Université de Liège

BIRA•IASB

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

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AGO PhD Day

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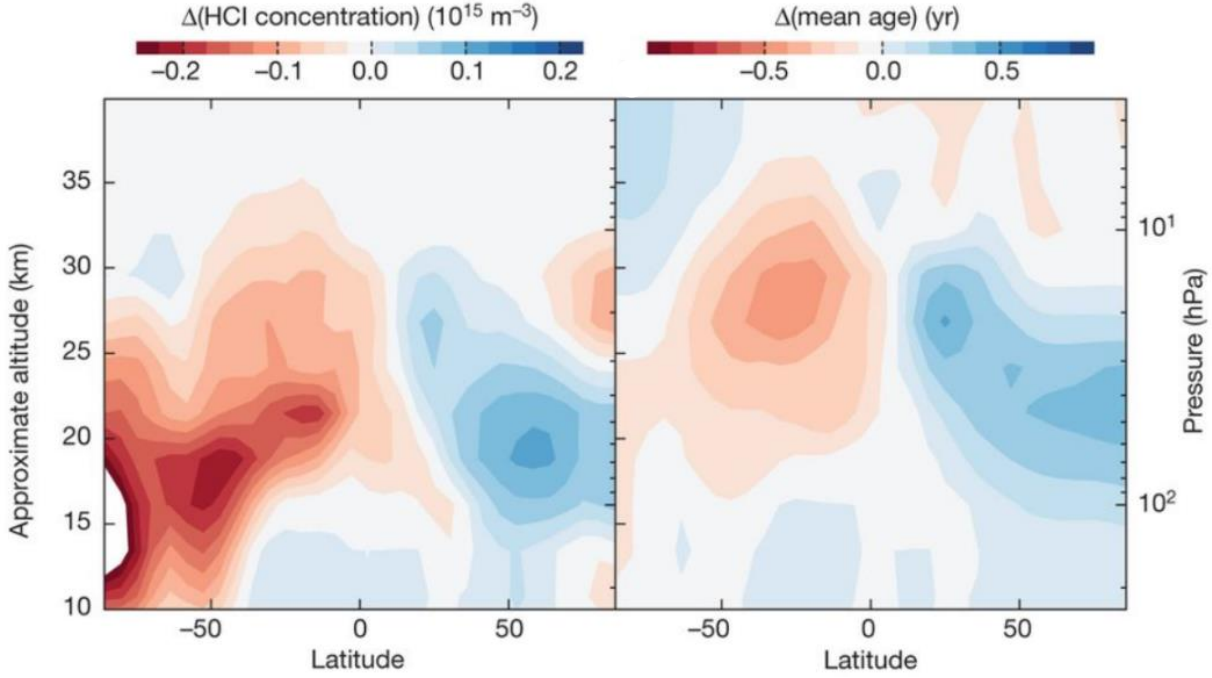
Introduction: the ***ACCROSS*** project

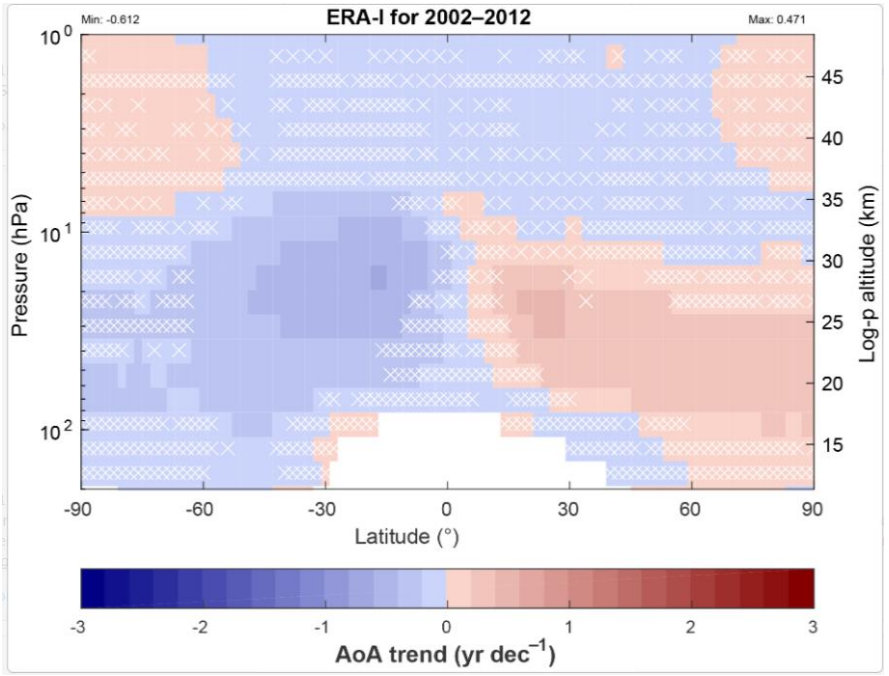
(Atmospheric Composition and Circulation investigated with meteorological Reanalyses, Observational datasets and models for the Study of the Stratosphere and its changes)

Study the ***stratospheric dynamics*** using long-lived chemical ***tracers*** with models, reanalyses and observations.



Mahieu et al, *Nature*, 2014

HCl and age of air (theoretical measure of stratospheric transport) trends.

