

The authors are grateful to the anonymous referee for the constructive and insightful comments and suggestions, which are very valuable and helpful for improving the manuscript. We have addressed the comments/suggestions carefully and revised the manuscript accordingly. Listed below are the point-by-point responses (in blue) to the comments (in black).

Major comments:

A) The figures 1, 6, 9 and 10 do not go down to the surface (terminate at 500 or 200 hPa), which is in my eyes unjustifiable. The results section then completely omits the possible near surface dynamical impacts, which will be of the first order importance, as can be seen from the tip of Himalayas in Fig. 6. Without considering low-level processes (near surface breaking; the impact of the near surface drag modifications on resolved wave EPFz at at least 850hPa) the analysis of the dynamical mechanisms cannot be complete. An illustrative example of this bad praxis is the referenced catalytic wave-mean-flow positive feedback by White et al. (2021) - more on this in a minor comment.

Reply: Thanks for your valuable comments and suggestions. Figs. 1, 6, and 10 have been extended downward to 850 hPa so that the vertical structures can be examined continuously from the lower troposphere to the stratosphere. According to the reviewer's subsequent comments, Figure 9 has been deleted.

B) Wave-induced secondary circulation - I suggest to omit this subsection in the revision, because the explanation invoking the Downward Control Principle by Haynes et al. (1991) is conceptually flawed. Eq. 6 uses the steady state version of the principle, which is completely unjustified for the 10-day forecasts, i.e. of a length comparable to a few radiative timescales in the stratosphere. In the original Haynes et al. (1991) paper you can find results of numerical experiments documenting how the transient response differs from the steady state response you assume in your explanations.

Reply: Thanks for your valuable comments and suggestions. The previous version invoked the steady-state downward-control framework too strongly for a 10-day forecast context, and this interpretation was not sufficiently justified. Accordingly, in

the revised manuscript we have removed the entire subsection “Wave-induced secondary circulation”, including Eq. (6) and the associated discussion. Instead, the revised manuscript now adopts a more cautious interpretation focused on diagnostics that are more directly supported by the medium-range forecast experiments, namely the changes in parameterized OGWD, resolved EP flux, and refractive properties associated with Rossby-wave propagation. In this way, the mechanistic discussion is now better aligned with the forecast timescale considered in this study.

Minor comments:

L70-L73 - Delete the sentences in brackets. They add no new information.

L73-74 - I know what you mean but this statement about horizontal propagation has to be rephrased more carefully, because it can be misleading in a sense that nonhydrostatic GWs can propagate equally oblique as for example near-inertia OGWs that can travel hundreds to thousands of kilometers horizontally.

Reply: Thank you. The sentence is revised to avoid over-emphasizing horizontal propagation distance and instead highlight the stronger horizontal dispersion of wave energy in the nonhydrostatic regime. The sentence has been revised to: “*Compared with hydrostatic OGWs, nonhydrostatic OGWs experience stronger horizontal dispersion of wave energy, which reduces wave amplitude and can suppress wave breaking and momentum deposition into the mean flow.*”

L106 subgrid orographic ->subgrid scale orography effects

Reply: Thank for the suggestion. It is revised.

L154 and L172 and 173FR0 is in fact an inverse Froude number, which is another important distinction from your horizontal Fr.

Reply: Yes. The horizontal Fr is equal to the wind speed over the mountain half width and buoyancy frequency (i.e., U/Na). Fr_0 represents the flow nonlinearity (i.e., $Fr_0 = \frac{Nh_0}{U}$).

L193 Beljaars'->modified Beljaars'?

Reply: Thank for the suggestion. It is revised.

L199 write the time and date indication according to a proper English grammar

Reply: Thank you. It has been modified to: *“Both experiments consist of 31 individual forecasts, each initialized at 00 UTC for the days from 1 to 31 December 2023”*.

L213 and 218 tropospheric jet -> upper tropospheric lower stratospheric jet, because the subtropical jet is located in UTLS

Reply: Thank for the suggestion. It is revised.

L220 Given in the summer - rephrase.

