

## ***Interactive comment on “Long-range isentropic transport of stratospheric aerosols over Southern Hemisphere following the Calbuco eruption in April 2015” by Nelson Bègue et al.***

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This paper presents both experimental and theoretical studies of aerosol (plume) transport in the Southern Hemisphere stratosphere after the 2015 Calbuco eruption. The experimental part was performed with space-borne and ground-based lidar observations together with balloon-borne aerosol particle counting (over Reunion Island). The theoretical part was based on the use of the MIMOSA advection model and DyBAL code. The results of this study are interesting and even contradict to those obtained by other researchers (see below the first general comment). The conclusions of this study are sufficiently valid for the paper to be potentially published in ACP, but the paper re-

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quires major revisions. I have two general and several minor comments and concerns to be addressed by the authors.

General comments:

1. There were two remarkable events related to the Southern Hemisphere stratosphere in 2015: 1) the Calbuco eruption in April and 2) the reaching of the record ozone hole size in October. Based on the results of the SD-WACCM\* and FR-WACCM\*\* simulations, Solomon et al. (2016) and Ivy et al. (2017) declared that the first event (eruption) led to the second one. In other words, according to Solomon et al. (2016) and Ivy et al. (2017), the Calbuco aerosol plume (including various volcanic gas emissions) penetrated the polar vortex and caused the record Antarctic ozone hole size after the eruption. On the other hand, according to the findings presented by the authors (Bègue et al., 2017), the Calbuco aerosol plume could not penetrate the polar vortex and lead to additional ozone depletion, because the plume was confined between the subtropical barrier and polar vortex. Since the results of the SD-WACCM and FR-WACCM simulations were published before, the above-mentioned contradiction between the conclusions made by two different research groups should be considered, analyzed, and discussed by the authors of the paper under consideration (Bègue et al., 2017).

\*SD-WACCM is the specified dynamics Whole Atmosphere Community Climate Model

\*\*FR-WACCM is the free-running Whole Atmosphere Community Climate Model

References:

Solomon, S., D. J. Ivy, D. Kinnison, M. J. Mills, R. R. Neely III, and A. Schmidt (2016), Emergence of healing in the Antarctic ozone layer, *Science*, 252(6296), 269–274, doi:10.1126/science.aae0061.

Ivy, D. J., S. Solomon, D. Kinnison, M. J. Mills, A. Schmidt, and R. R. Neely III (2017), The influence of the Calbuco eruption on the 2015 Antarctic ozone hole in a fully coupled chemistry-climate model, *Geophys. Res. Lett.*, 44, 2556–2561,

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2. The paper cannot be published in its current form due to the poor quality of English and figures. When reading the paper, it was almost not possible to understand the meaning of some phrases and sentences. The text of the paper contains a lot of grammar mistakes and syntax errors. The quality of all figures should also be improved. Figures 1 and 4 seem to be out of focus. The font sizes of letters and numerical symbols in Figures 1, 3, 4, 10, and 11 should be enlarged, if possible. Figures 2, 5, 6, 7, 10, and 11 should have appropriate fonts to be more readable. I will recommend publication in ACP only after the text of the paper is carefully checked or even completely rewritten by a native English speaker. Note also that References are not, but should be, in alphabetical order.

Below are my several minor comments and suggestions concerning the text content (using Sections 1 – 3.1.1 as an example). To help the authors, I also attached the highlighted discussion paper with my concerns for Abstract and Sections 1 – 3.1.1. I suppose that there is no need to reply to every comment on errors and omissions in English grammar, because the text of the paper should be substantially improved.

Minor and technical comments:

Page 1.

- lines 1–3: Perhaps it would be better to write "the 2015 Calbuco eruption" instead of "the Calbuco eruption in April 2015". (No other Calbuco eruptions occurred in 2015). My suggestion for the title: "Long-range isentropic transport of stratospheric aerosols in the Southern Hemisphere following the 2015 Calbuco eruption"
- lines 4–7: There is no need for dots between author's first name and surname.
- line 25: This claim (1 week after the eruption) is in contradiction with the claim made in Summary and Conclusion (two weeks after the eruption). See Page 16, line 19.
- line 26: "21°S" → "21.1 °S"

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- lines 26–27: I suggest enclosing "in comparison with "background" conditions" in parentheses.
- line 27: "18 km to 21 km" → "18 to 21 km", i.e. the first "km" should be omitted.

Page 2.

