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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Variability of the Brewer-Dobson circulation's meridional and vertical branch using Aura/MLS water vapor" *by* T. Flury et al.

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The authors thank the referees for their work and constructive comments on the article. Please find our answers to major comments in the beginning followed by minor comments at the end.

Comment 1.1) The vertical transport velocity is related to the tape recorder signal due to slow crossisentropic (diabatic) ascent. The meridional transport velocity, on the other hand, is related to along-isentropic dispersion / mixing between the tropics and mid-latitudes. The former transport is advective in nature (justifying the term 'tape recorder'), the latter is diffusive in nature. The net transport of the quasi-horizontal

dispersion is poleward, but mixing by definition is bi-directional. That is, some mid-latitude air is mixed into the tropics at the same time that tropical air is mixed into mid-latitudes. This process will have a tendency to homogenize background gradients in tracer fields with corresponding changes in local tracer mixing ratios. An important consequence of the above is that the here inferred (apparent) vertical velocity needs to be interpreted very differently from the inferred (apparent) meridional velocity. I feel that a discussion of these conceptual differences needs to be included in the manuscript.

Answer 1.1) Yes, the vertical transport is advection by nature. We also agree that the horizontal transport is diffusive inside the tropical pipe. But results clearly suggest that transport is predominantly directed towards the poles at the 100hPa level. As soon as the air masses leave the tropical pipe the transport becomes advective and is steered by high latitude wave breaking. We do not think that diffusive processes progress with latitude. However, the amplitudes of the annual cycle are smaller at midlatitudes (0.5 ppm) than in the tropics (1 ppm) which underline the influence of mixing along the way. Nevertheless, the tropical signal is strong enough to be observed at midlatitudes.

Comment 1.2) The diffusive nature of the meridional transport leads to dilution of the tape recorder signal (see the discussion in Mote et al. 1998, JGR). As such the vertical and meridional transport velocities as diagnosed by the authors appear to be naturally coupled. Obviously, the same does not necessarily hold for the actual transport velocities. This may offer a more fundamental explanation of the anti-correlation between the two inferred velocities observed by the authors. That said, the QBO effect may still be manifested in the way discussed by the authors, but may not constitute the ultimate cause of the anti-correlation.

Answer 1.2) Initially we thought that the interannual variations of meridional (v) and vertical (w) transport velocities should be in phase since both are steered by the Brewer-Dobson circulation (BDC). The surprising phase difference found in the observations needed an explanation which we have found in the Quasi Biennial Oscillation (QBO) meridional circulation anomalies. On the other hand the anticorrelation is not perma-

nently observed and we assume that this is an effect of the interaction of ENSO (El Niño Southern Oscillation) and QBO. The anticorrelation of v and w vanishes in the same year during which ENSO and QBO go out of phase. This special case requires some more analysis which is beyond the scope of the current article since it requires a detailed analysis of ENSO and its interaction with the QBO.

Comment 1.3) Meridional transport from the tropical tropopause is not the only way for air to reach the 100 hPa level in mid-latitudes. Vertical (diabatic, advective) transport from above as well as meridional transport from further poleward (quasi-adiabatic, diffusive) both influence the tracer mixing ratio at 100 hPa in mid-latitudes. It is not clear to me how the inferred meridional transport velocity should be interpreted given this issue. If the authors feel that v can still be inferred in the way they propose then at the least, this issue should be reflected in the uncertainties of v.

Answer 1.3) In the same kind of analysis higher up above 68 hPa we did not find a strong meridional transport because firstly the tropical pipe inhibits mixing out of the tropics and secondly the horizontal gradient between the tropics and midlatitudes is weaker at higher altitudes. We need a significant gradient to monitor advective transport processes. Similarly the meridional gradient between the tropics and midlatitudes at 100 hPa is stronger than the gradient between mid- and highlatitudes as well as the vertical gradient just around the 100 hPa level at midlatitudes. We thus assume that advection from the tropics is the main contributor to midlatitude water vapor (H2O). On the other hand we agree to add some more comments about tropical advection not being the only contributor to midlatitude H2O at 100 hPa. Moreover, to establish an uncertainty of v based on the different contributions of H2O at midlatitudes we would need to budget the contributions numerically. How much of the observed H2O at midlatitudes is of tropical- and how much of polar origin? As long as we don't know the composition it is difficult to quantify the uncertainty. Also the computed speed of the meridional transport is not to be interpreted as the average meridional wind speed.

Minor comments:

Page 21293, L9: Symmetry of the circulation cells: We do not observe symmetry between the two hemispheres. However, the drawings in some of the cited literature about the QBO meridional circulation anomaly show symmetry between the two hemispheres. In Figures 9 and 11 we show that this is not the case in our observations of the meridional component. The reason for this is the asymmetric BDC in both hemispheres due to different extratropical planetary wave breaking.

L27: We will adapt the sentence to make this point clear.

Page 21294, L1/2: We will check the literature and modify if necessary.

L7: Yes we agree. The main point is that according to the models the trend should be negative which was not observed by Engel et al. 09. We will adapt the sentence.

Modifications in the manuscript

We will add a more thorough discussion of the different mechanisms that lead to the transport of the water vapor signal (advection vs. mixing) as pointed out in answer 1.1. We will also leave some room for discussion on the influence of the troposphere on the BDC. However, we will maintain our method of deriving a measure of the meridional component of the BDC by correlating equatorial and midlatitude zonal mean time series of H2O at 100 hPa and will also stick to our interpretation of the observed anticorrelation of the meridional transport with the vertical transport.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 21291, 2012.