1 Response to reviewer 1

We thank the reviewer for their careful consideration of the manuscript. Initial responses to all comments and questions are provided below.

Comment 1.1

To look into the seasonal evolution of tracers in the UTLS from prior to monsoon to post monsoon you have considered the period from May to October. However, majority of the studies mainly focussed on the chemical composition within ASMA between July and August corresponding to peak monsoon months (or June to September). Why did you consider the zonal anomalies of the PCWV, PCO3 and PCCO from May to October.

Response:

Thank you for this question. While most previous studies have focused on the peak monsoon months, adopting May–September as the analysis period enables a more comprehensive and detailed examination of the seasonal cycle and subseasonal variability of composition in this region. The selected period is motivated by results from two recent studies examining this region, namely those of Santee et al. (2017) based on MLS observations and Manney et al. (2021) based on reanalysis products.

Although the anticyclone is strongest during the peak monsoon months, anomalies in the thermodynamic structure and composition of the monsoon UTLS are often initiated in May as pre-monsoon convection intensifies and typically extend to the end of September when the anticyclone dissipates (see, e.g., Santee et al. 2017, their Fig. 3, and Manney et al. 2021, their Fig. 2). Our analysis period ends on 2 October (the pentad centered on 30 September), consistent with MLS observations for the 370 K and 390 K potential temperature surfaces (Santee et al. 2017, their Fig. 2).

In our work, the extended analysis period allows us to better explore how the pre-monsoon state affects concentrations during the peak monsoon season, as discussed in Section 3.3 (persistent dry bias at 100 hPa in JRA-3Q) and our companion paper (persistent moist or dry anomalies associated with interannual variability; Zhang et al. 2025).

Comment 1.2

There is a shift in the bias (both for O3 and WV) in all the reanalysis compared to MLS which has limitations due to the coarser vertical resolution. Is the vertical resolution in all the reanalysis used in this study are nearly same?

Response:

The underlying vertical resolutions of these reanalyses are different (Fig. R1). For the intercomparison, all five reanalysis datasets were interpolated to consistent pressure levels of 68 hPa, 83 hPa, 100 hPa, 121 hPa, and 147 hPa that match those of Aura MLS water vapor and ozone (CO retrievals and comparisons adopt the coarser spacing of 68 hPa, 100 hPa, and 147 hPa).

For ERA5, CAMS, MERRA-2, and M2-SCREAM, we have retrieved model-level fields with finer vertical resolution (see Fig. R1). We interpolated these model-level fields to pressure levels directly, accounting for spatio-temporal variations in surface pressure (Sections 2.1 and 2.3). For JRA-3Q, we have used pressure–level fields. Whereas the standard pressure-level grids of other reanalyses do not include a level between 70 hPa and 100 hPa, JRA-3Q includes a pressure level at 85 hPa. The vertical spacing of pressure levels from JRA-3Q is thus already consistent with that of Aura MLS.

Vertical biases relative to Aura MLS may arise in part from the interpolation, but sensitivity tests examining distributions before and after interpolation indicate that such effects are small, consistent with these reanalyses typically having native vertical levels close to the MLS levels (Fig. R1).

In addition, as mentioned in the text, we have not applied the MLS vertical weighting functions in this analysis. Here, our main interest is in reanalysis intercomparison and the potential for reanalyses to help close the impending gap in observations of this region. The vertical interpolation step thus serves primarily to establish consistent weights for the vertical integrals and for convenience in creating the plots.

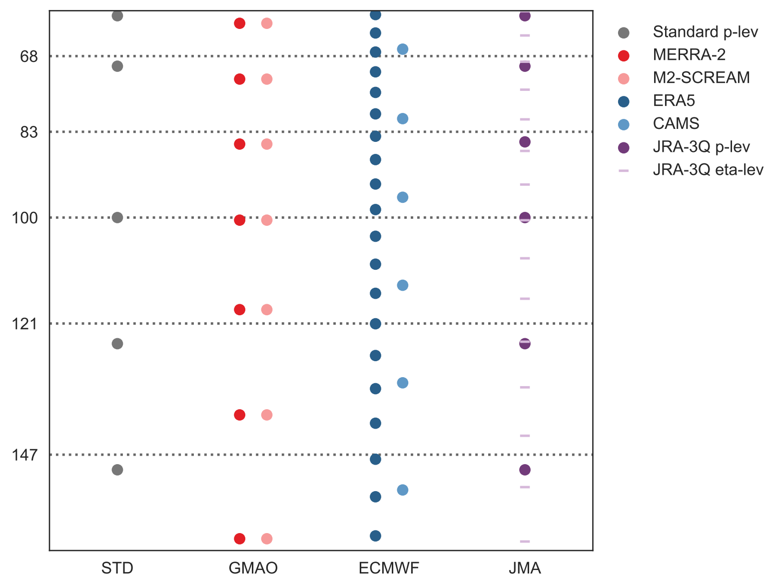

Figure R1: Vertical levels for a surface pressure of 1000 hPa for the five reanalyses examined in the manuscript. Both pressure levels and model levels are shown for JRA-3Q; we used the pressure-level fields in this case. Other reanalyses provide pressure-level products on the standard pressure-level grid (far left), which is insufficient to match the 83 hPa Aura MLS level. The pressure levels used in the analysis are marked by horizontal dotted lines.

Comment 1.3

For better clarity in the interest of readers, it would be useful if you mention in the figure caption what the values in the square brackets represent, though you have mentioned in the body of the manuscript.

Response:

Thank you for this suggestion. We will add an explanation of these values in the revision.

Comment 1.4

What could be the possible reasons for the negative and positive tendencies in the water vapor over the southern and northern part of the Tibetan Plateau? Which dominate (physics, advection, assimilation)?

Response:

This pattern (as seen in Fig. 7f and Fig. 12c of the manuscript) is dominated by the physics term (Fig. 7f), largely offset by the assimilation (Fig. 12c). In our calculation, these two terms are computed independently: the physics term from the model moisture tendency due to parameterized physics and the assimilation increment from the difference between forecast and analysis fields. Unfortunately, we cannot pinpoint the source more exactly than that based on the published outputs, as ERA5 only provides a total physics tendency. We will follow up with contacts at ECMWF and share any further information here and/or in the revised manuscript.

Comment 1.5

Lastly, I would suggest to write many simpler sentences when much information has to be conveyed so that it would be easy for the readers.

Response:

We appreciate your suggestion and will revise the text accordingly in the revision.