Review of 'The tropospheric response to zonally asymmetric momentum torques: implications for the downward response to wave reflection and SSW events' by Ning et al.

General comments:

This study uses an intermediate-complexity GCM (MiMA) with imposed stratospheric momentum torques to investigate how zonally asymmetric forcing affects the tropospheric and surface response following SSWs and wave reflection events. By comparing symmetric forcing with different wave-1 forcings, the authors isolate the causal impact of stratospheric zonal structure. The manuscript is generally well written and the analyses are systematic. However, the current manuscript lacks integration across sections, which weakens the logical flow. In addition, a clearer illustration of the experimental design is needed. Therefore, I recommend a major revision.

Major Comments:

1. Improve integration and narrative flow. While individual sections provide informative analyses, they are currently disconnected. This is reflected in several aspects:

- First, the introduction section heavily focuses on the SSWs, while wave reflection receives less attention, despite both being central in the title and abstract. In my opinion, a more balanced structure is needed, perhaps starting with general features and influence of stratospheric polar vortex variability would better frame the study.
- Second, the analyses of SSW-like events and wave reflections appear as separate topics, although they arise from the same experiments. This suggests that these SSWs and wave reflections are dynamically linked. One implication could be that SSWs are associated with different types of wave reflections depending on the phase of the imposed stratospheric wave forcing, which itself is an important conclusion worth highlighting.
- Third, the surface response results from both the wave reflection and the downward coupling discussed in Section 4.4. However, in the current format, these aspects are presented rather separately.

I highly suggest adjusting the structure to make the story more coherent. For instance, emphasize that multiple mechanisms can together explain the surface response (wave reflection, mass streamfunction). Alternatively, the authors could first introduce and discuss the features and dynamical processes, and then link them to the surface response.

2. Clarify and illustrate the experimental design. The description of the model experiments is a bit hard to follow. There are several groups of experiments, the control runs (9 runs times 50 years), the CTRL run (the median gravity wave drag one, 50 years), and the branch

experiments (50 years of the CTRL run times different forcings). This information is described across multiple paragraphs and I had to re-read Section 2 several times to fully understand it. To help readers quickly grasp the essentials of the model settings, I suggest adding a schematic diagram or a concise summary table to visually summarize the experimental setup.

Specific Comments:

1. Introduction: The Introduction currently spends many paragraphs on SSWs while only briefly mentioning wave reflections. Since both are emphasized in title and abstract, I suggest the authors to restructure it to (i) introduce the general polar vortex variability and its tropospheric impact, (ii) introduce SSWs and wave reflection in turn and their linkage, and (iii) identify the gaps that this study aims to address. This will provide a more balanced background and better motivate the focus of this work.

2. L50: 'cleanly' should be 'clearly'.

3. L142: by 'In all, 48 SSW events are identified across all nine control runs during the JFM period', do you mean 48 SSWs in total over the 9 runs*50 years (i.e., 450 winters)? Please clarify. If so, this implies a very low frequency of SSWs even only JFM is considered, which may warrant brief discussion.

4. Figure 1: the color bar in the upper panel spans from -120 to 120m/s. Are the zonal wind anomalies really this large in your experiments? Please clarify whether this reflects the imposed forcing amplitude and discuss whether the results are sensitive to the forcing amplitude.

5. Figure 1 and Figure 2 focus on different period, why is that? Also, should the unit in Figure 2 should be gpm?

6. Section 4.2. Figure 4 suggests that the peak surface response amplitude is similar across experiments, but the control run response occurs earlier. Please discuss the possible reason. I also suggest the authors including a time-height evolution of the NAM index or zonal wind anomaly to illustrate the zonal-mean downward propagation, which might be helpful to understand the different surface response.

7. Figure 4 and 5. I suggest the authors including the tropospheric circulation to briefly compare if the circulation differs among different experiments. Even a brief illustration would help clarify the connection between stratospheric forcing and surface patterns.

8. L303-304: In the symmetry ensemble, the Fz is not centrally located above the pole, but shows downward propagation over NA in Day 1-12. This might be related to the climatological wave propagation.