Shape and Chemical Diagnostics of the Polar Vortices in WACCM

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Why do we care about the vortex?

- Lower vortex coupled to troposphere.
- Ozone hole in the Antarctic.
- Need vortex area to compute flux of NO_x responsible for O_3 loss.
- Knowledge of the jet is important for GW studies. GW generation and filtering.
- Instrument sampling and data separation
- CEDAR - Ionospheric disturbances during SSWs. The mesospheric vortex is likely a link between the two.
- S-RIP: Use as a diagnostic to compare reanalyses at the top levels. Compare MERRA and WACCM as first step.

Outline

- How does the mesospheric polar vortex differ in MERRA and WACCM?

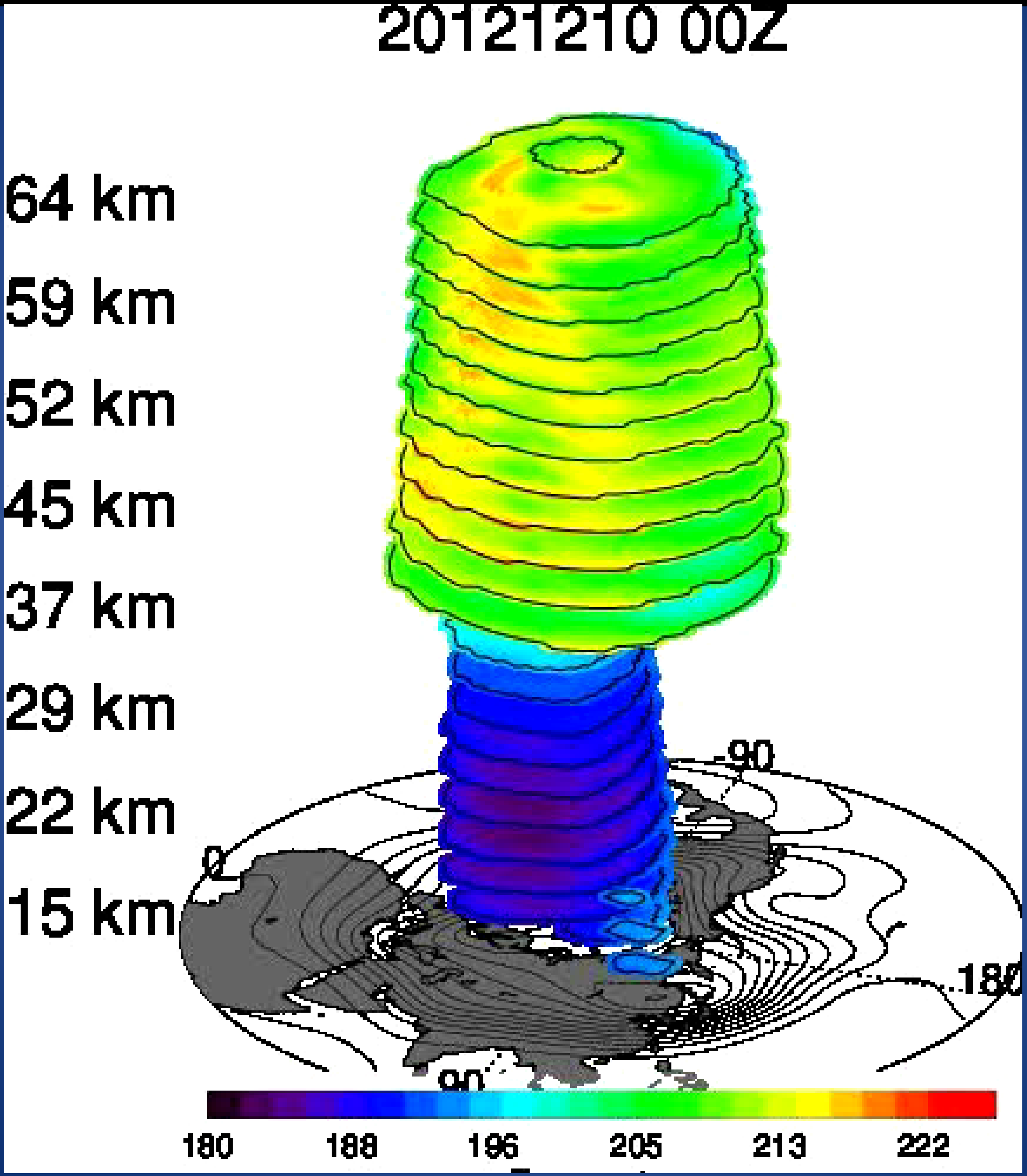
- Specified Dynamics WACCM nudged by MERRA to 50 km. Nudging linearly decreased to zero at 60 km.
- Vortex Area, Centroid, Ellipticity, # lobes (PWB, splits)
- Arctic
- 35-year climatologies
- Compare to vortex based on MLS.
- Differences in PWs and zonal winds.
- Mesospheric chemical definition of vortex air

