Interactive comment on "Reanalysis comparisons of upper tropospheric/lower stratospheric jets and multiple tropopauses" by Gloria L. Manney et al.
Anonymous Referee #2

General Comments

In this paper Manney et al. present an intercomparison of UT/LS and stratospheric jets and tropopause diagnostics derived from five recent meteorological reanalyses. The study covers ERA-Interim, JRA-55, MERRA, MERRA-2, and NCEP's CFSR for a 35-year time period (1980-2014). The study found very good qualitative agreement between the climatological features. It is speculated that quantitative differences, which are found to be largely related to differences in resolution of the forecast models and output grids, would still be important for transport and variability studies. Overall, I found this to be a carefully designed study. The paper is well-written and fits in the scope of ACP. I would recommend it for publication once the few remaining minor comments and technical corrections listed below have been considered.

We thank the referee for their helpful comments. The referee's comments are shown in blue italics and our responses in black. (Note that in addition to addressing the referees' comments, the figures have been re-done to use the recently updated "standard" S-RIP colors for each reanalysis.)

Specific Comments

p4, l16: It might be worthwhile mentioning some of the updates from MERRA to MERRA-2 that are possibly relevant for this study at this point?

We have added this to the text as follows:
"MERRA-2 (Gelaro et al., 2017) uses a similar model and assimilation system to MERRA, with updates also described by Bosilovich et al. (2015), Molod et al. (2015), and Takacs et al. (2016). Some of the changes between MERRA and MERRA-2 that may affect UTLS dynamical fields are:
– New observation types have been added in MERRA-2, including hyperspectral infrared data from IASI (Infrared Atmospheric Sounding Interferometer) and CrIS (Cross-track Infrared Sounder), GPS-RO (Global Positioning System-Radio Occultation) bending angles, and polar wind observations from AVHRR (Advanced Very High Resolution Radiometer).
– MERRA-2 treats conventional temperature data differently, including changes in their error statistics and usage of adaptive bias correction for aircraft temperature data.
– Changes were made to the general circulation model, most notably a different horizontal grid and an improved convective parameterization scheme."

p6, l7-11: I was wondering if the estimation of tropopause heights does involve any kind of higher-order interpolation (e.g. cubic spline) of the coarse-grid temperature profiles from the reanalyses on a fine vertical grid?

No higher order interpolation is used because it may exaggerate extrema in regions of strong temperature gradients (such as often occur near the tropopause). A linear interpolation between the two levels on either side of the threshold is used to locate the tropopause between adjacent levels; we have added a sentence to this effect in the text (which has also been modified to address a comment from Dr. Añel).

p6, l14: Why doesn't it make sense to construct means of frequency distributions from multiple reanalyses?

To compare fields between multiple reanalyses, a "reanalysis ensemble mean" is often used, wherein the fields from each reanalysis are summed and the result divided by the number of reanalyses. What we meant to convey here is that using this procedure for frequency distributions does not produce a field that is useful for comparisons, since a mean constructed that way is no longer a frequency distribution, does not "weight" each reanalysis equivalently, and differences from that field would be problematic to interpret. Since we need a "reference" to take differences, we have chosen to use MERRA-2, the most recent of the reanalyses studied here. In the revised text, we state: "A reference distribution is needed to evaluate differences between the frequency distributions. However, taking a mean of the frequency distributions from the five reanalyses would result in a field that is problematic to interpret since it no longer represents a frequency distribution, and the reanalyses would not be equally weighted. Therefore, we have chosen to compare the other reanalyses to MERRA-2…."

p6, l17-21 (and other places): It might be more clear if arithmetic differences of percentages would be referred to as "percentage points (pp)" rather than using "%" as the unit for these differences.

This is a very good idea, and we have implemented it in the revised text. The discussion of arithmetic differences of percentages has been modified as follows:
"Because the frequency distributions are expressed as a percent (representing the fraction of the time there is a jet core, multiple tropopause, or subvortex jet in the bin, as discussed below in relation to normalization), the arithmetic differences (i.e., Freq_r1 − Freq_r2, where r1 and r2 are two reanalyses) between two frequency distributions that are shown in the figures are expressed as "percentage points" (pp); this should not be confused with the approximate percentage values for relative differences (e.g., (Freq r1 − Freq r2)/0.5(Freq r1 + Freq r2) × 100) mentioned in the text...."

Also, the units of % for frequency distributions and pp for arithmetic differences of frequency distributions have been added to all of the figures. In the Figure 1 caption, we now state "In this

and all following figures, frequency distributions are expressed in percent (%) and arithmetic differences of frequency distributions in percentage points (pp)."

The statement in Section 3.2 regarding this has been modified as follows: "(Recall that, as described in Section 2.3, since frequency is expressed as a percent, the arithmetic differences between MERRA-2 and other reanalysis frequency distributions are expressed as percentage points (pp); the relative (percent) differences noted here are obtained by dividing the pp value in the difference plot by the percent value in the MERRA-2 frequency distribution plot.)"

p8, l9-16: Can you provide a physical explanation of the northward shift of the jets between the MERRA-2 ASM and ANA fields?

We have added the following statement to the text:
"Because of the IAU procedure used (see, e.g., Bloom et al. 1996, Fujiwara et al. 2016), the differences between ASM and ANA are to first order half of the analysis increment, with ASM being closer to the model results for a short forecast, and ANA (albeit less balanced) being closer to the observations. The ASM-ANA differences thus largely reflect small biases between the model and observations that develop over a short forecast period. These might be expected to be qualitatively similar to the biases between the free-running model and the reanalysis. Molod et al. (2012) noted zonal mean wind biases between MERRA and a free-running GCM suggesting differences in both strength and position of the subtropical jet, as well biases in the eddy geopotential height fields that suggest regional variations in wind biases. Biases of this sort persist between MERRA-2 and corresponding free-running models (Clara Orbe, personal communication) that appear broadly consistent with the shift of the jets seen here."

p9, l12-21: Here I was also wondering if you could possibly provide a more detailed physical reasoning for the differences, the jet shifts in particular?

A detailed analysis of the differences each observational input makes in the assimilated fields is beyond the scope of this paper. However, the satellite radiance inputs play a large role in determining the temperature profiles, and without them the SH high latitude fields are poorly constrained by data. They directly and substantially affect the multiple tropopause distributions, and are also expected, via thermal wind balance, to play a large role in constraining the winds in the UTLS. We have added a note to this effect in the text (at the end of the paragraph on the JRA-55 / JRA-55C comparisons): "Because the SH middle to high latitude fields are poorly constrained by conventional data, the assimilated satellite radiances are critical to constraining the temperature profiles here and, via thermal wind balance, are expected to be an important constraint for the wind fields as well. Thus poor agreement in multiple tropopause distributions in SH middle to high latitudes, as well as larger differences in the jet distributions than in other regions, is consistent with expectations."

Technical Corrections

p6, l14: doesn’t -> does not

The wording has already been changed per a previous comment.

p10, l18-19: "in the both the" -> "in both the"

Corrected.

p12, l9-11: A verb seems to be missing in this sentence.

The verb “show” has been added.

p18, l1: The acronym "JETPAC" was not introduced before.

We have modified the first sentence of section 2.2 to correct this omission, it now reads “The JETPAC (JEt and Tropopause Products for Analysis and Characterization) package described by Manney et al. (2011, 2014) is used here to characterize the UTLS jets and the tropopauses.”