Response to the Anonymous Referee #2.

We thank the Anonymous Referee #2 for constructive remarks on the manuscript.

General Comments:

1. *There should be some more discussion of the limitations associated with long-term trajectory analyses, especially when using 30-day backwards trajectories. While using ERA-5 with a higher temporal resolution may improve the reliability of the trajectories compared to previous generation reanalyses, there is still a concern of large spatial errors given the length of some of the trajectory-matched convective sources presented in Figure 5c.*

The following text has been added into Sect. 2.4.:
"It should be noted that the trajectory model integrates 1000 backward trajectories per data point along the flight track which are submitted to a random noise equivalent to a diffusion D=0.1 m2 s−1 as in Bucci et al. (2020). As such, the integration is a discretization of the adjoint equation of the advective diffusive equation, which is well posed for backward integration (Legras et al., 2005). Unlike single-trajectory Lagrangian calculations, this method does not generate spurious small-scale features as backward time increases, and can be shown to converge with time for a pure passive scalar. With that, the trajectories from each data point come from several, possibly, many sources and the results presented are a statistics over these 1000 trajectories.
Obviously, the results can be affected by biases in the wind field, heating rates and the cloud height product used in this study. The ERA5 is presently considered as the most advanced reanalysis and it was shown to display very consistent transport properties of diabatic versus kinematic trajectories (Legras & Bucci, 2020), which are in excellent agreement with observations (Brunamonti et al., 2018; von Hobe et al., 2021). The main concern in the Asian monsoon region is that ERA5 displays high penetrative convection over the Tibetan Plateau, which might bias the heating rates in the upper TTL over this region (SPARC S-RIP report, 2021). As the trajectories involved in this studied are mostly outside the Plateau, we do not expect any significant impact."

2. *The figures presented throughout the paper are very informative but are also quite busy and hard to digest. One major improvement that I suggest would be to find a color table that is less harsh than rainbow for many of the Figures. I think rainbow is fine for designating individual flights like in Figure 5c, but when it comes to analysis in Figure 1, Figure 5a and b, etc., a less harsh color table will make the analysis feel less overwhelming on a first time read through. This will also allow layered contours of different variables to stand out against the background color.*

The color table in Fig. 1 has been changed to a less harsh one. Some modifications have been applied to other figures to improve their readability.

Line 36 – A citation should be added for further information on stratospheric ozone chemistry, specifically Anderson et al. 2017 and similar papers discuss the potential for ozone destruction via activation of inorganic chlorine due to convective increases of H2O in cold lower stratosphere environments

Obviously, Anderson et al., 2017 is very relevant for this study. The citation has been added.

Line 79 – Please define FP7

Done.

Lines 152-155 – The horizontal resolution and some precision/accuracy information about the MLS measurement should also be provided here

Done.

Lines 158-163 – As above, please provide a sentence regarding horizontal resolution and precision/accuracy information

Done.

Lines 176-178 – This sentence should either be reworded or include an addition to provide a little more detail into the ozone-water vapor relationship and how that is a reliable method for diagnosing the transition layer.

The text has been modified: "Another approach is based on the TTL thermal structure, where the lower and upper boundaries are defined respectively as the level of minimum stability and the cold point tropopause (CPT) (Gettelman and Forster, 2002). Pan et al. (2014) found that the thermally-defined TTL boundaries are consistent with those derived from the ozone-water vapour relationship. In this study, we adopt the thermal definition of the TTL as in this case the boundaries can be derived from the local instantaneous measurements provided by the Geophysica aircraft"

Line 184-185 – This sentence should include a citation

Reference to Danielsen, 1993 has been added.

Lines 184-188 – Some discussion of above anvil cirrus plumes could be warranted in this paragraph, see Homeyer et al. 2017 (https://doi.org/10.1175/JAS-D-16-0269.1) and O'Neill et al. 2021 (https://www.science.org/doi/10.1126/science.abh3857)

The paragraph has been modified: "A convective overshoot (also termed "ice geyser" by Khaykin et al. (2009)) is defined as detrainment of ice crystals above the local CPT (Danielsen, 1993). Depending on the relative humidity at the level of detrainment, this process can lead either to CLS moistening by rapid ice sublimation, or to irreversible dehydration via uptake of vapour by the injected ice crystals, their growth and sedimentation (e.g. Jensen et al., 2007; Schoeberl et al., 2018). The clouds that have formed in the CLS as a result of local cooling are termed *in situ* cirrus. An *in situ* cirrus cloud is not to be confused with the above anvil cirrus plume (AACP), which is a plume of ice and water vapour in the LS that occurs in the lee of overshooting convection (Homeyer et al., 2017; O'Neill et al., 2021). A *secondary cloud* refers to an *in situ* cirrus that has nucleated from an air mass enhanced in water vapour as a result of convective overshoot."

Lines 190-196 – As noted in general comments, some discussion of trajectory errors and limitations is appropriate here.

Cf. response to general remarks above.

Line 211 – What is the reasoning for examining convective hits at 100 hPa only? Could this have an impact on your results where 100 hPa is farther into the stratosphere in the northern AMA (with high tropopause pressures) and closer to the tropopause in the southern part of the region?

The statistical analysis of convective hits shows a rapid decrease of the number of convective hits starting above 100 hPa. While the lower-pressure threshold does not allow identifying convective sources for the lower-altitude hydration features (e.g. A2), the higher-pressure threshold adds ambiguity to the source identification for the higher-altitude and/or older-age features (e.g. B7). As for the higher tropopause pressure in the northern AMA, this should have very limited impact on the analysis since the warmer temperatures at and above the tropopause in this region enable high water vapour mixing ratios (cf. Fig. 1a). Otherwise said, the altitude of convective detrainment relative to the local tropopause in the subtropical AMA is much less important than in the Southern AMA, where the colder tropopause limits the hydration potential of overshooting convection.

