Atmos. Chem. Phys. Discuss., 8, S5635–S5638, 2008
www.atmos-chem-phys-discuss.net/8/S5635/2008/

Atmospheric Chemistry and Physics Discussions

ACPD

8, S5635–S5638, 2008

Interactive Comment

Interactive comment on “Seasonal changes in gravity wave activity measured by lidars at mid-latitudes” *by* M. Rauthe et al.

Anonymous Referee #1

Received and published: 6 August 2008

The paper analyzes a long term data set of lidar temperature measurements for wave activity. The data cover the entire troposphere and middle atmosphere. The temporal and spatial resolution are sufficiently fine to resolve mid frequency gravity waves. This unique data set is analyzed using established mathematical methods. The paper hence provides very valuable information on the annual cycle of gravity wave activity and merits publication in ACP. However, there are some weaknesses in the interpretation of the data. In addition, though the paper is well organized in its general structure it needs editing in detail. In this review the major comments are given. Detailed comments will be provided separately.

The most problematic point is the discussion of the vertical wavelength. The dispersion relation in mid-frequency approximation is

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Interactive Discussion

Discussion Paper

$$\frac{\hat{\omega}}{N} = \frac{\lambda_z}{\lambda_h}, \quad (1)$$

where λ_z and λ_h are the vertical and horizontal wavelength, N is the buoyancy frequency and $\hat{\omega}$ is the intrinsic frequency of the wave. Since $\hat{\omega}$ is the intrinsic frequency, it may differ largely from the ground based frequency, which you measure, by Doppler shift. The best example are mountain waves, which have zero ground based frequency. It is therefore much more common to express the vertical wavelength in dependence of the intrinsic phase speed $\hat{c}$ of the wave

$$\lambda_z = 2\pi \frac{\hat{c}}{N} = 2\pi \frac{c-u}{N}, \quad (2)$$

with c the ground based phase speed and u the wind velocity in the direction of the horizontal wave vector. In order to obtain equation 2 of your paper you need to argue that wind velocities in the stratosphere and mesosphere are small compared to the phase speeds of the waves. However, wind velocities can be 60 m/s or more corresponding to a shift in vertical wavelength of roughly 20 km, your average wavelength!

The general wisdom assumes a spectrum of GWs which follows an m^{-3} (m vertical wavenumber) scaling law for the saturated, short wavelength part of the spectrum, reaches a peak at mid vertical wavelengths and decreases at long vertical wavelengths. As density decreases and amplitudes increase, more and more waves reach the saturation limit and hence the peak-wavelength (or critical wavelength) shifts towards longer vertical wavelengths. Assuming a power law also for the non-saturated part of the wave spectrum (e.g. m^{+1}) and chopping of everything which is beyond saturation according to the concept of Warner and McIntyre (2002), one can easily calculate the shift of the peak-wavelength with altitude (Gardner, 1993):

$$\lambda_z^* = \lambda_{z,0}^* \, \exp\left(\frac{z}{H(q+s)}\right) \tag{3}$$

with λ_z^* being the wavelength of the intensity peak, H the scale height, s the exponent of the unsaturated part of the spectrum (usually assumed to be 1 or 2) and $-q$ the the exponent of the saturated part of the spectrum (i.e. $q = 3$).

An increase of the average vertical wavelength is observed in Fig 5b. However, the observed average wavelength at 20 km is much larger than expected from previous measurements (10 km instead of 2-4 km) and the increase towards 80 km altitude is much smaller than expected. Doppler shift by the background winds also will largely influence the wavelength at which the vertical wavelength distribution maximizes.

Such concepts of a spectrum of GWs with higher phase speeds (longer vertical wavelength) having low amplitudes at low altitudes but becoming more important when the slower waves getting saturated, are the basis for most of the currently used GW parameterizations (Hines, Warner and McIntyre, Alexander and Dunkerton) and were used successfully to model, for instance, global distributions measured by satellite instruments (Alexander 1998, Ern et al. 2006, Preusse et al., 2006). They predict dependence of both amplitude and vertical wavelength from the background winds. Though the mechanisms are more complex and not depending on the observation altitude only, some correlations with background winds are expected.

Both global scale waves and GWs interact with the background winds in a similar way. This can explain similar annual cycles without any direct interaction of GWs and planetary waves. The discussion on page 13753 relies strongly on the results of Gerding et al. (2008) but does not adequately summarize the results of that paper. This would be necessary, however, for a self-explaining publication. Either this point of the discussion needs to be strengthened considerably, or (preferably) just note the similar behavior without further interpretation.

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Interactive Comment

Also you should explain the wavelet analysis in a few sentences. In particular, how long is the wavelet you convolve with the data, how does the cone of influence result from this and how are the boundaries of the data set treated (i.e. which significance have values at the edge or just outside the cone of influence).

P13746 Equation (1) is based on the assumption of a sinusoidal wave integrated over one period. Substituting the amplitude by the average absolute fluctuation results in a slightly lower value.

P13751 The conserved quantity is not potential energy E_{pot}, but wave action A

$$A = \frac{E}{\hat{\omega}}. \tag{4}$$

Thus, as the wave is refracted by the background winds, E_{pot} can change. In addition, since waves propagate obliquely, they might propagate in and out of your measurement volume, which is just one vertical profile. However, the strong decrease of amplitude at larger altitude (please emphasize the logarithmic scale) of a statistical ensemble indicates strong wave dissipation throughout the entire middle atmosphere (with the few exceptions you note). This is a very important result, since it is naturally produced for instance by the Warner and McIntyre scheme, but GCM modelers favor such GW parameterizations which deposit their momentum close to regions of strong windshear only (Charron et al., 2002, McLandress and Scinocca, 2005).

P13746 Why should it be necessary to use a climatology for the density? You have measured the entire temperature profile from the ground to 100 km without gaps and you can measure the surface pressure. From this you can hydrostatically rebuild the density profile, in particular since you use this relation already for the stratospheric temperature retrievals.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 13741, 2008.