable. We will add the following text to section 5.3 "Climate variables": The calibration uncertainties of the reconstructions vary with differences in statistical methods and in calibration datasets; e.g., for pollen-based reconstructions, reported uncertainties can be as low as 0.2C (Kerwin et al. 2004) and as high as 2.5C (Andreev et al. 2005). The largest calibration uncertainties are found in the pollen reconstructions of winter temperature while the smallest uncertainties are found for the pollen reconstructions of summer or annual temperature and for diatoms. One reason for this is likely that the pollen assemblages have a comparatively high correlation with summer temperature in areas with short growing season, or with annual temperature in areas with longer growing season (e.g. Seppä et al., 2009). One conclusion from Sundqvist et al. (2010) is that the uncertainties are generally large, compared to the climate changes depicted by the data. Given the size of calibration and other uncertainties compared with the relatively small amplitude of most climate change within the Holocene, users of this database should bear in mind reconstruction uncertainties when using the proxy data. The original data sources (papers cited here for each study) characterize the unique uncertainties associated with each individual reconstruction.

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2. Issues with the Geochronology accuracy score: While I fully appreciate the attempt to provide an objective and quantitative score, there are some aspects of the scoring that seem illogical and overly complex.

a) For the uniformity of trend, I can't follow the definition in Appendix A. It is the root mean square error of individual dates with respect to the spline? Or the root mean square error of a linear trend with respect to the spline? The name "uniformity of trend" suggests to me that records with more linear trends should have higher uniformity scores. Is this the case?

- P 24, line 10 states, "The uniformity (u) of the trend is quantified as the root mean standard error (RMSE) with respect to a cubic smoothing spline with degree of freedom (df) = 4." Downcore trends that fit a spline (including a linear trend) are more uniform than those that deviate from a smooth curve.

b) For the reliability score p, it seems strange that having one or more rejected dates would lower the reliability. For example, sometimes researchers date a material in the hopes of getting reliable dates from it, determine that the dates for that particular material are not reliable, and reject them all. Why should such a data collection approach yield a lower reliability measure than measuring dates from just one material and not rejecting any of them?

- We agree that judging the quality of dated material can be subjective. Nonetheless, the proportion of author-rejected analyses could be indicative of a multitude of problems related to the age of the dated material relative to the enclosing sediment or to laboratory errors. We note that excluding outliers has a major impact on curve-fitting statistics, and maintain that the occurrence of rejected outliers is important as part of a full assessment of overall reliability of an age model. In the case of experimental analyses, as described by the reviewer, the logical approach would be to not include them as part of the tally of rejected ages. To our knowledge this situation does not apply to any of the results in the current version of the database.

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c) In terms of age reversals negatively impacting the p score, it seems like having a high sampling density for 14C (especially in the vicinity of a radiocarbon plateau) would lower the reliability score. Generally, though, high sampling density should improve reliability, not hurt it.

- We agree: The number (frequency) of 14C ages is the primary metric for the Chron Score. Also, in the current for formulation, reversals must exceed 100 yr before they are counted as a reversal.

d) The accuracy score defined here seems like too much of a "kitchen sink" approach and might be more robustly defined using just 2-3 of the most important elements identified by the authors (eg, frequency, regularity, material). A different way of doing the weighting factors that might be less arbitrary is to average the percentile ranks for each of the elements being scored. The final accuracy score would, of course, just be relative to the other records in the data set (no improvement over current approach) but the score would have a physical meaning and not be on some arbitrary scale.

- We designed the accuracy score to include all of the factors that potentially could influence the reliability of 14C-based age models. We also designed it to be flexible. Users can easily exclude any of the factors that they feel is extraneous or poorly defined, or to weight them differently. The beauty of the approach is that these choices can be made explicit by future users and can be easily coded in R for reproducible results. If this approach to assessing chronological accuracy gains acceptance and use in the community, we will follow up with a publication focused on testing the sensitivity of the accuracy score to the primary input parameters.

3. Formatting issues in excel file: Different names for the same variable are used across records, eg, upper depth, depth_up, depth top, top depth. There is also no consistent column ordering for the data or chronology tables (eg, depth, age, variable in that order). These formatting inconsistencies make machine reading very difficult. I wasn't able to locate the machine-readable vplR text files from the WDC-

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Paleoclimatology site, so was unable to evaluate these.

- We will make sure that the excel column names standardized and the vplR files together for upload with the final version of the manuscript.

4. It would be helpful to show a figure with the number of records available through time. I know that every record has data between 2-6 ka, but how quickly does the number of records drop off beyond 6 ka?

- We agree with the reviewer and will add a figure (2c) showing the number of sites over time divided by region against the time period they cover according to their durations.

