Replies to comments by Referee 1 Daniele Visioni

Comments, replies**,** *„changes in the manuscript“*

References to added publications not already cited in the first version of the paper are listed in the replies.

In this paper, Löns et al use anomalies in stratospheric aerosol extinction, detected using multiple satellite products, to track the transport of air towards the poles, in particular through streamers – persistent ozone-rich masses of air coming from sub-tropical latitudes – and in particular look at the behavior of one identifiable event using this methodology in 2017. I found this paper extremely interesting and well written, and the analyses robust, and therefore recommend publication after some comments I attach below are addressed.

Thank you very much for your clear and helpful comments.

L. 9: “in that year” rather than “this year” (might be confusing)

Done.

L. 43: define what the “tape recorder” is, a reader might not necessarily be familiar with this term.

In combination with the community review to shorten the introduction, the reference to the tape recorder signature has been omitted.

L. 185: this section title shouldn’t be “ECMWF”, that’s just the name of the Center.

Title changed to *„ERA5 reanalysis data“*

L. 187: the dataset needs to be cited following Copernicus, not just with the long title, and the reference (with its own DOI) needs to be added to the Data Availability section.

Both done.

Related to ERA5, it would be useful to include some references that validate ERA5 stratospheric transport. Here are a few suggestions, which the authors should try to include and talk about in Section 2.3:

Vogel, B., Volk, C. M., Wintel, J., Lauther, V., Clemens, J., Grooß, J.-U., Günther, G., Hoffmann, L., Laube, J. C., Müller, R., Ploeger, F., and Stroh, F.: Evaluation of vertical transport in ERA5 and ERA-Interim reanalysis using high-altitude aircraft measurements in the Asian summer monsoon 2017, Atmos. Chem. Phys., 24, 317–343, https://doi.org/10.5194/acp-24-317-2024, 2024.

Ploeger, F., Diallo, M., Charlesworth, E., Konopka, P., Legras, B., Laube, J. C., Grooß, J.-U., Günther, G., Engel, A., and Riese, M.: The stratospheric Brewer–Dobson circulation inferred from age of air in the ERA5 reanalysis, Atmos. Chem. Phys., 21, 8393–8412, https://doi.org/10.5194/acp-21-8393-2021, 2021.

Xiaozhen Xiong, Xu Liu, Wan Wu, K. Emma Knowland, Qiguang Yang, Jason Welsh, Daniel K. Zhou, Satellite observation of stratospheric intrusions and ozone transport using CrIS on

SNPP, Atmospheric Environment, Volume 273, 2022, 118956, ISSN 1352-2310, https://doi.org/10.1016/j.atmosenv.2022.118956.

Thank you for all your remarks on this subsection. The paragraph has now been expanded and the publications of Ploeger et al. 2021, Diallo et al. 2021 and Vogel et al. 2024 on the validity of the ERA5 dataset for stratospheric transport have been included:

"ERA5 data products are widely used and generally provide a good representation of transport processes in the atmosphere. Several studies have validated stratospheric transport in ERA5. Age of air analyses were used to investigate the representation of the Brewer-Dobson circulation in ERA5 and to compare it with observational data (Ploeger et al. 2021). Here, in the lower and middle stratosphere in the Northern Hemisphere, there are indications that ERA5 is at the upper edge of the observational uncertainty in terms of mean age of air and that the Brewer-Dobson Circulation therefore appears to be low biased, also in comparison to the previous version ERA-Interim (Diallo et al. 2021). ERA5 was also used to verify the upward transport of greenhouse gases and pollution during the Asian monsoons via age of air and trajectory analyses (Vogel et al. 2024). Comparison with in situ data showed that the transport into the lower stratosphere was well represented."

References:

Diallo, M., Ern, M., and Ploeger, F.: The advective Brewer–Dobson circulation in the ERA5 reanalysis: climatology, variability, and trends, Atmospheric Chemistry and Physics, 21, 7515–7544, https://doi.org/10.5194/acp-21-7515-2021, 2021.

L. 295: it would be useful to add some more details (and a reference here to a volcanic dataset) where a reader can see the location and magnitude of the mentioned eruptions. I also think the claim that only Hunga reached the mid-stratosphere is a bit stretched, and the authors could provide some more details: in Li et al. (2023) for instance, the aerosols from La Sourfrier are clearly shown to reach 22-23 km.

