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Interactive comment on "Bipolar volcanic synchronization of abrupt climate change in Greenland and Antarctic ice cores during the last glacial period" *by* Anders Svensson et al.

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COMMENT: The paper presents the results of bipolar volcanic synchronization, which is a challenging task, and discusses bipolar phasing of DO events. Utilizing 80 volcanic eruptions during the second half of the last glacial period recorded in both Greenland and Antarctic ice cores, age control of the multiple bipolar ice cores is greatly improved. The paper confirms the previously proposed centennial-scale lag of Antarctic temperatures after abrupt Greenland temperature changes during DO events. The improved age control provided by this study significantly reduces the duration of the lag. This new important finding will give better constraints to climate modeling and contribute to

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further understanding of the mechanisms of DO events. The improved age control will also have a wide range of applications not only in ice core studies but also in other fields of geophysics and geochemistry.

REPLY: We very much appreciate the positive mentioning and we will reply to the concerns in the following.

COMMENT: I have a concern about how the bipolar volcanic signals are pinpointed. The criteria need to be more clearly explained. I have the following questions and comments regarding this. 1. Lines 201-203: To my eyes, the inner two spikes are not very clear. The second one from the left does not seem to be seen in the EDC core.

REPLY: It is sometimes the case that eruptions identified in WDC and EDML are not visible in the EDC record. This is probably because EDC is a low accumulation site, where 1) some events are not archived due to the intermittency of snow fall and snow drift and 2) that the EDC sulfate record has comparable low temporal resolution. In this specific case, the second EDC spike from the left is present in the DEP record and the 3rd EDC spike from the left is visible in the sulfate record (Fig. 2).

COMMENT: 2. Lines 209-211: I don't see the 12.17ka peak in the EDC core.

REPLY: This is another example of a minor peak that is hard to identify in the lower-resolution EDC ice core. The peak has been identified in the Antarctic volcanic synchronization of Buizert et al., 2018, so the EDC depth is included in the bipolar list as well. For this work, the Antarctic eruptions are pinpointed mostly in EDML and WDC, whereas EDC is mainly applied to support the major eruptions. However, when the corresponding EDC depth is known from the Antarctic synchronization it is included in the bipolar list for completeness.

COMMENT: 3. Line 236: "the bipolar volcanic matching pattern is easily recognized". I'm not convinced. Please explain how the bipolar volcanic signals are selected. For example, why is the spike around 16.3 ka not selected?

REPLY: The main focus of this study has been to determine the exact bipolar phasing in the neighborhood of the abrupt Greenland warming and cooling transitions. Away from the transitions there are additional bipolar volcanic events not identified in this study. We have now included the 16.3 ka peak in the bipolar volcanic list (Table 1).

COMMENT: 4. Lines 241-242. In the WDC core, there are small acidity peaks around 15.63 ka and 15.71ka. Couldn't one of these peaks correspond to the 15.68 ka peak in Greenland? Are these peaks too far from 15.68ka?

REPLY: Those links are prohibited by the layer counting constrains. Assuming the bipolar link at 15.56 b2k GICC05 is correct, then it would require a counting uncertainty of some (15.71-15.68)/(15.68-15.56)*100 = 25% to allow for the suggested match. That is far more than the counting uncertainty can allow. There is however another pair of minor peaks in the WDC sulfur record that fit with the 15.68 ka peaks in Greenland that we now included in the bipolar volcanic list (Table 1).

COMMENT: I have other minor comments and questions. 1. Lines 32-34: Where in the main text is "more coherent Antarctic water isotopic signals" discussed?

REPLY: The sentence in the abstract is now reformulated: 'In response to Greenland abrupt climatic transitions, we find a response in the Antarctic water isotope signals (d18O and deuterium excess) that is both more immediate and more abrupt than found with previous gas-based interpolar synchronizations.' Figure 5 shows the more immediate response of the Antarctic water isotopic signal for the volcanic synchronization as compared to the gas synchronization.

