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Interactive comment on "Ship-borne lidar measurements showing the progression of the tropical reservoir of volcanic aerosol after the June 1991 Pinatubo eruption" *by* Juan-Carlos Antuña-Marrero et al.

Juan-Carlos Antuña-Marrero et al.

antuna@goa.uva.es

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We thank the reviewer for his comments which contributed to improve the manuscript. The comments were numbered. Our answers to his comments are detailed below.

The paper discusses a very old shipborne lidar data set on stratospheric Pinatubo aerosol observations. The data were collected on two Russian research vessels almost 30 years ago, in July-September 1991 and in January-February 1992. The measurements were published in two papers (in GRL 1993).

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Discussion paper

1) Why do we now need another paper on this? This question needs to be answered more clearly! I did not get the point. Now, in this publication, all 48 out of 48 and 11 out of 20 lidar measurement sessions are reanalyzed. Ok! But the question remains!

Answer: Following reviewer suggestion, in line 77 we included the following paragraph:

"Apart from the figures and few magnitudes of stratospheric aerosols extinction reported in the two papers already cited, no other information is available. Those two datasets never were publically available, been absent in the numerous simulations conducted about the climate effects and the evolution of the stratospheric aerosols from the 1991 Mt Pinatubo volcanic eruption. In this paper we make public the two lidars scattering ratios datasets, reconstruct the stratospheric aerosols extinction vertical profiles and produce the stratospheric aerosols backscattering vertical profiles from both lidars by first time."

2) Abstract : : : formation of an associated cirrus cloud: : :. This hypothesis on the role of the volcanic particles on cirrus crystal nucleation : : :. is based on what? : : : Are the ash particles favorable INPs? : : :or were the sulfuric acid particles responsible for ice nucleation? Sulfuric acid leads to homogeneous ice nucleation. All this remains speculative.

Answer: There is a joint answer in relation to all the comments about cirrus clouds at the end of this document.

3) Table 1: Both lidars had a huge receiver mirror (110 cm diameter of the primary mirror). What motivated the Russians to have such big lidars on both ships: : :? This is just a question! You do not have to answer that in the paper.

Answer: It is a big mirror. It contributed to maximize the backscattered laser signal collection, a critical issue considering the contribution to AOD from marine aerosols (on top of the stratospheric AOD) to the two way transmittance attenuation of the signal. The main goal of the lidar onboard Zubov was to measures mesospheric temperature

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Discussion paper

(Nardi et al., 1993). However, there have been several other lidars with mirrors of the diameters in the same order. The lidar at Langley Research Center, NASA, had a mirror of diameter 48 inches 122 cm. The LITE space lidar had 1m diameter mirror. Two French lidars in the 90′s had mirrors with 120 cm the one at Centre d'Essai des Landes at Biscarosse -CEL: 44 °N, 1°W). and 150 cm the one onboard Henri Poincare ship).

4) Lines 95-96: These personal notes sound strange in a paper: : : I would avoid : : : to mention Prof. Keckhut and : : : PhD dissertation of the lead author: : : Is that information really worthwhile to be mentioned?

Answer: It is a common practice in scientific publications to report the origin of the data used and it became more relevant in current times, seeking transparency and reproducibility in the reported research. That is more important when a data rescue work is published to explain where the data was found or who contributed with it. In addition we feel compelled to explain why the data was not used in when it was contributed by Prof. Keckhut, a little more than 20 years ago.

5) Line 118: Did you use CIRA-86 atmospheric profiles here in the re-analysis? I hope not. You probably used 'modern' GDAS or ERA-Interim reanalysis data or ECMWF profiles, I hope?

Answer: Yes, we used CIRA-86 and not any other modern reanalysis. As it is stated in the paper our goal was to reconstruct the two stratospheric aerosols extinction datasets. To comply with that goal we followed all the methodological steps the authors mention in their two papers and also used the same parameters (aerosol backscatter-to-aerosol extinction coefficients, wavelength exponent to convert aerosol backscatter from 589 nm to 532 nm and the Rayleigh backscattering coefficient at 532 nm). For determining the molecular backscatter profiles they used the CIRA-86 atmosphere.

6) Line 124: You did not use Russel et al., 1979, right? You used the Fernald (1984) procedure, I hope! Otherwise you have to repeat the re-analysis by using the Fernald

(1984) approach.

Answer: Nardi et al.,(1993) describe how they derived the scattering ratio and normalized it at 40 km or above (scattering ratio = 1.0). In fact the review of that variable in Supplement 4 reveal in the case of Zubov all the profiles at 40.1 km have the value of 1, been in most cases the only value of 1 in the individual profiles. That is procedure described by Russell (1979). We do not know any reason for them to not apply it. In the manuscript we describe how our processing began from those scattering ratio profiles.

