Tropical expansion measured by isentropic and potential vorticity fields and age of air

Juan A. Añel[1], Petr Šácha[1] and Laura de la Torre[1]

j.anhel@uvigo.es

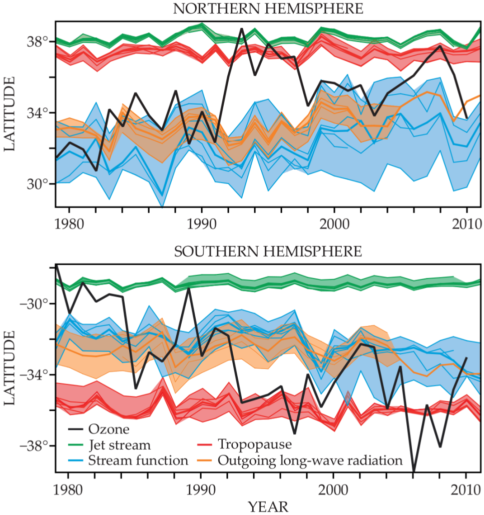
EPhysLab

Universida de Vigo

[1]Ourense, Spain

Some methods used to evaluate tropical width

- SSTs
- subtropical jet stream/barriers
- tropopause height - with 'artificial' thresholds -
- surface winds
- outgoing IR radiation - maximum at subtropics
- precipitation-evaporation difference
- [O_3] change tropics-subtropics



Birner et al.(2014) adapted from IPCC AR5

Problems assessing tropical width

- Some methodologies can only be applied to a given subset
- Some variables are very poor from models limiting future projections
- Most of them depend on randomly chosen threshold values
- Tropical widening is a problem more complex that getting a single 2D perspective

Global Distribution of Potential Vorticity at the tropopause level

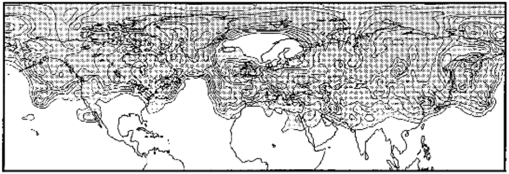


FIG. 1. Potential vorticity on the 320-K isentropic surface at 0000 GMT 15 February 1994, in lat–long projection for the Northern Hemisphere. Isolines are plotted every 1 PVU. Field produced by Dr. P. van Velthoven, using analyzed data from the European Centre for Medium-Range Weather Forecasts.

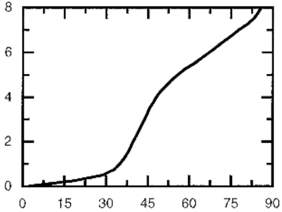
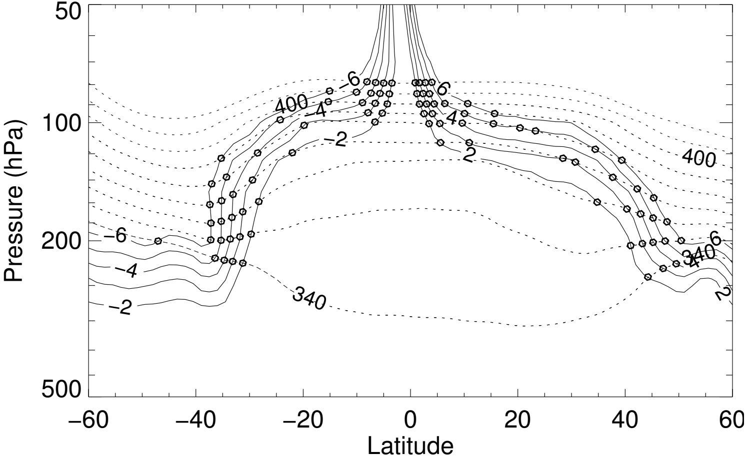


FIG. 2. Potential vorticity (in PVU) for the case of Fig. 1 plotted as a function of the area that is covered by potential vorticity values that are larger than the value at hand. Area is expressed as equivalent latitude, i.e., the latitude of a zonally symmetric contour enclosing the same area.

Ambaum M. (1997), Isentropic Formation of the Tropopause, J. Atmos. Sci., 54, 555-568.

Data & Methodology



Data & Methodology

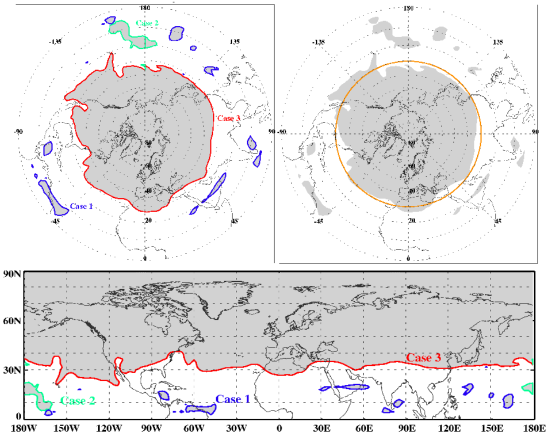
- Analysis of the pressure leveles between 500 and 50 hPa.
- Datasets used: WACCM, WACCM UTLS, ERA-INTERIM, JRA55, NCEP2, MERRA

