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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Carbonyl sulfide in air extracted from a South Pole ice core: a 2000 year record" *by* M. Aydin et al.

M. Aydin et al.

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We are going to address the points raised by the reviewer in the order they were stated in the comments.

Length of the volcanic proxy record: The reviewer correctly points out that the record of volcanic emissions presented in the manuscript goes back 1000 years, hence does not prove useful in evaluating the potential impact of volcanism on the apparent rise of atmospheric COS levels between 500 C.E. and 1,100 C.E. There are various volcanism records available, primarily from Antarctic ice cores that cover a longer time period than the Crowley (2000) record presented in the manuscript. However, by nature, records from individual ice cores can be heavily biased towards more localized signals and lead to erroneous conclusions if interpreted as being representative of the impact of volcanism on a global scale. For this reason, we refrained from trying to extend the

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composite record of Crowley (2000) using individually published volcanism data.

Outliers in the COS data: Based on the presence of the clear outliers in the data, the reviewer is justified in questioning whether all data points are affected by in situ production to some degree. As pointed out in the manuscript, the agreement between the Siple Dome and the SPRESSO data presented in this manuscript provides some assurance that in situ production does not compromise all data points. We need more data from contemporaneous ice cores drilled at different sites to answer this question more confidently.

We are currently analyzing samples from WAIS Divide, Taylor Dome, and Vostok, Antarctica. However, even the results of these analyses may not provide an answer to why we occasionally observe outliers. We are measuring several other trace gases in the samples and so far we only found correlation with CS2 in the samples that have elevated COS levels, although not always to the same degree.

Smoothing: The most serious concern of the reviewer is about the impact of different time scales involved in the smoothing of the temperature proxy data, volcanic emission data, and the smoothing that occurs naturally in the firn on the discussions related to Figures 2 and 3. Below, we address the issues raised by the reviewer in the order that they were written in the review and argue that the use of smoothed records, both in the case of volcanism and climate records, do not invoke a subjective bias to the discussion of the COS data. Therefore no changes were done to the original manuscript with the exception of a minor modification as mentioned in the 5th paragraph below.

It is not within the scope of this manuscript to engage in a comparative discussion on the temperature proxy records of Mann and Jones (2003) and Moberg et al. (2005). This is ongoing in relevant literature.

The choice of a 40-year filter is not entirely ours. The Mann and Jones (2003) record is available in decadal and 40-year smoothed formats (http://www.ncdc.noaa.gov/paleo/globalwarming/jones-mann.html). We simply pre-

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ferred to use the Mann and Jones (2003) record as it was presented in Figure 2 of that paper. The only the difference between the decadal and 40-year smoothed records is that the latter version does not display variability on decadal time scales. Variability over 50-year or longer time scales are not impacted by this smoothing. Since our manuscript does not contain any discussion on decadal time scales either, this choice has no effect on conclusions reached based on the SPRESSO COS record. It was only appropriate to apply a 40-year FFT smoothing to the Moberg et al. (2005) data, which is available at annual resolution (http://www.ncdc.noaa.gov/paleo/pubs/moberg2005/moberg2005.html). A choice of an 80- or a 160-year filter, as the reviewer questions, essentially smoothes out all variability in the temperature records shorter than the cut-off used in the filter but variations at lower frequencies would remain unaltered. Even using a 160-year filter, we could still present all the discussion in the manuscript unchanged, with the possible exception of the relatively short-lived warming event around 1400 C.E. This feature gets smeared out with the 160-year smoothing because of the duration of the event is comparable to 160 years.

The reviewer is correct that there is not a scientific consensus on the intensity, or maybe even the existence, of the MCA and LIA. This is precisely why we chose to present two separate records of climatic variability, which differ significantly in terms of the intensity of MCA and LIA. On the other hand, there are numerous published paleo records that display anomalies associated with these time periods. A short review of this literature is provided in our manuscript. There is one very important point that we would like to emphasize: the temperature anomalies related to MCA and LIA do not appear or disappear with the 40-year smoothing applied to the data. Since the relevant time scales for MCA and LIA are longer than 40 years, this should not come as a surprise. All discussion of COS variability as a function of climatic changes is also on time scales significantly longer than 40 years.

The volcanic emissions record of Crowley is presented after a 5-year averaging. This

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was done to smooth out some of the annual spikes in the volcanism data and present this record in a way that more closely resembles the emission and distribution of COS in the atmosphere due to volcanic events. COS lifetime in the atmosphere is estimated to be in 2.5-5 y range. It should also be noted that even though the volcanic eruptions last only a few days, the post eruptive gas emissions can last a year or longer after the eruption events (Belviso et al., 1986). It is important to remember that even if the record presented here with a 5-year smoothing was a perfect representation of the dispersion of volcanically emitted COS in the atmosphere, which it is not, the resultant spikes in the atmospheric levels would be further smoothed in the firn, as the reviewer points out later in his comments. Therefore it is not possible that the COS data identified as outliers can be explained by excessive COS flux into the atmosphere from large volcanic events. It is possible, however, to hypothesize that excessive particulate deposition from a large or nearby volcanic event may induce the type of intermittent in situ production that the COS data seems to indicate although it is not clear how large an eruption would be necessary. We did look into this possibility in our earlier work but did not see a correlation in depth space between volcanic ash layers and anomalous COS gas data.

It is true that the real atmospheric record of any gas gets filtered in the firn column (this is essentially a natural low-pass filter) before it gets locked in ice core air bubbles. The low-pass filter that operates at South Pole has about a 50 year width at half height. This information was not provided in the first version of this manuscript. In the revised version, it is included in the caption of Figure 2 of the manuscript, along with the width at half height for Siple Dome. Unfortunately, the information loss that occurs in the firn is permanent. There is no way to inverse the filtering to recover information at a higher resolution than the cut-off of the firn filter that operated at a given site. Further filtering, as suggested by the reviewer, should only be done at longer periods than the natural filtering that has already occurred and only if the time scales of interest are significantly longer than the cut-off of firn filter. This is very uncommon in the literature of ice core gas measurements and we do not think it is appropriate for the current data

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either. Presenting all 106 data points displays the potential problems (as in the case of outliers) with the COS ice core analysis. What is important is to avoid the temptation to interpret the SPRESSO data over unreasonably short time scales (e.g. decadal).

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 16763, 2008.

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