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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Net effect of the QBO in a chemistry climate model" *by* H. J. Punge and M. A. Giorgetta

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The authors thank referee 2 for the comments and careful reading. In reply to the specific comments, we would like to state the following:

(1)
Clearly using zonal wind nudging towards observations from only one equatorial site, Singapore in our case, is a potential source of artifacts, as there exist stationary zonal asymmetries in the lowermost equatorial stratosphere at the Equator. However, we think that above 70 hPa, where the nudging sets in, stationary zonal asymmetries are small, and it is reasonable for the purpose of this study to assume a zonal symmetry of the QBO jets, supported by earlier studies. For example Najokat (1989) states that for the levels of 70 to 10 hPa the longitudinal differences in phase are small enough to be ignored. In the model simulations, we find that zonal asymmetries, such as zonal winds

more easterly than the zonal mean by about 5 m/s in SE Asia, are present but decay quickly towards 70 hPa in both the nudged and free-running simulations. Hence we think no artificial net effect on the SMC or the BDC is created due to the use of a single equatorial station for the nudging towards a zonally symmetric QBO jets. The SMC, as the QBO related modification of the BDC, is a dynamic response to the vertical and meridional shears of the zonal wind structure of the QBO, which results in the QBO run from the QBO nudging. Hence the SMC is created by the model dynamics, as represented by the discretized primitive equation system of the models. This equation system is adequate for the representation of the temporal and spatial structure of the QBO and the SMC.

Naujokat, B., An update of the observed quasi-biennial oscillation of the stratospheric winds over the tropics, J. Atmos. Sci., 43, 1873-1877, 1986.

(2)

The time constant used for the nudging is 7 days. This time scale is a compromise between a time scale as long as possible to avoid impacts on fast wind fluctuations that are not part of the QBO time evolution and a time scale short enough to obtain a realistic QBO structure. Tests showed that a timescale of about 7 to 10 days is reasonable. Here we used the 7 day timescale to have more realistic wind amplitudes. Natural timescales related to the observed QBO are its quasi period (28 months), the rotation frequencies of air parcels embedded in the westerly or easterly jets (20 to 30 days) and the timescales of equatorial waves driving the QBO. Kelvin waves have periods of 14 days, while all other equatorially trapped waves or gravity waves that are relevant for the QBO have typically periods of 5 days or less. Hence the nudging timescale is approximately in the middle between timescales related to the QBO jet and timescales of waves, except for Kelvin waves. Naujokat (1986), compared data from 5 equatorial stations including Singapore and finds phase differences small enough to be ignored between 70 hPa and 10 hPa.

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Lines will be added in the final version of the article.

(4)
The long term cooling trend during 1980-2000 is due to the combined effects of reduced ozone due to CFC emissions, which leads to a reduced amount of short wave radiative heating, and the increase in greenhouse gases, especially of CO2, which leads to increased long wave cooling in the middle atmosphere. For reference see, for example, Akmaev et al. (2006).
Akmaev, R. A.; Fomichev, V. I.; Zhu, X., Impact of middle-atmospheric composition changes on greenhouse cooling in the upper atmosphere, J. Atmos. Sol.-Terr. Phys., Volume 68, Issue 17, p. 1879-1889, 2006

(5)
It will be clarified that reference is to Fig. A1a and A2a-d. It is not entirely clear to the authors what is meant by the comment. The analysis of stream function differences suggests that the net horizontal transport differences occur mainly at three levels, at about 60, 10 and 4 hPa. The net flow anomaly is directed along isolines of stream function anomalies, and the strength is proportional to the isoline density, which is highest around these levels. Flow differences are clockwise (counterclockwise) around positive (negative) stream function differences.

(6)
SAO will be defined in the earlier text. Temperature and wind shear in the equatorial stratosphere are connected by thermal wind balance, e.g., see Eq. 1 in Baldwin et al. (2001), also mentioned before on p8, l8. Punge and Giorgetta (2007) found that thermal wind balance is kept to a high degree in this region in the ERA-40 reanalysis.

(7)
The statement in question refers to p. 12132, l. 20. and Fig. 11a. The losses to O3+O and the ClOx cycle are indeed reduced above 5 hPa and balance part of the increased loss to the NOx cycle. The more important contribution however comes from increased

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production, especially between 5 and 10 hPa, see Fig. 11a. We will add "... and reduced losses to other loss processes."

(8)
The current text is unfortunately misleading here and will be changed. As stated earlier on p. 12131, l. 12, net easterly shear in the region in the equinoctial seasons is associated with cooling due to thermal wind balance. On the other hand, the net meridional circulation associated to the net wind shear leads to increased upwelling, in this case of NOx rich air from below. Hence we find the connection between cold temperatures and high NOx concentrations. We do not wish to claim changes in NOx production or loss due to different temperatures. We propose to replace the sentence by the following: This is explained by enhanced net upwelling of NOx rich air in the equinoctial seasons caused by the net easterly shear (see Fig. 8b and d) that also causes cold temperature anomalies (see Fig. 10 b and d).

Thank you for the numerous technical corrections.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 12115, 2008.