	N levels 500-50 hPa	Horizontal grid
WACCM	14	1.9x2.5
WACCM UTLS	40	1.9x2.5
ERA-INTERIM	14	0.5x0.5
JRA55	14	1.25x1.25
MERRA	11	1.25x1.25
NCEP2	9	2.5x2.5

Data & Methodology

- θ is computed for each grid point
$$\theta(\lambda, \phi, p, t) = T(\lambda, \phi, p, t) \cdot (p_0/p)^{(R/c_p)}$$
- u, v and z fields are interpoled to the θ levels interesting for our study (from 340K to 420K)
- the isentropic relative vorticity of the air $\xi_\theta$is computed
- then we have the absolute vorticity
- $d\theta/dp$ is computed and then interpoled to isentropic levels.
- PV is computed
$$PV(\lambda, \phi, \theta, t) = -g \cdot (\xi_\theta + f) \cdot (d\theta/dp)$$
- the PV field is interpoled to the desired values (1.6, 2, 3, 3.5, 4, 5, 6 PVU and the subsequent for the Southern Hemisphere).
- ϕ_e is computed

Equivalent latitude



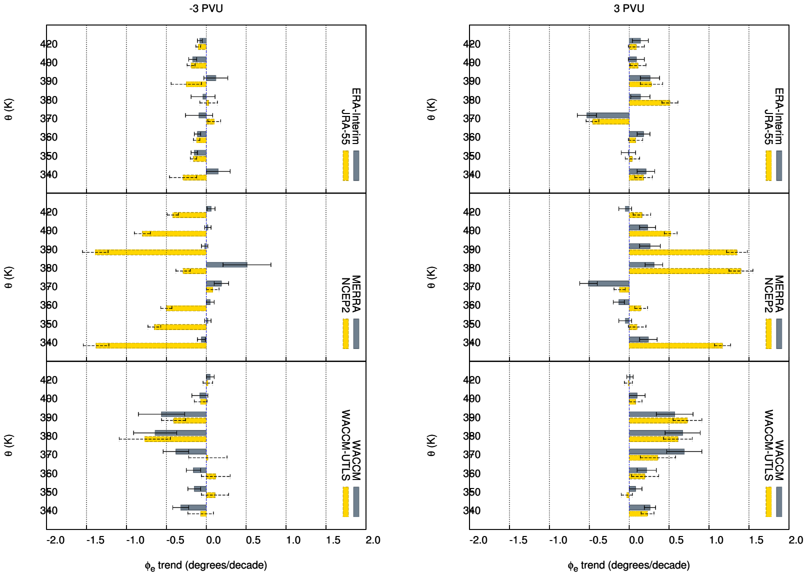
Añel et al. (2013) Equivalent Latitude Computation Using Regions of Interest (ROI). PLoS ONE 8(9): e72970

Period of study:

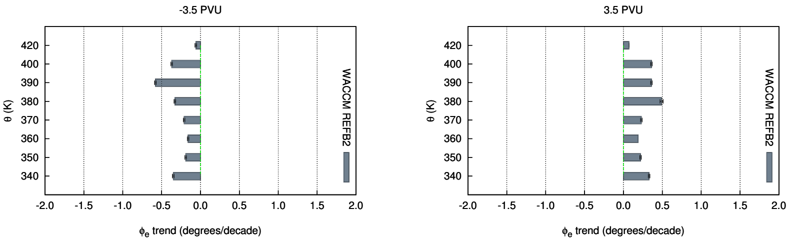
WACCM — 1979-2006
WACCM-UTLS — 1979-2006
ERA-INTERIM — 1979-2013
JRA55 — 1979-2013
MERRA — 1979-2013
NCEP2 — 1979-2013

ϕ_e trend (degrees/decade) averaged for 340 K, 350 K and 360 K. Positive trends: northward displacement; negative trends: southward displacements

