N2O-based climatology of the Brewer-Dobson Circulation in WACCM, a chemical reanalysis and a CTM driven by four dynamical reanalyses

A33S-3090

D. Minganti[1], S. Chabrillat[1], Y. Chistophe[1], Q. Errera[1], M. Prignon[2], M. Abalos[3], D. Kinnison[4], E. Mahieu[2]

[1] Royal Belgian Institute for Space Aeronomy, BIRA-IASB, Brussels, Belgium. [2] Institute of Astrophysics and Geophysics, University of Liege, Liege, Belgium. [3] Universidad Complutense de Madrid, Spain. [4] National Center of Atmospheric Research, Boulder,CO, USA

Abstract.

The Brewer-Dobson Circulation (BDC) plays a major role in the stratospheric dynamics in terms of tracer transport through the mean residual meridional advection and the isentropic two-way mixing. The climatological BDC in the Whole Atmosphere Community Climate Model (WACCM) is separated in those components and evaluated through a comparison with a chemical reanalysis of Aura MLS (BRAM2) and with a chemistry-transport model driven by four modern reanalyses (ERA-Interim, JRA-55, MERRA and MERRA2), using the Transformed Eulerian Mean (TEM) analysis of the long-lived tracer N2O and focusing on the vertical residual advection and the horizontal two-way mixing terms.

In the wintertime Southern polar region the horizontal mixing term in WACCM shows near-zero values, while all the reanalyses show strong negative contributions. This disagreement is likely due to the different representation of the polar transport barrier, that affects the mixing inside the polar vortex. In this region the reanalyses are characterized by large uncertainties of the TEM analysis, i.e. the residual term of the budget is quite large (the N2O TEM budget is not fully closed). In the wintertime Northern polar latitudes WACCM shows smaller values of the horizontal mixing term compared to the reanalyses, which show lower uncertainties of the TEM budget. The agreement is improved in the middle and low latitudes, especially in the Northern Hemisphere: the differences are smaller and the residual term is lower compared to the polar latitudes.

The inter-annual variability of the horizontal mixing term is large in the Southern polar latitudes during austral fall and in the Northern polar latitudes during boreal winter.

Methods.

- **WACCM** (Whole Atmosphere Community Climate Model version 4, *Garcia et al., J. Atmos. Sci.,2017*)
- **BASCOE CTM** (Belgian Assimilation System for Chemical Observation Chemistry-Transport Model, *Chabrillat et al., ACP, 2018*)
  -Driven ERA-Interim, MERRA2, MERRA, JRA-55 (*Fujiwara et al., ACP, 2017*)
- **BRAM2** (BASCOE Reanalysis of AURA MLS release 2, driven by ERA-interim) (*Errera et al., ACP, 2019*): **A44F-07** Thursday, 12 December 2019, 17:30 - 17:45.
- **TEM analysis** (*Abalos et al., J. Atmos. Sci.,2017*)

$X = N_2O$ ϵ = *residual*

$$A_y = -\bar{v}^* \bar{\chi}_y, \qquad A_z = -\bar{w}^* \bar{\chi}_z,$$

$$\bar{\chi}_t = A_y + M_y + A_z + M_z + (\bar{P} - \bar{L}) + \bar{\epsilon}$$

$$M_y = e^{z/H} cos\phi^{-1} (M^{(y)} cos\phi)_y \qquad M_z = e^{z/H} (M^{(z)})_z$$

