General comments

Cavitte and others extracted 11 tie points between the Vostok deep ice core and the EPICA Dome C (EDC) ice core by tracking Z scope image data of the radar sounding. The pulse widths of the radar were 250 n-second (~21 m in EM wave in ice) or 100 n-second (~8m in ice). By assuming errors in the timescales of the Vostok ice core is less than 2 ka, the authors attempted to transfer the Vostok O_2/N_2 age (Suwa and Bender, 2008) to the EDC core. The authors claim that the age transfer error by radar data is within several hundreds years. Then, they claim that the time scale of the EDC core can be improved in 126 ka-247 ka age interval.

In our Glaciology community, many researchers have accepted an idea of isochronous nature of the radar internal layers. But at the same time, there were many examples of failure of transferring a timescale from one existing ice coring site to future candidate sites. Such failure have occurred both in East Antarctic sites and Greenland sites. We have recognized errors much larger than the authors of the radar papers had claimed only after ice coring was completed at EDC, NGRIP and NEEM. In the review process, no critical views worked in the cases of the past.

My major concern to the present paper is highly plausible underestimation of errors and uncertainty. The authors synchronization work was done basically independently from real ice core signals. But we see that a few papers are already available to synchronize between Vostok ice core and EDC core (Delmonte et al., 2004;Parrenin et al., 2012). These two kinds of signals agreed well with each other. Disagreement between the radar-based tie points and the ice-core-based tie points are often well above 20 m. See Figure 1 of this review (next page). The sign of the disagreement is both plus and minus. Thus, we cannot see nature of errors as simple systematic errors. In addition, if we transfer Vostok age scale to EDC core based on ice core tie points, the discrepancy between radar-synchronization-based age and the core-synchronization-based age sometimes exceeds 6 ka (see Figure 2 in this review). I suggest the authors try by themselves to check the Figures 1 and 2. And, if my analysis is correct, I suggest the authors to reconsider their claim of the very small errors and low uncertainty. My view is that the authors' recalibration of the EDC3 time scales is not practically useful. More detailed comments are listed below.

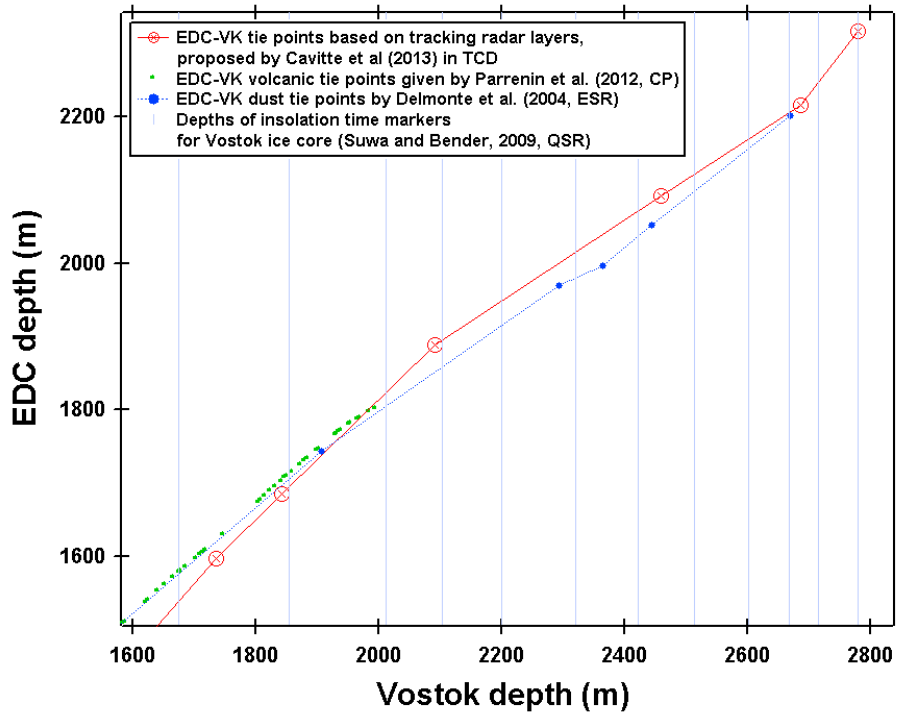

Figure 1. Radar layer tie points proposed by the authors are compared with the ice core volcanic synchronization (Parrenin et al., 2012) and the dust tie points (Delmonte et al., 2004). The vertical thin lines are discrete depths of the insolation (O_2/N_2) age markers given by Suwa and Bender (2008)