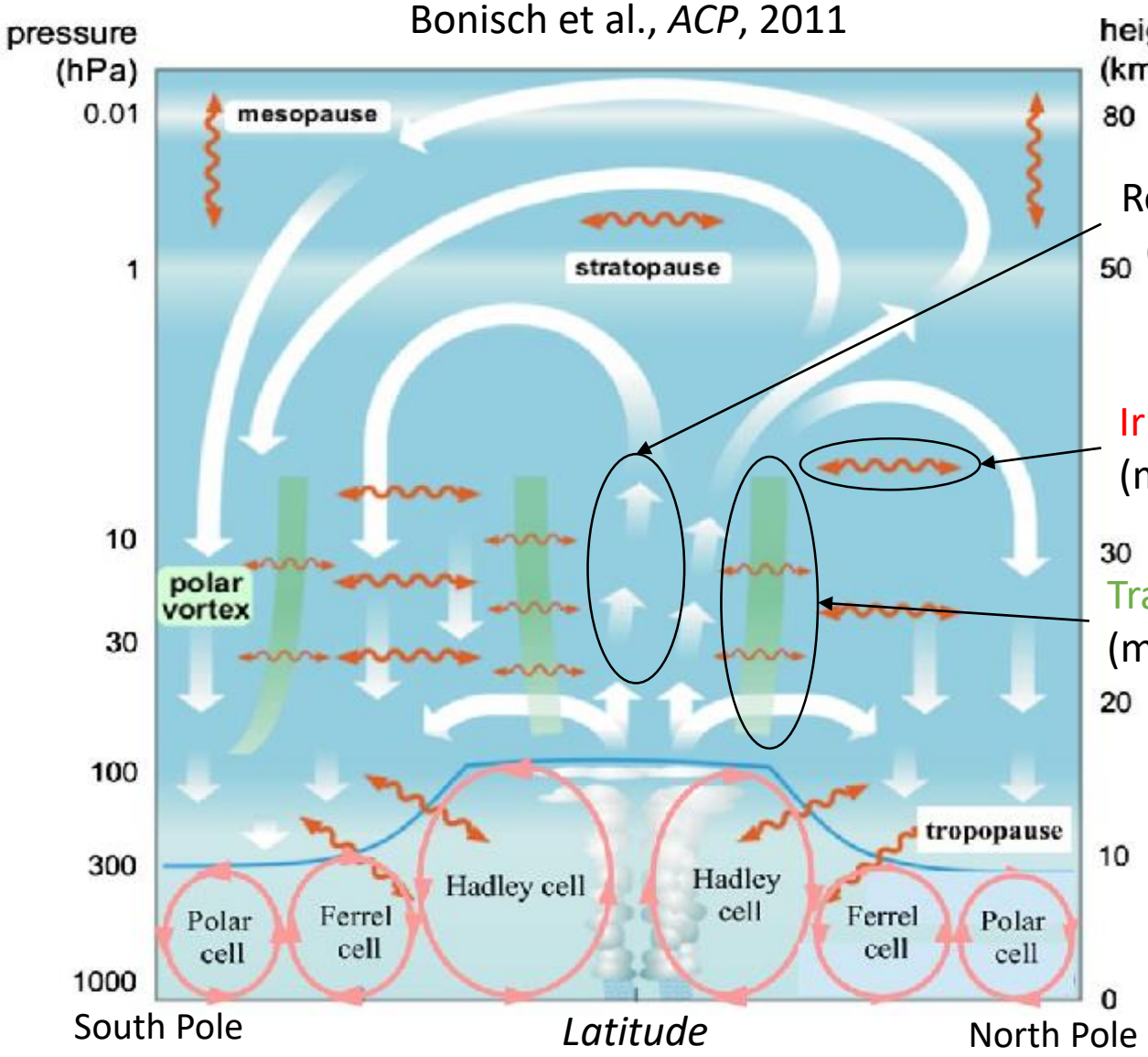


Chabrillat et al, *ACP*, 2018

Age of air air (theoretical measure of stratospheric transport) trends.

Introduction: the ***Brewer-Dobson Circulation*** (BDC)

Bonisch et al., *ACP*, 2011



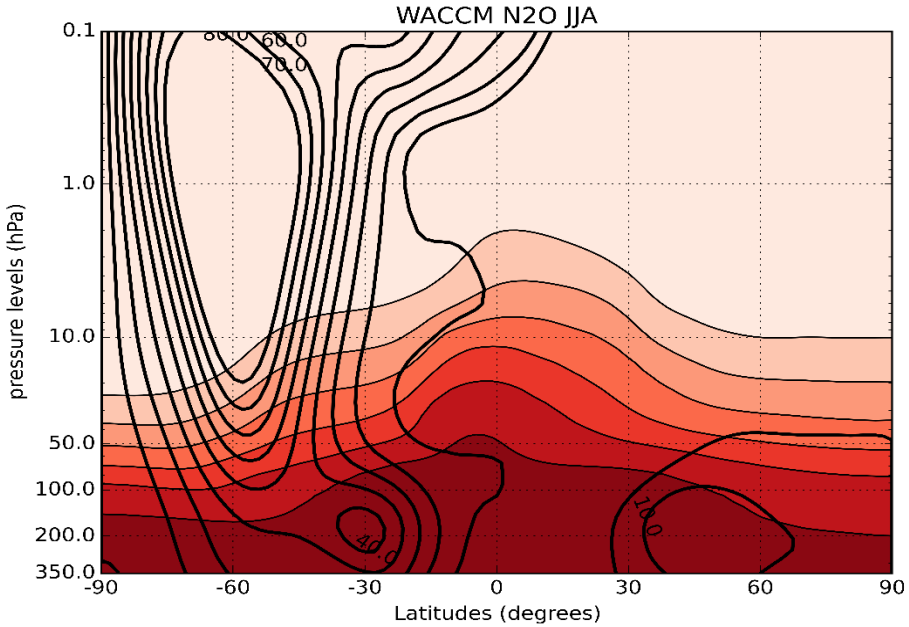
Residual advection (mostly vertical)

Irreversible mixing (mostly horizontal)

Transport barriers (mixing is inhibited)

Long lived tracer: ***N_2O***

No major sources nor sinks in the stratosphere→ any changes you see is due to dynamics



Latitude-height cross section of the schematic of the Brewer-Dobson Circulation (left). WACCM N_2O latitude-vertical cross section for the JJA season mean, black thick lines are the zonal mean zonal wind contours (right).

Methods

Considered period: 2005-2015

- ***WACCM*** (Whole Atmosphere Community Climate Model version 4) (Marsh et al, *JC*, 2013).
- ***ERAI*** (Belgian Assimilation System for Chemical Observation Chemistry-Transport Model driven by ERA-Interim) (Errera et. al, *ACP*, 2008; Prignon et al, ACPD, 2019).
- ***JRA55*** (BASCOE CTM driven by JRA-55) (Fujiwara et al, *ACP*, 2017).
- ***MERRA2*** (BASCOE CTM driven by MERRA2) (Fujiwara et al, *ACP*, 2017).
- ***MERRA*** (BASCOE CTM driven by MERRA) (Fujiwara et al, *ACP*, 2017).
- ***BRAM2*** (BASCOE Reanalysis of AURA MLS release 2, driven by ERA-Interim) (Fujiwara et al, *ACP*, 2017).

TEM (Transformed Eulerian Mean) analysis (Abalos et al, *JAS*, 2017):

$X \rightarrow N_2O$

residual

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

time_der | mer_adv | div1 | vert_adv | div2 | chem

$$M^{(y)} \equiv -\rho_0^{-1}(\overline{v'\chi'} - \overline{v'\theta'}\bar{\chi}_z/\bar{\theta}_z),$$

$$M^{(z)} \equiv -\rho_0^{-1}(\overline{w'\chi'} + \overline{v'\theta'}\bar{\chi}_y/\bar{\theta}_z),$$

$$\bar{v}^* \equiv \overline{v} - \rho_0{}^{-1}(\rho_0\overline{v'\theta'}/\overline{\theta}_z)_z,$$

$$\bar{w}^* \equiv \overline{w} + (acos\phi)^{-1}(cos\phi\overline{v'\theta'}/\overline{\theta}_z)_\phi.$$

div1: horizontal mixing (~eddy mixing)

vert_adv: residual vertical advection (~residual circulation)

Each term of the budget denotes the N_2O ***increase***/***decrease*** caused by the specific physical/chemical process.

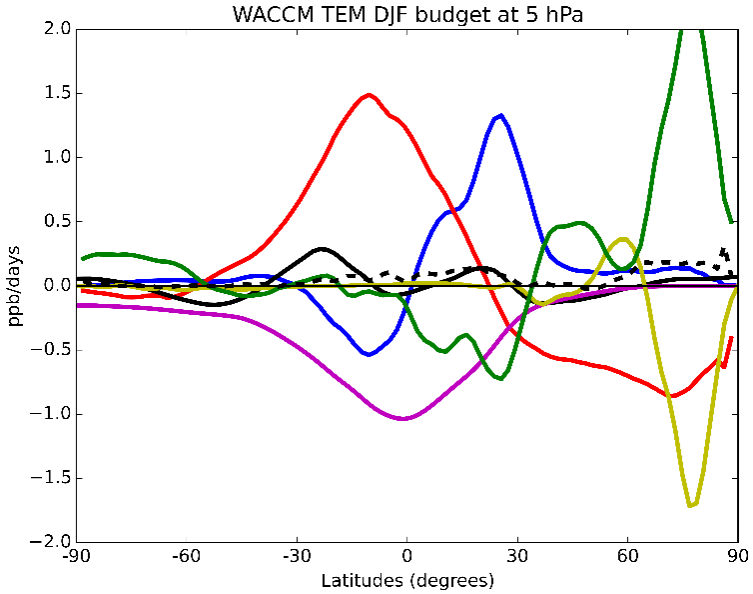
$$\epsilon \equiv time\_der - (mer\_adv + div1 + vert\_adv + div2 + chem)$$