5. Figure 1: More information is needed to explain this analysis. Was the Reanalysis used for both summer (which months?) and the Arctic Oscillation? How is the Arctic Oscillation defined? What years were analyzed? Please provide citation information for the Reanalysis and credit to the data center that provided the Reanalysis output. Also, explain in the main text whether or not there is any indication that this same correlation pattern existed over the last 6k.

- We will change "Map colors indicate strength of correlation between summer temperature and the Arctic Oscillation (from NCEP/NCAR Reanalysis data)" to "Map colors indicate the strength of correlation between summer (JJA) surface air temperature and the Arctic Oscillation from 1950 to 2011 within the NCEP/NCAR Reanalysis data. Output from NOAA/ESRL Physical Sciences Division." Whether the same pattern existed during the last 6000 years is one of many analyses that we hope will be facilitated by this database.

Minor comments

Page 8, Line 9: Equation 1 doesn't fully describe "records with an average sample resolution of at least 400 yr and two standard deviations of less than +/- 200 yr." Equation 1 can be simplified to: $R = (t_1 - t_n)/n$, which is just the average sample resolution. How is the standard deviation criterion expressed mathematically? Is it the same as the

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expression for regularity provided in the appendix?

- We realise that Equation 1 can be simplified into $R = (t_n - t_1)/(n-1)$. The standard deviation criterion is mathematically similar to the regularity in the appendix. In this case $r = 2\sqrt{[t_n - t_1]}$. We will add this equation to the text.

Page 24, end of line 11: change "spine" to "spline"

- We will replace "spine" by "spline".

Table 2: Do question marks in the statistical detail column mean "unknown"? Please explain this abbreviation.

- Yes, the question mark in the statistical detail column mean unknown and this abbreviation will be explained in the final version of the table.

Please provide complete citations (not just eg, Smith et al. 2001) in the excel/archived files. This is essential to link back to the original publications and to give people full credit for their work.

- The complete citations for the references in Table 1 are included in the references cited list in the text. Table 1 is also included as an excel file in the supplement, along with Table S1 and we will add two tabs to the excel file – one called "Table 1_references" and one called "Table S1_references" and list all of the references alphabetically in each of the two tables.

References Andreev, A. A., Tarasov, P. E., Ilyashuk, B. P., Ilyashuk, E. A., Cremer, H., Hermichen, W.-D., Wisher, F., and Hubberten, H.-W.: Holocene environmental history recorded in Lake Lyadhej To sediments, Polar Urals, Russia, *Palaeogeogr. Palaeoclimatol.*, 223, 181–203, 2005. Fisher, D.A.: High-resolution multiproxy climate records from ice cores, tree rings, corals and documentary sources using eigenvector techniques and maps: assessment of recovered signal and errors, *Holocene*, 12, 323–340, 2002. Ljungqvist, F.C, Krusic, P.J., Brattström, G. and Sundqvist, H. S.: Northern Hemisphere temperature patterns in the last 12 centuries. *Clim. Past*, 8, 227–249, 2012. Kerwin,

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M. W., Overpeck, J. T., Webb, R. S., and Anderson, K. H.: Pollen-based summer temperature reconstructions for the eastern Canadian boreal forest, subarctic, and Arctic, *Quaternary Sci. Rev.*, 23, 1901–1924, 2004. Seppä, H., Bjune, A. E., Telford, R. J., Birks, H. J. B., and Veski, S.: Last nine-thousand years of temperature variability in Northern Europe, *Clim. Past*, 5, 523–535, doi:10.5194/cp-5-523-2009. Sundqvist, H. S., Zhang, Q., Moberg, A., Holmgren, K., Körnich, H., Nilsson, J., and Brattström, G.: Climate change between the mid and late Holocene in northern high latitudes – Part 1: Survey of temperature and precipitation proxy data, *Clim. Past*, 6, 591–608, 2010. Vinther, B.M., Clausen, H.B., Fisher, D.A., Koerner, R.M., Johnsen, S.J., Andersen, K.K., Dahl-Jensen, D., Rasmussen, S.O., Steffensen, J.P. and Svensson, A.M.: Synchronizing ice cores from the Renland and Agassiz ice caps to the Greenland ice core chronology. *J. Geophys. Res.*, 113, D08115, doi: 10.1029/2007JD009143, 2008.

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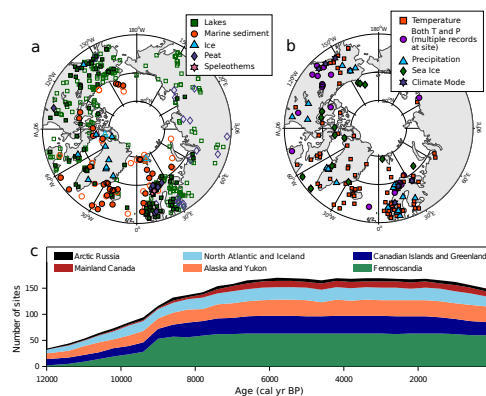


Fig. 1.

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