Methodology - Vortex Shape Diagnostics

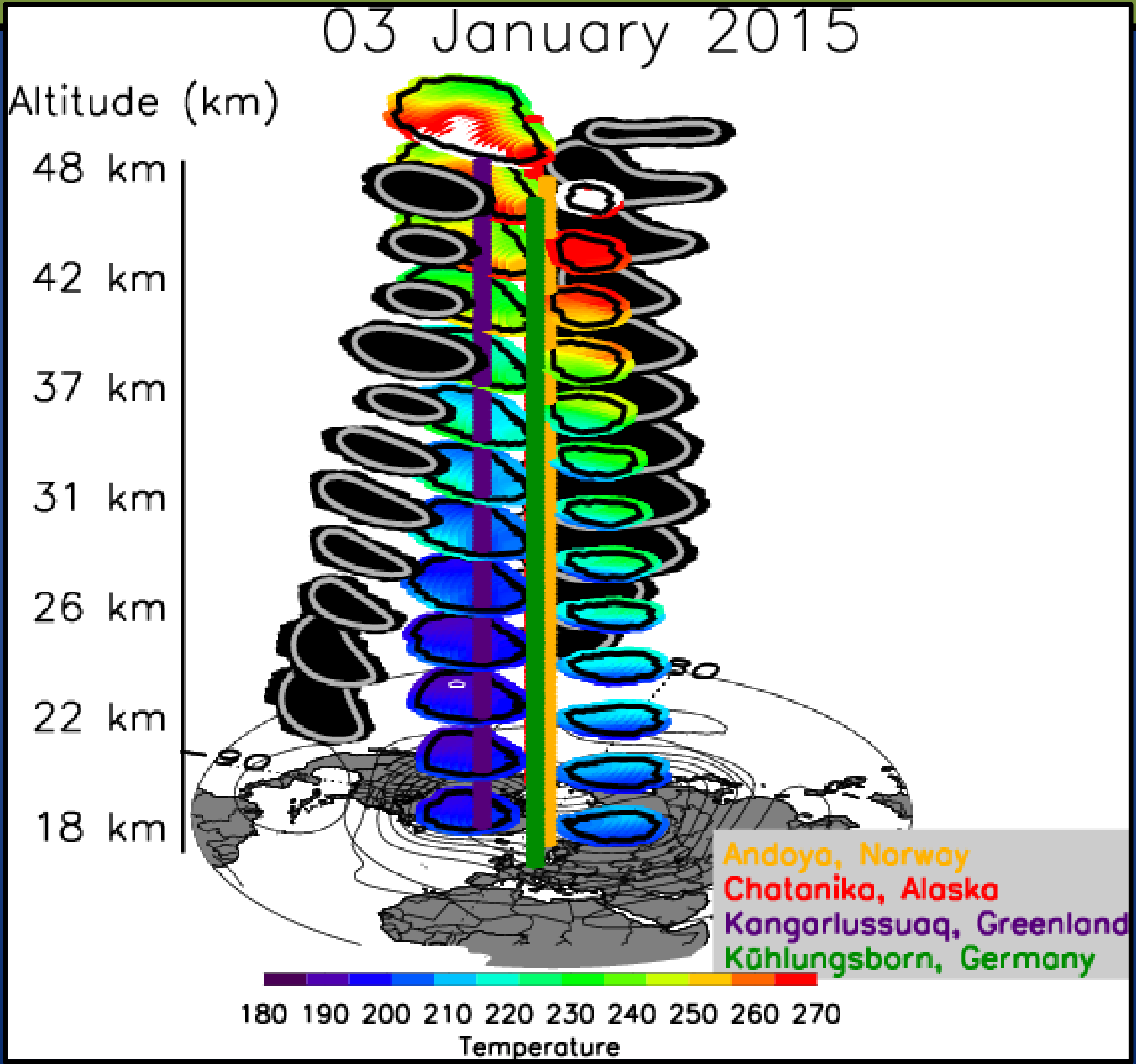
- 35 years of MERRA and SD-WACCM
- On each day define a vortex center-of-mass at each altitude.
- How does the vortex tilt in longitude and latitude?
- What is the vertical profile of vortex area and ellipticity?
- Keep track multiple lobes due to vortex splitting and PWB.
- Compare vortex properties in WACCM, MERRA, and MLS 2004-2014.