Reply: Thank you. The sentence is modified to: *“During austral summer, the SH stratosphere is dominated by easterlies, which is distinctly different from the NH”*.

Fig. 1 - see my comment A)

Reply: Thank you. As noted in our response to Major Comment A, we have extended Fig. 1 downward to the 850 hPa and revised the related discussion accordingly.

Fig. 2 - adjust the color scale to better visualize the differences in plot d).

Reply: Thank you. The color scale is adjusted in Fig. 2d to better visualize the differences between the two experiments.

L299-L300 ...which are significantly reduced in EXP_NHE... Please add some significance indicator to the Fig. 3.

Reply: Thank you for this suggestion. The significance at day 10 between the two experiments are statistically significant at the 90% confidence level.

Forecast time (day 10)	Mean bias (0-90°N)	Mean bias (60-90°N)	RMSE (0-90°N)	RMSE (60-90°N)
P value	0.1	0.09	0.02	0.03

Fig. 6 - see my comment A)

Reply: Thank you. As noted in our response to Major Comment A, Fig. 6 has been extended downward to 850 hPa, and the associated discussion has been revised.

L389 - delete the By the way statement

Reply: Thank you. It has been deleted.

L405-442 see my comment B, because I think that this section should be deleted.

Reply: Thank you. The subsection has been deleted, as noted in our response to Major Comment B.

L447-450 see also my comment A. The term catalytic wave-mean-flow positive feedback (White et al., 2021) is very vague and possibly erroneous, because White et al., (2021) absolutely fail to account any compensating or amplifying dynamical interaction between the processes from SSO and resolved orography, which can also play a big role in your study. can you for example simply check the differences in EPFz at 850 hPa? Moreover, the original reference has nowhere proven that indeed the width of the wave spectrum that can enter the stratosphere plays a role in their results. You are welcome to prove this in your manuscript. But, I think that the Cohen et al compensation mechanism or related numerous works by other authors on parameterized GWD effects on the refractive index in the wave layer should be used as a reference here.

Reply: Thanks for your valuable comments and suggestions. In the revised manuscript, we have therefore removed this terminology and substantially rewritten the relevant discussion. This revised interpretation is more consistent with Cohen et al. and related studies on the interaction between parameterized wave drag, resolved wave forcing, and wave propagation conditions. Following the referee's suggestion, we have added a new diagnostic of refractive index to explicitly document the lower-tropospheric resolved-wave response. *“As shown in Fig. 9, positive RFI values for both zonal wavenumbers 1 and 2 are found over the northern mid- to high latitudes in EXP_CTL, indicating that the basic-state flow is favorable for the upward propagation of planetary waves (Figs. 9a, 9c). In EXP_NHE, however, the RFI is generally reduced over the same region, especially in the upper troposphere and lower stratosphere. These negative RFI anomalies suggest that the strengthened background westerlies in the polar stratosphere make the environment less conducive to the vertical propagation of Rossby waves (Figs. 9b, 9d). Similar behavior is found for both wavenumber-1 and wavenumber-2 components, although the wavenumber-1 signal appears more spatially*

coherent. Therefore, the reduction of RFI provides a dynamical explanation for the weakened upward EP-flux branch seen in Fig. 8b.

Physically, the revised OGWD scheme weakens the parameterized drag in the northern polar stratosphere, which strengthens the local westerlies. Stronger background westerlies narrow the range of planetary-wave numbers that can propagate vertically into the stratosphere. Consequently, the upward propagation of resolved Rossby waves is suppressed, and less resolved wave forcing reaches the polar stratosphere. This effect acts together with the weakened parameterized OGWD to reduce the easterly wind bias in the polar stratosphere. At the same time, the associated redistribution of resolved wave forcing favors a weakening of the polar-tropospheric westerlies, thereby contributing to the improvement of the large-scale circulation over the northern high latitudes.” is added in section 4.b.

