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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Some experimental constraints for spectral parameters used in the Warner and McIntyre gravity wave parameterization scheme" *by* M. Ern et al.

M. Ern et al.

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The authors would like to thank Anonymous Referee #1! The manuscript will definitely benefit from his/her helpful comments! Especially the discussion of Comments (1) and (6) will help the reader to get a better overview of the problems that arise when measurements and modeling of gravity waves (GWs) (and especially gravity wave momentum flux (GW-MF)) are compared.

First we will address to the specific comments:

(1) Referee Comment: The GW data might still be contaminated by non-GW contributions after applying horizontal Kalman filtering with zonal wavenumbers 0–6.

and:

(6) Referee Comment: Why do the authors compare GW pseudo-momentum fluxes and not GW temperature fluctuations?

Reply to Referee Comments (1) and (6):

The reviewer points to a problem which is common to nearly all experimental work on GWs. The atmospheric fluctuations caused by GWs need to be discerned from other kinds of variations by a scale separation approach. Evidently, several problems arise: First, there might exist other phenomena in the atmosphere inside the scales considered as GWs, second, other phenomena could leak into the scales considered as GWs, third, GWs can have scales outside the limits of the scale separation approach, and, fourth, the applied detrending algorithm can redistribute GW energy in space or wavelength.

Apparently, the third is the smallest problem, because the detrending can be specified and the results therefore properly characterized. However, a too limited wavelength range can make interpretations very difficult (e.g., Alexander, 1998, Preusse et al., 2006).

Validation, whether the scale separation approach is working properly, can be performed in three ways: First, the GW dispersion or polarization relations can be used to actually prove that an observed pattern is a GW. This requires, however, to measure either the horizontal and vertical wavelength as well as the frequency of the wave to test the dispersion relation or the wind and temperature amplitudes as well as two of the above mentioned quantities to test the polarization relation. Such tests have been performed in case studies e.g. for radio sondes (polarization relation) and for

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CRISTA data investigating a large scale wave observed above super-typhoon Winnie (Preusse, 2001). If it can be assumed that the observed waves are mountain waves, the dispersion relation can be tested with the vertical wavelength alone (Eckermann and Preusse, 1999, Preusse et al., 2002). Second, one can try to understand in case studies the nature of the waves, e.g. one can perform regional or global modeling and show that salient features of the waves or global distributions match (e.g. Eckermann and Preusse, 1999, Preusse et al. 2002, or, to quote different measurement techniques, Dewan et al., 1998, Jiang et al., 2004). One also can sometimes compare to proxies of GW sources and find reasonable agreement in the distribution patterns as well as wave characteristics matching with the sources (e.g. Preusse et al. 2001, Jiang et al., 2004). This can raise the confidence that in general the patterns retrieved by the scale separation approach are best explained in terms of GWs though it is not a strict proof. Third, one can try to think of different processes, such as balanced motions, and estimate their influence on the estimated GW distributions. This approach has two disadvantages: First, one investigates only what comes to ones mind and the investigation can therefore never be complete, and second, it can be performed only in case studies, too.

How can we apply this discussion to the Kalman filter? There is a large number of case studies (the quoted references are only a few examples) which fall in the first and second category. There are, in addition, some findings indicating that the scale separation by the Kalman filter works. We have run the Kalman filter up to wave number 16. However, for temperatures most of the spectral power is contained in the first three wave numbers and the amplitudes at wave numbers higher than six are small compared to average GW amplitudes at corresponding latitudes. On the other hand high wave numbers of the Kalman filter are required to map balanced-motion signatures in trace gases, such as streamers and filaments (cf. Offermann et al., 1999). We have also compared GW patterns with the location of streamers and filaments in CRISTA data. In general there are no enhanced GWs connected with such patterns. There is a heuristic argument why balanced motions do not contribute largely to the observed temperature fluctuations. Any wave-like temperature structure in the atmosphere experiences damping due to dissipation as well as radiative transfer. The estimated typical damping time scales for waves depend on horizontal and vertical wavelengths and are of the order of one day for structures of the size of streamers and filaments (Fels, 1982, 1984, Marks and Eckermann, 1995). Typical lifetimes of structures in tracers are of the order of one week. The abundance of streamers and filaments in tracers is therefore likely not reflected in corresponding temperature signals.

Based on these three arguments, i.e. tests of the dispersion relation, explanation of wave properties and global distributions, and observed power decrease at higher wavenumbers, we are therefore confident that the Kalman filter truly isolates GWs from other kind of signatures in the stratosphere and mesosphere. Problems could be posed by fast propagating waves, though of global scale, as e.g. the two-day wave and ultra-fast Kelvin waves. Here, analyzing momentum flux instead of temperature fluctuations or wave potential energy has the additional advantage of focusing on the shorter horizontal wavelengths and thereby strengthening the scale separation approach. Compared to the uncertainties introduced by instrumental noise, distortions from the radiative transfer and, in particular, the undersampling of the horizontal wave structure, the uncertainties due to the scale separation approach can be considered as small.