Representative day

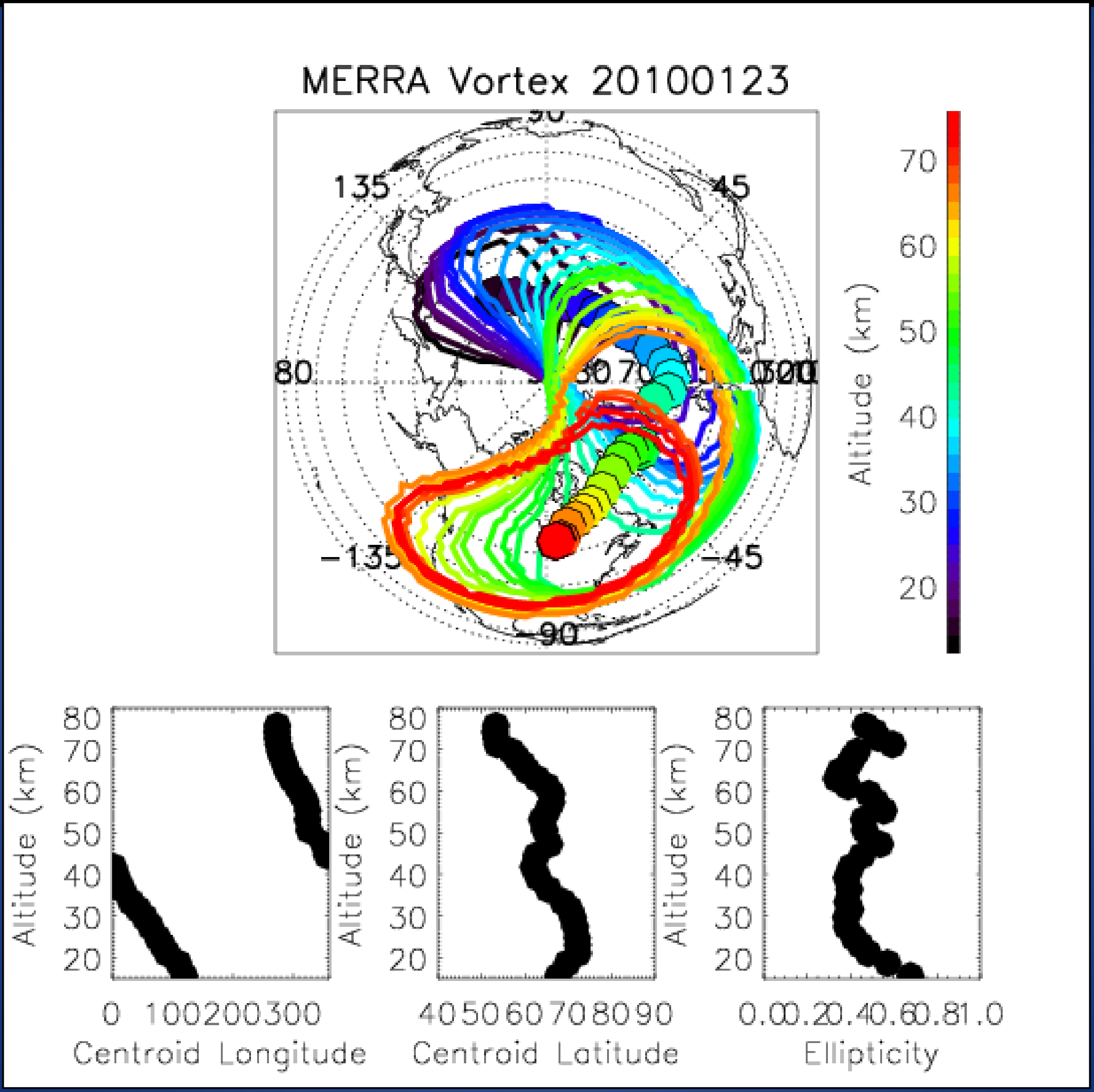
2012-2013 Arctic Vortex



Arctic Vortex Split 1-6 Jan 2015



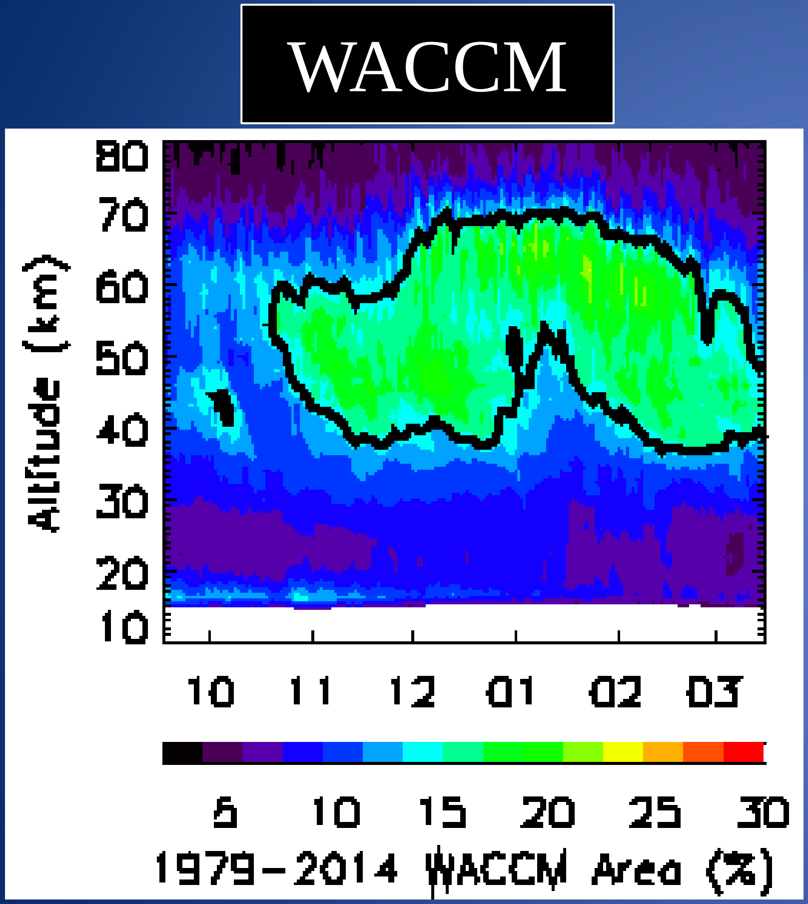
Daily Vortex Structure

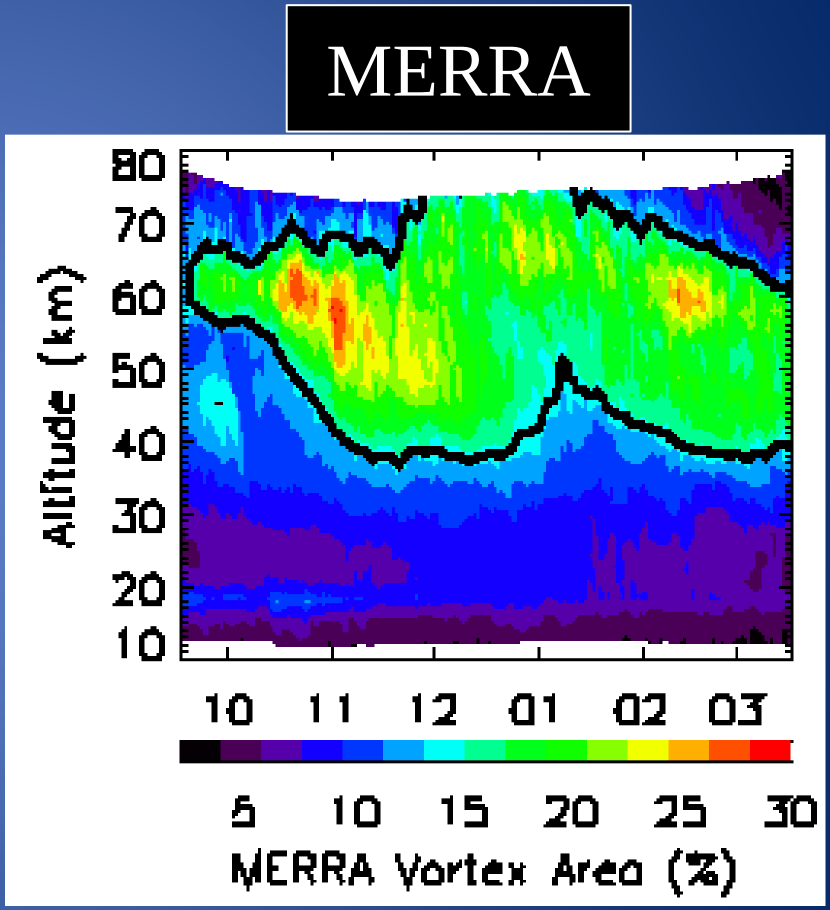


Daily profiles are contoured in time

