Investigation of stratospheric circulation using long-lived tracers with WACCM, BASCOE CTM, and a reanalysis of MLS observations

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Abstract.

The stratospheric circulation is investigated using WACCM4 (Whole Atmosphere Community Climate Model version 4), together with BASCOE CTM (Belgian Assimilation System for Chemical Observations Chemistry-Transport Model) and a reanalysis of stratospheric composition observed by MLS: BRAM2 (BASCOE Reanalysis of AURA MLS release 2) over the period 2005-2015. Three different reanalyses of the wind fields (ERA-interim, JRA55 and MERRA2) are used to drive the CTM, providing an estimate of the uncertainties in our representation of the actual stratospheric circulation.

We use a long-lived tracer (N_2O), and the Transformed Eulerian Mean (TEM) framework to analyse the tracer budget. We focus on the residual advection (mainly vertical) and eddy mixing (mainly horizontal) contributions to the N_2O variations, studying the mean annual cycle and variability in the higher stratosphere and how it is depicted in the different datasets.

The BRAM2 mean annual cycle, for both the vertical and the horizontal terms, is nearly in the middle of the spread. WACCM is in good agreement concerning the vertical term but differs considerably from the other datasets in the horizontal (~mixing) term. WACCM present a smaller variability with respect to the reanalysis in the Tropical higher stratosphere, especially for the vertical term.

The next step of our research is to perform such analysis with the newer version of WACCM (version 6) as well as new BASCOE CTM runs using other reanalysis products. Multi-decadal changes in the terms of the budget, and their space dependence, will be investigated as well.

Methods.

- **WACCM** (Whole Atmosphere Community Climate Model version 4) (*Marsh et al., 2013*)
- **BASCOE CTM ERAI** (Belgian Assimilation System for Chemical Observation Chemistry-Transport Model driven by ERA-interim) (*Errera et al., 2008*)
- **BASCOE CTM JRA55** (BASCOE CTM driven by JRA-55) (*Fujiwara et al., 2017*)
- **BASCOE CTM MERRA2** (BASCOE CTM driven by MERRA2) (*Fujiwara et al., 2017*)
- **BRAM2** (BASCOE Reanalysis of AURA MLS release 2, driven by ERA-interim) (*Errera et al. in preparation*)
- **TEM analysis** (*Abalos et al., 2017*)

time_der *horz* *vert* *chem* *remaining*

$$\overline{\chi}_t = \left[-\bar{v}^*\bar{\chi}_y + \rho_0^{-1}cos\phi^{-1}\left(M^{(y)}cos\phi\right)_y\right] + \left[-\bar{w}^*\bar{\chi}_z + \rho_0^{-1}\left(M^{(z)}\right)_z\right] + \left(\bar{P}-\bar{L}\right) + \bar{\epsilon}$$

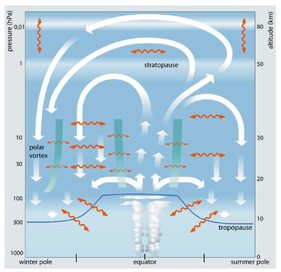


Figure 1. Latitude-height cross section of the schematic of the Brewer-Dobson Circulation. The thick white arrows depict the meridional circulation, while the wavy orange indicate the mixing. The thick green lines represent the stratospheric transport barriers. After *Bonisch et al., 2011*.

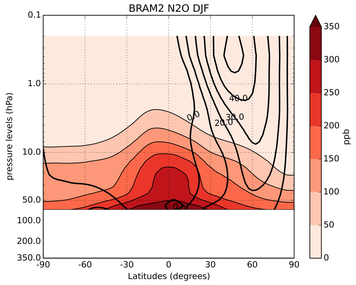


Figure 2. Latitude-pressure cross section for the DJF mean (2005-2015) of N_2O for BRAM2. Thick black lines are the ERA-interim zonal mean zonal wind contour lines (every 10 *m/s*).

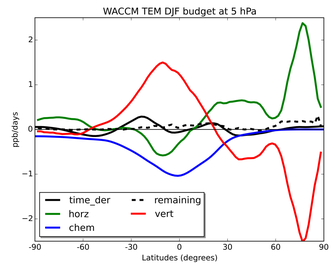


Figure 3. DJF mean (2005-2015) latitudinal profile of the TEM budget terms at 5 *hPa* for WACCM. The color code is in the legend.