7) Line 131: The question on the lidar ratio of 25 sr for 539 or 589 nm: : : Please have a look into the article of Jager and Deshler (correction paper, GRL 2003). I think, 25 sr is ok for the first phase after the eruption. And later on the lidar ratio increased with decreasing mean or effective size of the sulfuric acid droplets. Jäger, H. and Deshler, T.: Lidar backscatter to extinction, mass and area conversions for stratospheric aerosols based on mid-latitude balloon-borne size distribution measurements, Geophys. Res. Lett., 29, 1929, doi:10.1029/2002GL015609, 2002. Jäger, H. and Deshler, T.: Correction to "Lidar backscatter to extinction, mass and area conversions for stratospheric aerosols based on midlatitude balloon borne size distribution measurements", Geophys. Res. Lett., 30, 1382, doi:10.1029/2003GL017189,2003.

Answer: We agree there are better estimates of the extinction to backscatter ratio than the one used by Avdyushin et al., (1993) and Nardi et al., (1993) for processing Zubov and Vize lidars. However, as it have been explained our goal was to reproduce the original aerosol extinction dataset.

8) Line 148-155: If there is agreement, why do you then publish the observations again? I did not get the point.

Answer: The two datasets have not been published before. The figures and few mentions of the stratospheric aerosols extinction magnitudes in the two papers were used to validate the results of the reproduced vertical profiles stratospheric aerosols extinction. We are making public both datasets. Each of then consists of the reproduced

vertical profiles of the stratospheric aerosols extinction by first time (only available in the two cited papers figures and the citation of some of its values); the backscattering ratios (never published before) and the vertical profiles of the aerosols backscatter (never available before).

9) Figure 1: Would be nice to have an x-axis also in terms of latitude: : : You need to explain all shown features in the figure caption. To have the explanation in the main text body is not sufficient. The white line: : :shows what? The color scale is quite poor.

Answer: In answer to reviewer 1 a plot with the location of the measurements was included in the manuscript, identified as "Figure 1" and a text describing it was it was added. Page 5 Line 109: "The trajectories of both ships are depicted on figure1 by the positions where the lidar measurements were conducted. Professor Zubov (red stars) began its measurement on July 12th 1991 around 40 °N and 30 °W, moving to the Caribbean. Upon reaching the Caribbean, near Punta de Maisí the eastern point of Cuba, by the last week of July its trajectory consisted in loop around the Antilles, except, Cuba. By early August it moved from around 20 °N and 65 °E across the Atlantic in direction to Africa reaching10 °N and 20 ° E by the first week of September. Then it moved northeast in direction to Europe, conducting it last measurement on September 21st in the vicinity of the northern Spain. A map of the Caribbean loop trajectory is available as Supplement S2. Professor Vize measurements (blue diamonds) began at 0° longitude and -10 °N on January 26th 1991 moving northward, mainly bordering Africa and Europe ending on February 20th around 60 °N and 20 ° E." Also the Supplement S2 (Attached in the answer to reviewer # 1) was added, consisting a map of the Caribbean Trajectory Loop describing it in detail.

10) Line 164: Please avoid any speculation. You need a convincing argumentation when it comes to the point: volcanic influence on cirrus. Even Ken Sassen's paper (Science, 1992?) could not explain it. And offered just speculative arguments.

Answer: There is a joint answer in relation to all the comments about cirrus clouds at

the end of this document.

11) Line 176: day 250 is probably 8 September : : : and not 8 August: : :

Answer: Corrected. It is September 8th.

12) Line 184: : :alpha increased: : : not decreased: : :

Answer: There was an error in the magnitude assigned for the aerosols extinction at 17.3 km in the manuscript: it is 0.010 km-1 instead of 0.020 km-1. In the profile it is clear that the extinction decrease from 18 to 17.3 km and then increases up to the second maximum at 14 km. The error in the magnitude of the aerosols extinction and 17.3 km was corrected.

13) Line 190: Cirrus and volcanic liquid particles : : :. Even if the volcanic particles would have had an influence on cirrus development, it would be homogeneous freezing, because there is no solid phase: : : and thus there is no chance to distinguish that from the influence of background sulfate particles.

Answer: There is a joint answer in relation to all the comments about cirrus clouds at the end of this document.

