**Climate
of the Past**
Discussions

# *Interactive comment on* "Variability of sulfate signal in ice-core records based on five replicate cores" *by* E. Gautier et al.

**E. Gautier et al.**

elsa.gautier@ujf-grenoble.fr

Received and published: 19 November 2015

Anonymous Referee #2

Received and published: 24 September 2015

The manuscript discusses the issue of multiple ice coring for extraction of a volcanic record at the Antarctic Dome C location. The manuscript represents a substantial amount of dedicated and careful work and the results are of interest to a large community and relevant in the context of climate change, constraining of volcanic forcing, IPCC, etc. The manuscript is generally well structured and written, the figures are relevant and referencing is appropriate, except as mentioned below.

General comments:

I urge the authors to study a recent publication by Gfeller et al., that is also concerned with multiple ice coring at a single site, although at a higher accumulation site in Greenland. That study is concerned with both seasonal and inter-annual variability of the cores. Whereas seasonality is probably irrelevant for the present study, it may be of interest to try out the approach of Gfeller et al. for the longer term variability, i.e. the volcanic record. In particular, the representativeness parameter as introduced in Gfeller et al. would be interesting to derive for the Antarctic cores. The requirement for applying the the Gfeller approach is that the sulfate concentrations are similar to log normal distributed (Gfeller et al., figure 3). I am uncertain about if that is the case for the Antarctic sulfate records with their volcanic spikes, but in the Gfeller et al. study the method works for conductivity that is often similar to sulfate, so it should be worth investigating.

–> The sulphate concentrations do have indeed a log normal distribution (see figure 1 attached , based on core 1 concentrations), and Gfeller approach seems appropriate.

You already have a common timescale for your five cores based on your synchronization, so the analysis should be fairly straightforward.

–> Gfeller approach is quite different from the approach we adopted because the variability assessment is based on the entire record, while we base our study on isolated peaks. Indeed one of the major differences resides in the fact that in Gfeller all data are equivalent where in our case we used the a priori information that a peak is considered as volcanic if it is detected at least in two cores. Using the Gfeller approach, where all data are used, including background data, delivers the following results on time period of -570 to 1952, common to the 5 cores (4825 concentration values per cores) (Fig. 2) However, these representativeness coefficients aggregate the background + volcanoes and thus cannot be directly compared with our approach. Nevertheless the same trends are observed, with a decreasing noise as the number of cores increases (our Figure 6). Because the Gfeller's approach is not compatible with discret signal, we have decided to leave our approach unchanged but add the above table and the associated figure in the supplement material, to give a comparison with the Gfeller Âń

scale Âż when the full dataset is taken into account.

It is important that you provide a table or a column in table 2 showing your best estimate of the volcanic flux and sulfur deposition for each eruption, i.e. that you somehow provide the mean of the five cores including the error/uncertainty estimate. This is the number that is important for geographical deposition interpolations, databases, and modelers. In other words, your main result for a larger community.

–> We thank the reviewer for this comment and this information is now added in our Table 2.

Are there no existing datasets you can compare your results to? What about the EDC volcanic record of Severi et al., 2007? It would make much sense to see how the sulfur fluxes of an independent study compare to your results. Do they fall within your error estimates? One could even discuss the effect of the EDC deep core being drilled further away from your closely spaced cores (again following the approach of Gfeller et al.)

–> Sulfate flux of identified volcanic eruption are not provided in Severi et al. 2007, but they are calculated in Castellano et al. 2005. For similar peak, Castellano's flux generally falls into the average flux + 40% uncertainty, but it sometimes exceed this value. Castellano's concentrations and flux are generally higher than our result (Castellano's data are now displayed in Table 2) Regarding the comparison with EDC cores, it would indeed be very interesting to follow Gfeller approach but first all the cores will need to be synchronized and interpolated to reach the same sampling resolution. As mentioned before this will lead to a comparison of the whole time series profiles and not only of the volcanoes peak similarity. This could be the scope of a future work that wants to measure the representativeness of a time series at DC but we don't think that Gfeller's approach is well fit for discret events like volcanoes, e.g. deciding what should be tagged as volcano is not included in the Gfeller's approach.

Specific comments:

Peak discrimination method: 1) I wonder why you determine the background based on 1m long sections when you sometimes have volcanic spikes covering almost half of that interval length? In figures 3b and 8 this approach appears to result in too high background determinations for core 1? I would suggest to work on longer sections. C1782

–> We are actually working on a 1m-moving window, therefore the background corresponding to one even is calculated a large number of time (each point is considered in at least 50 runs). The 1m-window was also chosen because ice cores were treated, logged and decontaminated by 1m section.

2) To determine the background, why do you use the mean across 1m intervals rather than the median? The median is much more efficiently discriminating outliers (in your case volcanic spikes).

