Response to Anonymous Reviewer #1

I appreciate your carefully considered review and your insight on how to interpret the results of my analyses in terms of any changes in the net circulation of the stratosphere. Please refer to my Response to Reviewer #2 for more details and for new Figure A1 and revised versions of most of the other Figures (in the Supplement).

General remarks:

a. **How to interpret the linear trend term of the MLR model**: My use of the term "net circulation" refers to the Brewer-Dobson circulation (BDC) or transport and includes the effects of both the mean mass transport and two-way mixing, as you surmised. I agree with your general concern that diagnosing changes in the BDC is strictly inappropriate from analyses of time series of a chemical tracer like methane. I will make use of expression (A1) from your reference to Volk et al. For the results in this manuscript, I note that the time series of the annually-averaged, tropospheric source gas of methane or χ_o(t') was increasing at a rate of about 4.7 %/decade from 1983 to 1992, 3.0 %/decade from 1992 to 1999, and at a near zero rate from 1999-2005, based on its observed time series from benchmark stations. The vertical dashed line of 3.0 %/decade in revised Figures 6 and 7 is the linear difference based on end-point values of the station data from 1990 to 2003. The product G(r,t')*L(r,t') is difficult to analyze for its separate terms in the middle stratosphere, where there are large meridional gradients in the observed methane. To first order, the annually-averaged, chemical loss term L(r,t') varies with altitude in the middle to upper stratosphere, but much less so with time. The chemical loss for methane should be nearly symmetric between the southern and northern hemispheres; dynamical effects may be quite different though. New Figure A1 hopefully provides more insight into the likely effects of dynamics on the methane trends. Finally, I would argue that a more comprehensive model transport study is required, as I alluded to at the top of p. 24199. Specifically, one would need to analyze the results of a model study for a tracer, like CH_4, that uses assimilated temperatures (and perhaps ozone) for the 14-yr period of the HALOE measurements. MLR analyses of the modeled methane could be compared with the ones herein from the HALOE data to see how well they agree.

Accordingly, I will use Brewer-Dobson circulation instead of the term "net circulation", and I will give my assumptions about it in the first two paragraphs of revised Section 1. In several respects I will paraphrase some of the excellent discussion from your review, and I will include the key references that you provided to me.

b. **Choice and use of fixed latitudinal bands for the subtropics and the extratropics**: Extending on my answer to point (a) above, I note that the zero line for the Transformed-

Eulerian Mean (TEM) circulation of Rosenlof (her Figure 10, JMSJ, 2002) occurs at about 35 degrees latitude, although the TEM does not include the effects of meridional mixing. One could also delineate methane trends using potential vorticity contours from the meteorological data fields that are assimilated into a model study of a methane-like tracer. That study, however, is beyond the scope of what I can achieve for the revised manuscript.

In new Figure A1 (attached as part of my Response to Reviewer #2) I show CH_4 trends versus latitude and pressure-altitude from my MLR analyses of the many individual time series. Those results clearly indicate that there are significant hemispheric differences in the BDC, particularly in the low and middle stratosphere. The results in revised Figures 6 and 7 are shown for 10±5 degrees and 60±5 degrees latitude, instead of the wider latitude zones of the original manuscript. CH_4 trend profiles at 35±5 degrees latitude are compared with H_2O trend profiles in terms of their mixing ratios in revised Figures 9 and 10, as a qualitative check of my findings for methane in the middle and upper stratosphere. I also conducted MLR analyses for methane, using somewhat different latitude bin widths to evaluate the sensitivity of my results to that variable. Accordingly, I will focus on the trend profiles at 10±5 degrees, at 35±5 degrees, and at 60±5 degrees latitude in the revised manuscript. The tropical bin is more nearly within the tropical pipe region and the bin at 60 degrees is just outside of the polar vortex region, at least for most of the year.

Specific remarks: Section 2

I will expand the description of the multi-linear regression model (MLR) and my treatment of lag-1 autocorrelation effects as follows:

In an MLR analysis of time series data for their trends it is very important to account for all significant, periodic structure in the data. I will summarize the steps for my present MLR analyses that I described earlier in Remsberg (JGR, 2008). Originally, I included interannual terms having 28-mo (QBO) and 21-mo (sub-biennial) periods. For the revised manuscript I re-analyzed the de-seasonalized residuals more closely and at each level and latitude zone for any specific interannual, periodic structure, and I generally found terms with 838-dy (27.5-mo) and 690-dy (22.6-mo) periods for the low to middle latitudes. There is also a weaker, biennial (23.5-mo) term in some of the time series. Those are the three interannual terms that I have included in my final MLR models. The 22.6-mo oscillation agrees closely with what Dunkerton (2001) found from his EOF analyses of a shorter time series of HALOE methane (from 1992-1999). To account for lag-1 autocorrelation effects, which are important for zonally-averaged data time series, I used to approach of Tiao et al. (their Appendix A, JGR, 1990).

New material for Section 4:

I have extended my analyses of extratropical trend profiles for HALOE water vapor into the lower stratosphere for revised Figures 9 and 10, and I will discuss how they compare with the recent model studies of Hegglin et al. (2014). I will also refer to Damiani et al. (2014) with regard to how a sudden stratospheric warming event can dramatically alter the distribution of HCl near the polar winter stratopause.

Additional References:

Diamiani et al., J. Geophys. Res., doi:10.1002/2014JD021698, 2014.

Hegglin et al., Nature Geoscience, doi:10.1038/NGEO2236, 2014.

Rosenlof, J. Meteorol. Soc. Japan, 80, 831-848, 2002.

Tiao et al., J. Geophys. Res., 95, 20,507-20,517, 1990.