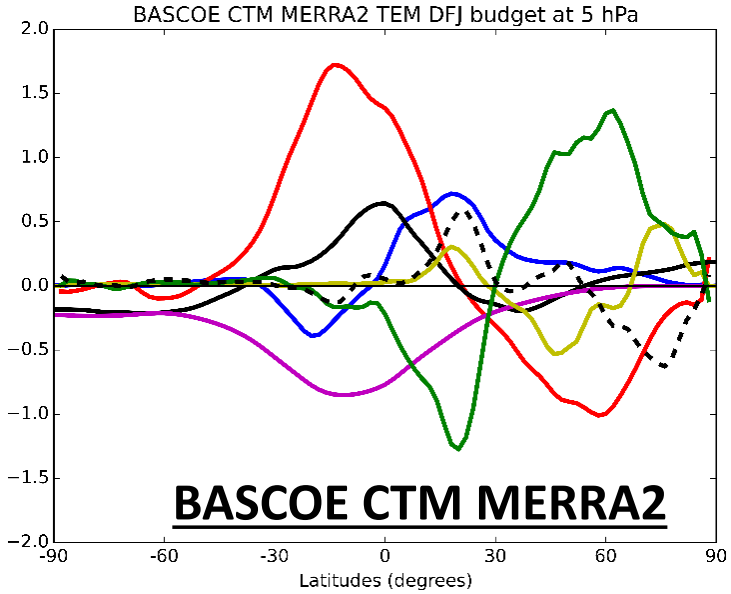
TEM budget at 5 *hPa*

WACCM

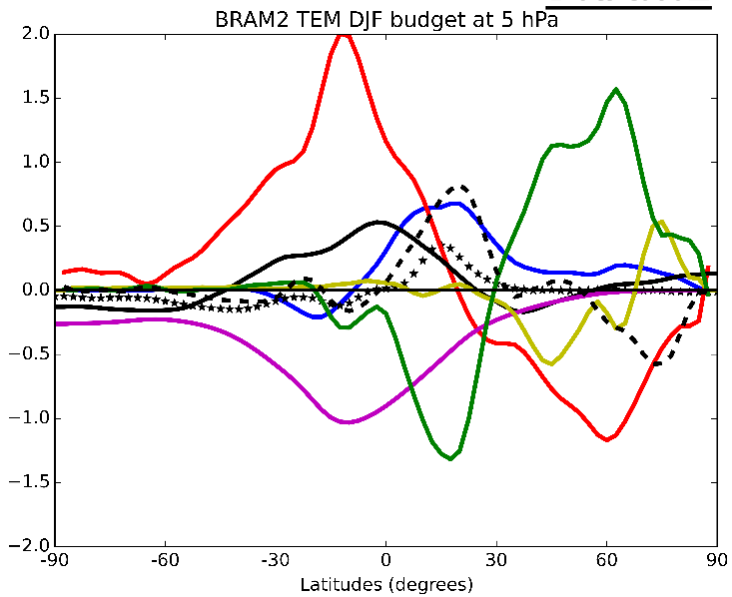
BRAM2

DJF

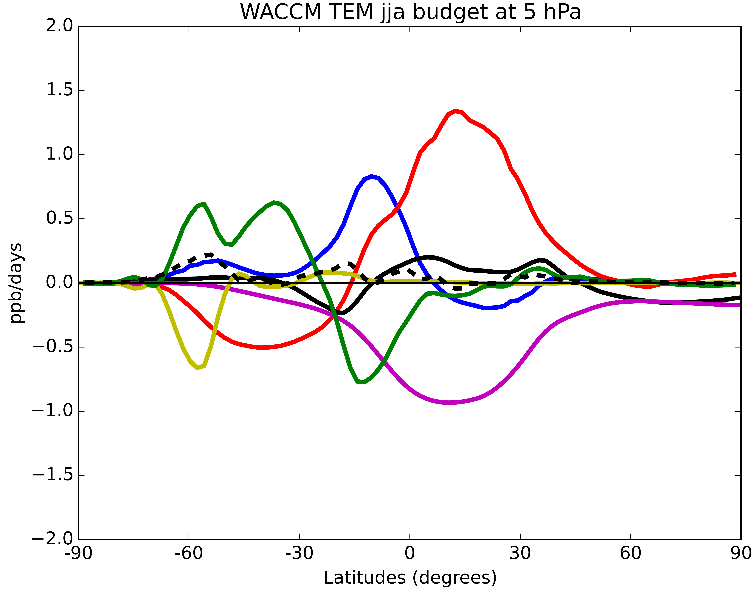


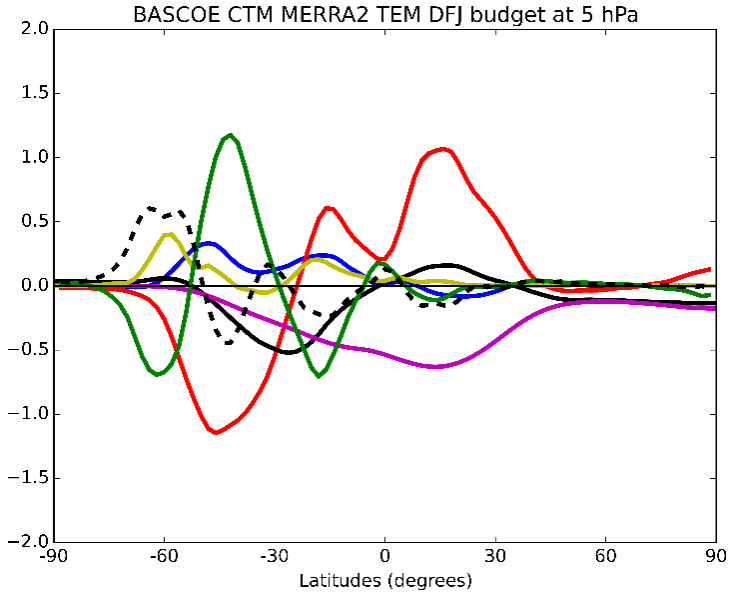


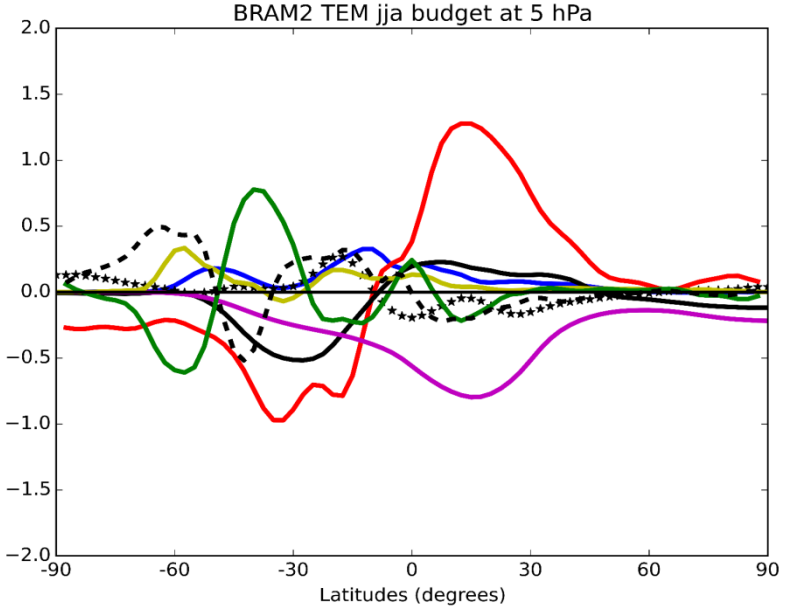
BASCOE CTM MERRA2



JJA







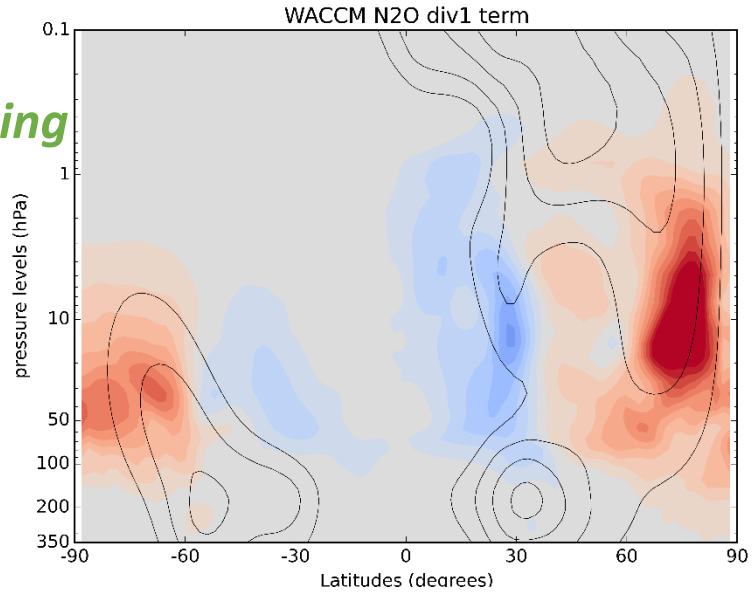
mer_adv Al residual vert_adv time_der chem div2 div1

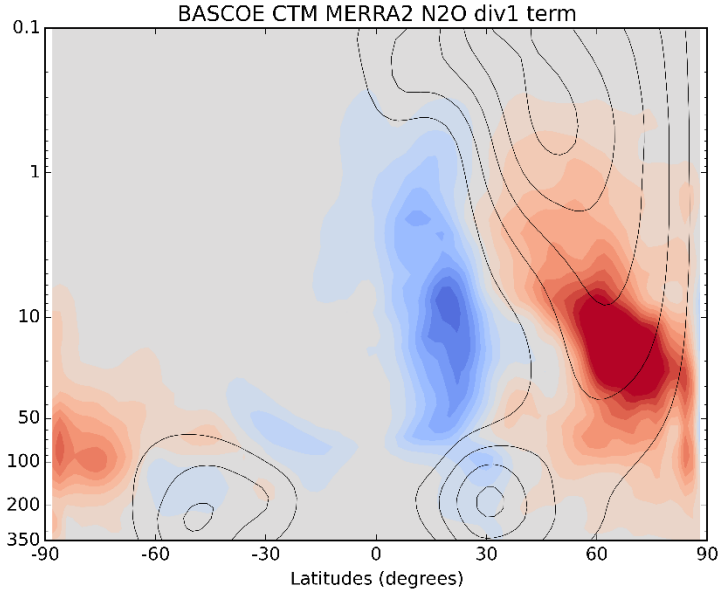
Black lines: zonal mean zonal wind contours from 0 to 50 m/s every 10 m/s.