14) Line 194: : : so if there are only a few cirrus clouds in the volcanic layers: : : the link to volcanic aerosol is not very solid: : :. And meteorological conditions (midlatitudes vs tropics) play a role as well: : :

Answer: There is a joint answer in relation to all the comments about cirrus clouds at the end of this document.

15) Figure 2: please explain Ho, Hf, UTS, UT, S in the caption: : :It is just one sentence:
16) Figure 3: similar to Figure 2: : :

Answer: The terms Ho and Hf were described in both figure captions. The terms UTS-AOD, UT-AOD and SAOD were also described in the caption of figure 2. The terms UTS-AOD and UT-AOD were eliminated in figure 3 caption, because they do not

contributed to the discussion. Because a figure showing the trajectories along what the measurements were conducted was added to the manuscript (in answer to Reviewer # 1, comment # 3) then former figure 2 and 3 are now figures 3 and 4 respectively

17) Figure 4 results. Are there other tropical lidar observations for comparison? Hawai lidar observations, maybe?

Answer: Yes there are several. We consider it is not necessary to conduct a comparison or discuss them here, because it is not the goal of the manuscript. However, we may refer the reviewer to a PhD Thesis where they are listed as part of a global compilation conducted in 2002. There is a table with all its information, including its respective references. Also a map show the locations of the ground based lidars and the trajectories of the lidars onboard aircrafts and ships: Antuña, Juan Carlos, 2002, Comparison of SAGE II and lidar stratospheric aerosol extinction datasets after the Mt Pinatubo eruption. PhD Thesis, Rutgers University, 91 pp. (Available at: http://rizalls.lib.admu.edu.ph:8080/proquestfil/3066744.pdf)

18) Figure 4 top: : : :Heitgh: : :

Answer: The figure 4 was replaced by a new one with the typo corrected. Because a Figure showing the trajectories along what the measurements were conducted was added to the manuscript (in answer to Reviewer # 1, comment # 3) former figure 4 is now figure 5.

Joint answer to the comments on the cirrus profile showed in the manuscript:

General Answer: are not reporting the study of the potential interaction between cirrus clouds and volcanic aerosols. Any discussion on this subject if completely out of context. We are showing the potential of the information from this profile and the other 4 from Prof. Vize lidar in early 1992, to conduct case studies. We do not speculate, we show facts and call the attention to it to motivate further research.

2) Abstract : : : formation of an associated cirrus cloud: : :. This hypothesis on the

role of the volcanic particles on cirrus crystal nucleation : : :. is based on what? : : : Are the ash particles favorable INPs? : : :or were the sulfuric acid particles responsible for ice nucleation? Sulfuric acid leads to homogeneous ice nucleation. All this remains speculative.

Answer: In the Abstract we changed the expression: "... and the formation of an associated cirrus cloud" By "... and the detection of a cirrus cloud below it."

10) Line 164: Please avoid any speculation. You need a convincing argumentation when it comes to the point: volcanic influence on cirrus. Even Ken Sassen's paper (Science, 1992?) could not explain it. And offered just speculative arguments.

Answer: The sentence commented by the reviewer is: "This feature may be associated to the combination of what seems to be a downward transport of stratospheric aerosols with the presence of a thick cirrus cloud attached below." This is a fact no an speculation.

13) Line 190: Cirrus and volcanic liquid particles : : :. Even if the volcanic particles would have had an influence on cirrus development, it would be homogeneous freezing, because there is no solid phase: : : and thus there is no chance to distinguish that from the influence of background sulfate particles.

Answer: The sentence commented by the reviewer is: Cirrus were reported to grow often within the stratospheric aerosols layer from Mt Pinatubo as in the case we are discussing (Guasta et al., 1994). This profile shows, probably, the earlier case of a cirrus observed in lidar measurements of the Mt Pinatubo stratospheric aerosols. We cite what is inconcluded in a peer review published paper.

14) Line 194: : : so if there are only a few cirrus clouds in the volcanic layers: : : the link to volcanic aerosol is not very solid: : :. And meteorological conditions (midlatitudes vs tropics) play a role as well: : : The sentence commented by the reviewer is:

Answer: An interesting feature is that in the 48 αaer(z) profiles from the lidar on Profes-

sor Zubov vessel between July and September 1991 only in one profile a cirrus cloud was detected, only 2 % of the profiles. However, in 4 of the 11 available αaer(z) profiles from the lidar on Professor Vize vessel between January and February 1992, 4 profiles showed the presence of cirrus clouds, around 40% of the observations. These percentage is similar to the reported by a lidar located at Sodankyla, Finland (66 °N), during the EASOE campaign between December 1991 and March 1992 (Guasta et al., 1994). We are reporting a fact, no speculating.

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