Time-altitude sections of area

35-Year Mean Vortex Area





Altitude-time sections of vortex area for 1979-2014. 15% contour.

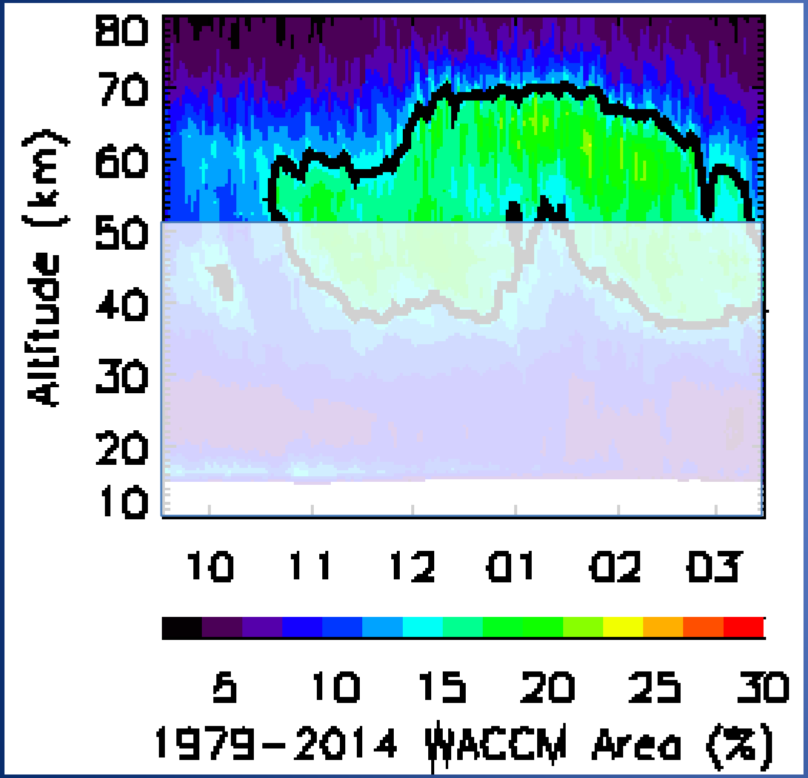
WACCM CCMI REFC1SD simulation [*Eyring et al*., 2013] nudged by MERRA to 50 km.

GWs as in Garcia et al. [2013].

