Response to interactive comments on "The tropical tropopause layer in reanalysis data sets" by Tegtmeier et al.

We thank the reviewer for his/her comments which have helped us to improve the paper in revision. Comments are reproduced below, followed by our responses in *italics*.

Anonymous Referee #3

General comments:
This paper evaluates the temperature structure and tropopause characteristics in the tropical tropopause layer from various meteorological reanalysis data sets. The paper is generally well written and the results of the comparison are valuable for the community. Therefore, I recommend publication after the following specific and technical comments have been addressed.

Specific comments:
1. As accurately stated in p4 L44-45, this paper investigates "key characteristics of the temperature and tropopauses in the TTL". The title, however, gives the impression that other TTL properties are also being investigated (i.e., too broad). I suggest revising the title to indicate that the study focuses on the temperature structure and tropopause characteristics in the TTL.

> *We agree that the title was too broad and have changed it to 'Temperature and tropopause characteristics from atmospheric reanalyses in the tropical tropopause layer'.*

2. The reasoning for choosing a certain data for certain analyses and is not always clear. Without sufficient explanation, it appears that the authors are cherry picking their results. For example:
a. Why doesn't the vertical profile for CFSR (green) in the right panel of Fig. 4 extend down to 140 hPa? Fig. 1 shows that CFSR has a model level at or just above the 140 hPa level. One of the key results, as presented in the text (e.g., Summary), is that tropical mean temperatures between 140 and 70 hPa in CFSR agrees best with those of GNSS-RO observations. I would like to see the CFSR data point near 140 hPa.

> *Indeed, the CFSR model level at around 138 hPa should be included in this evaluation. We have added CFSR at this level to Figure 4. Results remain unchanged as CFSR temperature at the model level around 138 hPa also agrees very well with the GNSS-RO data.*

b. I would also like to see a panel using ERA5 data in Fig. 7. In all previous analyses and plots, ERA5 data are shown, but not here. Since ERA5 dataset is the newest of these reanalyses, readers will be most interested in seeing this result.

> *We have added the latitude–longitude comparison of cold point temperature for ERA5 to Figure 7. It shows a structure very similar to the other reanalyses when compared to the observations.*

c. In Fig. 10, the temperature anomaly time series at 70 hPa (top panel) includes a time series using the RAOB radiosonde data. The second panel showing the temperature anomalies at the cold-point tropopause includes a time series using the IGRA radiosonde data. Why are the radiosonde data sources different in these two panels? Is there a reason for showing one data at 70 hPa and another at the cold point?

For consistency reasons we decided to rely on the radiosonde data sets used in Wang et al., 2013, where the authors provide detailed evaluations of the temporal variability and trends of radiosonde temperature in the TTL. Wang et al. (2013) use the unadjusted quality-controlled radiosonde data set IGRA for the cold point and several independently adjusted radiosonde temperature data sets RATPAC, HadAT, RAOBCORE, and RICH for temperatures at 70 and 100 hPa. The motivation for evaluating interannual variability of cold point temperature, height and pressure only from the unadjusted temperature profiles is that temperature adjustments can change the location of the cold point tropopause in a profile. Therefore, we show RAOBCORE in the top panel at 70 hPa and IGRA in the lower panels for the cold point. The interannual anomalies at 70 hPa are shown only for RAOBCORE for a better clarity of the figure, while the other data sets are mentioned in the text. We have added a detailed explanation to chapter 2.1 (Observational data sets) to make clear which data sets are used at which levels for which reasons.

d. Why doesn't the right panel of Fig. 11 include data points from RATPAC, RICH and RAOBCORE (as in the left panel)?

Same reason as above.

e. The choice of radiosonde dataset in Fig. 12 is HadAT and RAOBCORE. Again, it is unclear why these two radiosonde data sets were chosen for this particular analysis. Perhaps it is best to stick to the same set of radiosonde data throughout the entire analyses?

For the trends at 70 and 100 hPa, we show the smallest and largest trends derived from the four adjusted radiosonde data sets as reported in Wang et al. (2012) and consider their range (including the reported error bars) as the observational uncertainty range. We have added this information to the Methods section.