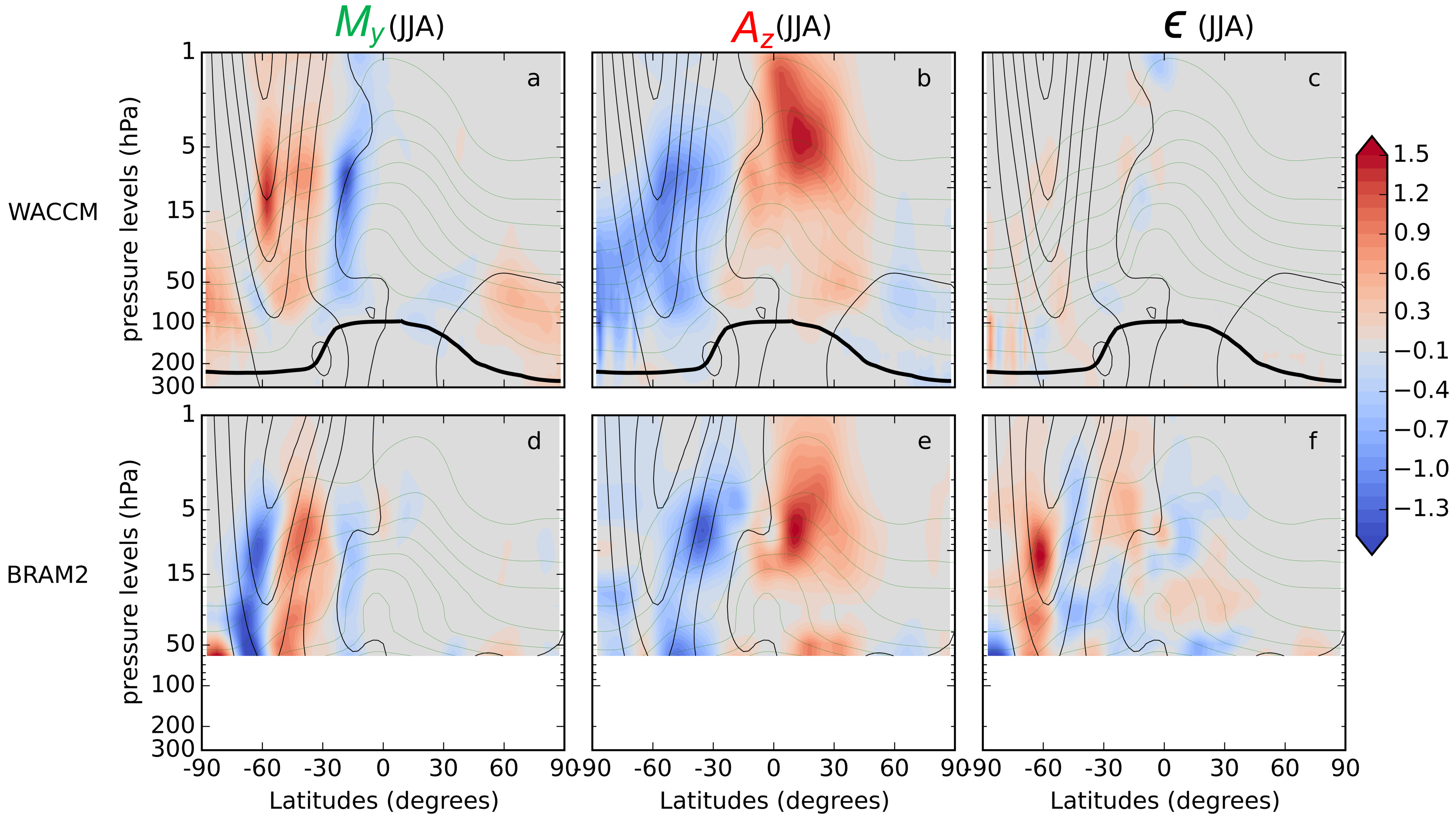

Figure 3. M_y (left), A_z (middle) and residual term (right) JJA mean (ppb/day, 2005-2014). Top row: WACCM, bottom row: BRAM2. Thin black line: zonal wind (0 to 140 m/s every 20). Thick black line: dynamical tropopause. Green lines: climatological N2O (20 to 300 ppb every 40).