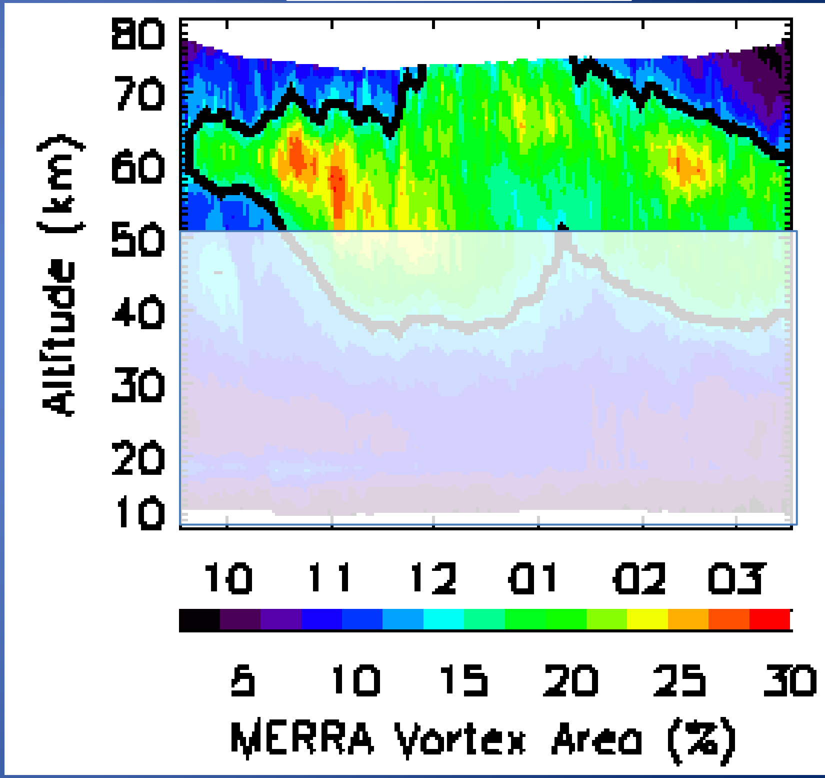
Vortex broadens with increasing altitude. Jan “bite” due to PWs.