3. There is a lot of discussion about the vertical resolution for obvious reasons (e.g., large impact on tropopause temperature). There is no mentioning of the horizontal resolution of the reanalyses data used for these comparisons. While the horizontal resolution likely plays a limited role, it would be good to document what resolution was used.

We have added information on the horizontal resolutions of the reanalyses data sets.

Technical comments:

- p5, L20: RATPAC data are mentioned, but none of the results shown in the paper use this data.

RATPAC results are shown in Figure 11.

- The second paragraph of Section 2.1 describes the various GNSS-RO measurements assimilated by the reanalyses, which are shown in Table 1. Table 1 also shows MetOp and C/NOFS data, but these are not mentioned in the text.

We have added the information to the text.

- p6, L32: ATOVS suite has a higher number of channels *compared to TOVS*?

We have changed the sentence accordingly.

- p6, L42 and p7, L12: What do you mean by "high vertical resolution"? How much higher are they compared to those of the reanalyses discussed in detail here?

*We have added the following information to the manuscript '*The GNSS-RO 'wetPrf' temperature profiles from CDAAC are provided on a 100-m vertical grid from the surface to 40 km altitude. The effective physical resolution is variable, ranging from ∼1 km in regions of constant stratification down to 100-200m where the biggest stratification gradients occur e.g. at the top of the boundary layer or at a very sharp tropopause (Kursinski et al., 1997; Gorbunov et al., 2004), most often being somewhere in between.*'*

Regarding the vertical resolution of radiosondes, in addition to mandatory levels (which near the tropical tropopause are 150, 100, 70, and 50 hPa), individual radiosonde soundings include data at "significant levels," where the observations between mandatory reporting levels depart from a linear interpolation, such as would occur at the tropopause. As the number of significant levels can vary over time and with station, a conclusive statement on the vertical resolution is not possible. We have therefore removed 'high-resolution' from the sentence.

- p7, L7: Is RICH also a radiosonde data (like RAOBCORE)? It is the first time this data set has been mentioned.

We have added RICH to Section 2.

- p7, L5: ERA-40 reanalysis data are not analyzed in this paper. Best to leave it out?

We have now included ERA-40 in two supplementary figures covering earlier time periods and therefore retain this text.

- p8, L12: Section 3.1 does not exist. Do you mean Section 3? Or Section 2.1?

We have changed the text to section 2.3.

- While I see the Fig. 3 caption describing the overlapped symbols, I suggest using a different symbol so that all the data points are visible.

We have produced different versions of this figure (including different symbols or symbols slightly shifted vertically), but found that the visibility does not improve sufficiently. Therefore, we prefer to keep the figure in its current version and to mention the overlaps in the caption.

- It may be worthwhile to mention again at the beginning of Section 4 that the interannual variability of ERA5 variables are not analyzed due to the short data record. The sentence "In particular, . . .interannual variability" on p22, L25-28 is slightly misleading since the interannual variability in ERA5 is not analyzed.

We have added this information to the beginning of Section 4. We change the sentence on page 22 to 'In particular, the more recent reanalyses ERA-Interim, ERA5, MERRA-2, CFSR and JRA-55 mostly show very good agreement after 2002 in terms of the vertical TTL temperature profile, meridional tropopause structure and interannual variability.'

- p17, L34: I am having difficulty seeing the positive temperature anomalies related to Mt. Pinatubo eruption in Fig. 10 (top two panels).

Thanks for pointing this out. It is true, that following Mount Pinatubo only weak temperature anomalies occur at 70 hPa and no anomalies occur at the cold point. This is consistent with Fujiwara et al. (2015) who show that the positive temperature anomalies *following Mount Pinatubo do not propagate down as far into the TTL as the ones following El Chichón. We have changed the text accordingly.*

- The color of the lines for GNSS-RO and JRA-25 in Fig. 10 are difficult to distinguish. I suggest using a different color (or line style?) for JRA-25.

  We have decided to keep the colors used for the reanalyses consistent with the S-RIP colour scheme. We have changed the color used for GNSS-RO to a slightly darker grey to make it more distinguishable from JRA-25.

- Fig. 11 caption: It would be helpful to mention the 1980-2010 time period in the caption.

  We have added the time period to the caption.

- p21, L31: "small negative bias at model levels *and small bias shift*, has the most realistic."

  We have added 'and a small bias shift' to the text.