Reply to the Interactive comment on “Verifications of the high-resolution nonlinear numerical model and polarization relations of atmospheric acoustic-gravity waves” by N. M. Gavrilov and S. P. Kshevetskii

Anonymous Referee #1

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We would like to thank the reviewer #1 for useful comments, which help to improve our paper. Our replies to his comments are given in bold font below.

The main motivation of the discussion paper “Verifications of the nonlinear numerical model and polarization relations of atmospheric acoustic-gravity waves” by N. M. Gavrilov and S. P. Kshevetskii is to perform comparisons of amplitudes of atmospheric gravity waves (AGWs) and related characteristics of direct numerical simulations (DNS) with linear polarization relationships (LPR) given by the steady-state theory of nonrotational non-dissipative AGWs. Authors considered to use their DNS results for monochromatic sources of AGWs as a potential tool for testing and verifications of LPR used in the simplified parameterizations of AGWs. The abstract provides a concise and complete summary of the paper. As suggested, DNS of AGWs may be useful tools for testing of simplified GW parameterizations employed in the climate and weather models. The nonlinear breaking of AGWs by DNS and limitations for applications of LPR during wave breaking, however, are not examined in the article.

Wave breaking violates applicability of LPR due to two main reasons. First, wave breaking leads to generation of a spectrum of secondary wave modes instead of one main mode in stable region. Parameters of these secondary modes change in time, which make difficult estimations of their LPR. Second, breaking AGW generate wave induced mean flow very fast growing in time. This also makes difficult LPR estimations, as far as all analytical AGW theories assume background fields slowly varying in time. We added such statements into the revised version of the paper.

As discussed in the paper, comparisons between numerical simulations and analytical expressions for AGW parameters, “reveal atmospheric regions, where analytical theories give substantial errors”. Modeling protocol of results is summarized in two tables for two selected AGW modes. It is suitable approach for addressing difference between the DNS and analytical solutions of the linear theory of AGWs. Authors emphasized that the DNS are required to accurately represent the transient wave fields after "switching on" the monochromatic wave source at the surface. However, for the steady state wave regimes, the representation of the DNS and analytical solutions by illustrations for vertical profiles of the energy, heat and momentum fluxes can enhance the presentation of results and conclusions, when and where LPRs are not valid for variable intensity of the AGW amplitude at the source level.

From analytical AGW theory, we can get local linear polarization relationships, but not vertical profiles of wave characteristics for dissipative atmosphere and realistic temperature profiles. Therefore, direct comparisons of DNS numerical solutions with “analytical” profiles in wide altitude regions are problematic. Many vertical profiles of AGW characteristics at different times and their changes at different altitudes calculated with the DNS model readers may find in our paper by N. M. Gavrilov and S. P. Kshevetskii. “Dynamical and thermal effects of nonsteady nonlinear acoustic-gravity waves propagating from tropospheric sources to the upper atmosphere”, which should be printed soon in Advances in Space Research (2015).

Authors provided proper credit to related work and reference on their previous modeling studies. The title of the technical report reflects content of the paper. However, stress on the nonlinear aspects of numerical model results (that present in the title) is not fully discussed in the paper. The text and tables are more solicited on the initial transience of the quasi-linear wave packets.

We replaced the word “nonlinear” by “high-resolution” in the title of revised manuscript.

There are no discussions on the impact of strength of wave sources on the development of the nonlinearity and transience of simulated AGWs.

We added some discussion of the impact of strength of wave sources.

Perhaps authors can make explicit statements that they considered (a) the quasi-linear DNS of monochromatic dissipative waves to verify their model by the LPR valid for non-dissipative AGWs, and (b) explain their motivation to evaluate the spin-up of transient (for $t < te$) model results by the steady-state LPR that can be applied for $t > te$. It appears, the analytical transient linear wave solutions in the windless isothermal non-dissipative background atmosphere can be more appropriate analytical approach to verify transient propagation of the broad spectra of linear AGW forced in the DNS by localized sources.

We agree, “analytical transient linear wave solutions” can be more appropriate analytical approach to verify transient AGW propagation”. However, recently we do not know such analytical solutions. May be the reviewer can help to find them. Our results show that such transient linear wave solutions are strongly needed. We hope, such AGW theories will be developed in the future.

The upper part of tables that summarizes comparisons between DNS and the analytical steady-state ($t > te$) LPRs is the most appropriate for verification of DNS results for the quasi-linear monochromatic waves, while for DNS verifications at $t < te$ (second part of tables) it would be difficult to rely on the validity of LPR for single steady-state wave without considerations of the analytical solutions for transient waves.

Our results are not only for DNS verification, but also for verification of LPRs themselves. One of the results of our paper is poor validity of steady state LPR in transient conditions. However, in many cases such steady-state LPRs are used for parameterizations of transient AGW effects. We hope, our results will help in developing more realistic parameterizations.

The discussions paper of N. M. Gavrilov and S. P. Kshevetskii represents a substantial contribution to modeling science of AGWs, and it is definitely within the scope of Geoscientific Model Development Journal.

Specific comments.

(a) Abstract. “Reasonable agreements between simulated and analytical wave parameters satisfying the scope the limitations of the AGW theory proof adequacy of the used nonlinear numerical model”. Sentence needs additional clarification.

We changed the word “nonlinear’ to “wave”.

(b) 7812-20 “The modeling was performed beginning from the MSIS initial state (zero wave fields)..." It is worthy to mention the windless background flow.

The phrase is modified.

(c) 7816-15 “Therefore, waves with longer vertical wavelengths can better penetrate to the upper atmosphere, where they can produce larger dynamical and thermal effects than those with shorter vertical wavelengths (see Gavrilov and Kshevetskii, 2014b)”. This sentence requires more clarification, because indeed AGWs with larger vertical wavelength can faster propagate from the surface to the upper layers but they also subject less effective dissipation and nonlinear breaking in the thermosphere. DNS results can also depend on the non-zero background flow.

The phrase is modified in the revised manuscript.

Yours Sincerely.
N. M. Gavrilov, S. P. Kshevetskii