On:
"Emulating lateral gravity wave propagation in a global chemistry-climate model (EMAC v2.55.2) through horizontal flux redistribution'
GMD, 2023, by Eichinger et al..

August 10, 2023

1 Reply to Review #2

Dear Anonymous Referee #2,

thank you for your time and effort to review our paper. Please find our answers (in italic) to the points of your revision (in bold) below.

Best wishes
Roland Eichinger and Sebastian Rhode, on behalf of all authors

1. **Section 2.1: What is the reason of using idealized, Gaussian-shaped mountain ridges for the MW parameterization?**

   We use idealised, Gaussian-shaped mountain ridges as these are oftentimes the object of study in MW generation investigations [e.g. Lott et al., 2020, 2021]. This allows for a straightforward conversion of mountain parameters, i.e., width and height, to the initial GW parameters, i.e., wavelength and amplitude. By using these sets of idealised mountains, the MW sources can be localised in the orography.
   For clarification, the following sentence has been added to the manuscript:
   "The Gaussian mountain shape has been used in many MW studies and

allows straightforward conversion of ridge parameters, i.e., width and height, to the initial GW parameters, i.e., wavelength and amplitudes."

2. **Eq 3. Just a clarification, the terminology may have confused me: the momentum flux τ_{m1} that is being redistributed is taken at the model level 65, right below 15 km. And this model level is labeled "src" in eq (3)? So "src" is not the GWMF at source level in the parameterization, but at the chosen level for redistribution?**

   Yes, right, all this refers to GW flux at the level of redistribution, not at the GW source level. To make this more clear and avoid any confusion, we slightly adapted the explaining sentence there to read:
   *".... and the subscripts tar and src denote **(horizontal)** target and source **grid cell** of the GWs **at the level of redistribution, respectively.***

3. **Figs. 8 and 9, Lines 405 and 450: Regarding the increased drag at upper levels with redistributed flux, part of the reason of this behavior might indeed be due to more favorable vertical propagation conditions around the polar night jet. If a fraction of the momentum flux generated at the Andes and the Antarctic Peninsula is redistributed around 60S, where the zonal mean wind maximum is located, the saturated flux given by eq. (4) would be larger, hence allowing the waves to propagate upwards without dissipating. Does this make sense? Plougonven et al. (2017) reported a tendency in observations and high resolution simulations for large momentum fluxes to be located at the jet maximum, which was explained in terms of horizontal propagation.**

   Thank you for this interesting theory. This makes sense to us and we have now included it in the explanation part in section 3.5. This part now reads:
   "... regions with more favourable propagation conditions for the GWs. A physical reason for this could be that around 60°S, where the zonal mean wind maximum is located, the saturated GWMF given by Eq. 4 is larger, hence allowing GWs to propagate upwards without dissipating. This is supported by Plougonven (2017), who reported large GWMF to be located at the jet maximum in observations and high-resolution simulations. Another systematic change through GW redistribution are the absolute..."

Moreover, we added it to the Summary stating:
"... and from more favorable vertical propagation conditions around the polar night jet where some GWMF has been redistributed to."

4. **Fig. 11. I would suggest to add some panels to this figure showing the comparison with ERA5, this would be valuable to assess whether the implemented redistribution works in the right direction, with all the caveats regarding the lack of refined tuning.**

   Thank you for the suggestion, but we refrain from adding these panels. This is certainly a good idea for a follow-up study, but it opens a can we do not want to open in this one. The caveats you mention are too many to deal with here. Using the two different SSOs already leads to unclear results as to how the vortex is altered through the OGW modifications. This means, that already here, we receive ambiguous results and cannot clearly state how exactly the dynamics will change. As further work on this will require large tuning efforts, an eye will have to be kept on stratospheric dynamics and systematic analyses will allow clear statements. For now, however, we want to leave it at the point where we show that the OGW redistribution has the potential for significant changes of polar vortex dynamics and based on what we know from previous EMAC model evaluations, they point into a good direction, although not as clearly as one would have wished for.

