Answers to comments of Reviewer 2

We thank Reviewer 2 for his/her review, which adds value to our manuscript. Comments are addressed below. Each comment by the reviewer is first recalled (in italics), then the corresponding authors replies are given.

General comment
"[...] Unfortunately in the current version of the data set both total optical depth and latitudinal distribution in some important cases are unrealistic and using this data set in climate simulations would be misleading. See below the detailed comments. "

Authors reply
We do not agree with the reviewer's statement that "the total optical depths and latitudinal distributions in some cases are unrealistic" and we show below that the reviewer misread our total optical depth results and do not sufficiently acknowledge the uncertainties in latitudinal distributions for historical eruptions. Specific responses are given in the detailed comments section below.

Specific comment 1
P971, L14: Change "1 km-1" to "km-1"

Authors reply
Done.

Specific comment 2
P977, L1-5: It is misleading. We do not know how well the AER-2D model produces vertical distribution of aerosols in particular cases. Coarse observations, when available, might be better. In the current configuration the vertical structure is very sensitive to the altitude of the injection. The authors did not explain how did they use the volcanic plume model to estimate the altitude of injections and how reliable those estimates are.

Authors reply
The vertical structure in AER-2D for the Pinatubo eruption shows an accurate extinction peak altitude and a too wide distribution compared to SAGE v6.0 observations (see text with reference to Arfeuille et al., 2012 at the end of section 3) . The aerosol altitude distribution in AER-2D for the Pinatubo eruption is well into current uncertainties and does even provide a better altitudinal distribution compared to outdated SAGE datasets (Arfeuille et al., 2012).
Before the satellite period, no altitude data is available and scaling to Pinatubo is a difficult and uncertain task as the location of the volcanoes, time of eruptions, amount of aerosols and size of particles, all impact the altitude distribution. Using an aerosol modelling approach is hence very valuable. Previous datasets covering the 1600-present period provide total optical depths. For models using extinction coefficients, this AOD information is then for instance distributed among the 20-86hPa levels with a peak at 50hPa (as in Junglaus et al., 2010).

This matches roughly with our data for the tropical region but cannot describe well the extra-tropics, where aerosols fall down.
Concerning the injection height of SO_2 and the use of the volcanic plume model Plumeria: The variations in injection heights do not change much the altitude distribution of the aerosols as stated in the "Altitudinal distribution" subsection.
We also do mention uncertainties in the volcanic plume modelling (in the "Altitude of injection" subsection.)

Specific comment 3
P978, L6: It is not consistent with Thordarson and Self (2003).

Authors reply
We thank the reviewer for this comment.
Sentence changed from "[..] the SO_2 release was mainly tropospheric (Highwood and Stevenson, 2003) [..]" to " According to previous studies, the SO_2 release was either mainly tropospheric (Highwood and Stevenson, 2003) or distributed in the UT/LS region, with however 85% of the formed aerosol being removed in summer/fall 1783 (Thordarson and Self (2003). Due to difficulties to model accurately such an eruption with our approach, we chose not to implement it in the final dataset. Further work could be done in the future to add this particular eruption."

Specific comment 4
P979, L1-3: What is the temperature change? Did you model it?

Authors reply
The temperature change is modelled from a Pinatubo size eruption scenario. Sentence added in the manuscript.

Specific comment 5
Section 4.3: AER-2D model is a core of this study. It has to be better described.

Authors reply
AER-2D model description is now described in more details in the manuscript. The model is further described in the cited literature (Weisenstein et al., 2007)

Specific comment 6
L983, L2: Optical depth of 2.76 for a Pinatubo size eruption is too much by an order of magnitude.

Authors reply
The optical depth of 2.76 for the Pinatubo size eruption refers to a 24 month cumulative value as stated in the text. The peak optical depth for this eruption can be derived from equation (3) and is 0.20, which is indeed an order of magnitude smaller.

Specific comment 7
P984, L4: What does it mean?

Authors reply

Rephrased to " Sensitivity studies made for the Tambora eruption with initial injection at 23–25 km and 27–29 km tend to indicate a non-negligible impact on the aerosol distribution, with shorter time residence in the tropical region for the 27–29 km simulation and stronger extra-tropical transport.

Specific comment 8

Section 5.3: The AER-2D model does not have QBO, uses prescribed climatological winds, does not account for aerosol heating, does not have wave structure. It cannot skillfully calculate what hemisphere the equatorial volcanic cloud will go. It is a very sensitive process that critically depends on all mentioned factors.

Authors reply

These factors are already acknowledged in the manuscript as being shortcomings to our method. However, we disagree that the hemispheric partitioning of the cloud cannot be, within uncertainties, partly constrained by the timing of the eruption. Some previous works are also based on this assumption. For instance parameterizations of the aerosol transport in Ammann et al., (2003) relies on the assumption that transport from the tropics to the mid-latitude takes place in the lower stratosphere in the winter hemisphere only. It is also important to note that the alternative method to derive the hemispheric partitioning of equatorial volcanic clouds is based on hemispheric ice core data and is prone to large uncertainties as stated in our manuscript.

Specific comment 9

P984, L.21-24: I do not thing the Tambora's cloud was that asymmetric. Could you please compare with other sources, not only with Crowley.

Authors reply

Values from Gao et al., (2008) and Sigl et al., (2013) are already discussed in the manuscript and the uncertainties of hemispheric calibration from ice cores are also presented (section 2.4). We can note that our method captures well the very asymmetric aerosol distribution of the Agung eruption, as shown in fig.13. For the Tambora eruption of 1815, the lack of direct precise observations strongly limits what can be safely said about the latitudinal distribution of the aerosols.

Specific comment 10

P985, L25-30: Compare with SAGE.

Authors reply

Comparison is now done with SAGE.

Specific comment 11

P986, L1-5: We know that the AVHRR strat optical depth is contaminated by the effect of tropospheric aerosols. AVHRR overestimated the Pinatubo optical depth, and have to be used with caution.

Authors reply

Comparison is now done with SAGE.

Specific comment 12
P986, L26-29: I do not think you can claim this. The Pinatubo optical depth of 0.7 in tropics does not sound realistic to me. It 2-3 times more than expected.

Authors reply
The 0.7 optical depth value does not correspond to the tropics but to the 5S-5N band. For the tropics (30S-30N), the value is 0.26 (see Figure 12). As Figure 14 can be misleading, we change it to show the tropical (30S-30N) optical depth of Pinatubo. Our dataset and Amman et al., (2003) overestimate the optical depth in the tropics by 100% compared to SAGE II for the first year after the eruption, while Sato et al., (1993) and Crowley et al., (2008) overestimate it by 50%. While this is indeed a characteristic to improve in the future, we argue that this uncertainty is reasonable as the strength of our dataset is in the pre-satellite period, when larger uncertainties are present and alternative methods to derive altitude/latitude monthly distributions involve uncertain parameterizations.