Response to comments by Reviewer #2

Thank you very much for your valuable comments and suggestions. Please see below for our answers to yours.

Review Comments for the Manuscript: "Climatology of the terms and variables of transformed Eulerian-mean (TEM) equations from multiple reanalyses: MERRA-2, JRA-55, ERA-Interim, and CFSR."

General Comments:

The manuscript presents an in-depth analysis of the principal variables and terms of the TEM momentum and thermodynamic equations, utilizing datasets spanning over thirty years from MERRA-2, JRA-55, ERA-Interim, and CFSR. The detailed scrutiny of the reanalysis ensemble mean (REM), alongside the notable discrepancies among individual reanalyses, substantially enriches our understanding of atmospheric dynamics and radiative equilibrium from the troposphere to the mesosphere. The study's potential to improve reanalysis datasets and enhance atmospheric modeling and simulation techniques is highly commendable and noteworthy.

Thank you very much for your full understanding of the nature of this manuscript.

Specific Comments:

1. Seasonal Tendency Analysis:

- The methodology involving DJF and JJA to analyze winter and summer tendencies in the northern hemisphere mainly captures transitions from December 1st to the end of February. This approach may only partially encompass the climatic variations in temperature, wind fields, and stream functions among the different reanalyses throughout the year. Notably, the TEM momentum equation analysis focuses on the differences between states separated by three months rather than the formation of an average state over an entire season. It is recommended to broaden the analysis to include the whole of the annual climatic mean or to analyze TEM terms for additional months. This could provide a more detailed understanding of the discrepancies among the datasets and their underlying causes.

First, please note that we provide the results for MAM and SON as well in the Supplement. We

chose to show and discuss only the DJF and JJA results in the main text because DJF and JJA are the two contrasting seasons often discussed in the literature. In this paper, we intend to show and discuss climatological means, and we decided to show 3-month climatological means as the first element of a full climatological analysis. We agree with the reviewer that there is no perfect definition for a climatology, but we believe that this choice will be useful for many colleagues.

- The need for more analysis for shorter time cycles, such as monthly budgets, is evident. For instance, events like Sudden Stratospheric Warming (SSW), typically accompanied by significant planetary wave activity, may take place within these three months and might resolve before the end of February. Consequently, the monthly variations in atmospheric momentum and thermodynamics and their causes still need to be addressed.

We could provide monthly climatologies rather than 3-month climatologies, but please note that we present 30-year averages to reduce the impacts of internal variability, including SSW events. In this manuscript, we intend to show and discuss the seasonal background states against which short-term fluctuations and events occur. Again, we agree with the reviewer that there are other valid and useful ways to define climatologies, but we believe that 3-month 30-year climatologies will be useful for many colleagues. Analysis of the TEM budget during SSW is beyond the scope of the present study, and it would involve grouping of data around the central date of the SSW, not simply considering monthly mean, and could constitute a separate paper, in line with Martineau et al. (2018).

Reference:

Martineau, P., Son, S.-W., Taguchi, M., and Butler, A. H.: A comparison of the momentum budget in reanalysis datasets during sudden stratospheric warming events, Atmos. Chem. Phys., 18, 7169–7187, https://doi.org/10.5194/acp-18-7169-2018, 2018.

1. Attribution of Differences in TEM Thermodynamic Terms:

- The study ascribes specific TEM thermodynamic terms variances to differences in parameters such as ozone and temperature across the datasets. A more detailed discussion and analysis of these parameters, especially ozone distribution, is advised to reinforce this attribution. This would solidify the argument and provide a more transparent explanation of the observed discrepancies, potentially elucidating the underlying mechanisms involved.

Thank you for this suggestion. We will add more detailed discussion including those suggested by Reviewer #1. Temperature differences in part explain the differences in longwave heating as

described in the response letter to Reviewer #1. Yes, ozone differences also contribute to the differences in shortwave heating, although we should note that the ERA-Interim ozone products analyzed here were not used for radiative transfer calculations in the ERA-Interim forecast model (an independent climatological ozone distribution was used instead), making interpretation of these differences a little bit complicated. However, in general, JRA-55 has less ozone in the middle to upper stratosphere than MERRA-2 and CFSR in both DJF and JJA. It is therefore consistent that JRA-55 has the minimum heating there among the three reanalyses. Differences in ozone and shortwave heating between MERRA-2 and CFSR are more difficult to explain from this perspective alone, suggesting that other factors in the radiative schemes also play a role. These two forecast models use different broadband models for both shortwave and longwave, and make different assumptions for the prescribed distributions of radiatively active gases (see Chapter 2 of SPARC, 2022), both of which will impact the stratospheric radiative equilibrium in ways that are difficult to untangle.

Reference:

SPARC: SPARC Reanalysis Intercomparison Project (S-RIP) Final Report, edited by Fujiwara, M., Manney, G. L., Gray, L. J., and Wright, J. S., SPARC Report No. 10, WCRP-6/2021, 612 pp., https://doi.org/10.17874/800dee57d13, available also at https://www.sparc-climate.org/sparc-report-no-10/ (last access: 16 February 2023), 2022.

Technical Corrections:

- Line 305: Clarification is needed on how the equatorward flow is observed from Figures 1(d) or Figure 4(b).

Figure 1(d) will be corrected as Figure 1(e). The signals we are referring to are located around 40°N and 200 hPa and around 50-60°S and 20-300 hPa, respectively. We will add this information in the text.

In conclusion, the manuscript significantly contributes to the fi eld of atmospheric sciences. I think addressing the points mentioned above could significantly enhance the depth and impact of your study. I eagerly anticipate the revised manuscript and am optimistic about the potential of this research to advance our understanding of atmospheric dynamics and modeling.

Again, thank you very much for your full understanding of the nature of the manuscript.