–> Correct, median could have been a better criteria but the difference between median and mean is not expected to be fundamental, as the difference will only play at the margin, for very small events. Looping based on the mean until no peak is further detected will reduce the difference between mean and median. If the background is assumed to be a noise controlled by surface processes, then a close to normal distribution is expected for the background which will result in the median equals the mean. As an example, on the first ten meters in core 1, the median of the background values is 79.67 ppb, while the mean is 81.87 ppb.

3) It would be good to show the derived background together with the data over a longer section of the ice core, so we can better visually judge how well the background determination works.

–> Fig.3 illustrates the variation of the background along depth in core 1, red dots are detected peaks, the dark line stands for the background concentration. If this is what the reviewer suggests, this figure can be added in the supplementary online materials.

Section 2.1: Please sketch/explain the lateral pattern of the five drill locations. Are the 5 cores drilled along a straight line on the snow surface? In that case, the distance between cores 1 and 5 would be 4m and not 1m?

–> Correct, we change the text as "drilled along a 5 m straight line, and spaced approximately 1 m apart" corrected on line 110.

P. 3981, l. 6: I suggest to replace 'global' with 'local' as global has a different meaning in the context of volcanism.

–> Correct, we have corrected the text.

Figures 3 and 8: Many coloured straight lines are shown close to the background level. If those represent the background level estimates then please mention in caption.

–> They actually don't. The different colors stand for different core profiles, none of them represents the background in itself.

Figure 4: The depth scale is wrong. In ice cores you rarely have both linear depth and age scales.

–> Correct, we made a poor manipulation to have both scales on the graph, which does not seems feasible with the program we use. We kept sulfate vs. age on the figure 4.

In figure 6, I am somewhat puzzled by the logarithmic fit to the data points. The fit suggests that the more ice cores you drill, the more volcanic events you will find. With no upper limit. That is not convincing. Instead, I would expect something similar to the representativeness parameter of Gfeller et al., with an upper limit for (infinitely) many cores.

–> The reason is simple. While Gfeller used an hypothetic upper limit to scale his coefficient, there is a priori not known upper limit for the number of volcanic peak to be detected. Again this is another illustration of the limit of Gfeller approach for discret event. We obviously agree that there should be a fix number of volcanic peaks at

C2388

the end and that an asymptotic value should be reached. However, as our criteria is based on the detection of a common peak at least in two ice cores, multiplying the number of cores increases the probability of such criteria to be verified, but as the number of core increases our criteria of common detection should also become more stringent (e.g. with 20 cores, a detection in 5 cores could be used), finally resulting in an asymptotic value as the number of core increases. All the difficulty resides in the number of occurrence that should be taken to label an outlier as a event (and therefore the level of confidence). We think that the log fit is actually an approximation (resulting from a poor statistic) of a more general law that should level off with more cores. To avoid such confusion, we decided to remove the equation.
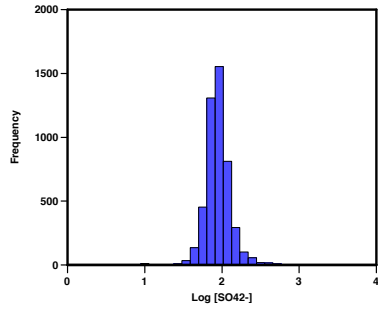
**Fig. 1.** SO4 log normal distribution

**SOM Signal Variability**

1. Gfeller et al. (2014) approach on Dome C 5 cores : calculation of the representativeness $\bar{R}^2_{n,\infty}$

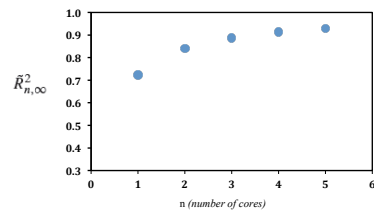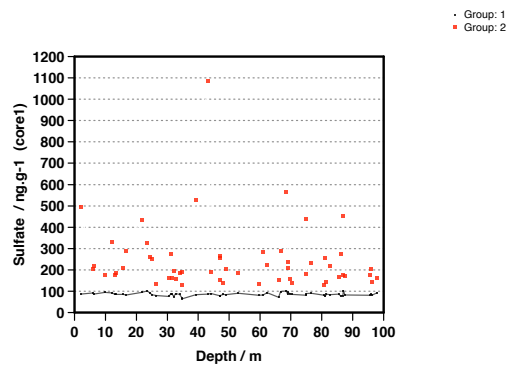| n *(number of cores)* | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $\bar{R}^2_{n,\infty}$ $SO_4{}^2$ | 0.72 | 0.84 | 0.89 | 0.91 | 0.93 |



**Fig. 2.** Table Gfeller approach

**Fig. 3.** Peaks and background detection in core 1

C2392