Response to Comments of Reviewer 2

The authors thank all reviewers for their constructive comments and suggestions, which have helped us to improve the quality of this paper both in sciences and writing. All comments are carefully considered and responded to. The response in italic letters follows each comment.

Review of "Evidence of Tropospheric Uplift into the Stratosphere via the Tropical Western Pacific Cold Trap"by Sun et al.

The authors use lidar and balloon measurement data, along with the trajectory model, to show the transport pathway over the tropical western Pacific cold trap. By comparing two typical cases, they find that the winter case shows the lowest temperature, coinciding with the RHi >150%. Nearly half of the air particles in the December cirrus cloud rise above 380 K after cloud formation. In contrast, the summer case shows a warmer tropopause and a non-supersaturated environment (RHi <100%). Only 3% of the air particles in the August rise above the 380 K level. The authors provide evidence of the uplift of tropospheric air to the stratosphere via the cold trap during NH winter. Analysis of such simulations is valuable and it is crucial to highlight the importance of the cold trap in driving air mass transport. I propose accepting the paper after the minor revisions listed below:

Line 27-29: The following ref. Such as Vogel et al., (2019) maybe useful.

Ref. Vogel, B., Müller, R., Günther, G., Spang, R., Hanumanthu, S., Li, D., Riese, M., and Stiller, G. P.: Lagrangian simulations of the transport of young air masses to the top of the Asian monsoon anticyclone and into the tropical pipe, Atmos. Chem. Phys., 19, 6007–6034, https://doi.org/10.5194/acp-19-6007-2019, 2019.

Response:

Thank you for the suggestion. Vogel et al. (2019) provide valuable insights into the Lagrangian transport of young air masses into the Asian monsoon anticyclone and the tropical pipe, which aligns well with our discussion on air mass transport pathways. We've incorporated this reference to strengthen our stratosphere-troposphere exchange (STE) analysis and further support our findings.

Line 30: ...in the lower atmosphere... to ...in the lower stratosphere...

Corrected.

For table 1: How should the mean cloud base or top height be considered for double cirrus layers in the UTLS region? Such as the cases on 13 December 2018 and 1 August 2022.

Response:

Thank you for bringing up this important point. In cases with double cirrus layers, such as those on 13 December 2018 and 1 August 2022, we treat each layer as a distinct cloud and calculate the mean cloud base and top heights individually for each identified layer. Table 1 is intended to illustrate that the cloud properties observed during these two case studies closely match the monthly mean, thereby demonstrating their representativeness of typical cirrus layers over Palau. For more comprehensive *details regarding the calculation methods, cloud layer heights, temperatures, and the handling of multi-layer cloud cases, we kindly refer readers to our previous publication, Sun et al. (2024), which provides an extensive discussion on cloud properties across different seasons.*

Line 98: the mid-cloud temperature? Please give more information.

We appreciate your suggestion for clarity. The mid-cloud temperature refers to the temperature at the vertical midpoint of each cloud layer, calculated by averaging the temperatures at the cloud top and cloud base. To improve clarity, we have revised line 98 as follows:

"The cloud base and top heights are determined for each cloud layer, and the mid-cloud temperature is defined as the temperature at the midpoint of each layer, calculated as the average of the temperatures at the cloud top and base heights. If more than one cloud layer is observed simultaneously, they are considered as separate cloud layers."

And we rewrote the paragraph regarding the cirrus cloud properties:

"These two months represent two distinct seasonal features of local cloud layers (Sun et al., 2024). The primary geometrical properties of the cirrus clouds observed over Palau are summarized in Table 1. The cloud base and top heights listed in Table 1 are determined individually for each cloud layer. The mid-cloud temperature is defined as the temperature at the midpoint of each cloud layer, calculated as the average of the cloud top and base heights. If more than one cloud layer is observed simultaneously, they are considered as separate cloud layers. Detailed discussions on quantifying cirrus cloud properties such as cloud layer heights, temperature, and the treatment of multi-layer clouds are given in Sun et al. (2024).