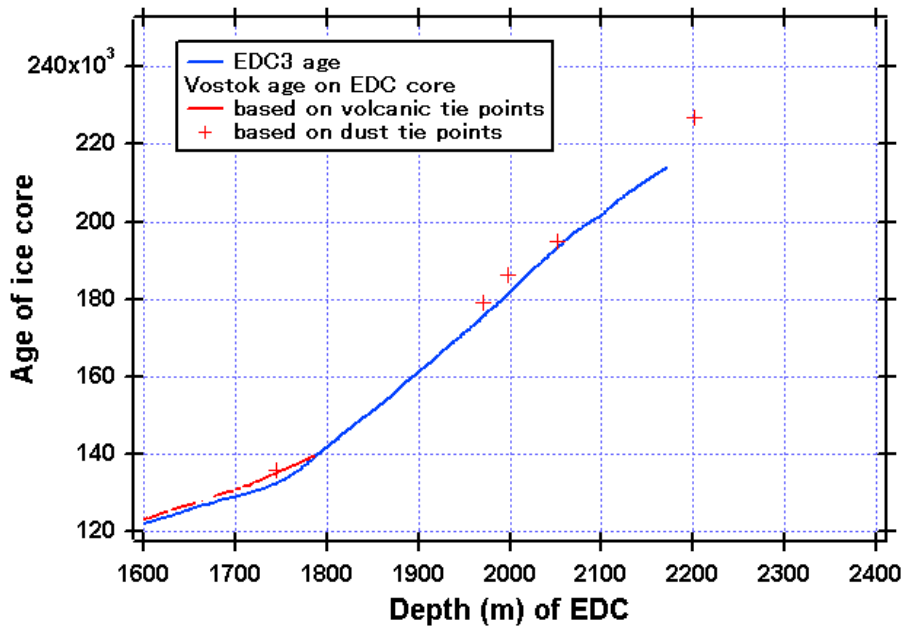

Figure 2. Age of ice core at EDC site. Blue trace is the EDC3 time scale. Red symbols are Vostok insolation time scale (Suwa and Bender, 2008) transferred based on ice core tie points. This figure should be compared with Figure 5 by Cavitte and others TCD paper. At depths between 1900-2100 m, age scale differences are more than 6 ka.

Detailed points

Title of the paper

It seems to me that constraints were not given successfully.

Abstract

P.322, L. 6: Radar depth uncertainty is much larger than the authors claim here.

P. 322, L. 11: Meaning of the "resolution of the ice core age" is unclear.

1. Introduction

P. 322, L. 17: Citation is not proper. Bender (1994) never represents EDC ice core project.

P. 322, L. 21: The paper should be Suwa and Bender, and not Bender and Suwa.

P. 322, L. 26: Rather than "validating" or "recalibrate", ice core researchers have used wording of "synchronization" so far in many papers. I believe that the latter is better wording because we can never say that dating of the Vostok core is much better than EDC core.

P. 323, L.10: It seems that point (1) was not properly demonstrated so far.

2. Data and methods

Figure 1: Show to readers pulse width used for each radar measurement line. In the present manuscript, this information is not given.

P. 323, L.17: When you mention pulse widths, show to readers equivalent widths in ice already here. These long pulse widths of 250 n-second (~21 m in EM wave in ice) or 100 n-second (~8m in ice) should be explicit.

P. 323, L.25: Readers will understand that the authors used some commercial software. But then readers cannot see how reliably the authors determined the layers. The authors must how much were the errors when they chose different routes of the radar transects, as statistic points of view. Also, demonstration of A-scopes indicating tie points will help for better understanding by readers.

P. 324, L. 2: The refractive indices of ice is dependent on both ice temperature and crystal fabric. The authors must give error estimates on how much are errors caused by the assumption of the constant wave velocity. If error is not negligible, effects on both ice temperature and crystal fabric must be used in analysis.

3. Correlating Dome C and Vostok

P. 324, L.7-10: Results are given suddenly. Readers need to see potential errors. See my comments for P. 323, L.25.

P. 324, L.14-19: Readers will not understand how much errors occurred in the previous attempt of the radar synchronization by Siegert et al. (1998b). We see just an excuse here.

P. 325, L.15: Why vertical resolution is 30 m in Vostok using the pulse width of 250 ns? It seems to me

that 30 m is equivalent to ~350 ns in ice.

P. 325, L.16: The authors claim that the picking accuracy is within one tenths of the pulse width. This claim is not credible. Radar layers are interference pattern of the all reflections within a pulse. Basically, depth of each single reflector is not resolvable.

Table 1: The claimed Z errors seem too small than real size of errors. In earlier papers of the radar sounding using pulse as large as 250 ns, I have not seen any examples of demonstration about small Z errors like this table. Even if we use pulses less than 100 ns, errors of a few meters naturally occur. It seems to me that underestimation of errors is the major problem of the present work.

