Reply to review comments on:

"The lapse rate and the cold point tropopause in the Asian Summer Monsoon anticyclone"

Reply to Review 2

We thank the reviewer very much for reading the paper and for valuable comments that helped improving the paper. All the comments are repeated below and the corresponding changes to the manuscript are reported also. The comments by the reviewer are repeated in the reply in *italics* and the response by the authors are in roman font.

The manuscript entitled 'The lapse rate cold point tropopause in the Asian Summer Monsoon Anticyclone' uses high altitude aircraft measurements from the StratoClim campaign in 2017 to explore the lapse rate and cold point tropopause characteristics in the Asian summer monsoon anticyclone (ASMA). This manuscript uses water vapour, ozone, and temperature measurements from multiple research flights, including convective flights. They find the lapse rate tropopause to better distinguish between the tropospheric and stratospheric air masses. In convective cases, there is hydration near and above the lapse rate tropopause. In strong convective cases, dehydration occurs near the cold point tropopause. I found this to be an interesting study, and section 3.3.5 to be particularly insightful. My main comments are bulleted below, and I recommend minor revisions prior to publication.

We thank reviewer 2 for these positive statements and for the recommendations on how to improve the paper. We have revised the paper along the lines suggested in the review.

- *Abstract: In the abstract, L3-4 state that this study finds the lapse rate tropopause, rather than the cold point, to be a good estimate of the upper boundary of the troposphere. However, the remainder of the abstract focuses on the cold point when referencing water vapour mixing ratios, ozone mixing ratios, as well as hydration and dehydration patches. If the lapse rate tropopause better serves as the boundary, why is there more focus given to the cold point?*
  This is a good point. In response, we have revised the abstract considerably with more extensive discussion on the lapse rate tropopause – of course some points should be made about water vapour and the cold point as well. Most of all, however, the ACP limit for the abstract (250 words) limits our flexibility for changes.

- *Introduction: L25: The impact to the radiation budget is an important part of the transport of water vapour to the lower stratosphere in the ref-*

erenced papers, it could strengthen this point to mention that specifically.
We agree and (in response) have added the following text in l. 25: "Lower stratospheric water vapour is a key radiative agent in the Earth's climate system; in particular, the regional Pacific moist bias in stratospheric models can be reduced through a Lagrangian transport scheme, which could be important for improving the simulation of regional circulation systems in the Asian monsoon region (Ploeger et al., 2024)."

- *L95-98: Could you include a reference for the differences between the lapse rate and cold point tropopause regarding water vapour in the ASMA?*
  Unfortunately, we were not able to find a good reference/citation for exactly this point. There is some discussion of the issue by Jeffery et al. (2022), a reference which is cited in the paper, but again this study is not explicitly for the monsoon. Indeed the results presented in this paper shed some light on the issue not available in previous publications.

- *Methods: It would be beneficial to have further information about the StratoClim campaign here. Including some details such as where the campaign took place, what aircraft was used, how many flights total versus what will be examined here, and what the objective were of the flights analyzed here would all provide helpful context to the reader.*
  We agree. In response have added the following text to the paper: "We use measurements on board of a high flying research aircraft (Geophysica) in July and August 2017 (that is during the Asian summer monsoon peak season), during the StratoClim campaign based in Kathmandu/Nepal (e.g., Legras and Bucci, 2020; Krämer et al., 2020; Singer et al., 2022). There were eight science flights out of Kathmandu during this period and the flights covered the altitude range from the ground to about 475 K." We think that this text (together with the references) provides helpful context to the reader. (See also reply to review one.)

- *L101: Please specify what the "research aircraft" is.*
  We agree. It is the Geophysica. We have added the information to the paper explicitly (see also comment on "Methods").

- *L137: Omit the "." in "particles. (Khaykin et al., 2022) are...".*
  Thanks. Typo has been corrected.

