Response to Reviewer #2's Comments

Ji-Hee Yoo and Hye-Yeong Chun

Department of Atmospheric Sciences, Yonsei University, Seoul, Korea

10 September 2025

General comment:

I thank the authors for their generally thorough address of the comments I made on their initial submission. There are several relatively minor comments I would still like to make, though, which I list by line number of the revised manuscript:

We thank the reviewer for the careful second review. Your feedback has substantially improved the manuscript. We have addressed all remaining comments in detail below and revised the text accordingly.

Minor Comments:

1. 19-20: The sentence "Nonlinear wave–wave interaction drove early wave generation, while the latter played a role near the onset" is confusing. I'm not entirely sure what "the latter" refers to, and it is not clear how different "early" and "near the onset" are. Is the phrase "Nonlinear wave–wave interaction drove early wave generation" a reference to point (i) of the previous sentence, while "the latter played a role near the onset" is a reference to point (ii)? This should be rewritten.

   In the original text, "nonlinear wave–wave interaction" corresponds to mechanism (i) and "the latter" was intended to refer to mechanism (ii) (over-reflection of upward-propagating PW2). By "early" we meant the first two days of the 4-day wave-generation period (from Lag = −3 to Lag = −2), and by "near the onset" we meant the final two days (from Lag = −1 to Lag = 0). To avoid any confusion, we stated the mechanisms and timing more explicitly in the revised manuscript (L18–20).

2. 101-103: This statement of the way the Charney-Stern-Pedlosky criterion is being satisfied is confusing. What you mean is "The criterion is met by Qy changing sign within the domain" but I think the current version of the text could easily be misinterpreted as "The criterion is met by having Qy<0 somewhere in the domain" which is not a correct statement of the criterion. The text should be updated for clarity.

   We agree that the original sentence could be misread as the criterion being satisfied by $\bar{q}_y < 0$ somewhere in the domain, rather than by a sign reversal of $\bar{q}_y$ within the domain. We revised the text to state this explicitly (L101–104).

3. 175: "sum of two terms" should be "sum of the two terms". Doing another proofreading of the paper is probably warranted.

Thank you for pointing this out. We changed the phrase to "sum of the two terms" (L176) and have proofread the manuscript again and made minor editorial corrections. We will also carefully review the proofs at the production stage.

4. 201: The listed publication year for the Jucker paper about E-P flux scaling is incorrect—it's actually 2021.

   Thank you for the correction. We corrected the citation year to 2021 for Jucker (L202).

5. 204-206: The discussion in the Song et al. (2020) paper is helpful, but (correct me if I'm wrong) it doesn't actually say anything about the sine and cosine tapering technique. I was not able to readily determine what was meant by this via a Google search, so some more explanation/ appropriate citation to this specific signal processing technique is probably in order.

   Thank you for the helpful suggestion. You are correct that Song et al. (2020) did not apply a sine/cosine taper. In our initial tests, Fourier decomposition without tapering exhibited spectral leakage, so we applied a symmetric 3-day raised-cosine (Tukey) taper to each 11-day window prior to decomposition in this study. We added a more detailed explanation and citation for this windowing technique in the figure caption.

6. 405: The phrase "the reason underlying the increasing frequency of SSWs with these easterlies, linked to climate change" is a little odd. Is this intended as a claim that the increasing tendency for enhanced stratopause wave driving to precede SSWs is a manifestation of radiatively forced climate change? Koushik et al. (2022) do not actually claim this, so it seems premature to make such an assertion. Alternatively if the intent is merely to suggest that there may exist a link to forced climate change, the language should be more tentative.

   Thank you for this important point. As the reviewer notes, Koushik et al. (2022) reported an increase in the fraction of SSWs preceded by equatorial upper-stratospheric easterlies after 2000, but did not attribute this trend to climate change. We revised the sentence to use clearly tentative language (L406–L407).

7. 409-412: This claim should have a citation for it, and may be a bit exaggerated: yes, Aura MLS didn't yet exist at the time in question but as I noted in my first-round review there should have been some AMSU-A channel 14 data. Looking at the text and Table 2 of the McCarty et al. 2016 technical report cited in my previous review, that channel was likely active on NOAA-16 and NOAA-17 during SSW02.

   Thank you for the careful reading. You are right that our original sentence overstated the lack of observations by omitting the AMSU-A channel-14 radiances assimilated in MERRA-2 during 2002 (McCarty et al., 2016). We revised the sentence to acknowledge this constraint and added the appropriate citation. We now state that AMSU-A channel-14 provides sensitivity mainly in the upper stratosphere (~30–45 km), so the pre-2004 upper stratosphere/lower mesosphere remains only weakly constrained (L412–415).

References

Jucker, M.: Scaling of Eliassen–Palm flux vectors, Atmos. Sci. Lett., 22, e1020, https://doi.org/10.1002/asl.1020, 2021.

Koushik, N., Kumar, K. K., and Pramitha, M.: A tropical stratopause precursor for sudden stratospheric warmings, Sci. Rep., 12, 2937, https://doi.org/10.1038/s41598-022-06864-7, 2022.

McCarty, W., Coy, L., Gelaro, R., Huang, A., Merkova, D., Smith, E. B., Sienkiewicz, M., and Wargan, K.: MERRA-2 input observations: Summary and assessment, NASA Technical Report Series on Global Modeling and Data Assimilation, NASA/TM–2016–104606/Vol. 46, NASA Goddard Space Flight Center, Greenbelt, MD, USA, 64 pp., 2016. available at: https://ntrs.nasa.gov/citations/20160014544 (last access: 10 September 2025).

Song, B. G., Chun, H. Y., and Song, I. S.: Role of gravity waves in a vortex-split sudden stratospheric warming in January 2009, J. Atmos. Sci., 77, 3321–3342, https://doi.org/10.1175/JAS-D-20-0039.1, 2020.