Comments to the paper entitled “Climatology of the terms and variables of transformed Eulerian-mean (TEM) equations from multiple reanalyses: MERRA-2, JRA-55, ERA-Interim, and CFSR” by Fujiwara et al.

General comment:

This study examines 30-year climatology of the major variables and terms of the transformed Eulerian-mean (TEM) momentum and thermodynamic equations by using four global reanalyses data including MERRA-2, JRA-55, ERA-Interim, and CFSR for boreal winter (December–February, DJF) and summer (June–August, JJA). By calculating the reanalysis ensemble mean (REM) of the individual terms in the TEM equations, the authors illustrate the climatological properties and relative importance of the terms. Through this analysis, a significant magnitude of the residual is identified in both the momentum and thermodynamic energy equations and their potential sources are also discussed. Differences in each of the four reanalysis datasets compared to the REM exhibit distinct features, indicating inconsistency among the reanalysis data in representing the dynamical structures of the troposphere and the stratosphere.

While the authors make the best effort to calculate and visualize the various terms in TEM equations with caution, 1) the sequence of analysis in this paper makes it challenging to connect specific results with their respective causes. In this regard, the differences among each reanalysis data are just listed without a comprehensive summary. 2) Insufficient elucidation regarding the causes of the differences also calls for additional clarification. Moreover, 3) despite the division of analysis into DJF and JJA, the discussion on seasonal variations appears insufficient, giving the impression that the aspects observed in winter are likewise depicted in summer. Therefore, I hope that the authors will refine the manuscript taking into account the suggested revisions, making it novel enough for publication in ACP. The specific comments are as follows.

Major comments

1. As the analysis alternates between the momentum and the thermodynamic equation, there appears to be a deficiency in establishing a seamless connection between the results and their underlying causes. Hence, it is recommended to commence the analysis with the momentum equation and subsequently address the thermodynamic energy equation, accompanied by a rearrangement of the figures accordingly.

2. A matter related to Major Comment 1 is observed concerning the discussion of differences among reanalysis datasets. The content addressing these distinctions appears detached and comes much later without a link, making it challenging to summarize the causes and outcomes of these differences. Examples are as follows:

   A. **Differences in the meridional circulation:**
   Regarding a stronger (weaker) residual-mean meridional circulation represented by JRA-55 (MERRA-2) compared to REM (Figure 5, L356–357), the authors attribute stronger (weaker) $\bar{v}^*$ described in Supplementary Folder 3 as a responsible cause. Since $\bar{v}^*$ is associated with the resolved wave forcing (Eq. 1), I expect the analysis of EPFD following this finding. However, the discussion about EPFD takes place in L412–418 with Figure 9 after the discussion on radiative heating. Accordingly, the fact that JRA-55 (MERRA-2) has negative (positive) EPFD differences in the dominant negative EPFD regions, which indicates that the overestimation (underestimation) of negative EPFD in comparison to REM, is not perceived to be connected to the stronger (weaker) meridional circulation in JRA-55 (MERRA-2). As Figure 8 describes the Coriolis forcing $f\bar{v}^*$, rearranging the order to present Figures 5 followed by Figure 8 and 9 could enable the authors to maintain the same explanation, while providing a comprehensive summary for the distinct meridional circulations between JRA-55 and MERRA-2.

   B. **Differences in the total radiative heating in Figure 11:**
   According to Figure 2, 6, and 7, it is identified that ERA-Interim and CFSR tend to overestimate the longwave (LW) cooling as well as shortwave (SH) warming, although the responsible cause are different. Conversely, MERRA-2 and JRA-55 tend to underestimate them. However, in Figure 11, MERRA-2 and ERA-Interim (JRA-55 and CFSR) exhibit positive (negative) deviation of the total heating from REM. Based on the findings in Figure 6 and 7, the differences in total heating shown in Figure 11 could be connected to the aforementioned tendencies with respect to LW and SW. In the case of CFSR (ERA-Interim), the overestimation of LW cooling is greater (less) than that of SW warming, contributing to the negative (positive) total heating difference. In contrast, for JRA-55 (MERRA-2), underestimation of LW cooling is less (greater) than that of SW warming, leading to negative (positive) total heating difference.

3. The authors conduct the same analyses during both winter and summer, presenting the same figures for both seasons. However, if seasonal variations do not significantly impact the results, it might be more concise and appropriate to show only the key differences in the main results and move the remaining details to the supplementary material, emphasizing the essential findings.

Minor comments

1. L90: The sentence is not well organized. Below sentence is one of the recommendations.
   We first present the findings for the reanalysis ensemble mean (REM), followed by an analysis of the discrepancies of each reanalysis from the REM during DJF and JJA.

2. L212–213: I think there is no need to separate the temperature description by altitude since the Northern Hemisphere stratosphere is consistently colder than the Southern Hemisphere stratosphere across all altitudes.

3. L215: Please specify the altitude of two maxima of the upwelling in the tropics

4. L244: reanalyses.The > reanalyses. The

5. L244: Remove the closing parenthesis at the end of this sentence.

6. L312: Podglajen et al., 2020 > Podglajen et al. (2020)

7. L351–353: Please consider adding a brief mention or acknowledgment of the observed temperature differences in the reanalyses, as the temperature plays a significant role in the radiative heating.

8. L310–315, L515–519: CFSR and MERRA-2 reanalysis data provide the parameterized orographic gravity wave drag (GWD) and the sum of orographic and non-orographic GWD, respectively. JRA-55 also offer the parameterized GWD, while the Rayleigh damping effect is also included. Therefore, it would be beneficial to analyze the contribution of these GWD to the residual as a means of validating the authors speculation.