- lines 1–3: My suggestion for this sentence: "Microphysical measurements, obtained over Reunion before, during, and after the Calbuco eruption, were analyzed to reflect the impact of the eruption on the lower stratospheric aerosol content."
- line 10: I suggest using "over" (for example, "over Reunion Island") instead of "above" (i.e. "above Reunion Island") in this context throughout the whole text for uniformity.
- lines 15–16: The sentence "The importance of stratospheric aerosol on the chemistry is meanly due to their role on ozone budget" should be rewritten to clarify the meaning. Instead of "meanly", it should be "mainly". My suggestions for this sentence: "The importance of stratospheric aerosol in atmospheric chemistry is mainly determined by its influence on the ozone budget." or "The importance of stratospheric aerosol in atmospheric chemistry is mainly determined by its role in the ozone budget."
- lines 18–19: To make the sentence more reader-friendly, I suggest using "ozone depletion that is significantly enhanced" instead of "ozone depletion, significantly enhanced"
- line 24: "the impacts" → "their impacts", because the word combination "their impacts" means "impacts of the processes governing the lifetime"
- line 25: It should be "the Junge layer"
- lines 26–27: The phrase "with some more complex characteristics" can be omitted without loss in meaning.
- lines 27–28: The phrase "the lower stratosphere and upper stratosphere where organic compounds and meteoritic dust can also contribute to its composition" should be

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rewritten to clarify the meaning. Where do organic compounds and meteoritic dust contribute to the Jungle layer composition: in the lower stratosphere, in the upper stratosphere, or in both parts of the stratosphere?

- line 31: "The injected SO<sub>2</sub> is then"? What part (or layer) of the atmosphere is SO<sub>2</sub> injected into? For example, it could be: "The injected into the stratosphere SO<sub>2</sub> is then". Anyway, please clarify the situation.

- lines 32–33: I suggest using "oxidized into H<sub>2</sub>SO<sub>4</sub>, which (after homogeneous nucleation and/or condensation onto existing aerosol particles) causes" instead of "oxidized into H<sub>2</sub>SO<sub>4</sub>, which after homogeneous nucleation and/or condensation onto existing aerosol, results in"

Page 3.

- lines 1–3: This sentence can be written, e.g., as: "Based on the control of the stratospheric aerosol burden over the last 25 years, Thomason et al. (2007) showed that volcanic effects dominate over natural and anthropogenic sources."

- line 3: Perhaps, it would be better to use "significantly" or "substantially" instead of "mainly",

- line 8: "perturbed significantly" → "significantly perturbed"

- line 14: "3,5 K" → "3.5 K", the text fragment "near the aerosol peak" should be clarified. What does the aerosol peak mean?

- line 16: I suggest adding an adjective to "studies". For example "different studies" or "various studies",

- line 23: Concerning the reference (Hofmann et al., 2009)... This decadal trend in stratospheric ozone loading (in the 2002-2012 period) was also determined over Garmisch-Partenkirchen (Germany) and Tomsk (Western Siberia, Russia), and can be seen from articles by Trickl et al. (2013) and Zuev et al. (2017), respectively.

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Trickl, T., Giehl, H., Jäger, H., and Vogelmann, H.: 35 yr of stratospheric aerosol measurements at Garmisch-Partenkirchen: from Fuego to Eyjafjallajökull, and beyond, *Atmos. Chem. Phys.*, 13, 5205-5225, <https://doi.org/10.5194/acp-13-5205-2013>, 2013.

Zuev, V. V., Burlakov, V. D., Nevzorov, A. V., Pravdin, V. L., Savelieva, E. S., and Gerasimov, V. V.: 30-year lidar observations of the stratospheric aerosol layer state over Tomsk (Western Siberia, Russia), *Atmos. Chem. Phys.*, 17, 3067-3081, <https://doi.org/10.5194/acp-17-3067-2017>, 2017.

- lines 24–25: "Three moderate volcanic eruptions are ranked in the top 10 of the most influential events on the stratospheric aerosol burden..."? Clarify please, what period of time is meant here? Is it the 2002-2012 period?

- line 25: "52° N" → "52.2 °N"

- line 26: "175°W" → "175.5 °W"

- line 28: "Kuril Islands" → "the Kuril Islands"

- line 30: "13°N; 41°E" → "13.4 °N; 41.7 °E", "SO<sub>2</sub>" → "SO<sub>2</sub> into the UTLS"

- line 32: "Mt Pinatubo" → "the Pinatubo eruption", because You intercompare eruptions from different volcanoes (It is not possible to compare a volcanic eruption and a mount.)

- lines 32–33: "contributed to counterbalance the global warming"? It is not clear to what extent these recurrent "minor" volcanic eruptions (in comparison to the Pinatubo eruption) contributed to counterbalance the global warming.

Page 4.

- line 1: It should be "dynamics," and "after the Pinatubo eruption"

- line 4: "lagrangian" → "Lagrangian"

- line 9: "meridional transport"? What is the transport (aerosol transport or air mass

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transport in total)? May be "the meridional air mass transport" could be more correct?

