

Dear Authors and Editor

Here follows my review of the manuscript titled "Tree ring effects and ice core acidities clarify the volcanic record of the 1st millennium".

Sincerely, Bo Vinther

Background and general comments

The manuscript titled "Tree ring effects and ice core acidities clarify the volcanic record of the 1st millennium" by Baillie and McAneney seeks to establish a series of new chronological links between acidity layers in Greenland and Antarctic ice cores and frost rings in bristlecone pines from Western United States. The main hypothesis being that both frost rings and acid layers are caused by explosive volcanism.

It is certainly true that explosive volcanism causes global acid fallout detectable in Greenland and Antarctic ice cores, making the acid layers an excellent proxy for past explosive eruptions. However, the link between explosive volcanism and frost rings is dependent on a climatic response localized exactly in the region of the bristlecone pines, and is as such less robust than the direct record of volcanic acidity fallout recorded in ice cores.

Indeed, it is possible to have cold years in the Western United States without an explosive volcanic eruption to point to, and it is possible to have an explosive volcanic eruption without causing extreme cold in the Western United States. Such examples are readily found in Salzer and Hughes (2007): An example of a volcanic eruption not causing a frost ring is the 1815 Tambora eruption (the most powerful eruption in the last 200 years). A frost ring not related to explosive volcanic eruptions can also be found in the 19th century, specifically in 1828.

Hence, it is clear that there is no one-to-one relationship between explosive volcanism and frost rings in trees and therefore a one-to-one relationship between frost rings and ice core acidity layers cannot and should not be expected. For this very reason ice core scientists (at least in the last 12 years where I have been personally involved in ice core dating work) have found it unwise to use links between frost rings and ice core acidity layers to guide ice core dating.

The approach followed in the creation Greenland Ice Core Chronology 2005 (GICC05) has been to count annual layers in the ice cores independently, only being guided by direct evidence of tephra layers in the ice cores, if such layers could be shown to be related to historically dated eruptions (for GICC05 tephras from the AD 79 Vesuvian eruption and the AD 1362 Öraefajökull eruption were used to guide the dating, see Vinther et al. (2006)).

The same holds true for the dating of the Law Dome core from Antarctica (Plummer et al., 2012). The annual layer counting was carried out independently (also independently of the Greenland ice core chronology). For the Law Dome ice core dating no tephra links were used to guide the dating.

Specific comments:

The following statements in the manuscript by Baillie and McAneney are incorrect or imprecise and therefore needs to be changed (statements in *italic*, my comments in **bold**):

Abstract, lines 10-12: *“Similar offsets are observed for the Antarctic Law Dome and West Antarctic Ice Sheet Divide WDC06A ice-core chronologies that have been linked to the Greenland record.”* **The Law Dome record is independently dated. In Plummer et al. (2012) links to Greenland and Antarctic ice cores are suggested, but these links were not used to guide the dating. The NEEM S1 and WDC06A ice core dating efforts were both guided by links to the GICC05 and are thus not independently dated. This difference needs to be clarified.**

Abstract, lines 14-15: *“In addition, it is possible to show that ice core researchers have used inappropriate linkages to tree effects to justify their chronology.”* **Neither the Law Dome nor the GICC05 dating efforts have made any use of linkages to tree effects to guide or justify their chronologies. Annual layer counting has been carried out independently and links to coinciding tree effects have only been presented after the dating has been established. It is Baillie and McAneney who wishes to use linkages to tree effects to justify their suggested changes in ice core chronologies. The ice core researchers have specifically avoided guidance by any such links. This needs to be clarified.**

