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Interactive Comment

Interactive comment on "Methane as a diagnostic tracer of changes in the net circulation of the middle atmosphere" *by* E. E. Remsberg

Anonymous Referee #1

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General Remarks

In this paper the author uses the methane time series from 1992 to 2005 derived from the HALOE satellite instrument for diagnostics of the "net circulation in the middle atmosphere". I am really in favour of using observations to constrain changes in stratospheric transport and I absolutely agree to the final statement of the author that "... near-global distributions of CH4, as remotely measured from a satellite, are an excellent diagnostic of the effects of seasonal and longer-term changes in the transport within the middle atmosphere."

The paper is very well written, concise and of scientific interest and should be published at ACP. However, I have two major concerns with this paper and both are related to the linear methane trends in the stratosphere: a) An oversimplified interpretation of the linear trend term of the MLR model and b) The choice and the use of 4 fixed latitudinal zones for BDC trend analysis. Both of these concerns should be addressed carefully before publications.

a) First of all, one should clarify what exactly denotes the terminus "net circulation" in the title in order to avoid any misunderstandings. To my point of view, the terminus "net circulation" in the context of chemical tracer observation is the stratospheric and mesospheric (tracer) transport, which is at the end simply the so-called Brewer-Dobson Circulation (BDC) including mean mass transport and two-way mixing, while only the former is related to the residual mean meridional mass circulation (see introduction Birner and Boenisch, 2011).

In case that "net circulation" would stand here for the net (air) mass transport or more precisely the mean meridional mass circulation in the sense of the residual stratospheric circulation (normally expressed in the well-known TEM formulation) then the time series of methane alone (or any other long-lived chemical tracer) is not a candidate to evaluate this, because two-way mixing is always involved in distributing tracers in the atmosphere.

If "net circulation" is a synonym for the stratospheric transport or the BDC (what I assume the author means here) then acceleration means decreasing age of air in the stratosphere (and mesosphere). Diagnosing an acceleration of the BDC from solely a time series of a chemical tracer is generally not possible, because the mixing ratio of a chemical tracer at a specific location in the stratosphere is given by its tropospheric time series $\chi 0$, the age spectra G (its first momentum being the age of air) and its chemical decay or loss fuction L (see supplementary). In general, the loss function at a given location in the stratosphere is related to the decay of the tracer along the complete path spectra (all different pathways from the entrance region, the tropical tropopause, to the specific location) and only tracers with constant tropospheric values (without transient effects) and of 'radioactive decaying' type in the stratosphere,

ACPD
14, C8932–C8936, 2014

Interactive Comment

mathematically the same as passive tracers that are linearly increasing in the troposphere (Hall and Plumb, 1994), are path independent. However, methane is neither constant in the troposphere nor it is a radioactive decaying type tracer, because the stratospheric sink distribution is obviously spatially highly inhomogeneous, primarily in the vertical but also in the horizontal direction. The consequence is that changes in the stratospheric time series of a chemical tracer like methane is always related to effects of tracer transience, acceleration (changes of the mean age of air) as well as changes in the pathway distribution (path spectra) of the BDC and it is not possible to disentangle the different effects from the deseasonalized linear trend of methane alone. A discussion of the effect of tracer transience (in the simplest case for a loss function that can be parameterized by mean age) can be found in the appendix of Volk et al. [1997]. In the publication of Schoeberl et al. [2000] one can find a conceptual view on the relationship between age of air and the tracer amount for long-lived chemical tracers in a Lagrangian framework. In summary, my main concern is the oversimplified massage that the deviation between the deseasonalized linear trends of methane in the stratosphere derived with the MLR model and the observed mean tropospheric trend for the time period just shifted by 2 years (1990-2003) can be directly assigned to an acceleration of stratospheric transport or BDC, respectively. My recommendation is to interpret the deviation between stratospheric and tropospheric methane trends as a “structural changes”, which includes effects of changes in the age and the path spectra on the time series of methane and both together representing the BDC or stratospheric tracer transport.

b) The choice and the use of fix latitudinal bands for the subtropics (14+-14) and the extratropics (55+/-15) are to my opinion highly problematic for diagnosing trends in stratospheric tracer transport, because of the strong quasi-horizontal gradients of methane between the different regions separated by the two stratospheric transport barriers – the edge of the polar vortex and the edge of the tropical pipe. Both are inside the chosen latitude bands used here for trend diagnostics. The consequence is that a simple shift of these transport barriers would cause a systematic shift of the mean methane

ACPD
14, C8932–C8936, 2014

mixing ratio in the affected latitudinal band during the observed time period. A simple thought experiment: The edge of the tropical pipe might (seem to) shift systematically towards the pole over the observed time period. This would look like a trend in methane in the subtropical latitude band, i.e. methane mixing ratios would increase because the fraction of tropical air with higher methane mixing ratios is increasing and the fraction of extratropical air with lower methane mixing ratios is decreasing in the chosen subtropical interval between 0 and 28 degree North (or South). Maybe this “systematic shift” is only caused by too small statistics, because the observed time period is too short to be representative for the long-term natural variability of the transport barriers. This is definitely an issue (and has also been mentioned by author) for the dynamical highly active polar vortex edge. Furthermore, I would refuse to call a possible widening of the tropical pipe simply an acceleration of the BDC. In order to avoid these issues, I recommend to use fix latitudinal bands for tropics and extratropics and a PV filter algorithm taking into account the position of the transport barriers. In order to keep the effort manageable, it might be enough to use the PV value at the measurement location derived from a reanalysis dataset and a PV thresholds defined on isobars as filter criteria for the different regions. These threshold could be derived from typical stratospheric PV distributions of the same meteorological reanalysis.

Specific Remarks

Section 2: Objectives and analysis Approach

To my opinion, maybe because I am not an expert in the field of multi-linear regression (MLR), it would be helpful to add a few words (or references) about the terms and the treatment of autocorrelation in your MLR model.

References

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ACPD
14, C8932–C8936, 2014

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Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/14/C8932/2014/acpd-14-C8932-2014-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 14, 24183, 2014.