- line 12: "is mainly favored" → "is more favored". I think that the use of "more" is more correct than the use of "mainly", because this is a comparison of two QBO phases (westerly and easterly). "the QBO"? This is the first mention of the quasi-biennial oscillation in the manuscript; therefore it should be "the quasi-biennial oscillation (QBO)" instead of "the QBO" here.

- line 16: "Reunion Island" → "Reunion Island (21.1 °S; 55.5 °E)". This is the first mention of Reunion in the paper (not in the abstract).

- lines 19–21: This sentence should be rewritten to explain more clearly the aim of the study.

- line 30: There is no need for coordinates here.

- line 32: It should be "UTLS" instead of "Upper Troposphere-Lower Stratosphere (UTLS)" This abbreviation (UTLS) was already introduced in Section 1 (Introduction).

Page 5.

- lines 1–4: I am confused about the meaning of this sentence. "Lidar systems" and "measurements" are intercompared in the sentence. Otherwise speaking, "measurements" cannot be among "lidar systems". My suggestion for this sentence: "Among measurement data from four lidar systems operated during this campaign, we used data from the Differential Absorption Lidar (DIAL) system built for stratospheric ozone monitoring (Baray et al., 2013)."

- line 4: It would be better to write: "It is also possible to retrieve"

- line 7: It would be better to write "a frequency-tripled"

- line 11: "DIAL lidar"? Well, I think there is no need to write the word "lidar" here. The abbreviation DIAL already contains this word.

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- line 12: It would be better to write: "detects signals in the UV regions of the spectrum".

- line 16: It would be better to write "nighttime" instead of "nocturnal".

- line 18: "method"? What is the method about? It is not clear. There was no description of any methods above. Please clarify it.

- lines 18–19: My suggestion for this sentence: "The aerosol measurement method described by Klett (1981) involves obtaining the aerosol extinction and backscatter coefficient from Rayleigh-Mie lidar measurements."

- line 20: "is similar and has"? To be more clear, it also can be written as: "is similar to the Klett method and has" instead of "is similar and has".

- line 21: "Several parameters are needed:"? What are the parameters needed for (or to)? Please clarify it. It should be written: "Several parameters are needed for" or "Several parameters are needed to".

- lines 21–22: It would be better to write "the temperature and pressure data are obtained from" instead of "the temperature and the pressure come from".

- lines 22–23: "The profile is completed by the Arletty model"?? What is this profile? Is this profile of temperature or pressure, or both of them? The verb "completed" should be substituted by an appropriate verb. Please clarify the meaning anyway. What is this (Arletty) model about? The model description and corresponding reference are required.

- line 24: "The second parameter"? Is this parameter really the second??? The fact is that TWO parameters (temperature and pressure) are already mentioned in the previous sentence. The same remark is for the "third" parameter (altitude) on line 27.

- line 25: It should be "also called the lidar ratio" instead of "also call the lidar coefficient". Please rewrite the sentence in accordance with the following definition at the website: [http://glossary.ametsoc.org/wiki/Lidar\\_ratio](http://glossary.ametsoc.org/wiki/Lidar_ratio) It would be better to write "The

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ratio value depends on" instead of "It depends of".

- line 26: Perhaps, it would be better to write "Under the background stratospheric aerosol conditions," instead of "In the case of background stratospheric aerosol,". "in the literature"? Some references are required here.

- line 27: "The third parameter"? Please see remarks concerning the second parameter (line 24). I suggest using "the reference altitude" instead of "the altitude of reference".

- line 28: What is this profile? Please clarify it.

- line 31: Perhaps it would be better to write: "to analyze the evolution of the" instead of "to analyze the".

Page 6.

- line 6: (Vignelles 2017). This is an incorrect reference.

- line 7: What kind of uncertainties is meant here and further? Please clarify it.

- line 9: Are size bins "less than" (<) or "less than or equal to" (<=)  $1 \mu\text{m}$ ?

- lines 10–11: Perhaps it would be better to write "are governed by Poisson statistics and estimated" instead of "is dominated by Poisson law statistics estimated".

- lines 16–17: It should be "was launched to a Sun-synchronous polar orbit in 2006".

- line 17: (Winker et al. 2007). This is an incorrect reference.

- line 23: Is it a CALIPSO orbit?

- lines 24–25: It should be: "the scattering ratio and depolarization ratio" or "the scattering and depolarization ratios". "coefficients" should be omitted.

- line 26: "full zonal mean"? According to Vernier et al. (2009) it should be the word "means" (not mean). What are the full zonal means? Are these means of: the scattering ratio, the depolarization ratio, or both of them? Please clarify it.