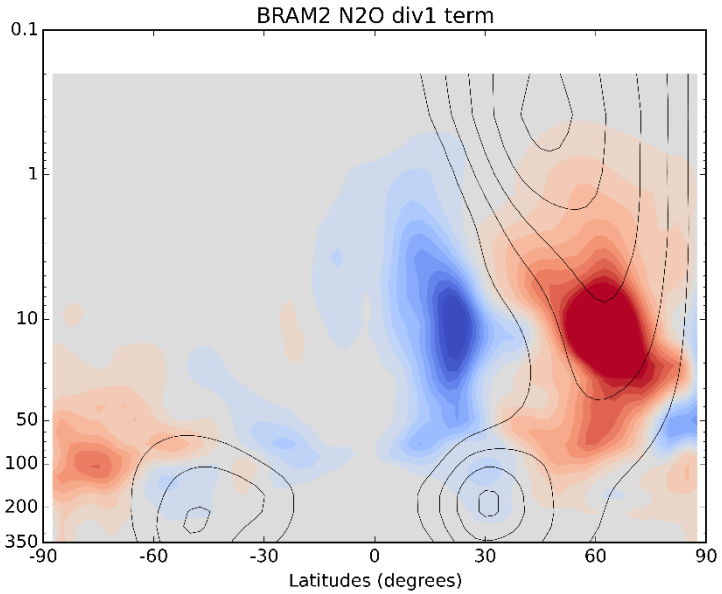
Seasonal mean DJF

WACCM **BASCOE CTM MERRA2** **BRAM2**

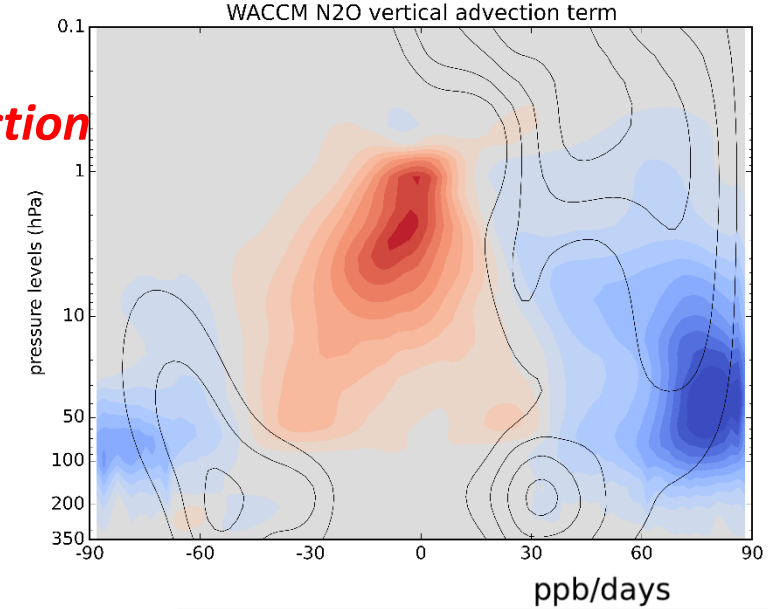
mixing

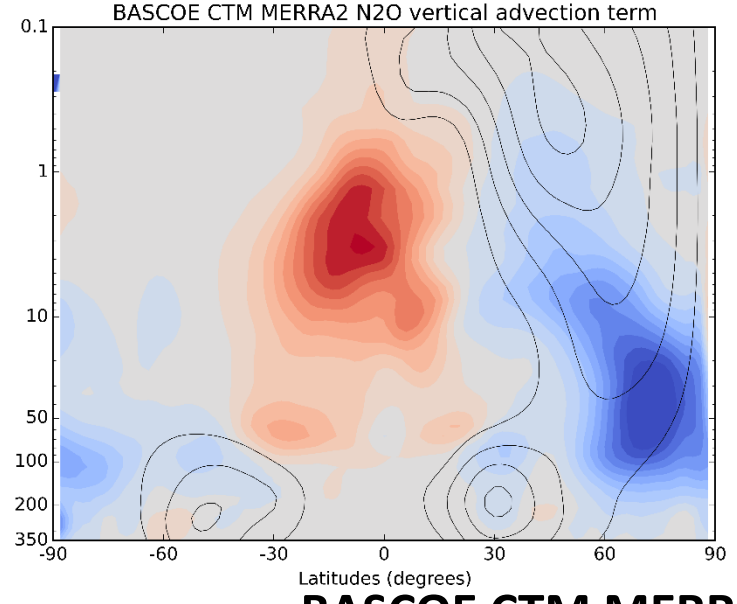


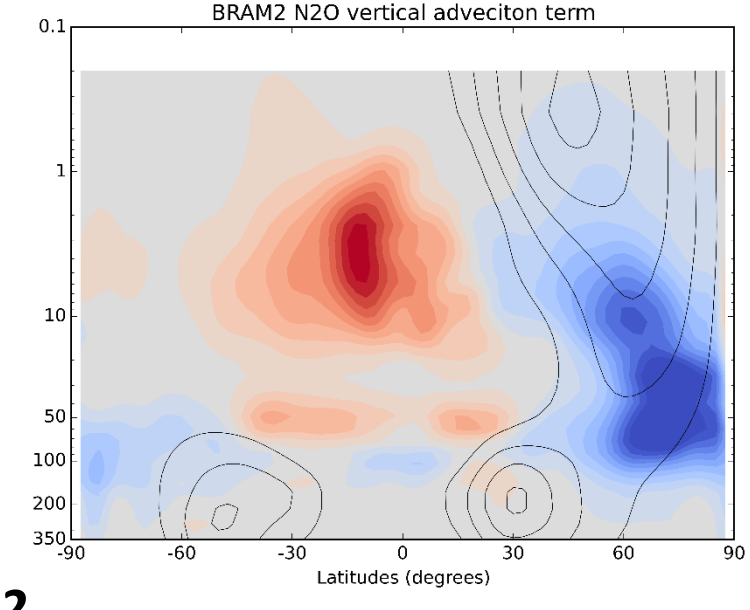


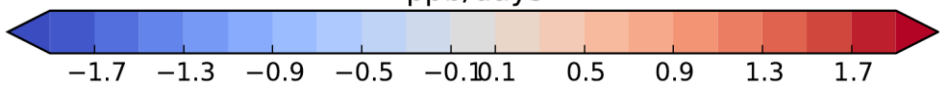


advection









BASCOE CTM MERRA2

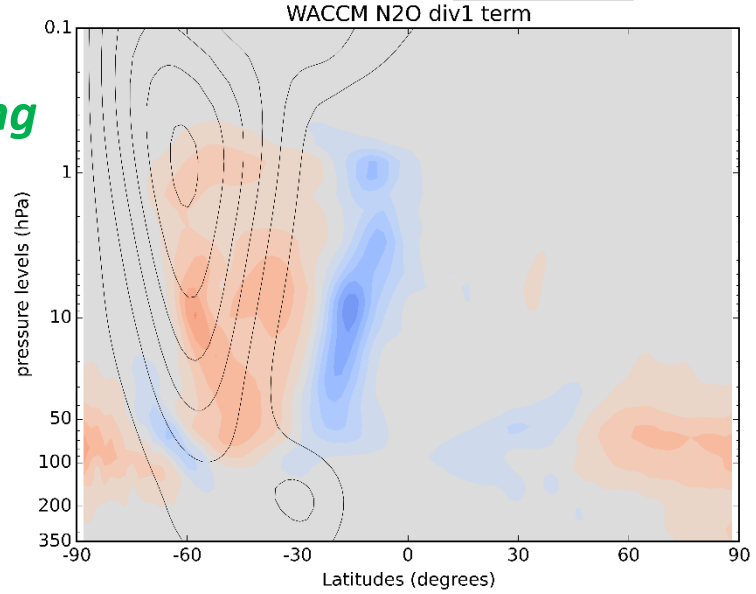
Black lines: zonal mean zonal wind contours from 0 to 140 m/s every 20 m/s.