Mesospheric vortex smaller in WACCM

WACCM



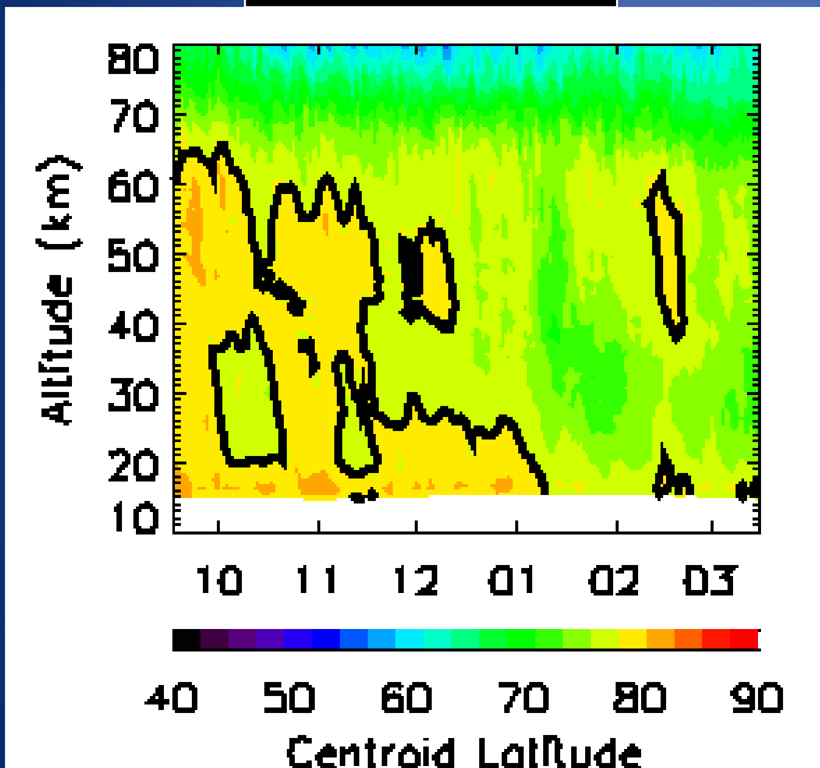
MERRA



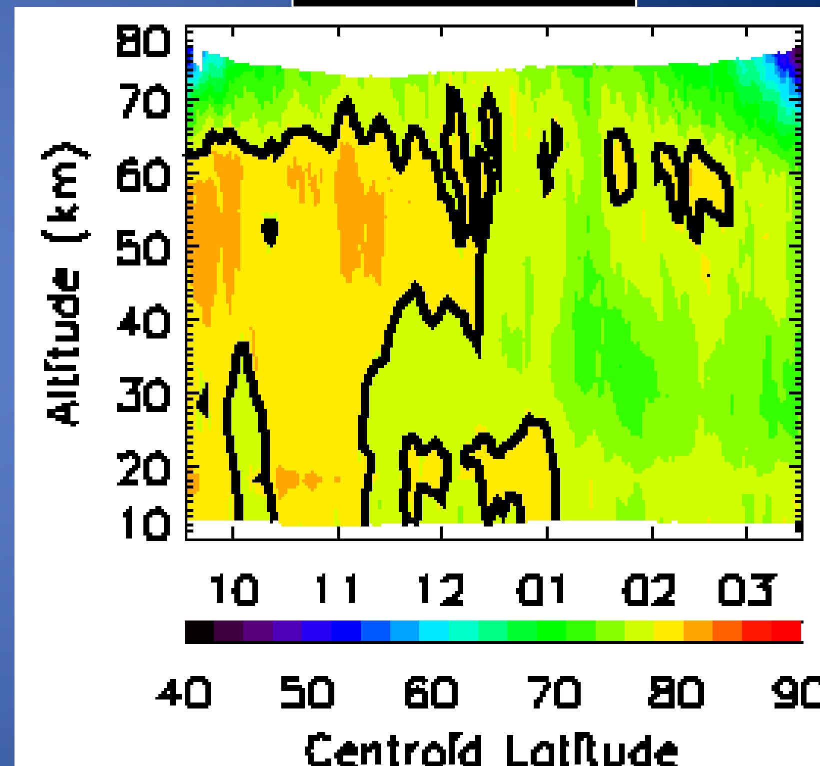
Centroid Latitude

35-Year Mean Centroid Latitude

WACCM



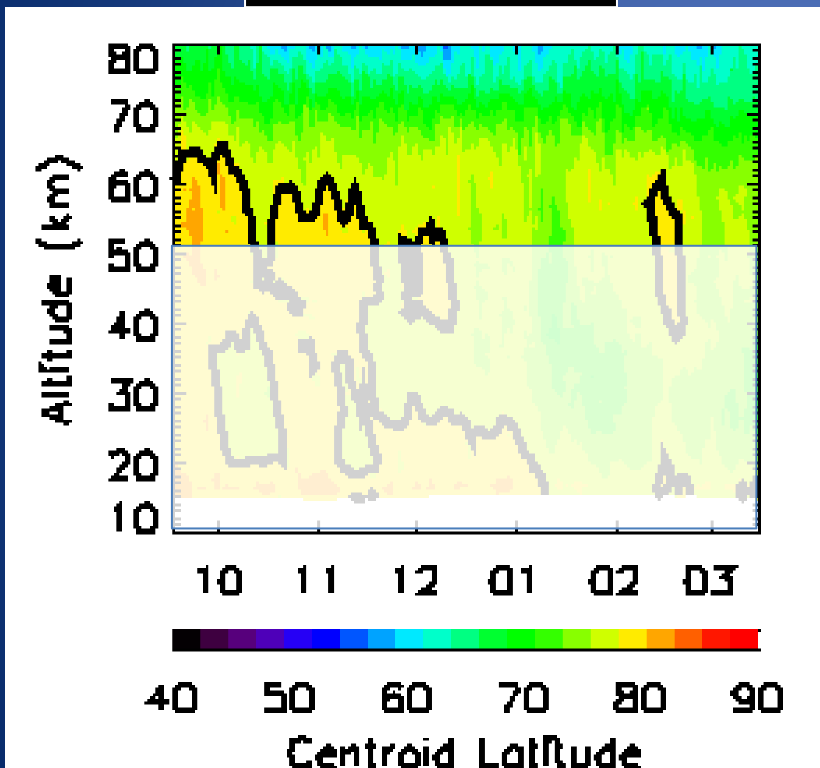
MERRA



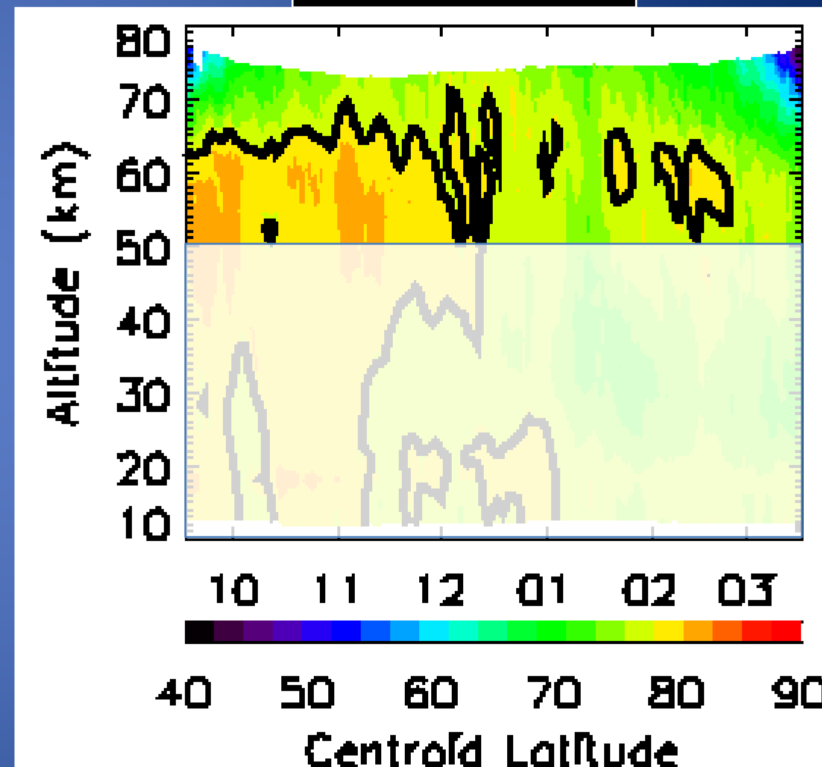
Altitude-time sections of vortex centroid latitude for 1979-2014. 80N contour. Pole centered in fall. Displaced in mid-December.

