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Geoscientific Model Development Discussions

Interactive comment on "IceChrono v1: a probabilistic model to compute a common and optimal chronology for several ice cores" *by* F. Parrenin

Anonymous Referee #2

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General comments: Parrenin presents a probabilistic model for computing multiple ice-core chronologies simultaneously. Named IceChrono v1, this model is essentially the same as the Datice model except that the optimization is done numerically rather than analytically. While this slows the computation time, it simplifies the code and makes the program accessible to more people. IceChrono v1 is publicly available on github, a useful site that provides good version control. There are also a few additional updates of Datice with respect to allowable age constraints.

The release of IceChrono v1 is potentially quite useful as this dating method can now be used by other researchers. It could also provide insight into the dating method itself as adoption of the Datice chronologies has been hampered by poor explanation of the

methodology. Unfortunately, the paper suffers, as the Datice papers did before it, from mathematical descriptions that are not intuitive and from incomplete diagnostics of the resulting timescale. The IceChrono solver is shown to work, but the improvements to Datice are not tested.

Evaluating this paper has been particularly difficult. Should I limit my review to just whether IceChrono v1 functions as described in the paper? Or should the paper be expected to address the limitations that have been identified with Datice and also exist with IceChrono? The Datice chronologies (first Lemieux-Dudon et al., 2010 and then AICC2012) have not been universally accepted as the best timescales for the various ice cores, and have caused widespread timescale confusion. (A recent paper in Nature by Weber et al. 2014 is a good example of this confusion). I have structured this review in two parts: first, I focus on just the description of IceChrono and second, discuss limitations in the overall Datice/IceCrhono framework. I will let the editor decide if the manuscript should address the more general Datice/IceChrono comments.

First, general comments about the manuscript:

1) Remove all discussion of the Berkner Island ice core. The underlying data for the timescale have not been published so there is no ability to evaluate the inputs to the timescale. The Berkner Island core is challenging to date due to the thin, brittle ice and the first timescale for the cores needs to be accompanied by a full description of the methods used.

2) The additional age and uncertainty constraints described in Section 3.1 (particularly the third and fourth points) do not appear to be used in either example. The utility of these additions need to be described and their implementation needs to be evaluated.

3) Describe the mathematical equations in plain English. For instance, P6817 L2-8 discusses transforming "so-called jeffreys variables" into "Cartesian variables" but does not discuss what the benefit is. This is one example but more description is necessary throughout.

4) The language in the paper needs significant improvement. I have not tried to edit the writing but there are many instances of basic grammatical errors. For instance, the subject and verb don't agree in the very first sentence of the abstract: Polar ice cores provide, not provides.

5) The references are deficient. From the introduction, one gets the impression that only Europeans (and particularly the French) have done anything noteworthy with ice cores.

Line by line comments: Please include a table with all the variables described. There are a lot of very similar symbols and they are difficult to track down in the text.

P6812,L2 – the second sentence is too long with too many parentheses to understand

P6812,L12 – I don't understand the phrase "confidence interval" and how that applies to a chronology. Do you mean the uncertainty in the chronology for each age?

P6813, L5-12 – Please rewrite this paragraph so that the ideas flow more easily.

P6813, L13 – What does "these" refer to? Do you mean that there are 4 broad ways to date ice cores?

P6813, L17 – support your statement that this method is generally accurate for event duration.

P6815, L12 – I find equation 2 difficult to follow. Please describe in more detail.

P6817,L1 – please describe why logarithmic correction functions are needed in plain English. I'm not sure I follow the motivation.

P6817,L13 – how are you solving Equation 2 for deltaDepth?

P6821,L15 – I don't understand "A class exist for the ice core object and does:"

P6821,L14 – This paragraph could use more explanation about object oriented paradigms and object classes

P6821,L25 – This paragraph needs better explanation. I can't follow what is being done "inside each term of the cost function" and why a "change of variable" is occurring. Please write out the steps and add a plain English explanation.

P6822,L8 – how does this Datice assumption really differ from the IceChrono assumption. In describing equation 2, the author assumes a constant value of 1 for thinning in the firn. So isn't the Datice assumption of a constant thinning function at depth very similar? I'm guessing there is a subtlety here that I'm missing and should be better explained. It also seems like in the AICC2012 comparison later in the paper, the effect of this difference should be specifically diagnosed.

P2822,L14 – Please explain why adding mixed ice-gas and gas-ice stratigraphic links is important. You comment that this is new with respect to Datice, but never explain (1) whether the lack of this functionality limits AICC2012, (2) if you used any ice-air or air-ice links in the IceChrono version of AICC-2012, or (3) and concrete example of ice-air and air-ice links.

P2822,L17 – The allowance of correlated errors gets considerable attention in this manuscript, yet I get the impression at both the AICC-like and Berkner Island test cases don't make use of this functionality. The writing even seems to emphasize that you don't need to input error correlation for IceChrono to run. If this is an important advance, the impact of it needs to be assessed.

P2822,L20 – Using a numerical solver of the residuals means that there is the potential to find local minima in the cost function. The paper needs to test whether the solver is robust to different initial conditions.

P6823,L4 – I was able to find and access IceChrono easily. I did not download and compile it. My quick impression is that it could use more documentation.

P6823,L11 – I think calling AICC2012 "the last official chronology" is a little strong. AICC2012 is "an official" chronology, though not universally accepted, and I doubt it

will be “the last” official chronology.