Page 1803, lines 13-18: *“it is freely admitted that the subsequent European ice cores, GRIP and North Greenland Ice Core Project (NGRIP), were dated by identification of volcanic marker horizons that allowed them to be tied to the Dye3 chronology (Vinther et al., 2006). Thus these three main ice cores, unlike tree ring chronologies, are not independently replicated, and their chronology ultimately depends on a layer count carried out on the Dye 3 core in the early 1980s”.* **In the framework of the GICC05 dating effort (Vinther et al., 2006), the chronologies of Dye-3, GRIP and NGRIP were all changed. Hence the statement that their dating all “depends on a layer count carried out on the Dye 3 core in the early 1980s” is incorrect. In Vinther et al. 2006 the methodology used is stated on page 3: “The dating of the three ice cores is carried out in four steps. First the ECM records of the three cores are used to match up volcanic reference horizons. Secondly, between consecutive match points annual layers are counted independently in each core. In the third step it is decided if possible discrepancies in the annual counts between the cores can be resolved. If this is not possible, a return to step 1 (the ECM match) is deemed necessary. The fourth step is to find the number of years which is consistent with all available data, and then impose the resulting dating on all three ice cores. In this step the records showing the clearest annual cycles are given the greatest weight.”** Hence the statement on line 13-18 of page 1803 needs to be deleted or completely rewritten to reflect the actual methodology used in creating the GICC05 dating.

Page 1805, lines 13-16: *“Taken together these indicate that Plummer et al. (2012) have taken a less than robust view of ice to tree ring linkages and chosen only those links appearing to confirm the existing ice chronology placement.”* **The links with the trees shown in Plummer et al. (2012) were included to show possible connections between ice core acidities and tree ring signatures, not to substantiate nor evaluate the ice core dating.**

Page 1809, lines 24-26: *“Here we are being told that NEEM is linked to NGRIP and through bi-hemispheric volcanic events to WDC06A and Law Dome, and, further, that all this consistency is at the cost of a loss of independence.”* **As stated earlier the Law Dome dating was carried out independently (see Plummer et al., 2012), while WDC06A and NEEM S1 are linked to GICC05 (see Sigl et al., 2013). This should be clarified.**

Page 1813, lines 25-27: *“It has been possible to reconstruct how the ice cores from Dye3, GRIP, NGRIP, NEEM, Law Dome and WDC06A are an integrated group, all offset, with only DML apparently retaining*

independence, and showing less of an effect.” Again, the Law Dome ice core was independently dated and the GICC05 dating of the Dye-3, GRIP and NGRIP ice cores were carried out independently as described in the methodology section of Vinther et al., 2006. This needs to be clarified.

Page 1814, lines 1-7: *“It has been possible to suggest how the error was brought about, namely by the selection of an acid layer in the first detailed long core – Dye3 – and its attribution to the Vesuvius eruption (Hammer, 1984; Clausen et al., 1997). This error has been built into the fabric of the ice core chronologies through the flawed procedure of using selected volcanic marker horizons and thereby effectively cloning the original Dye3 chronology. By adopting this procedure, rather than counting each new ice core independently, the principle of replication was not applied, and the error was not brought to light.” As there is no imprint of the Vesuvian eruption in the Law Dome core, no guidance from the Vesuvius date was used for the independent Law Dome dating. This needs to be clarified here.*

Page 1814, lines 7-11: *“Of necessity, if this proposed error is correct, the recent location and analysis of tephra in the GRIP core and its attribution to Vesuvius would have to be seen as flawed; something implicit in the less than absolute attribution of the alleged Vesuvius tephra (Barbante et al., 2013).” Do Baillie and McAneney have any evidence beside their hypothesized frost ring link to substantiate the suggestion that this tephra identification is wrong? If not, this statement seems speculative.*

Conclusion:

While it cannot be completely ruled out that the ice core acidity to frost ring links suggested by Baillie and McAneney are correct, their idea seems speculative given the tephra links underpinning the GICC05 dating and the independent confirmation of GICC05 provided by the Law Dome dating effort. Baillie and McAneney addresses neither of these issues in any substantive manner. Furthermore, many of their statements concerning the ice core dating efforts are incorrect or imprecise. Hence I recommend that the this manuscript is either substantially revised to properly reflect and discuss the relevant ice core dating work carried out (see Vinther et al., 2006 and Plummer et al., 2012) and to substantively address the tephra work (Barbenate et al., 2013) and independent ice core dating replication countering their hypothesized tree to ice links, or that the manuscript is rejected due to its above mentioned shortcomings.