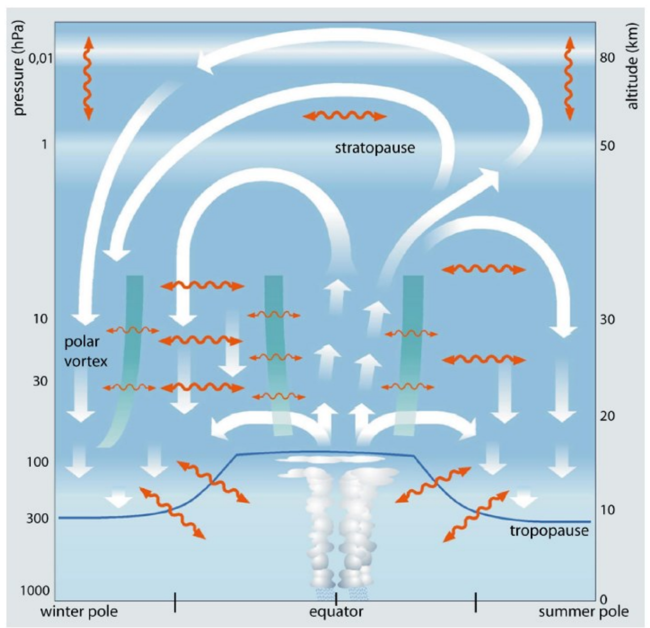

Figure 1. Schematic of the Brewer-Dobson Circulation. Thick white arrows: meridional circulation; wavy orange: mixing. Thick green lines: stratospheric transport barriers. After *Bonisch et al., 2011.*

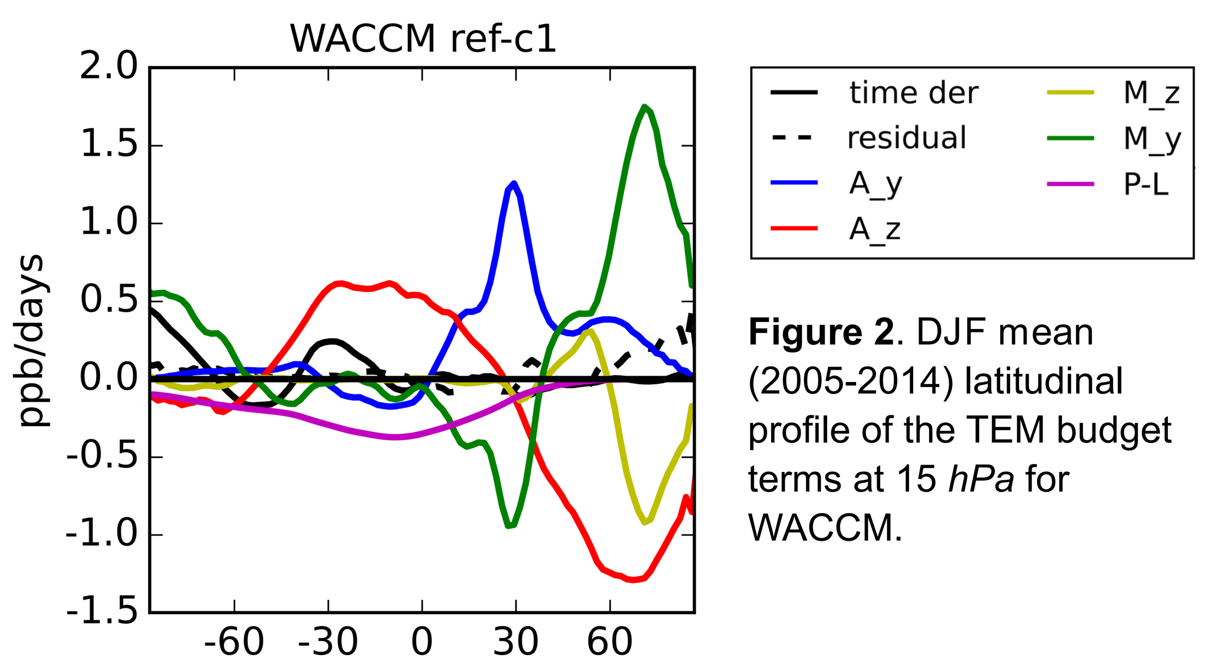

Figure 2. DJF mean (2005-2014) latitudinal profile of the TEM budget terms at 15 *hPa* for WACCM.