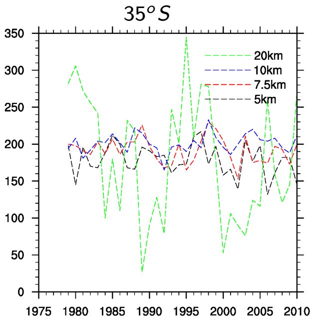
	WACCM	WACCM-UTLS	ERA-Interim	MERRA	NCEP2	JRA-55
-6.0	$-0,27 \pm 0,11$	**-0.04**$\pm$0,17	**-0.17**$\pm$0,14	**0.02**$\pm$0,13	**0.72**$\pm$0,12	**0.06**$\pm$0,16
-5.0	$-0,27 \pm 0,09$	**0.00**$\pm$0,17	**0.08**$\pm$0,11	**0.14**$\pm$0,10	**0.66**$\pm$0,10	**0.15**$\pm$0,11
-4.0	$-0,24 \pm 0,08$	**0.05**$\pm$0,18	**-0.04**$\pm$0,11	**-0.21**$\pm$0,07	**-0.04**$\pm$0,05	**-0.05**$\pm$0,06
-3.5	$-0,23 \pm 0,08$	**0.06**$\pm$0,18	**0.19**$\pm$0,16	**0.09**$\pm$0,08	**0.87**$\pm$0,11	**0.15**$\pm$0,11
-3.0	$-0,21 \pm 0,09$	**0.05**$\pm$0,17	**-0.04**$\pm$0,08	**0.00**$\pm$0,04	**-0.84**$\pm$0,10	**-0.19**$\pm$0,08
-2.0	$-0,24 \pm 0,10$	**-0.01**$\pm$0,18	**0.00**$\pm$0,08	**0.06**$\pm$0,05	**-0.41**$\pm$0,08	**-0.05**$\pm$0,09
-1.6	$-0,29 \pm 0,12$	**-0.08**$\pm$0,21	**0.04**$\pm$0,10	**0.16**$\pm$0,07	**-0.16**$\pm$0,08	**0.05**$\pm$0,09
1.6	$0,38 \pm 0,13$	**0.25**$\pm$0,17	**0.41**$\pm$0,12	**0.45**$\pm$0,12	**-0.01**$\pm$0,09	**0.23**$\pm$0,09
2.0	$0,31 \pm 0,11$	**0.23**$\pm$0,15	**-0.27**$\pm$0,15	**0.05**$\pm$0,14	**0.76**$\pm$0,12	**0.00**$\pm$0,14
3.0	$0,19 \pm 0,09$	**0.13**$\pm$0,11	**0.13**$\pm$0,09	**0.02**$\pm$0,09	**0.47**$\pm$0,10	**0.10**$\pm$0,09
3.5	$0,15 \pm 0,08$	**0.10**$\pm$0,10	**-0.43**$\pm$0,15	**-0.27**$\pm$0,09	**0.10**$\pm$0,07	**-0.20**$\pm$0,10
4.0	$0,12 \pm 0,08$	**0.06**$\pm$0,09	**-0.04**$\pm$0,13	**0.01**$\pm$0,08	**0.59**$\pm$0,07	**-0.02**$\pm$0,07
5.0	$0,17 \pm 0,09$	**0.03**$\pm$0,10	**-0.10**$\pm$0,06	**0.03**$\pm$0,04	**-0.60**$\pm$0,08	**-0.17**$\pm$0,06
6.0	$0,23 \pm 0,12$	**0.05**$\pm$0,12	**0.04**$\pm$0,08	**0.17**$\pm$0,05	**-0.19**$\pm$0,07	**0.02**$\pm$0,07

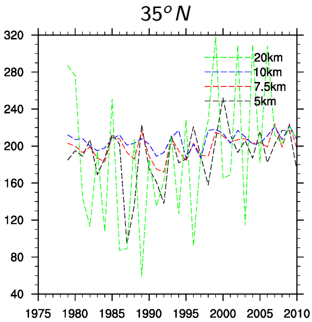

-3 PVU
3 PVU
θ (K)
420
410
400
390
380
370
360
350
340
ERA-Interim
JRA-55
MERRA
NCEP2
WACCM
WACCM-UTLS
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
ϕe trend (degrees/decade)

WACCM REFB2

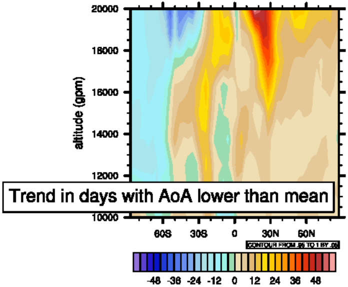

-3.5 PVU
420
400
390
380
370
360
350
340
θ (K)
WACCM REFB2
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
ϕe trend (degrees/decade)
3.5 PVU
420
400
390
380
370
360
350
340
θ (K)
WACCM REFB2
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
ϕe trend (degrees/decade)

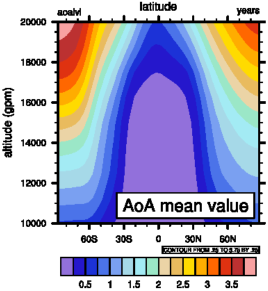
Number of days with AoA < mean value for 1979-2009. Source: CMAM

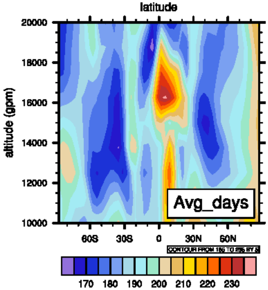




Period: 1979-2009. Source: CMAM







Conclusions

- WACCM gives a clear poleward signal of the movement of the PV field
- Reanalysis give contradictory signals in several cases, but mostly agree for the isentropic levels closer to the tropopause
- The competing phenomena of tropopause rising vs broadening is clear.
- At UTLS levels the latitudinal gradient of AoA seems clear and average days under the mean could be an useful fingerprint