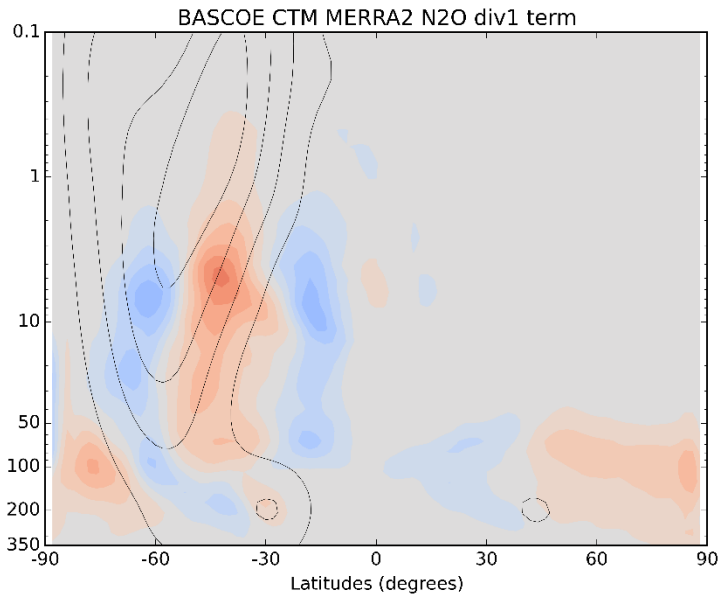
Seasonal mean JJA

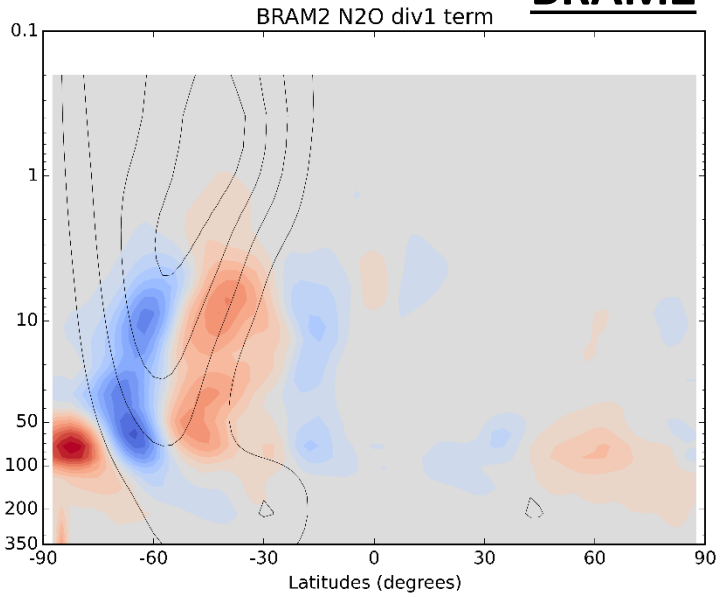
WACCM

BRAM2

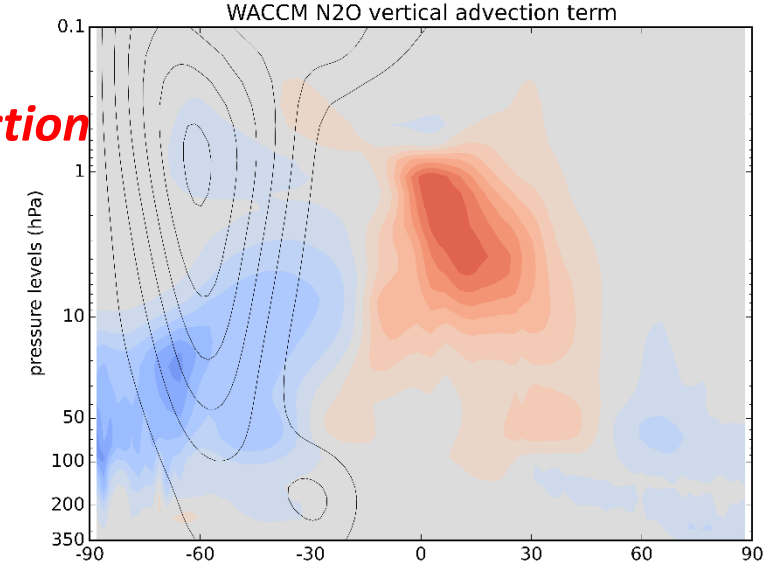
mixing

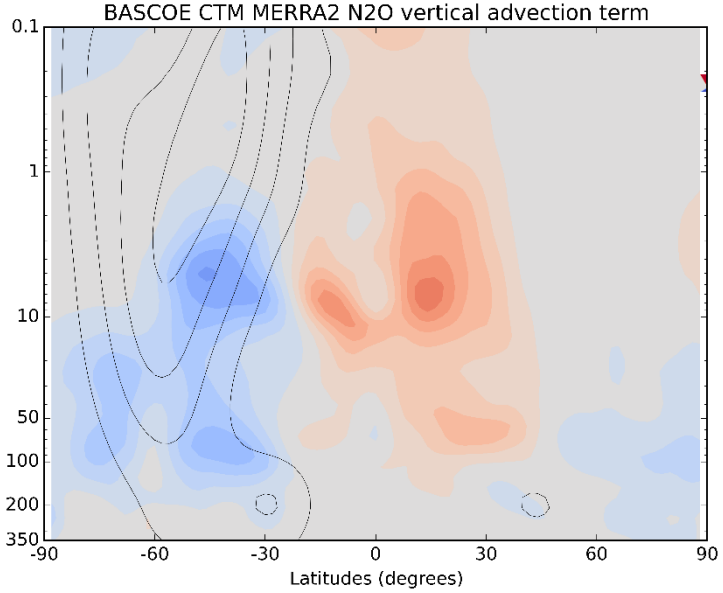


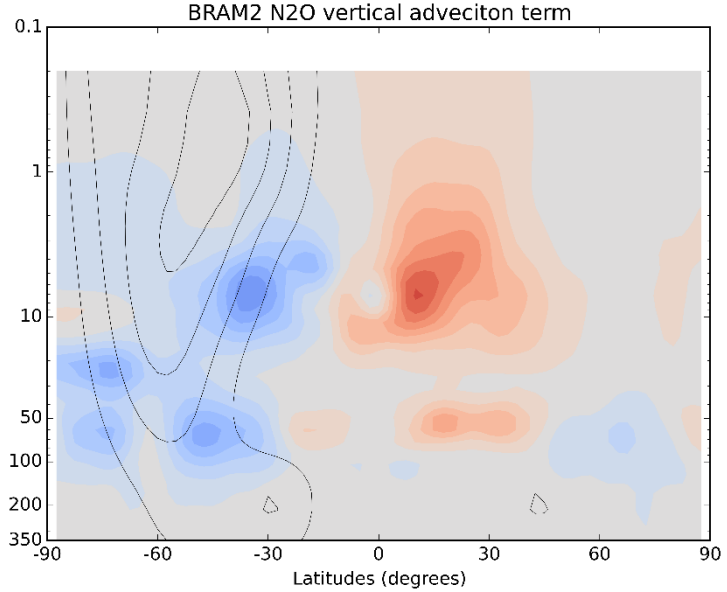


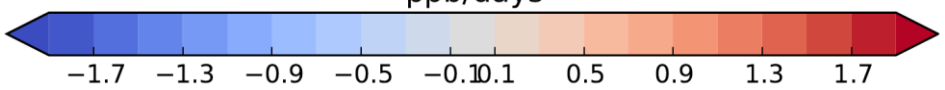


advection





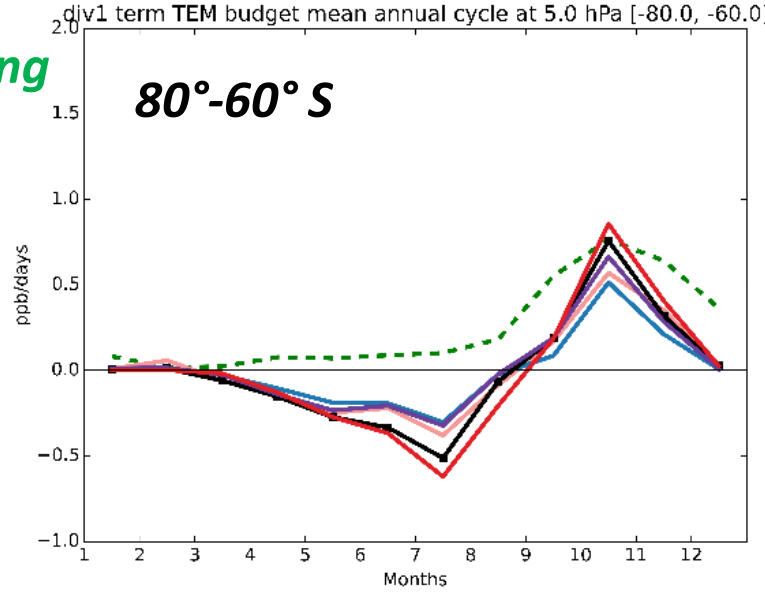


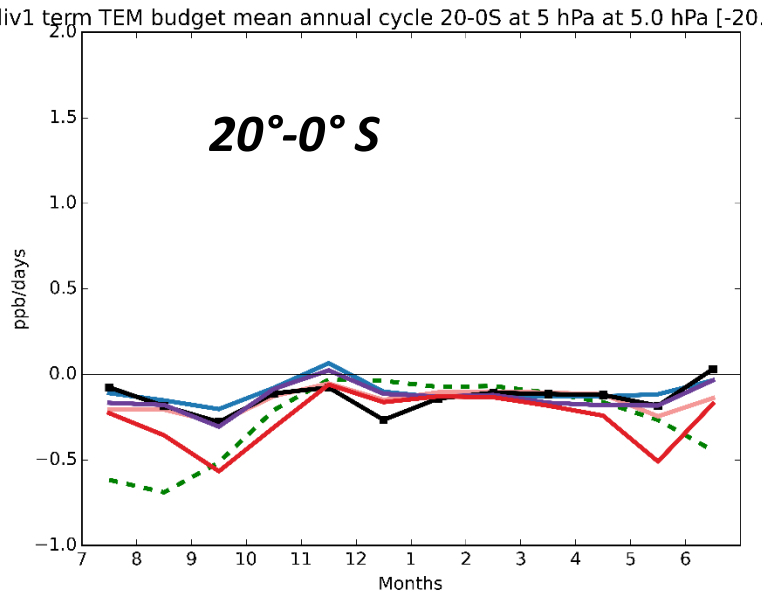


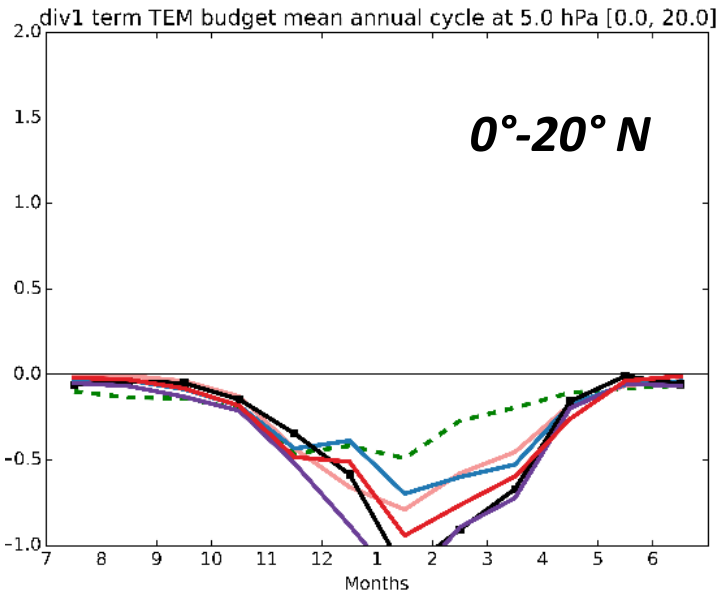
BASCOE CTM MERRA2

Mean Annual cycle at 5 *hPa*