@15 hPa ~30 km

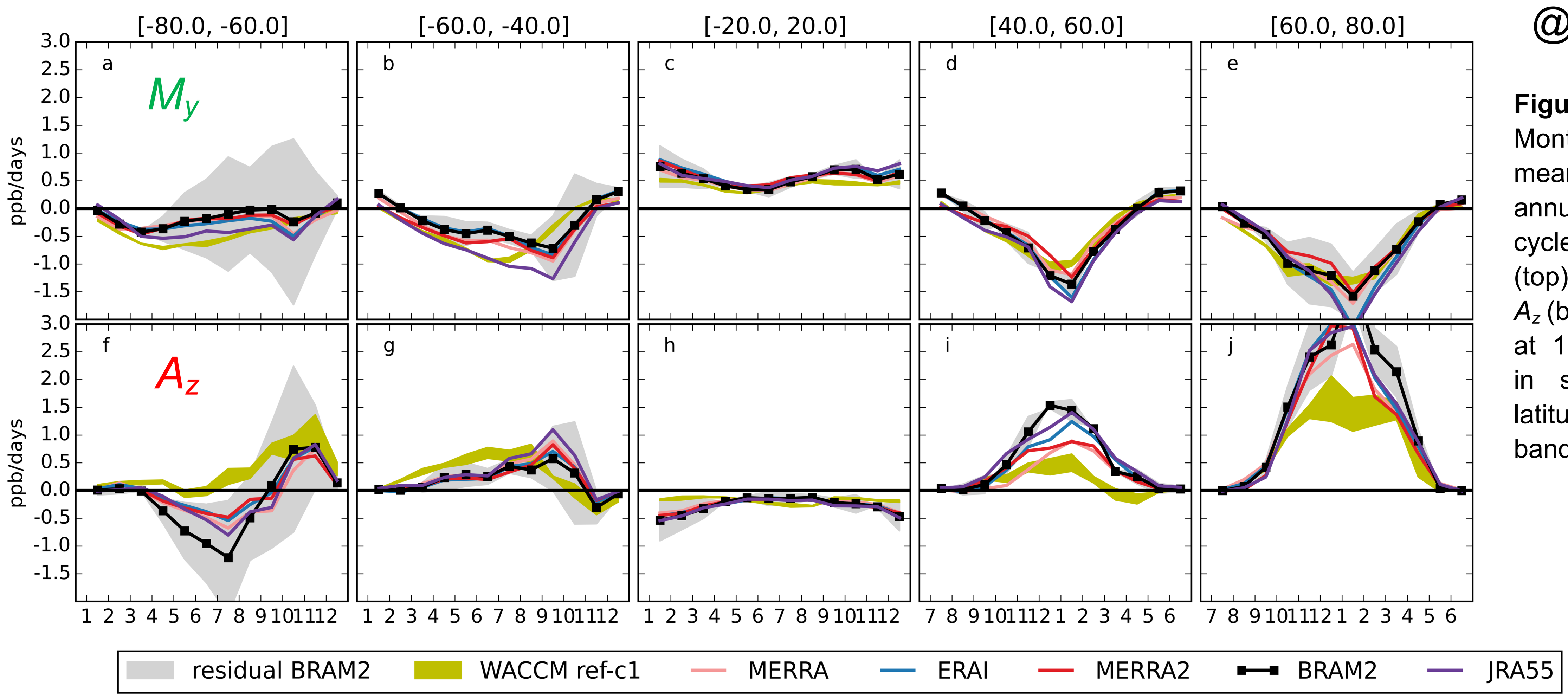

Figure 4. Monthly mean annual cycle of M_y (top) and A_z (bottom) at 15 *hPa* in several latitude bands.

