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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Wave fluxes of equatorial Kelvin waves and QBO zonal wind forcing derived from SABER and ECMWF temperature space-time spectra" *by* M. Ern and P. Preusse

M. Ern and P. Preusse

m.ern@fz-juelich.de

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The authors would like to thank Anonymous Referee #1 for the very helpful comments!

The technical corrections given will be included in the revised manuscript as suggested. In the following we will address to the Reviewer's Specific Comments. In particular for Specific Comment #1 (error estimation) we added some discussion of the possible error sources. The detailed discussion will be given in the revised manuscript.

Best regards,
Manfred Ern

Specific Comments:

Specific Comment #1: Uncertainties in Kelvin wave momentum fluxes and accelerations should be estimated!

Yes, indeed, momentum fluxes and especially accelerations are small, derived parameters and therefore can have considerable errors.

The first kind of error source are the typical error sources of measurements like offsets or measurement noise. Systematic offsets in the temperature data will have no effect since only temperature perturbations are analyzed. Also measurement noise will have only little effect if we assume white noise. Therefore this error source will not be treated in our work.

The second error source are assumptions that are made when we apply the space-time spectral analysis. For example, we have to assume stationarity of the spectral components over the length of the time windows used (31 days). Probably these errors will be small compared to other error sources and they are hard to quantify and depend on the atmospheric state in each time window. Therefore this error source will also not be treated in our work.

The most important error source will be the accuracy of the derived space-time spectra. There are several effects that have to be taken into account:

1. observed vertical oscillation of spectral amplitudes (possible SABER retrieval artifact)
2. accuracy of the spectral background that has to be subtracted (this background is mainly due to non-resolved gravity waves)

3. spectral artifacts (leakage, aliasing) or non-Kelvin wave contributions

These three main error sources will be discussed in the revised manuscript. Here we give some first discussion:

(1) vertical oscillation (SABER only):

The comparison of smoothed and unsmoothed SABER momentum fluxes and accelerations shows that there can be considerable effects due to this oscillation. Since for the SABER accelerations the effect of the oscillation looks very similar for the two zonal wavenumber ranges 1–6 and 4–6, respectively, this error seems to have the nature of a relative error with respect to integrated wave variances. The comparison between SABER and ECMWF results suggests that smoothing the SABER data vertically with a suitable length of about 4 km leads to an almost complete cancellation of this artifact.

The remaining errors can be estimated in the following way: For the accelerations we assume that the perturbation has the characteristics of a harmonic oscillation with 4–6 km vertical wavelength superimposed on the "unperturbed" Kelvin wave accelerations, assumed as a peak with 5–7 km vertical extent and, for example, triangle or quadratic shape as function of altitude. The perturbation (oscillation) will be assumed to have an initial amplitude the same size as the assumed "unperturbed" acceleration peak and is damped to zero towards lower altitudes over an altitude interval of about 10 km. In this way the two bands of negative accelerations (which can be seen in Fig. 7) can be explained by an overshooting of the oscillation (perturbation) towards negative values.

Then we will apply vertical smoothing and the perturbations remaining after smoothing can be taken as rough measure of the expected error after smoothing.

(2) accuracy of the spectral background

The spectral background is estimated from zonal wavenumbers $\geq$3 and then subtracted

to obtain the real Kelvin wave signal without bias. It is assumed that the background is constant over the whole spectral domain (white noise). Although almost true there are some minor effects which can be seen, for example, from the results shown in Ern et al. (2008). In this paper the spectral background is estimated from the complete (symmetric + antisymmetric) spectra as well as from the "westward" part of the antisymmetric spectra only. Although the results are very similar the estimate for the antisymmetric westward spectra is lower than the estimate for the "full" spectra: about 25% lower for SABER and about 35% lower for ECMWF. Based on these values and on the assumption that they represent a realistic error range for the spectral background we will perform simulations with increased and reduced background to estimate uncertainties due to this error source for both SABER and ECMWF.

(3) spectral artifacts and non-Kelvin wave contributions

Since Kelvin waves are the main spectral contribution in temperatures this will only be a minor effect for the low zonal wavenumbers where the bulk of Kelvin wave temperature variances is located. For higher zonal wavenumbers this can also be a considerable error source. This will especially be the case if the wavebands for integrating the spectral contributions are extended too far towards higher frequencies. This is one reason why we limited our study to frequencies lower than 0.4 cycles/day. For these low frequencies uncertainties due to this error source will likely be less than 10% even for high zonal wavenumbers, taking into account the very dominant spectral feature of Kelvin waves (see Figs. 1 and 2).

Specific comment #2: P5631, line 21: Why do you not separate the spectra into symmetric and antisymmetric components? ... please mention ...

Yes indeed, some more information should be given here!

There are mainly two reasons for not splitting the spectra into their symmetric and antisymmetric parts. First, Kelvin waves are the by far dominant wave mode in tem-

perature. Therefore the Kelvin wave signal will be almost not distorted by other wave modes. The second reason is that by calculating symmetric and antisymmetric spectra automatically symmetry or anti-symmetry of the different wave modes is assumed with respect to the equator and latitudinal averaging is introduced by combining northern and southern latitudes. For Fig. 10 however, we wanted to check upon this assumption and wanted to produce latitudinally resolved results for southern and northern latitudes independently.

This will be discussed in the revised manuscript.

Specific comment #3: P5638, line 13: "This enhancement looks to be just inside or at the edge of the n=1 equatorial inertial gravity wave band (...), although as mentioned ... this enhancement may be due to spectral aliasing."

Yes, indeed, the abovementioned spectral feature could also be due to inertia gravity waves. But it does not seem to be a Kelvin wave feature because it is well separated from the lobe-shaped Kelvin wave spectral peak. This will be mentioned in the revised manuscript.

Specific comment #4: P5638, para 3: "Were SABER data assimilated into ECMWF during the period 2002–2006?"

No, SABER data were not assimilated into ECMWF! Sorry for not explicitly stating this! This statement will be included in the discussion on page 5638.

Specific comment #5: P5640, lines 11–14: "You can remove the sentences 'For comparison ...' because these are mentioned in the caption of Figure 3"

Will be done!

Specific comment #6: P5644, lines 20–22: "Once again, you could remove the sentences 'The values given ...' as they're in the Figure 6 caption."

Will be done!

Specific comment #7: P5646, para 1: "A large part of this paragraph repeats the Figure 7 caption. If possible it would be good for this to be condensed in either the text or the caption to avoid repetition."

Will be done!

Specific comment #8: P5653, line 9: "The ECMWF winds could also be added to each panel in Figure 10 to aid clarity of the discussion."

Will be done!

Specific comment #9: P5653, line 22: "When you say, 'QBO east periods', do you mean 'easterly', 'eastward', 'easterly shear', 'eastward shear'? Please clarify."

Here we mean "during QBO easterly wind phases". To avoid confusion we will replace the abovementioned expression in the revised manuscript where applicable.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 5623, 2009.