Mesospheric vortex center at lower latitudes in WACCM

WACCM

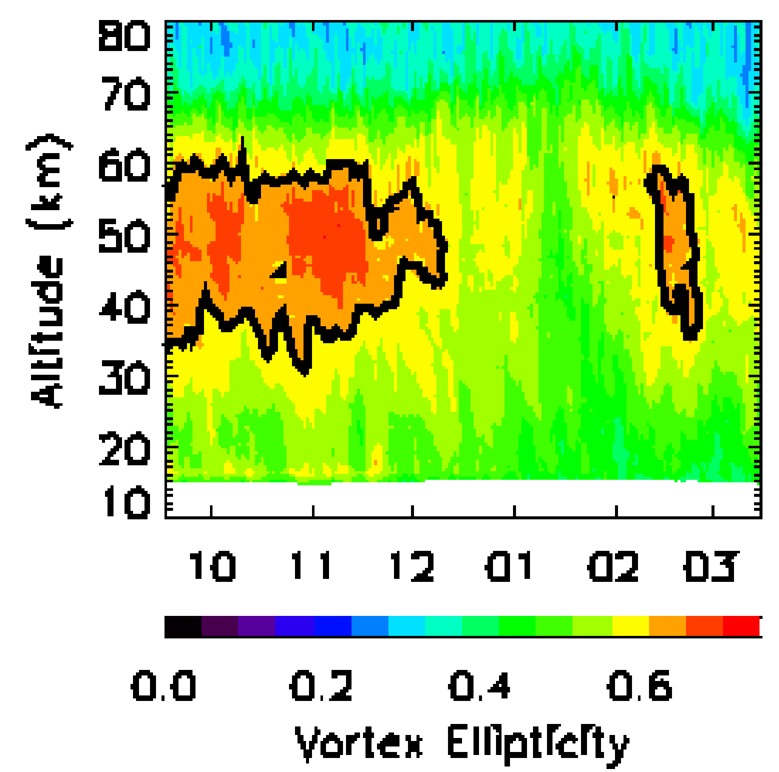


MERRA

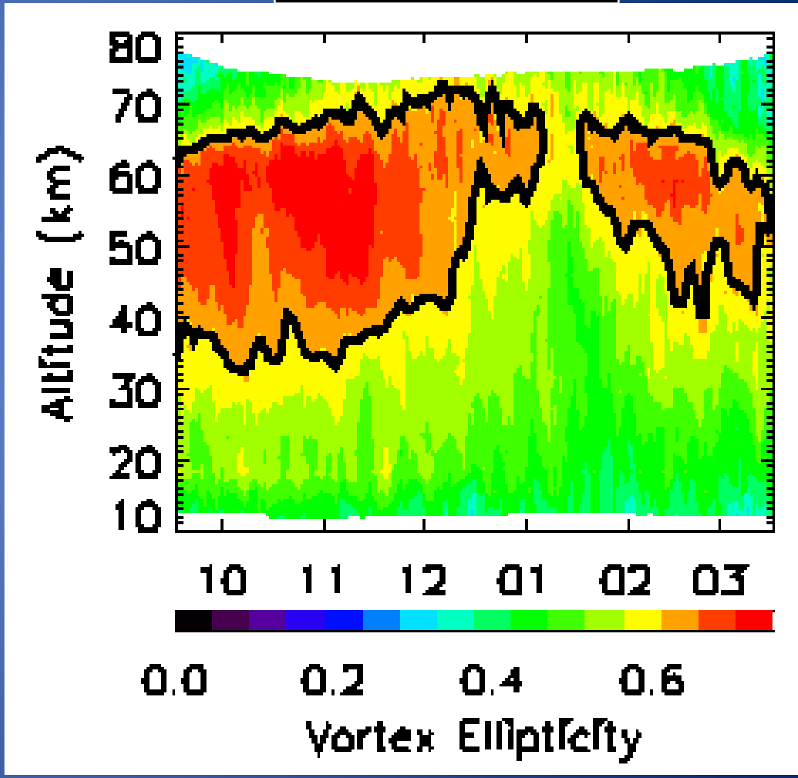


35-Year Mean Vortex Ellipticity

WACCM

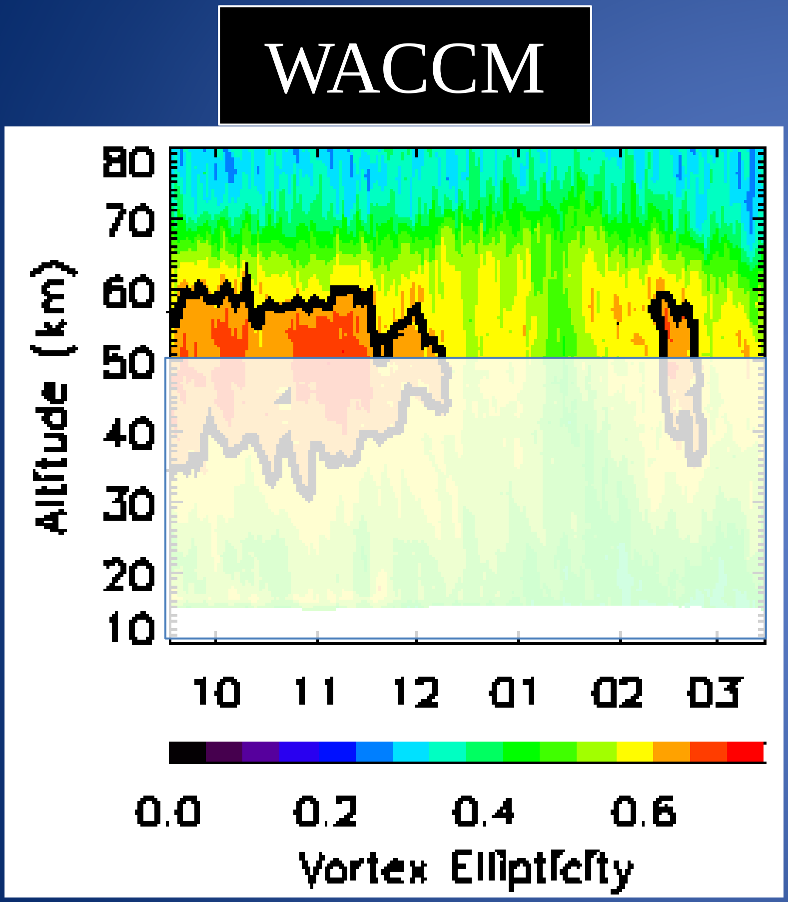


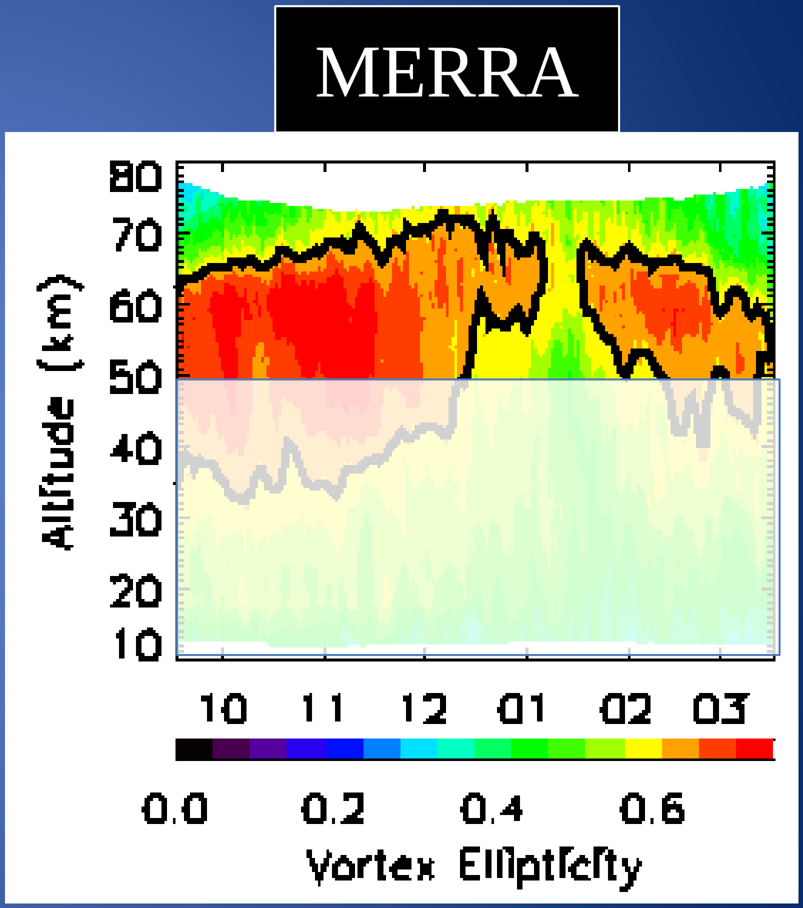
MERRA



Altitude-time sections of vortex ellipticity for 1979-2014. 0.6 contour.