Table 1 demonstrates that the selected cases from December and August effectively represent typical cirrus cloud conditions observed during these two distinct seasons over Palau. The mid-cloud temperature in December is generally lower, and the cloud layers are higher compared to August, reflecting seasonal variations in meteorological conditions associated with the cold trap. These seasonal differences will be further described in Sect. 3.1, supporting reasons for selecting these two months for the following analysis."

Line 136: Figure 1a and b... to Figures 1a and b...

Corrected.

Line 142: ...over the tropical region (±30°N)... to ...over the tropical region (30°S-30°N)...

Corrected.

Figure 1: why were reanalysis data from different periods used for Fig. 1a-b (1980-2019) and Fig. 1c-d (1992-2022)? The cold point temperature is usually not used in mid- and high-latitude regions.

Response:

Thank you for your comment. The reanalysis data periods differ because Fig. 1a-b uses cold point temperature (CPT) data from Hoffmann and Spang (2022), which is only available up to 2019. However, *the reanalysis data in Fig. 1c-d is directly derived from ERA5 reanalysis, and since our study focuses on the period 2018-2022, we extended the ERA5 dataset to 2022 for consistency with our observations. We updated the reanalysis data for Fig. 1c-d 1980-2022 to keep these two datasets with the same starting time.*

We acknowledge that CPT is generally not used in mid- and high-latitude regions. However, in Fig. 1a-b, we included data up to 60°S–60°N for completeness of visualization. In contrast, Fig. 1c-d does not include mid- and high-latitude regions in the averaging, ensuring the focus remains on the tropical regions relevant to our study.

Line 263:...the relevant/dominant transport...?

Corrected as "the dominant transport".

Figure 8: ...on the 10-d trajectory analysis (compare 6). (compare 6)? more details

Corrected as "following the same approach with Fig. 6."

Line 387: In August, only 3% of the air masses... In the discussion and sect. 3.4, the value is 5%?

Corrected here to 5%.

For Figures A1-A4: The differences between the ATLAS and HYSPLIT trajectories are larger in December 2018 than in August 2022, please clarity?

Response:

Thank you for your comment. The larger differences between ATLAS and HYSPLIT trajectories in December 2018 compared to August 2022 can be explained by the seasonal differences in the strength of upwelling and tropopause temperatures. During December, the upwelling is stronger, and the cold trap is colder. Under these conditions, HYSPLIT forward trajectories, which use kinematic vertical velocities, exhibit greater sensitivity to small perturbations or uncertainties in vertical motion. Schoeberl et al. (2011) pointed out that kinematic trajectories are more likely to encounter colder temperatures than those calculated using diabatic heating rates. This difference is reflected in our results, where HYSPLIT forward trajectories in December exhibit a more pronounced circling pattern within the TWP cold trap, whereas ATLAS trajectories mainly follow an eastward movement, with only one trajectory showing a circling pattern.

In contrast, during August, the cold trap is warmer with a weaker vertical temperature gradient, resulting in smaller differences between the two trajectory models. Despite these discrepancies, our seasonal conclusion remains robust: air masses show upward transport in winter and downward motion in summer based on the combined forward and backward trajectory analysis. Furthermore, as noted in the main text (L189), the strong upward motion observed in HYSPLIT's 20-day forward trajectories is likely an artificial signal, which does not affect our overall findings.

We have added the following explanation for clarity:

"As noted by Schoeberl et al. (2011), kinematic methods have a higher probability of encountering extremely low temperatures compared to diabatic methods, this may lead to overestimated

geopotential heights in HYSPLIT trajectories. This effect is evident in December when lower temperatures of the cold trap intensify temperature gradients. HYSPLIT trajectories therefore frequently exhibit circling patterns within the colder cold trap, whereas ATLAS shows only a single case of similar motion. In August, due to the warmer cold trap and weaker temperature gradients, differences between the two models are less pronounced."

For figure A5: title "Forward trajectories in 13 Dec14:00" to "Forward trajectories on 13 Dec14:00"

Corrected.