5. **Although the interaction between the modified GW drag, planetary wave driving and the mean circulation well deserves a separate study, it would be very interesting to briefly analyze changes in planetary wave driving in these 4 EMAC runs. I would suggest to add the corresponding latitudinal distribution of WP flux divergence to the panels in Fig. 10. According to Garcia et al (2017), there is a strong compensation between GW drag and resolved forcing around 60S due to the columnar approach followed by orographic GW parameterizations. Besides, these plot may help explain to a first order the changes in the zonal mean zonal winds and temperatures given in Fig. 11.**

   To meet your point, we added a figure to the supplement displaying zonal mean differences of OGWD, NGWD and EPfd (see also below). Moreover, we added to the text:
   "As noted before, OGW drag strongly increases in the upper strato-

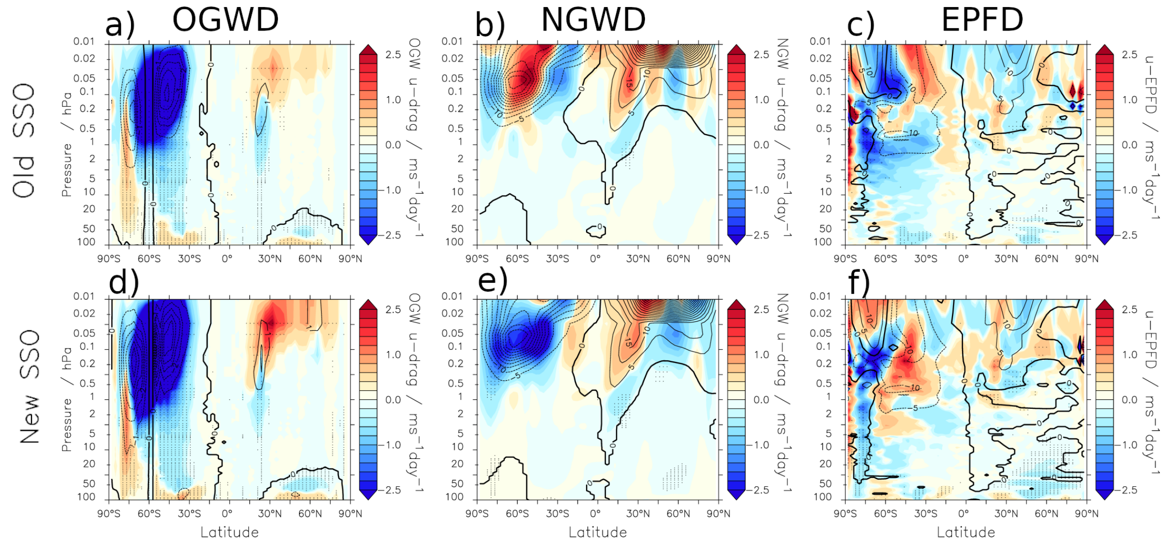

Figure 1: Zonal mean difference of (a, d) orographic gravity wave drag, (b, e) non-orographic gravity wave drag and (c, f) Eliassen-Palm flux divergence between simulations with OGW redistribution and with columnar OGW approach for (a-c) new SSO and (d-f) old SSO. The contours show the respective climatology of the columnar approach simulation and stippled regions show where the differences are signficant on the 95% level.

> *sphere. This increase is partly compensated by a decrease in non-orographic GW drag, and partly by planetary wave drag. However, we do not find a systematic compensation of the (missing) drag at* 60°*S as reported by Garcia et al. (2017). As shown by Eichinger et al. (2020), the occurrence of compensation and thereby also the impact on zonal winds seems to strongly depend on the basic state, and in cases also amplifying effects are found. An in-depth investigation of the wave-wave and wave-mean flow interactions will be needed to determine what exactly are the crucial mechanisms here."*

References

F. Lott, B. Deremble, and C. Soufflet. Mountain waves produced by a stratified boundary layer flow. part i: Hydrostatic case. *Journal of the Atmospheric Sciences*, 77(5):1683 – 1697, 2020. doi: https://doi.org/10.1175/JAS-D-19-0257.1.

F. Lott, B. Deremble, and C. Soufflet. Mountain waves produced by a stratified shear flow with a boundary layer. part ii: Form drag, wave drag, and transition from downstream sheltering to upstream blocking.

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