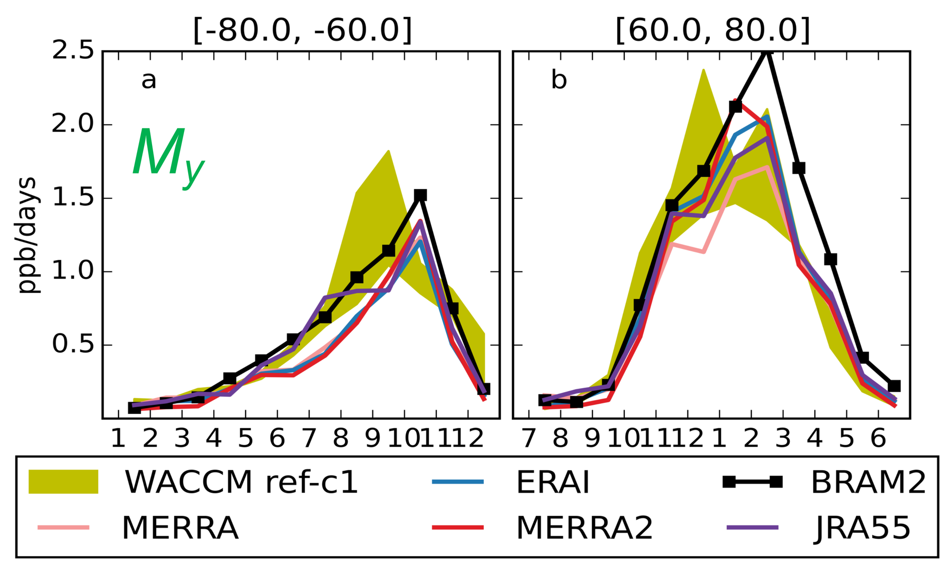

Figure 5. Monthly standard deviation of M_y at 15 *hPa* in the Northern (right) and Southern polar regions (left).

Conclusions.

- Wintertime NH: smaller values of M_y in WACCM compared to the reanalyses (**Fig. 4i,j**).
- Wintertime Antarctic regions: M_y largely negative in the reanalyses and near-zero in WACCM (likely due to different polar jet which affects mixing) (**Fig. 3, Fig. 4a,d**). The reanalyses also show large residual term (sub-scale mixing): TEM analysis less robust (**Fig. 3f, Fig. 4f**).
- Middle and the tropical latitudes: TEM budget is well-closed; differences are smaller with respect to the polar regions for M_y and A_z (**Fig. 4b,c,d,g,h,i**).
- Polar latitudes: inter-annual variability of M_y is the largest: related in the SH to vortex breakup during fall, while in the NH to the more variable Arctic polar vortex (**Fig. 5**).
- Future research:
  1) additional reanalysis products as well as free running CCMs and CTMs.
  2) Further study the multi-decadal variations of the BDC as depicted in this study, including impact of the QBO.

References.

- Bönisch, H., Engel, A., Birner, Th., Hoor, P., Tarasick, D. W., and Ray, E. A.: On the structural changes in the Brewer-Dobson circulation after 2000, *Atmos. Chem. Phys.*, 11, 3937-3948, https://doi.org/10.5194/acp-11-3937-2011, 2011.
- Garcia, R.R., A.K. Smith, D.E. Kinnison, Á.d. Cámara, and D.J. Murphy, 2017: Modification of the Gravity Wave Parameterization in the Whole Atmosphere Community Climate Model: Motivation and Results. *J. Atmos. Sci.,* **74**, 275–291, https://doi.org/10.1175/JAS-D-16-0104.1
- Fujiwara, M., Wright, J. S., Manney, G. L., Gray, L. J., Anstey, J., Birner, T., Davis, S., Gerber, E. P., Harvey, V. L., Hegglin, M. I., Homeyer, C. R., Knox, J. A., Krüger, K., Lambert, A., Long, C. S., Martineau, P., Molod, A., Monge-Sanz, B. M., Santee, M. L., Tegtmeier, S., Chabrillat, S., Tan, D. G. H., Jackson, D. R., Polavarapu, S., Compo, G. P., Dragani, R., Ebisuzaki, W., Harada, Y., Kobayashi, C., McCarty, W., Onogi, K., Pawson, S., Simmons, A., Wargan, K., Whitaker, J. S., and Zou, C.-Z.: Introduction to the SPARC Reanalysis Intercomparison Project (S-RIP) and overview of the reanalysis systems, Atmos. Chem. Phys., 17, 1417–1452, https://doi.org/10.5194/acp-17-1417-2017, 2017
- Abalos, M., W.J. Randel, D.E. Kinnison, and R.R. Garcia, 2017: Using the Artificial Tracer e90 to Examine Present and Future UTLS Tracer Transport in WACCM. *J. Atmos. Sci.,* **74**, 3383–3403, https://doi.org/10.1175/JAS-D-17-0135.1

Acknowledgements.

This work has been primarily supported by the F.R.S.-FNRS, Brussels, through the research project ACCROSS (convention T.0040.16).

Contact: daniele.minganti@aeronomie.be