P. 326, L. 28-27: The authors mention that errors in ice core dating are for absolute ages. Errors for synchronizations are for transferring dating markers from one core to another. Nature of the errors are different. This point must be clarified to readers.

P. 327, L. 1-2: It is not a fair emphasis that age discrepancy is less than 1 ka at a single very deep tie point. The other shallower tie points have much larger errors. In addition, the agreement of a single point may be just accidental.

P. 327, L. 3-17: The discussions need to be reconsidered totally. It seems not fair to give most of error causes to ice core dating. Ice core tie points in this review are against the view of the authors.

4. The EDC3 timescale

For me, there seem various errors in transferring the O_2/N_2 age markers from Vostok core to EDC core. Suwa and Bender (2008) gave variation of the gas O_2/N_2 profile. But they did not explicitly provide errors at the depths of the O_2/N_2 marker points and interpolated depths. Ice core dating is done only by combination of reliable age marker and the ice core modeling for the best interpolation among age markers. See Kawamura et al. (Kawamura et al., 2007) paper on this point. They very carefully assessed errors around the tie points and the interpolated depths based on ice sheet modeling. The authors of the present paper just linearly interpolated age markers of the gas O_2/N_2 profile without assessing error for each tie point. I observe no careful handling of errors at this beginning.

Using pulse widths of both 250 ns and 100 ns causes errors as well. In addition, I wonder how much is the error caused by wave speed in ice handled as constant value. When the synchronization is compared with ice core signals (volcanic and dust), the errors seem much larger than the authors claimed. I do not suspect here ice core signals easily because in volcanic synchronization, errors are within centimeter scales. Dust synchronization agrees well with the volcanic synchronization. In contrast, I find many reasons to suspect errors of the radar layer synchronization in the analysis of the present paper.

I believe that, someday precise radar synchronization between two deep ice core sites will be demonstrated. But at the moment, from my view, present paper is an example of claiming too small errors than reality.

P. 328, L.15: The authors are providing just several age markers from Vostok ice core to EDC. The authors can claim to this stage of providing just several age markers. But they cannot claim validity of the

linear interpolation within the EDC core. It is too rough for ice core dating.

P. 328, L.18: Parrenin et al. (2007) used total air content for constructing EDC3 timescales to depths of ~2700 m. Thus, d18O time scale is not proper expression. See caption of the Fig.2 as well

P. 329, Last paragraph

The authors claim that their synchronization agrees well with the Delmonte et al. (2004) dust synchronization. But for me, the comparison just showed errors much larger than the authors claimed. See Figs. 1 and 2 in this review.

5. Conclusions

P. 330, L.4: No "continuous" synchronization was done. They are just for discrete 7 tie points.

P. 330, L. 10-11: No, traditional ice modeling is still very important for dating between reliable age markers. In addition, comparison between ice core markers are the most reliable. The present work failed to demonstrate that the radar-based synchronization have very small uncertainly of the order of several hundred years.

Other comments

Table 2 is repeating a part of Table 1. It seems unnecessary.

Fig. 6 provides nothing new visually.

References

Delmonte, B., Basile-Doelsch, I., Petit, J. R., Maggi, V., Revel-Rolland, M., Michard, A., Jagoutz, E., and Grousset, F.: Comparing the epica and vostok dust records during the last 220,000 years: Stratigraphical correlation and provenance in glacial periods, Earth-Science Reviews, 66, 63-87, 10.1016/j.earscirev.2003.10.004, 2004.

Kawamura, K., Parrenin, F., Lisiecki, L., Uemura, R., Vimeux, F., Severinghaus, J. P., Hutterli, M. A., Nakazawa, T., Aoki, S., Jouzel, J., Raymo, M. E., Matsumoto, K., Nakata, H., Motoyama, H., Fujita, S., Azuma, K., Fujii, Y., and Watanabe, O.: Northern hemisphere forcing of climatic cycles over the past 360,000 years implied by accurately dated antarctic ice cores, Nature, 448, 912-916, 10.1038/nature06015, 2007.

Parrenin, F., Petit, J. R., Masson-Delmotte, V., Wolff, E., Basile-Doelsch, I., Jouzel, J., Lipenkov, V., Rasmussen, S. O., Schwander, J., Severi, M., Udisti, R., Veres, D., and Vinther, B. M.: Volcanic synchronisation between the epica dome c and vostok ice cores (antarctica) 0-145 kyr bp, Clim. Past., 8, 1031-1045, 10.5194/cp-8-1031-2012, 2012.