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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.

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See the revised manuscript in the Supplement to this comment.

Reply

1.1 We elaborated more on the interpretation of normal mode projection: *i)* more information is given in third paragraph of section 2.1; *ii)* A new paragraph at the end of the Appendix and a new Figure A2 were added.

1.2 Although the UTLS anomalies may have some projections on shallower modes ($m = 6, 7$), their projections are much larger on the deeper mode $m = 4$. We mention this fact in the second paragraph of section 3.1.

1.3 Because the vertical structure functions are defined over the whole vertical extension of the atmosphere, the reviewer points the difficulty to relate the anomalies in the normal modes to the anomalies in the physical space.

The results in the appendix clearly rank the mode $m = 4$ as the most sensitive to the UTLS. On the other hand, the analysis of the eddy available potential energy corroborates the analysis of the normal modes. Although the reviewer does not comment on the analysis of the eddy available potential energy, its discussion was done to answer to the questions he raised.

2.1 The projection onto the 3-D normal modes allows for a decomposition of the atmospheric circulation into vertical scales and horizontal spacial scales. The results here show clearly that, during the last five decades, there was a positive trend in the energy of the largest vertical scales (deeper modes). As pointed by reviewer 2, a comment with which we agree, the negative trend for modes $m > 5$ may be magnified by a discontinuity in 1979, possibly associated with the inhomogeneity in assimilated data with the start of the satellite era. However, as clearly seen from Fig. 3, the trend in the total energy is dominated by the trend in the energy of $m = 4$. Note that the trends shown in Fig. 3 are normalized to the respective climatological values of the energy. Then, even considering negative trends that may be magnified, their absolute values are smaller than the absolute trend in the energy of $m = 4$. On the other hand, the trend analysis of the eddy available potential energy shows significant positive trends in the UTLS, confirming that the trends in the shallow and deep modes do not compensate in the UTLS. It also shows a negative trend in the lower troposphere which must be explained by the energy associated with the shallower modes.

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

2.2 In the normal mode analysis, we retained only zonal waves with wave numbers $1 \leq s \leq 10$. On the other hand, in the analysis of eddy available potential energy no zonal wave filtering was applied. We think that the agreement between the two analysis makes unnecessary to discuss the effect of truncation in the normal mode analysis. In Fig.Rev#1 below, we show the the trends in the eddy available potential energy, computed for the first ten zonal Fourier components $(s = 1, ..., 10)$ of the NCAR/NCEP reanalysis. This figure is almost indistinguishable from the pattern including all waves.

3. We agree that the mechanisms controlling the DT occurrence are not yet completely understood. However, 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.

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.

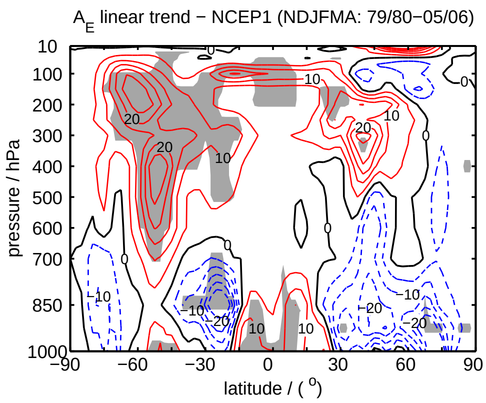

Fig. 1. Interannual trends in the area weighted eddy available potential energy ($A_{E}\,\cos\theta$) of the NCEP/NCAR reanalysis, retaining oly the first ten Fourier components.