This section was insufficiently referenced and the significance of our emphasis was unclear. The list of volcanic eruptions was meant to show that the direct volcanic influence is expected to be negligible in the high northern latitudes at an altitude of 25–35 km (where streamers are to be expected) in 2017. That was not clear enough, and the term 'mid-stratosphere' is open to interpretation. The paragraph has been slightly modified in several places, with the most important changes below:

"During the OMPS period from 2012 to the present, there were several volcanic eruptions that had an impact on the stratosphere (e.g. Carn, 2025; Kovilakam et al., 2025). (…) For the altitudes and latitude regions shown in Fig. 1, only a direct impact from the Hunga eruption is to be expected, whose plume was observed at an altitude of approximately 26 km (Duchamp et al., 2023). (…) The other eruptions referenced are not expected to exert a direct significant influence in the Northern Hemisphere on the altitudes shown."

References:

Carn, S.: Multi-Satellite Volcanic Sulfur Dioxide L4 Long-Term Global Database V4, https://doi.org/10.5067/MEASURES/SO2/DATA405, 2025.

Kovilakam, M., Thomason, L. W., Verkerk, M., Aubry, T., and Knepp, T. N.: OMPS-LP aerosol extinction coefficients and their applicability in GloSSAC, Atmospheric Chemistry and Physics, 25, 535–553, https://doi.org/10.5194/acp-25-535-2025, 2025.

Lastly on this point, it would be useful to acknowledge that Hunga was a peculiar eruption with a large stratospheric moistening, and discuss what this means for the air parcel and for the assumptions beyond the PSD.

The interaction of water vapour and aerosols and their possible influence on streamers and FrIACs in 2022 and 2023 are certainly interesting. However, apart from this mention, the Hunga eruption plays no role in the further analysis of the streamers and anticyclones described in this paper, and the question lies outside the scope of the study.

Fig. 3 and Fig. 4 and Fig. 7, 8: The colors in these two figures are essentially impossible to understand when overlaid with the gray shading of the continents. Please only leave the countours of the continents and make the color constrat a bit sharper, or use black contour lines like the third row of Fig. 4.

We increased the figure size of Figs. 4 and 8. The color scale in Figs. 3 and 7 has now been adjusted and the color scheme of O3 has been changed in Figs. 4 and 8. The continents are no longer filled.

L. 310: not sure “bins” is the right word here. Gridboxes?

Grid boxes sounds more appropriate. Changed.

L. 321: with all due respect to the Grainger PDF, which I’ve used often as well, as a reference with no permanent identifier is not really suitable for a journal. The internet often forgets…

The reference to the Grainger PDF has been replaced by a reference to Seinfeld and Pandis 2016. A mention of the Grainger PDF has been moved to the Acknowledgements.

References:

Seinfeld, J. H. and Pandis, S. N.: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, New York Academy of Sciences Series, John Wiley & Sons, Incorporated, Newark, 1st ed edn., ISBN 978-1-118-94740-1 978-1-119-22116-6, 2016.

Finally, I found the Conclusions particularly brief and dry. It seems to include some points that are more suitable for the Discussion section, and is lacking a final section that discusses future directions and an explanation of what this research contributes.

You're right, the conclusions section wasn't well formulated yet. The conclusions have been completely revised and the last paragraph now reads:

“The transport of tropical aerosol-rich air to mid-latitudes is not an uncommon phenomenon and occurs to a small extent multiple times every year. However, the observation of a tropical-subtropical streamer reaching high latitudes is a rare occurrence. In 2017, this is even evident in the zonal mean aerosol extinction at high latitudes. The correlation between streamer events and aerosol extinction coefficients was demonstrated for the first time in this study. This correlation as well as the connection between streamers and anticyclones in 2017 provide new insights into the poleward transport and persistence of tropical air in the middle stratosphere at the end of the polar vortex season.”

References

Li, Y., Pedersen, C., Dykema, J., Vernier, J.-P., Vattioni, S., Pandit, A. K., Stenke, A., Asher, E., Thornberry, T., Todt, M. A., Bui, T. P., Dean-Day, J., and Keutsch, F. N.: In situ measurements of perturbations to stratospheric aerosol and modeled ozone and radiative impacts following the 2021 La Soufrière eruption, Atmos. Chem. Phys., 23, 15351–15364, https://doi.org/10.5194/acp-23-15351-2023, 2023.