

## DETAILED ANSWER TO REVIEWER #1

First, we would like to thank Reviewer #1 for all the comments, queries, and suggestions for modification. We considered all of them and tried to answer all queries. We transcribed the reviewer comments below, organizing them in a sequential order to help their identification in the revised version of the manuscript.

The present manuscript deals with temperature and tropopause height measured over a tropical site, Réunion (21.10° S; 55.48° E), an island in Indian Ocean from 2006 to 2020. Three types of measurements are used to provide data: local balloon-borne temperature profiles (SHADOZ), satellite by using GNSS-RO technique at COSMIC-1, and reanalysis data from MERRA-2. Tropopause heights are obtained using the Cold Point Temperature (CPT) and/or Lapse Rate Temperature (LRT) methods. Those measurements are compared and show a good consistency, mainly from 10 to 30 km height between SHADOZ and COSMIC-1. So, their data was combined for constructing a more refined dataset, which was then used to fit a model which considers the AO, SAO, QBO, ENSO, SSN and IOD, as the linear trend. As expected, the analysis indicated a main influence of AO and SAO oscillations in Tropopause height dynamics, as well as a decreasing trend in CPT and a slight increase in the Lapse Rate Tropopause (LRT) height. The paper is well written and well-structured, the methodology seems to be correct, and the subject has merits and is of interest for *Annales Geophysicae*. However, this reviewer has concerns about some points that should be addressed by the authors before an acceptance recommendation. The authors should provide a complete revision of the references as indicated below. Therefore, as the subject of the paper is very interesting, I am ready to recommend this manuscript for publication after taken into consideration the above points and after giving a detailed response to my comments.

### Minor comments:

- Line 31: "Niño" not "Ninõ"

*Done*

- Line 334: Fig. 10 is Fig. 9 and the plots should contain a) and b).

*Done*

Also, in relation to Figure 9 what are the meaning of the two slopes inside the gray rectangles?

*The solid black lines represent the CPT and LRT temperature trends in figures a and b, respectively. The dotted black lines, in both figures, indicate the limits of the standard deviation of trends. As a general note, trends are usually noted at the 2 sigma level. Only trends whose value is greater than the 2 sigma threshold are characterized as 'significant'. All trends in this paper are indicated with standard deviation at the 1 sigma level. In order to improve the main document, the caption of figure 9 has been changed to:*

*“Figure 9: Trend model of CPT (a) and LRT (b) temperature variation. The black lines represent the trend of CPT and LRT temperature, in figures a and b, respectively. The dotted black lines, in both figures, represent the standard deviation of the temperature trend at the 1 sigma level.”*

Additionally, do the slopes lines have deviation increasing with time? Justify or correct.

Deviation increases with time because this is how trend uncertainty is computed in the model. The standard deviation associated with the trend value corresponds to uncertainty in the trend slope. It is important to consider that two successive measurements are not necessarily independent. The degree of dependence between successive measurements is evaluated using the autocorrelation coefficient. This coefficient makes it possible to determine the uncertainty on the estimated trend and on the contribution of each forcing. The trend uncertainty, therefore, represents the uncertainty in the trend slope value. Therefore, in order to improve the main text, the following text has been added:

Line 326

*“Figure 10 shows temperature trends at the tropopause, CPT (Fig.10a) and LRT (Fig.10b), as well as, their standard deviations at the  $1\sigma$  level (dotted line). So that the standard deviation associated with the trend value corresponds to uncertainty in the trend slope. Temperature at the CPT presents a significant decreasing trend of  $[-0.13 \pm 0.25]$  K/decade, where seasonal cycles (AO, SAO) seem to be the most dominant forcing”*

## References:

There are many inconsistencies in the references with works cited but not listed and listed and not cited. Although this is not a reviewer's duty I have patiently indicated to the authors the required changes as follows.