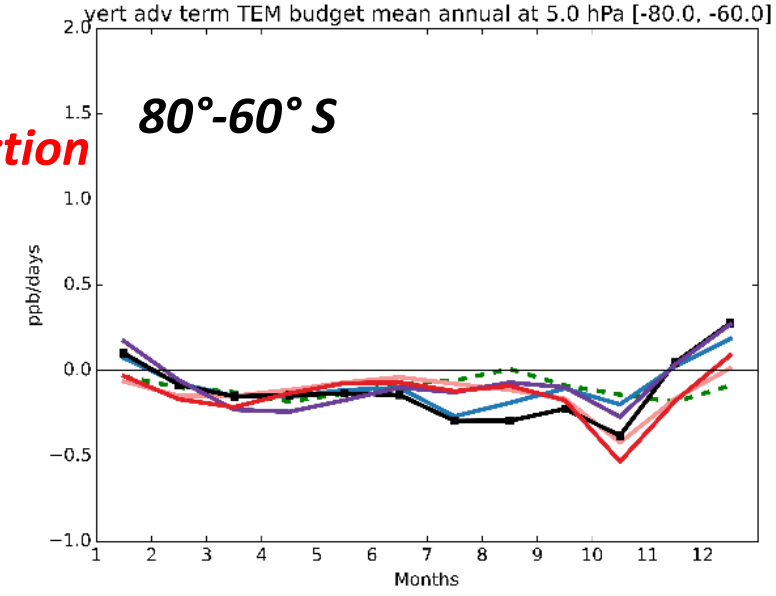
mixing

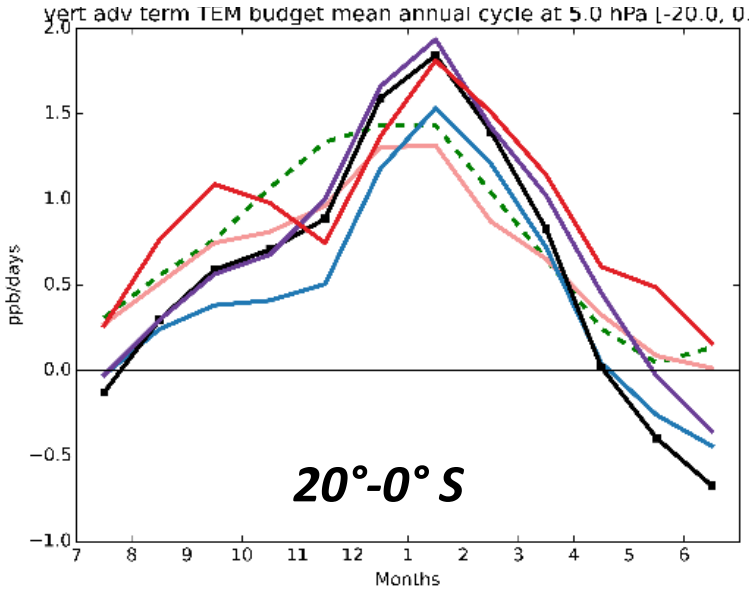


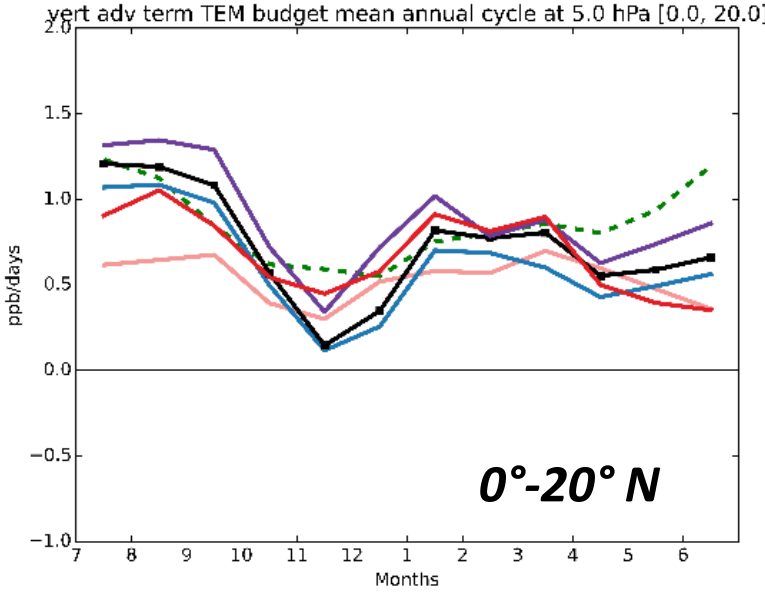




advection



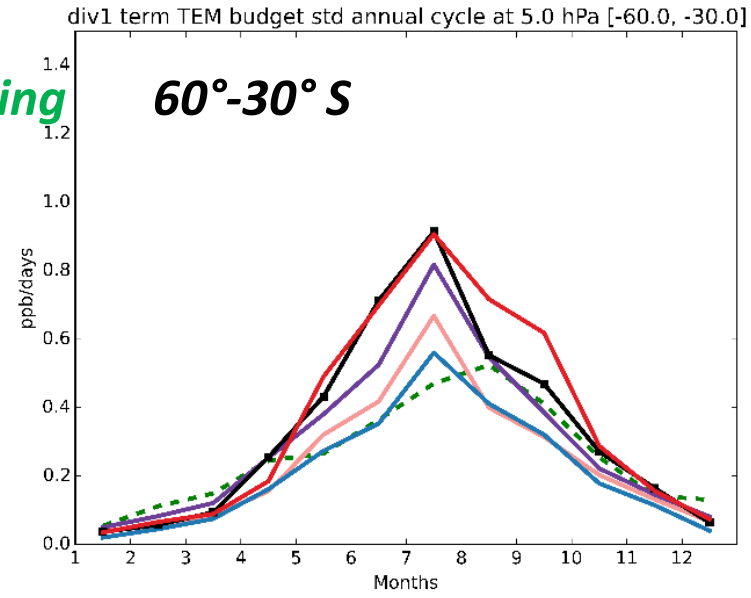


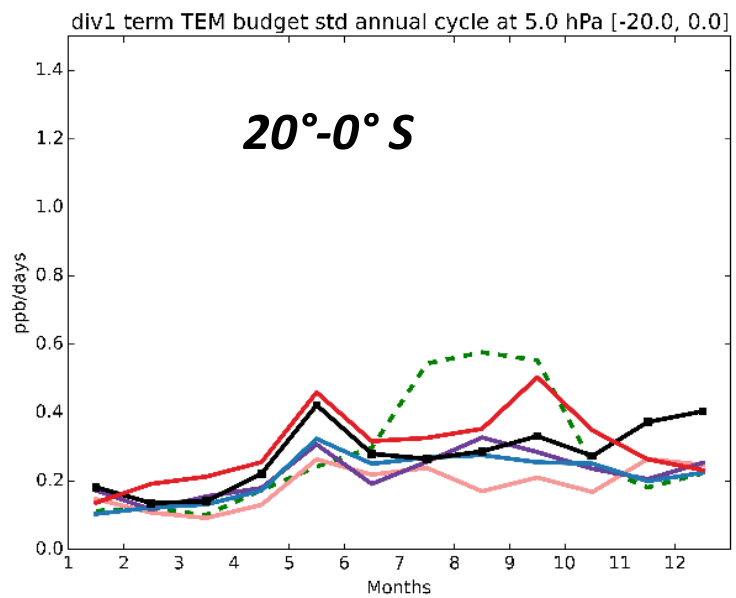


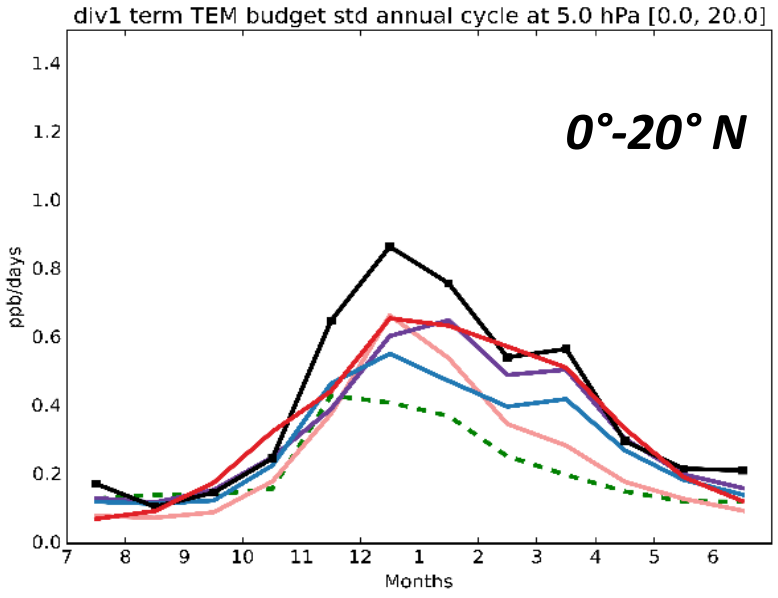
WACCM | BASCOE CTM MERRA | BASCOE CTM ERAI | BRAM2 | BASCOE CTM JRA55 | BASCOE CTM MERRA2

Standard deviation annual cycle at 5 *hPa*

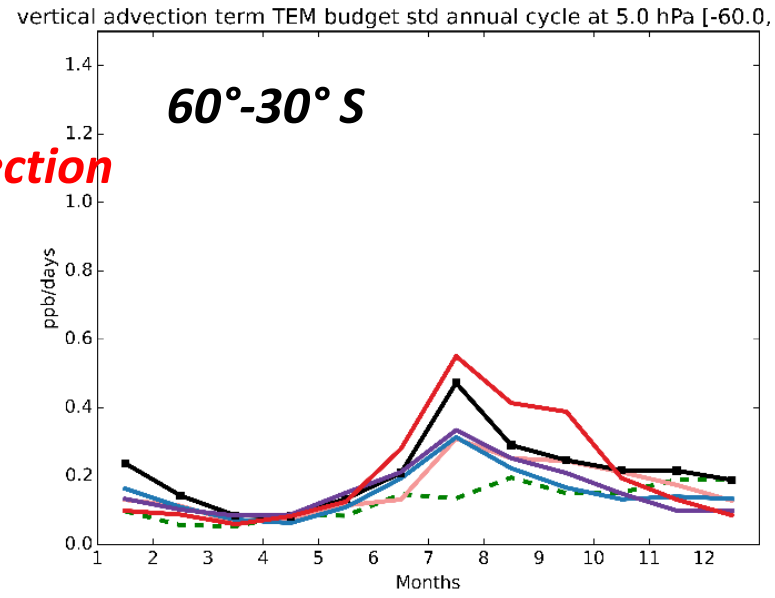
mixing

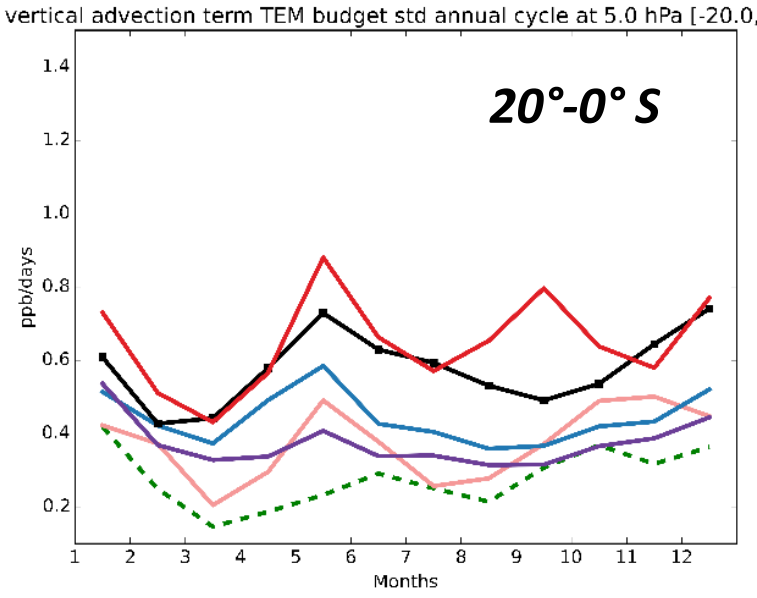