P6823,L14 – I’m confused about correlation matrices. Here you say the Datice background correlation matrices have a Gaussian shape. But on P6822,L18 you write that Datice only allows correlated errors for dated ice intervals. Please explain clearly in the text.

P6823,L17 – Please diagnose and describe the effect of changing from Gaussian to triangular matrices. What is the resulting difference in the timescale and uncertainty from making this change alone? What is the change in computation time?

P6823,L11 – More description is needed of the AICC2012-like inputs. Please describe at least all the different types of dating information used and provide specific references to the AICC2012 work (i.e. if you are using the same gas tie points, reference the appropriate tables in Veres et al. 2013 and Bazin et al. 2013). There is new functionality in IceChrono, is any of this employed? The reader should not be expected to have read all the Datice papers in detail.

P6824 – as discussed above, this section is lacking sufficient detail in the comparison with AICC2012.

P6824, L9 – Please provide more description of the different uncertainties compared to AICC2012. Why does Datice have such a larger uncertainty at the Laschamp event if both methods are using the same inputs?

P6824,L22 – remove this entire section. The first dating of the deep Berkner Island core needs its own paper with the data published. The records are not straightforward and will require significant explanation.

P6827,L10 – adding in glaciological models is a great next step. I think this paper would benefit from an extended discussion of why this is a limitation of IceChrono.

P6827,L18 – The appendix seems both repetitive and under-explained. All of the odd-numbered equations appear to be the same except that they are for different classes

of age markers. I think the appendix would be improved by condensing the odd equations and providing explanation (not just a description of the variables) for the even equations.

Figure 2 – This figure would benefit from a second panel with the most recent 60 ka (when the chronologies are tied to the GICC05 annual chronology). The ice and gas chronologies as well as the ice and gas uncertainties should be shown.

Figures – The removal of the Berkner Island figures will allow many more figures diagnosing the differences of the Datice/IceChrono methologies and the AICC example.

This second part of the review describes some of the limitations of the Datice/IceChrono methodology. While I will let the editor decide if this manuscript should address these issues, I want to emphasize that the manuscript would be much improved by taking a more comprehensive view. If the goal is to get IceChrono accepted as the best way to date ice cores, then a full description and real evaluation of the resulting chronologies will go a long way to achieving this goal.

The Datice and IceChrono methodologies have recognized limitations, which is part of why the chronologies have not been universally adopted. But there are two other reasons as well:

1) The methods have never been well explained. The Lemieux-Dudon papers are nearly impenetrable and the AICC2012 papers add very little in methodological description.

2) The methodologies have never been shown to actually yield improved timescales. Yes, Datice and IceChrono can produce timescales for all the various ice cores, but there has never been a test case that truly evaluates the resulting timescales. A synthetic test case has never been performed; why not develop “known” timescales, add noise, employ Datice/IceChrono, and then compare the inferred timescales to the “known” timescales? This would allow a much improved understanding of the method-

ology and greatly improve the confidence in the inferred timescales.

This work by uses the agreement with AICC2012 as validation for IceChrono. I admit that I bring a bias against the Datice chronologies because there are too many oddities: -the small glacial delta-ages of EDML -the reversals in the thinning function of EDML and Talos Dome in glacial-transition ice -the same uncertainties for the ice and gas timescales that have not been explained. I worry IceChrono may perpetuate many of the Datice methodological problems and create more, not less, confusion about ice-core timescales.

A few of the issues identified with Datice:

A) Ice-ice stratigraphic links are predominantly matches in sulfur peaks between cores. These matches are either correct, or wrong. However, the Datice/IceChrono methology assigns an uncertainty (I think Gaussian) to them. The final timescale results in the links no longer being exact, invalidating the premise of the links in the first place. This limitation needs to described with guidance about what types of analysis the Datice/IceChrono chronologies are not appropriate for.

B) The only glaciological constraints are in background scenarios. This leads to chronologies that are not glaciologically consistent. For the inferred thinning functions, this is revealed through reversals where deeper, older ice has thinned less than shallower, younger ice. For most ice core sites, this is not physically realistic (compressive flow can allow these reversals, but this is not appropriate for most dome sites). Impurity concentrations have been suggested as the cause, but these ideas ignore continuity and are implausible.

C) The gas-age and ice-age uncertainties are the same. This is odd because there should be different uncertainties based on whether the age markers are in the ice or gas. In tracking down this oddity, I found this was instituted after a reviewer of the Bazin et al. (2013) AICC paper found that the ice age uncertainties were smaller even when the age markers were in the gas phase and the gas age uncertainty should have

been smaller. The authors decided to make the uncertainty for both the ice and gas equal to the larger of the two uncertainties. This approach concerns me because (1) the error in the Datice methodology was never diagnosed and (2) the uncertainties are incorrect. While this may seem a minor point, it shows clearly that the output of Datice is not fully understood. If Datice cannot do a simple uncertainty correctly, why should anyone have faith that the more complicated implementations find an “optimal” chronology. This work has not provided enough detail to diagnose whether IceChrono suffers from the same problem.

While possibly outside the scope of this manuscript, addressing these (and other concerns) of the Datice/IceChrono methodology would provide confidence in the resulting chronologies.

Interactive comment on Geosci. Model Dev. Discuss., 7, 6811, 2014.