Atmos. Chem. Phys. Discuss., 9, C7248–C7253, 2009
www.atmos-chem-phys-discuss.net/9/C7248/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Increase of upper troposphere/lower stratosphere wave baroclinicity during the second half of the 20th century" *by* J. M. Castanheira et al.

J. M. Castanheira et al.

jcast@ua.pt

Received and published: 18 November 2009

See the revised manuscript in the Supplement to this comment.

Major comments

1.1 We rewrote the last paragraph of the Introduction section to add more motivation for the use of the 3-D normal modes. The information added in the third paragraph of the Data and Method section also gives more motivation for the use of normal mode.

The first two sentences in the last paragraph of section 2.1 also give motivation for the use of 3-D normal modes.

1.2 Although the physical nature of normal modes may be questionable, they form a complete basis to expand the circulation field. This basis provides a useful tool which allows filtering the data based on the three spatial dimensions and on the rotational or divergent nature of the circulation represented by each mode. On the other hand, the projection coefficients have a physical meaning, since the squared complex amplitudes are proportional to the total energy associated with the respective modes.

1.3 As shown by Randel et al. (2007) and, more recently, by Pan et al. (2009), the occurrence of double tropopauses is, at least frequently, associated with the tropospheric intrusions of subtropical air into the high-latitude lower stratosphere. The secondary tropopause results from a poleward excursion of the tropical tropopause accompanying the movement of the upper tropospheric tropical air over the extratropical tropopause. Also, as suggested by Pan et al. (2009), the occurrence of isolated high latitude events of double tropopauses may result from Rossby wave breaking of subtropical wave ridges. Therefore, at least frequently, the occurrence of DT events is associated with the relative motion of different air mass layers and this relative motion is the basic concept of baroclinic flows.

In order to clarify the connection between DT events and baroclinicity, we rewrote the first paragraph of section 3.2.

2.1 The meaning of wave baroclinicity is now given at the abstract.

2.2 We think that the second part of this major comment is tied to the third minor comment.

ACPD

9, C7248–C7253, 2009

Interactive Comment

Randel et al. (2007) and Pan et al. (2009) show, with several events, that the core of the subtropical jet is in the tropopause break region, with the tropical tropopause above the jet core and the extratropical tropopause below the jet core. Then an equatorward temperature gradiente must exist between the upper tropical troposphere and the lower most extratropical stratosphere below the jet core. The temperature gradient reverse to a poleward one above the subtropical jet core near the tropical tropopause.

The strength change of the poleward temperature gradiente above the core of the subtropical jet, due to the cooling of the extratropical stratosphere, must be, in part, canceled by the cooling of the tropical tropopause due to its uplift.

2.3 The normal modes do not separate positive and negative shears below and above the subtropical jet core. In fact, what this varying shear indicates is a curved structure of the zonal mean zonal wind profile in the subtropical UTLS, which will project strongly in the modal structures $m = 4$ and $m = 5$. This is the reason for the vertical energy spectra of the zonal mean circulation to present a strong peak at those two baroclinic structures (see Fig.Rev#2 below).

3. We elaborated more on the interpretation of normal mode projection: *i)* more information is given in third paragraph of the Data and Method section; *ii)* A new paragraph at the end of the Appendix and a new Fig. A2 were added.

4. Yes, the vertical structures are held fixed.

The trends in Fig. 3 are presented as percentages of the respective mean energies. As it may be observed in Fig. 4, the absolute trend of the energy associated with the deeper modes is approximately 5 times the trend of the energy associated with the shallower modes. Therefore, it does not seem that the positive trend in the deeper modes is simply associated with the shift of the max energy from mode 5 towards mode 4. On the other hand, as shown in Fig.Rev#2 below, the energy of the zonal $(s = 0)$ baroclinic Rossby modes peaks in modes $m = 4$ and 5. The trends in the energy of these modes are -11.5% and -7,0%, respectively. Both trends are negative and significant at the 99% level. This suggests that there may be a shift in the energy from the zonal mean to the eddy components. We will analyze this possibility in future work.

5. A discussion of APE trends in the NCEP/NCAR reanalysis was included.

6. We rewrote the last two paragraphs of section 3.1 and discuss the apparent discontinuity in the time series of the energy of shallower modes.

Minor comments

1. A reference to Liberato et al. (2007), and implicitly to Castanheira (2002, JAS) had already been included in the second paragraph of section 2.1.

2. We think that the decomposition into all frequencies and high frequencies appears in the right course of the work. If we had not presented this decomposition, the reader would have the following doubt: Will the change of baroclinicity manifest in the transient waves, in the stationary waves or in both?

3. The picture seems somewhat different (see response to the major comment 2.2).

4. The geopotential and wind fields are coupled only to the extension which the thermal wind balance is approximated, and they are not redundant.

5. We corrected the text.

References

Pan, L. L. , et al, 2009: Tropospheric intrusions associated with the secondary tropopause, J. Geophys. Res., 114, D10302, doi:10.1029/2008JD011374, 2009.

Randel, W. J., Seidel, D. J., and Pan, L. L.: Observational characteristics of double tropopauses, J. Geophys. Res., 112, D07309, doi:10.1029/2006JD007904, 2007.

Please also note the Supplement to this comment.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 18597, 2009.

ACPD
9, C7248–C7253, 2009

Interactive Comment

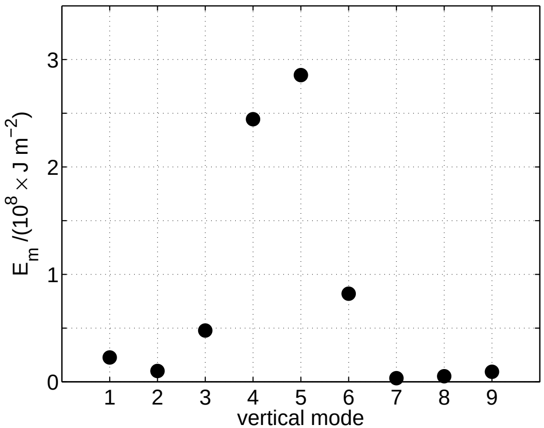

Fig. 1. Vertical spectrum of the mean energy (E_m) associated with the zonal $(s=0)$ baroclinic Rossby modes.