- *Results: L176, L179: Including some additional, but brief, context about the mentioned flights (ex: convective or not) would be helpful to the reader when certain flights are mentioned but not the main flight of the subdiscussion (ex: 4 August flight) to know why certain flights are focused on and what attributes may be similar to flights that receive more discussion.*
  We agree and added at the beginning of the result section: "Here we focus on three specific flights during the StratoClim campaign in 2017 based in Kathmandu, Nepal (e.g., Legras and Bucci, 2020; Krämer et al., 2020; Singer et al., 2022). We focus on measurements of temperature, ozone mixing ratios, gas-phase water vapour mixing ratios and water vapour in

the particle phase. Flight F2 on 29 July 2017 was designed as an ATAL flight, no particles were observed. Flight F7 on 8 August, designed as an ASMA survey, showed few particles and some enhancement of gas-phase water vapour at greater altitudes. Flight F8, on 10 August 2017, was probing fresh convection."

- *L215: More clearly distinguishing why the authors choose to focus on the cold point tropopause for water vapour in the results after stating that the lapse rate tropopause better separates between the troposphere and stratosphere would help emphasize the novelty of the results here. I find it can be less clear why the focus switches between tropopause definitions for different results discussion otherwise (similar to abstract comment above).*
  We agree with this point. We believe that the best location in the paper to mention this issue is at the bottom of the introductory paragraph of section 3.3. We have added the following text here: "For the water vapour and ozone measurements considered here, it is important that the tropopause is a different entity for different species. In contrast to practically all other species of tropospheric origin, gas-phase water vapour may freeze out (cirrus particle formation) at low atmospheric temperatures. Thus, for gas-phase water vapour, the cold point is most important as temperature is relevant here and not transport."

- *L225: This subsection is focused on a different flight, what is the nature of the 8 August 2017 flight? Is it similar to the 29 July 2017 flight?*
  We agree that there should be more information here in the paper; in response we have added in l. 225: "In contrast to flight F2 (on 29 July), which stayed in the airspace of Nepal, F7 (on 8 August) reached deep into Indian airspace and almost reached the Bay of Bengal (Singer et al., 2022)"; further information on the measurements during the 8 August 2017 flight follows immediately below.

- *L228: Is "this day" referencing the 8 August 2017 flight?*
  Yes, correct. This is now explicitly stated in the paper.

- *L252: Typo with "14 km ; they"*
  Thanks. Typo is corrected.

- *Conclusions: L360: The discussion of future work in this paragraph is nice; it would be beneficial to add some mention of limitations to this work within the Discussion or Conclusions sections as well.*
  We agree. A discussion of the limitations to this work has been included in the Conclusions: "Here we investigate solely measurements in the Asian monsoon anticyclone in 2017. However there is a substantial interannual variability of the monsoon. To address this variability, the analysis of measurements in other years is required. Moreover, it will be possible to further exploit the aircraft measurements in 2017 by extending the analysis to other measurements on the plane."

- *All Figures: Each figure has a .nc file name above it as a title. These titles do not seem to be needed, and the small text size makes it challenging to read. I recommend omitting these titles and replacing them with a descriptive title or omitting the titles altogether.*
  We agree. All the titles have been omitted as suggested. Information on the flights is given in the caption,

- *Figure 1: Typo in caption with extra parenthesis in "(16.8 km and (383.2 K, respectively)."*
  Thanks for catching this! The extra parenthesis is removed.

- *Figures 3,5: What do the red and blue dots represent?*
  Thanks! We added to the caption of Figures 3,5: "The red symbol in the bottom panel indicates location of the lapse rate tropopause; the blue symbol location of the cold point tropopause."

- *Figure 5: What is grey versus black for the upper right plot?*
  Thanks. In both the top right panel and in the scatter plot in the bottom panel of Fig. 5, grey symbols indicate the FISH total water vapour measurements and black points show the gas-phase water vapour measurements by the FLASH instrument. We have improved the caption (also Fig. 3) so that this is clear now.

References

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