COMMENT: 2. Line 65: Does Steinhilber et al paper really use 36Cl for bipolar synchronization? The paper does use 10Be. But 36Cl measurement needs large samples and it is usually difficult to use 36Cl for synchronization. Am I wrong?

REPLY: Indeed, 36Cl is not applied in the cited references and is now removed from the text.

COMMENT: 3. Line 164: Please give more details about “high-resolution. What are the resolutions of the stable water isotope records?

REPLY: The sample depth resolution of the water isotopic records vary from core to core and is provided in the cited references. Timewise, the sample resolution will depend on the accumulation and the layer thinning with depth. The term ‘high-resolution’ has been removed.

COMMENT: 4. Lines 175-179: I think wind-scouring is another factor affecting the low accumulation Antarctic sites particularly during colder periods.

REPLY: The wind-scouring effect is now mentioned in this context.

COMMENT: 5. Line 190: It would be nice to show GI-2 in Fig. 1 for readers who are not so familiar with GIs.

REPLY: The position of GI-2 is now indicated in the figure.

COMMENT: 6. Line 216: To my eyes, the EDML water isotope data seems to be increasing during 12.75-13.10 ka.

REPLY: The comment on the Antarctic water isotopes has been removed.

COMMENT: 7. Lines 227-232: I agree that this study gives no support for the Hiawatha crater to have formed around the onset of YD/GS-1. But I don’t understand that undisturbed stratigraphy can deny the Hiawatha crater hypothesis. Is the stratigraphy at NEEM really expected to be disturbed by the Hiawatha event which was 378 km away from NEEM? I’m not very sure about this.

REPLY: The study by Kjær et al., 2018, does not suggest that the Hiawatha crater was formed at the onset of the Younger Dryas event, so the discussion of the crater has been removed.

COMMENT: 8. Line 244: It is difficult to see from Fig. S3A that the spike is a triplet.

REPLY: There is now an inset in Fig. S3A showing the triplet in NGRIP and EDML.

COMMENT: 9. Lines 246-247: I could not understand this sentence. Is this a typo? 10. Lines 255-257: I could not understand this sentence. Please explain in more detail. 11. Line 280: Figure numbers seem to be wrong. Do you mean “such as GI-8 and GI-12 (Figs.S7B and S10B). For the GI-9 onset (Fig.S8B)”?

REPLY: Corrected.

COMMENT: 12. Lines 291-296: Larger variability in Antarctic ice cores could be also due to wind scouring. At low accumulation interior sites, wind scouring increases the noise in water isotope records.

REPLY: The effect is now mentioned.

COMMENT: 13. Lines 324-327: Please explain how the local cycle of sublimation-condensation affects the alignment of the water isotope records.

REPLY: The following text has been added to the manuscript: ‘Sublimation affects the isotope concentration and the deuterium excess of snow through kinetic fractionation. Snow sublimation requires large amounts of energy and it is controlled by the relative humidity, which in turn is linked to the large-scale atmospheric circulation. Sublimation effects are poorly constrained on the East Antarctica plateau.’

COMMENT: 14. Line 337: Please explain more about the logarithmic definition of deuterium excess for readers who are not so familiar with water isotopes.

REPLY: There is now a reference to Markle et al., NatGeo, 2016, where the logarithmic definition is discussed and applied to match Antarctica to the abrupt Greenland climate events.

15. Line 363: I’m confused. Why is there small uncertainty in the relative phasing? Isn’t the uncertainty zero if oxygen and hydrogen isotopes were measured in the same samples? If they were measured in different samples, I would expect almost negligible

uncertainty.

REPLY: The sentence is now formulated as: ‘The Antarctic dln and d18O signals (Fig. 5) are recorded in the same physical ice cores, and therefore the uncertainty in their relative phasing is small and only related to the stacking of the Antarctic cores and the change point determinations.’

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