The full discussion as given above will be added to the paper in an Appendix, because it might be good to have such a discussion in the literature at one place and not scattered over several publications. In addition, we will add a short paragraph in the introduction, which both motivates the analysis of momentum flux (reply to comment (6) of Referee #1) and points to the scale separation approach. The new paragraph starts after '... horizontal and vertical patterns of GW-MF' in the currently last paragraph of the introduction:

"This comparison has to be made in terms of momentum flux rather than comparing potential wave energy. The scale separation approach (cf. Sect. 2 and Appendix) to

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isolate GWs from other atmospheric fluctuations retains also inertio GWs of very long horizontal wavelengths. These waves predominately exist at the equator (Alexander et al., 2002), but can spread to higher latitudes with increasing altitudes (Preusse et al., 2006) propagating several 1000 km in the horizontal. These waves cannot be described by a model assuming mid frequency approximation and purely vertical wave propagation. Though these waves are contributing a large part of the measured wave potential energy they contribute little to the measured momentum flux (Ern et al., 2004, Preusse et al., 2006) and they are badly represented in the parameterization scheme. Comparing momentum flux, hence makes model and measurement comparable at all and, in addition, strengthens the scale separation approach by focusing on shorter horizontal wavelengths less likely influenced by non-GW signatures (cf. Appendix)."

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(2) Referee Comment: No discussion of the parameter β is given. Since this parameter does not enter into the GW fluxes at higher altitudes in a linear fashion, such an analysis seems desirable.
(see also Comment (1) of Anonymous Referee #2)

Reply to Referee Comment (2):

In the Warner and McIntyre scheme the parameter β enters the launch spectrum as well as the quasi-saturation curve at higher altitudes as linear constant. This means both GW fluxes and GW drag are scaled in a linear way: the relative distributions of GW fluxes and GW drag remain unchanged while the absolute values are scaled via β (this is valid for all altitudes). We have mentioned the fact that β is proportional to the amount of GW momentum flux and to the GW drag already on pg. 4758 lines 17–20 (the lines following after Eq. (1)). But we agree with the referee that this is not sufficient, and we should state more clearly that the relative distributions remain unchanged and β can be used to reduce the low-bias of model GW-MF without changing the relative distributions as well as the launch parameter ranges determined from the correlation criterion. In particular, this discussion should be given where the variation of β is discussed (on page 4774, lines 9ff).

Therefore we will add the following sentences after pg. 4774, line 8:

"In the Warner and McIntyre scheme the parameter β (see also Sect. 1) is proportional to the values of GW-MF as well as to the values of GW drag. Therefore scaling of GW-MF and GW drag with β as suggested in Sect. 4.3.2 can be used to reduce the low-bias of model GW-MF without changing the relative distributions of GW-MF and GW drag. This means the correlation between modeled GW-MF and CRISTA GW-MF as reference is left unchanged and also the ranges of launch parameters determined from the correlation criterion. Indeed, increasing of β makes sense because for the CRISTA-2 case..."

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(3) Referee Comment: Figures for the optimum set of launch parameters would be desirable!

Reply to Referee Comment (3):

We will add the figures for the optimum set of launch parameters ($\lambda^*_{z,launch}$=3 km, s=2, and launch level 464 mbar (where applicable)) in an appendix. This means we will provide reproductions of Figs. 3b, 3d, 3f, 4b, 4d (horizontal distributions of GW-MF), Figs. 5c, 6c (correlation coefficients vs. altitude and launch altitude), Figs. 9, 10 (panels for λ^*_z vs. latitude and altitude for $\lambda^*_{z,launch}$= 3 km and s=2) and also corresponding to Fig. 13 zonal mean zonal GW drag for the optimum parameter set.

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(4) Referee Comment: P. 4756, bottom: Lindzen (1981) should be cited!

Reply to Referee Comment (4):

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The reference Lindzen (1981) will be added.

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(5) Referee Comment: P. 4768, bottom paragraph, and Figs. 11 and 12: It is unclear how the "deviations" are determined!

Reply to Referee Comment (5):

Yes, Referee #1 is right, we should be more specific here. We will rewrite lines 22–27 on page 4768 in the following way:

"Figures 11a–c show deviations between horizontal distributions of GW-MF absolute values calculated with the Warner and McIntyre scheme and CRISTA-1 GW-MF as a reference. The deviations shown are the slopes of linear fits through the origin from scatter plots of model GW-MF vs. CRISTA GW-MF for every pair of horizontal maps. The reciprocal of the slopes has been taken for slopes <1 (at low $\lambda^*_{z,launch}$) to have the same color scale for GW-MF deviations in both directions. The logarithm of the..."

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(6) Referee Comment: Why are momentum flux values compared with CRISTA and not temperature fluctuations?

Reply to Referee Comment (6): see reply to (1)

There is also a technical correction recommended by Referee #1:

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(7) Referee Comment: In Figs. 3 and 4 same colors should be used for model and observation at each altitude and the contour labels are too small.
(see also Comment (2) of Anonymous Referee #2)

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Reply to Referee Comment (7):

To be able to see whether the relative structures in both model and measurements are the same we would like to keep the different color scales for model and measurement. Of course, then the range of the values shown in each panel should be easy to read to allow a better comparison of the absolute values. Therefore we will add individual color bars for each panel in Figs. 3 and 4 displaying the contour intervals (larger than the contour labels given in the old version, sorry for that!).

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 4755, 2006.

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