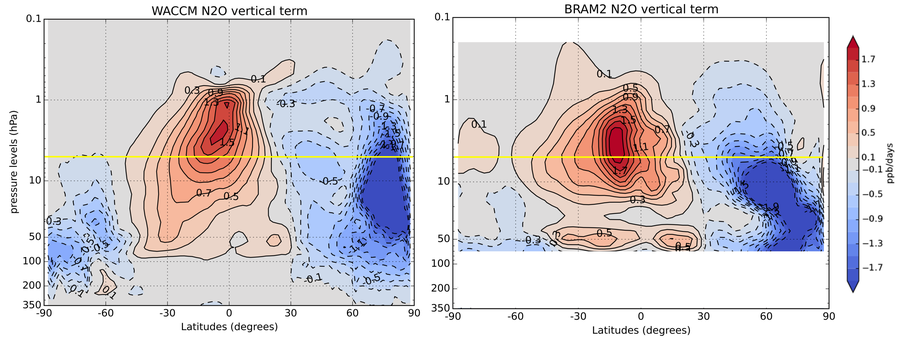
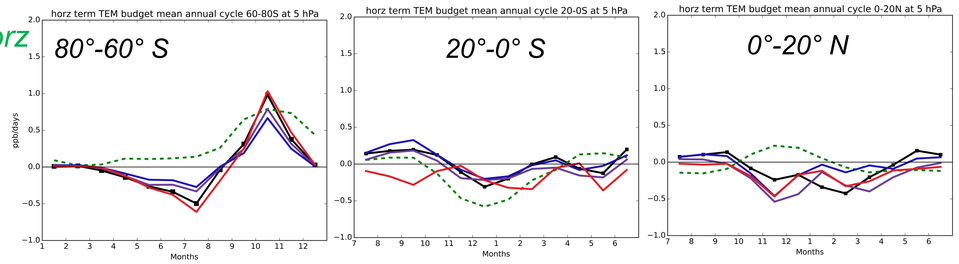


Figure 4. Latitude-pressure cross section for the DJF mean (2005-2015) vertical term of the N_2O TEM budget. The left panel is WACCM, the right panel is BRAM2.

~5 hPa ~35 km

horz



vert

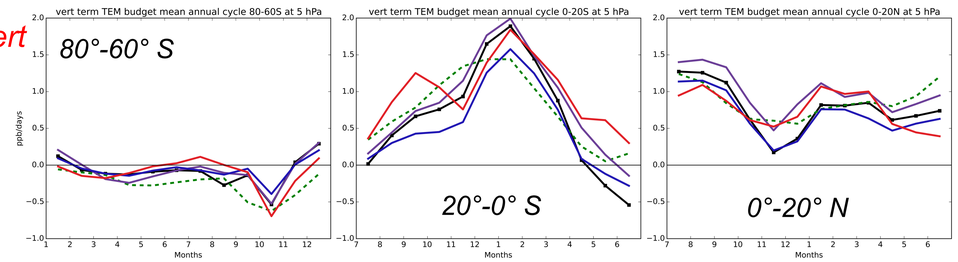


Figure 5. Monthly mean annual cycle of the horizontal and vertical TEM budget terms at 5 *hPa* for several latitude bands (first column: *80°-60°S*, second column: *0°-20°S*, third column: *0°-20° N*) for the different datasets. The color code is shown in the legend.

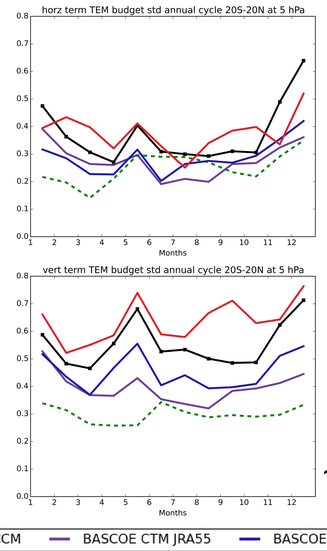


Figure 6. Monthly annual standard deviation of the horizontal and vertical TEM budget terms at 5 *hPa* for the *20°S-20°N* latitude band for the different datasets. The color code is shown in the legend.

20°S-20°N
~5 hPa ~35 km

BRAM2 WACCM BASCOE CTM JRA55 BASCOE CTM ERAI BASCOE CTM MERRA2

Conclusions.

- The 3 BASCOE CTM runs (ERA-interim, JRA55, MERRA2) agree quite well among each other and with BRAM2 (**Figs. 5, 6**) in the higher stratosphere in the considered latitudinal bands.
- The annual cycle in BRAM2 is in the middle of the model spread for most of the considered latitudinal bands (**Fig. 5**).
- WACCM presents some differences (in magnitude and sign) in the mean annual cycle with respect to the BASCOE runs (**Fig. 5**), especially in the horizontal (~mixing) term.
- WACCM delivers smaller variability in the annual cycle with respect to the CTM runs and BRAM2, especially in the vertical term in the Tropics (**Fig. 6**).
- In some regions (especially in the polar SH) the remaining term (ϵ) is relatively large (not shown): additional research is needed.
- Further research: use the newer version of WACCM (version 6) as well as other 2 dynamical reanalysis; investigate the interannual variability.

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