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Vernier, J. P., Pommereau, J. P., Garnier, A., Pelon, J., Larsen, N., Nielsen, J., and McDermid, I. S., Tropical stratospheric aerosol layer from CALIPSO lidar observations. *Journal of Geophysical Research: Atmospheres*, 114(D4), 2009.

Page 7.

- lines 1–2: "the Meteorological Operational satellite (MetOp-A and MetOp-B) launched in October 2006"? One IASI is on board two satellites, isn't it? Which meteorological operational satellite do you mean? MetOp-A and MetOp-B were launched in 2006 and 2012, respectively. Please clarify it. See, for example: Divakarla, M., et al. (2014), The CrIMSS EDR Algorithm: Characterization, Optimization, and Validation, *J. Geophys. Res. Atmos.*, 119, 4953–4977, doi:10.1002/2013JD020438.

- lines 2–3: Perhaps it would be better to write: "The IASI global spatial coverage and footprint of 12 km make it relevant for"

- line 6: height or altitude? The term "altitude" was used in the previous sentence, whereas "height" is used here.

- line 15: What is the spectrum? Please clarify it.

- line 16: What is the size distributions? Are these distributions of aerosol particle sizes? Again. What is the radiances? It should be clarified.

- line 18: "Rodgers' maximum likelihood technique" Perhaps, a reference to the technique is required.

- line 23: "2.2 MIMOSA model". The MIMOSA model description presented in this Section is almost entirely coincident with the description presented by Jumelet et al. (2009). Thus, this work (Jumelet et al., 2009) should be cited here.

Jumelet, J., S. Bekki, P. Seifert, N. Montoux, J.-P. Vernier, and J. Pelon (2009), Microphysical modeling of a midlatitude "polar stratospheric cloud" event: Comparisons against multiwavelength ground-based and spaceborne lidar data, *J. Geophys. Res.*,

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114, D00H03, doi:10.1029/2009JD011776.

- line 26: "isentropic surfaces". I suggest giving an explanation (e.g., in parentheses) what the isentropic surfaces are, as it was done in the work (Jumelet et al., 2009). See the comment on line 23.

Page 8.

- line 18: I suggest writing "Plume formation and transport" or "Calbuco plume formation and transport" for clarity.

- line 22: This abbreviation should be written as "TAB" instead of "ATB"

- lines 23–24: "he TAB signals, ranging from... and corresponding to..., can be attributed to..."

- line 26: Instead of "IAI", it should be "IASI"

Page 9.

- lines 2–3: This sentence must be rewritten to be understandable. My suggestion for this sentence: "The SO<sub>2</sub> e-folding time was estimated to be about 11 days that is in agreement with the time value reported for the 2009 Sarychev volcanic eruption"

- line 9: "this event"? Which event do you mean: the 2015 Calbuco eruption or the 2009 Sarychev eruption? Please clarify it.

- lines 10–11: I suggest writing "Comparing the amount of SO<sub>2</sub> emitted by the 2015 Calbuco eruption with that emitted by previous volcanic eruptions," instead of "Given that the amount of SO<sub>2</sub> emitted in comparison to previous volcanic eruptions,"

- line 12: It would be better to write "injected sulfur" or "stratospheric aerosol loading" instead of "produced aerosol loading". "Figure 2 also depicts the maximum altitude of the SO<sub>2</sub> plume"?? This description of Figure 2 and the Figure 2 caption contradict one another. Because the maximum altitude of the SO<sub>2</sub> PLUME and the maximum altitude

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of the SO<sub>2</sub> MASS are different matters. Please clarify it.

- line 13: "maximum of SO<sub>2</sub>"? What is this maximum? See the previous comment (line 12).

- lines 16–18: My suggestion for this sentence: "On 23 April 2015, a part of the Calbuco plume passed close to the Uruguay coast at an altitude of 17 km and then was transported by the general circulation."

- lines 20–21: "the plume is mainly located over the Atlantic Ocean near the east coast of South Africa"? How is it possible? It definitely should be "the west coast" instead of "the east coast".

- line 22: "as expected" should be placed at the beginning of the sentence, i.e. "As expected, the SO<sub>2</sub> plume extent ..."

- lines 23–24: Perhaps it would be better to write "in a thin 15-17 km altitude atmospheric layer" instead of "in a thin in a thin layer between 15-17 km"

- lines 24–25: It should be "and passing over" instead of " passing through".

Please also note the supplement to this comment:

<https://www.atmos-chem-phys-discuss.net/acp-2017-544/acp-2017-544-RC2-supplement.pdf>

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Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2017-544>, 2017.

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