1. Austin, J., and T. J. Reichler, Long-term evolution of the cold point tropical tropopause: Simulation results and attribution analysis, J. Geophys. . Res, 113, D00B10, 2008. It appears in the references list, but it is not mentioned in the text. Done
2. Astudillo et al., 2014, Astudillo et al., 2020 and Anthes et al., 2008 are cited in text but are not in the References list. Done
3. Birner et al., 2006 is cited in text but is not in the References list.
4. Cheng et al, 2006 is cited in text but is not in the References list.
5. Dameris et al., 1995 is cited in text but is not in the References list.
6. Fueglistaler et al., 2009 is cited in text but is not in the References list. Done
7. Hoinka, 1998 is cited in text but is not in the References list. Added
8. Li et al., 2008 is cited in text but is not in the References list.
9. Ladstädter, F., Steiner, A. K., and Gleisner, H. Resolving the 21st century temperature trends of the upper troposphere–lower stratosphere with satellite observations. Sci. Rep. 13, 1306, 2023. It appears in the references list, but it is not mentioned in the text.
10. Morioka et al., 2010 is cited in text but is not in the References list.
11. Mateus, P., Mendes, V. B., and Pires, C. A. Global Empirical Models for Tropopause Height Determination. Remote Sens., 14, 4303, 2022. It appears in the References list, but it is not mentioned in the text.

12. Randel and Cobb, 1994, Randel et al., 2000 ,Randel and Jansen, 2013, Reid and Gage, 1981, Reid and Gage, 1984 and Reid and Gage, 1985 are cited in text but are not in the References list.
13. Sivakumar et al., 2006 and Sivakumar et al., 2017 are cited in text but are not in the References list.
14. There are two references Sivakumar et al., 2011. Check what is a) and b).
15. Santer et al., 2004 is cited in text but is not on the References list.
16. Saji et al., 1999 is cited in text but is not in the References list.
17. Selkrik, 1993 is cited in text but is not in the References list.
18. Sterling, C. W., Johnson, B. J., Oltmans, S. J., Smit, H. G. J., Jordan, A. F, Cullis, P. D., Hall, E. G., 400 Thompson, A. M., Witte,J. C. Homogenizing and Estimating the Uncertainty in NOAA's Long Term Vertical Ozone Profile Records Measured with the Electrochemical Concentration Cell Ozone sonde, Atmos. Meas. Tech. 11, 3661-3687, 2018. It appears in the References list, but it is not mentioned in the text.
19. Thompson, A. M., Witte, J. C., Sterling, C., Jordan, A., Johnson, B. J., Oltmans, S. J., and Thiongo, K. First reprocessing of Southern Hemisphere Additional Ozone sondes (SHADOZ) ozone profiles (1998-2016): 2. Comparisons with satellites and ground-based instruments. Journal of Geophysical Research: Atmospheres, 122, 13,000-13,025, 2017. It appears in the References list, but it is not mentioned in the text.
20. Xian, T. and Homeyer, C. R. Global tropopause altitudes in radiosondes and reanalyses, Atmos. Chem. Phys., 19, 5661–5678, 2019. It appears in the References list, but it is not mentioned in the text.
21. Wang , J. S., Seidel, D. J., and Free, M. How well do we know recent climate trends at the tropical tropopause? J. Geophys. Res. Atmos. 117, D09118, 2012.
- Weyland, F., Hoor, P., Kunkel, D., Birner, T., Plöger, F., and Turhal, K.: Long-term changes in the thermodynamic structure of the lowermost stratosphere inferred from reanalysis data, Atmos. Chem. Phys., 25, 1227–1252, <https://doi.org/10.5194/acp-25-1227-2025>, 2025.
- Witte, J. C., Thompson, A. M., Smit, H. G. J., Fujiwara, M., Posny, F., Coetzee, G. J. R., Northam, E. T., Johnson, B. J., Sterling, C. W., Mohamad, M., Ogino, Shin-Ya, Jordan, A., and da Silva, F. First reprocessing of Southern Hemisphere ADditional OZonesondes (SHADOZ) profile records (1998-2015): 1. Methodology and evaluation, J. Geophys. Res. Atmos., 122, 6611-6636, 2017.
- Witte, J. C., Thompson, A. M., Smit, H. G. J., Vömel, H., Posny, F., and Stübi, R. First reprocessing of Southern Hemisphere ADditional OZonesondes profile records: 3. Uncertainty in ozone profile and total column. Journal of Geophysical Research: Atmospheres, 123, 430 3243-3268, 2018. Appear in the References list but are not mentioned in the text.
22. WMO, 1957 is cited in text but is not in the References list.

*We apologize for this mistake. All references have been properly cited in the main text or removed as indicated in the marked version of the new document*