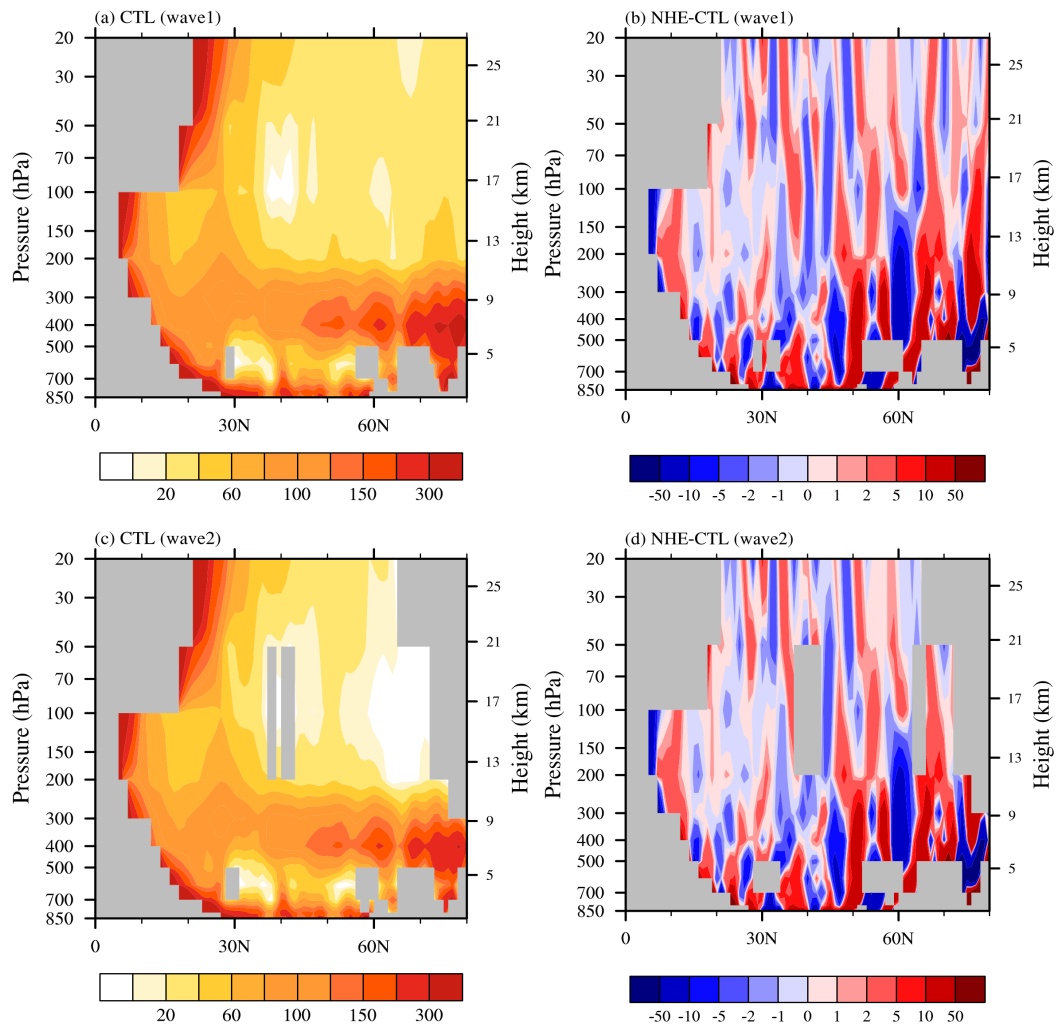


Figure 1. Refractive index for the (a) wavenumber-1 and (c) wavenumber-2 resolved

waves averaged over the period of 10 December 2023 to 10 January 2024 in the EXP_CTL experiment. (b) The difference between the refractive indices of wavenumber 1 in EXP_NHE and EXP_CTL (EXP_NHE minus EXP_CTL). (d) As in (b), but for wavenumber 2.

L490 From eq. 7 -> Why don't you plot the RFI differences?

Reply: Thank you for the suggestion. The RFI discussion is added in the revised manuscript.

L493 Is inhabiting the right word here?

Reply: Thanks, It has been corrected.