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.

This study uses an intermediate-complexity moist GCM to analyze the impacts of wave-1 momentum torques with varying longitudinal phases. The goal is to help understand the surface influences and mechanisms of wave reflection events. Forced with wave-1 forcings of opposite phases, simulations show distinct circulation and surface responses that are generally consistent with results from the reanalysis in existing literature. The surface air temperature anomalies are further connected to the stratospheric anomalies via mass streamfunction analysis.

The result is within the scope of the journal. The technical aspects of the study are solid, and the paper is generally well written. I believe this study could be accepted for publication after addressing the following issues.

General comments

My main concern is that the authors might conflate potentially related yet distinct concepts. The manuscript claims that the results indicate the surface response to stratospheric wave reflection events is causally forced by stratospheric perturbations (L17). Planetary wave reflection is a generally well-defined phenomenon in which planetary waves propagate upward from the troposphere into the stratosphere and are reflected back. Intuitively, upward wave propagation, a reflective surface, and downward wave propagation would be expected in a wave reflection event. The present experiment only shows the downward wave propagation, yet it seems to implicitly imply that downward wave propagation equals wave reflection. I think a discussion is warranted to discuss the model’s limitations and clarify the relationship between the results and wave reflection. The authors may also consider softening some related arguments regarding the implications of the results.

The authors claim to be the first to demonstrate that downward wave propagation can causally lead to surface impacts (L86, 427). I am concerned that this might be overstated; at least some of the aspects have been shown in the existing literature. Dunn-Sigouin and Shaw (2018) investigate the mechanism of extreme stratospheric wave-1 negative heat flux events with nudging experiments in a dry dynamical core model. They demonstrate the causal role of stratospheric waves in reproducing the tropospheric responses to negative eddy heat flux events. Through stratospheric nudging experiments in an AGCM, Ding et al. (2023) provide causal evidence that strong stratospheric wave activity leads to North American cold anomalies through vertical wave coupling. Their strong stratospheric wave events exhibit regional raw negative Plumb flux over North America (Fig. 2). They also analyzed weak wave events, during which the stratospheric planetary waves are in an opposite phase compared to those of strong wave events.

Neither of these studies presents exactly the same analysis/results as this study, so I think this analysis is still novel. But the authors should include these publications in their introduction/discussion. And perhaps the point can't be quite so strongly stated.

Individual comments

L5: The experiment names "90E" and "270E" do not feel very informative, as they represent the longitude where the zonally asymmetric component is 0. I'm unsure if it is a good idea, but the authors may consider using the longitude of the largest easterly forcing.

L56: Huang et al. (2018) show that the shifting direction of displacement events affects the surface responses in reanalysis.

L58: An imposed heating induces an effect on meridional circulation opposite to what?

L66: Ding et al. (2022) show the distinction between zonally symmetric and asymmetric stratospheric variabilities.

L88: Could you point me to the reference that suggests wave reflection events often occur after SSW events? A single case of 2021 does not read like enough evidence.

L139: easterly -> westerly

L141: The SSW frequency seems much lower than observed: 48 events in 9 runs of 50 years. How so?

L171: Why set the scaling factor of the asmmyeric component to 4? Do other settings change the conclusion?

Figure 2: Why show the geopotential height patterns during days 1 to 5 while showing zonal wind anomalies during days 6 to 12? Do the two periods differ a lot?

Figure 2: I suggest adding contours of 10 hPa anomalies, which would help readers understand through a different lens. Comparing the 10 hPa anomaly with the 500 hPa anomaly would provide insight into the vertical structure.

L245: This is confusing without showing the stratospheric anomalies.

L256: The downward propagation seems hard to see, as the peak anomalies at 500 hPa occur at the same time as those at 10 hPa (day 12) for the branch experiments. In contrast, a clear lag exists between stratospheric and tropospheric anomaly peaks for SSWs in the control experiment.

L265: There is no visible signal during days 1 to 12. How should we see the differences?

L283: Precipitation anomalies following symmetric forcing and control SSWs appear to be more persistent.

L311, 410: Cluster 5 in the references appears to represent weak polar vortex events. Please elaborate on how they are connected to the downard wave propagation reported here.

Figure 7: Why do the centers of poleward anomalies seem to shift 90 degrees westward from day 1-5 to day 6-12 in panels (c) and (d)?

L363: What do you mean by “wave reflection during weak vortex events”? Perlwitz and Harnik (2003) show that a reflective surface is more likely to form when the lower stratospheric polar vortex is anomalously strong. Ding et al. (2022) also present a stronger-than-normal polar vortex prior to strong stratospheric wave events that are associated with regional wave reflection.

References

Ding, X., Chen, G., Sun, L., & Zhang, P. (2022). Distinct North American Cooling Signatures Following the Zonally Symmetric and Asymmetric Modes of Winter Stratospheric Variability. Geophysical Research Letters, 49(6), e2021GL096076. https://doi.org/10.1029/2021GL096076

Ding, X., Chen, G., Zhang, P., Domeisen, D. I. V., & Orbe, C. (2023). Extreme stratospheric wave activity as harbingers of cold events over North America. Communications Earth & Environment, 4(1), 187. https://doi.org/10.1038/s43247-023-00845-y

Dunn-Sigouin, E., & Shaw, T. A. (2018). Dynamics of Extreme Stratospheric Negative Heat Flux Events in an Idealized Model. Journal of the Atmospheric Sciences, 75(10), 3521–3540. https://doi.org/10.1175/JAS-D-17-0263.1

Huang, J., Tian, W., Gray, L. J., Zhang, J., Li, Y., Luo, J., & Tian, H. (2018). Preconditioning of Arctic Stratospheric Polar Vortex Shift Events. Journal of Climate, 31(14), 5417–5436. https://doi.org/10.1175/JCLI-D-17-0695.1

Perlwitz, J., & Harnik, N. (2003). Observational Evidence of a Stratospheric Influence on the Troposphere by Planetary Wave Reflection. Journal of Climate, 16(18), 3011–3026. https://doi.org/10.1175/1520-0442(2003)016%253C3011:OEOASI%253E2.0.CO;2