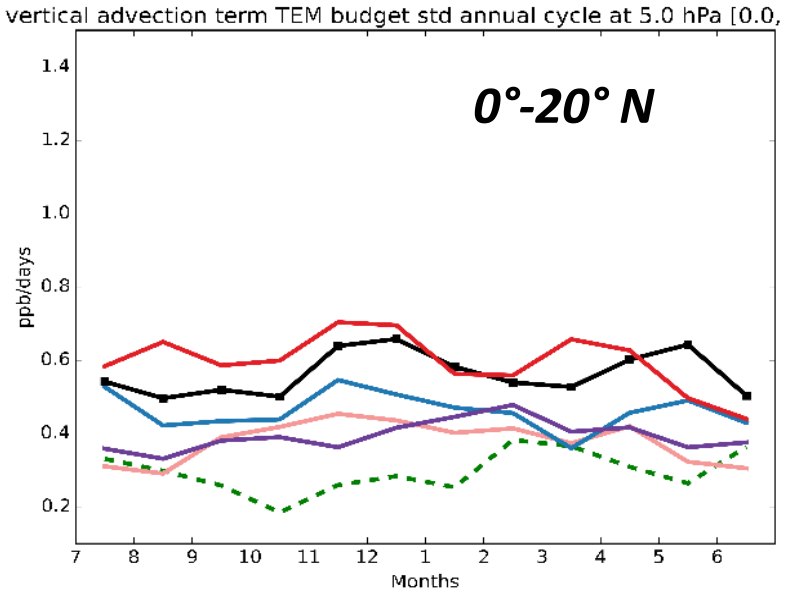




advection







WACCM | BASCOE CTM MERRA | BASCOE CTM ERAI | BRAM2 | BASCOE CTM JRA55 | BASCOE CTM MERRA2

Conclusions

- General agreement among the datasets through most of the stratosphere.
- BRAM2 annual cycle lies in the middle of the model spread for both *mixing* and *advection* for the considered regions.
- WACCM annual cycle presents differences with respect to the reanalyses in the *mixing* term (mostly) in the *80°-60° S* latitudinal band at 5 *hPa*.
- WACCM shows smaller variability in the *advection* term in the Tropical regions at 5 *hPa*.
- Large residual are found in the SH JJA (not shown): probably non-physical reasons (spurious mixing in the reanalyses).
- Future research:
  - Further investigate the residual term.
  - Apply this analysis other datasets (reanalysis and newer version of WACCM).
  - Investigate inter-annual changes (variability).

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