Lines 213-214 – A sentence further describing this method that is shown in Bucci et al. could be helpful, especially to indicate how convective hits would not be overly dependent on parcel age at time of convection due to trajectory ensemble spread over time

The respective text in Sect. 2.4 has been modified and completed (cf. response to general remarks above).

Lines 219-221 – This sentence is a bit wordy, I would suggest rewording and breaking into two separate sentences

The text has been modified: "The 2017 Asian monsoon season was not marked by an anomalous dynamical behavior (Manney et al., 2021), however the campaign occurred during a break - active transition. The strongest convective activity took place in late July and early August above the Southern slopes of Himalayas and the Tibetan plateau as shown by…"

Figure 1 – This figure has a lot of important information, but it is a bit overwhelming and hard to interpret. Following my general suggestions above, I think that reworking the color table for this figure and being sure to prominently display overlayed contours could help. Additionally, the black pixels representing likely sources of hydrated features seems important and should be emphasized; the black pixels almost make it look like a region of missing data on a first read through. Figure 1c and d–The vertical dashed lines could be labeled as they are in Figure 5 for consistency throughout the figures, and it could also help to clearly indicate what they are

The color table in Fig. 1 has been changed to appear less harsh and to improve the readability of the overlaid contours. The pixels, representing the likely sources of hydrated features are now colored pink. The vertical dashed lines in Fig. 1c and d have been labeled.

Lines 236-237 – For clarity, this should include a citation and some further explanation

The text has been modified: "This "cold/dry" period is marked by stronger convective activity in the region reflected by low OLR (Fig. 1c), i.e. colder and higher cloud tops, and higher carbon monoxide mixing ratio (Fig. 1d). Since the carbon monoxide is a tracer for troposphere to stratosphere transport,

the elevated CO concentration in the LS is indicative of the enhanced upward flux across the tropopause (e.g. Randel et al., 2010.).”

Line 240 – I think it would be helpful here to specify the time by which CLS water vapor mostly returns to late July values

Added “…by mid-August”.

Line 269 – What is the bin size here?

Bin size is 0.1 ppmv by 1 K (added to Fig.3 and Fig. 4 captions).

Lines 290-291 – Citation needed here

References to Moyer et al., 1996; Hanisco et al., 2007 have been added here.

Figure 5 – There is a lot going on in this figure as well, a couple of suggestions: (1) it would be helpful for the flight numbers to be as bold (as they are in the legend). (2) making the circles indicating the location of sampling more prominent by filling them in, making them larger, or both. (3) Increasing the density of wind vectors could help to fill in the areas of the map that are fairly empty, and also will help draw attention to them (it took me a while to notice them at first).

All remarks on Fig. 5 have been implemented.

Line 310/Figure 5 – Given that C2 represents a different observation than A2 and B2 for flight F2, it may be helpful to visually indicate that, perhaps with a ‘C2’. When first reading through, I was unsure if C2 was mislabeled until it was first mentioned on page 11.*

Done.

Lines 347-348 – What are these measurements coming from? Flight data? MLS? And is this the mean for the entire domain? Is it the mean for the entire warm/wet period, or just a selected portion?

This is based on the airborne measurements; a mention has been added to the text.

Line 372-373 – How many of the trajectories intersected the convective system vs. passing just south of it?

The following sentence has been added: “The fraction of trajectories intersecting this convective system amounts to 47%.”

Lines 402-403 – I suggest that this statement should be a little stronger, something along the lines of “It is still possible that some of these…” rather than “this does not rule out that…”

The text has been modified: “It is however still possible that some of these crystals were produced by overshooting”.

Line 450 – Suggest changing ‘a lot of evidence for’ to ‘ample sampling of’

Done.

Line 483-485 – Suggest breaking this sentence into two separate sentences

Done.

Page 14 – It would be nice to include a sort of 'looking forward' paragraph to the conclusions, particularly with regards to the future of in situ observations of stratospheric H2O. One example would be the ongoing Dynamics and Chemistry of the Summer Stratosphere (DCOTSS) field campaign, which should help to provide similar observations in the North American Monsoon Anticyclone.

The following paragraph has been added: "Further insights into the AMA gaseous/particular composition and dynamics will be provided by an upcoming airborne campaign within the Asian summer monsoon Chemical and Climate Impact Project (ACCLIP; https://www2.acom.ucar.edu/acclip), which will sample the Western Pacific mode of the monsoon and eastward eddy shedding using NASA WB-57 and NCAR GV aircrafts. The stratospheric impact of overshooting convection in the North American monsoon is a primary target of the Dynamics and Chemistry of the Summer Stratosphere (https://dcotss.org/) project, involving ER-2 high -altitude aircraft.

Technical Corrections:

1. Line 21 – 'the key contributor' should be changed to 'a key contributor'
2. Lines 120-121 – FISH instrument should be changed to "The FISH instrument" and "in flight" should be changed to "for flights"
3. Line 221 – typo: 'sown' instead of 'shown'
4. Line 253 – 'are hardly' could be replaced by 'cannot'
5. Figure 5 – There are two flights labeled F4, and no flight labeled F5.
6. Line 350 – 'Fig. 6a,b' could be replaced by 'Figs. 6a and 6b'
7. Line 396 – One hundred? Or multiple hundreds?
8. Line 474 – 'that the convective' should be changed to 'that convective'

All done.