More circular shape with increasing altitude. Jan PWs decrease ellipticity.

Mesospheric vortex more elongated in WACCM



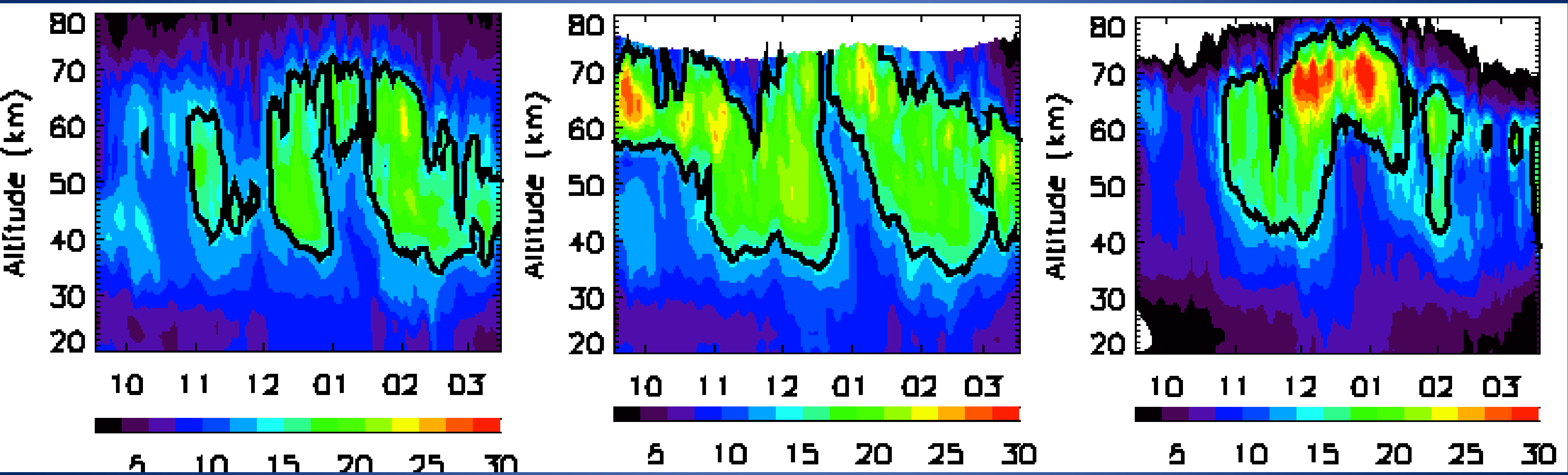


No obs assimilated at high altitudes in MERRA and WACCM is free running.
Where does this leave us? Which is right?

Vortex based on MLS

10-year Area WACCM, MERRA, MLS

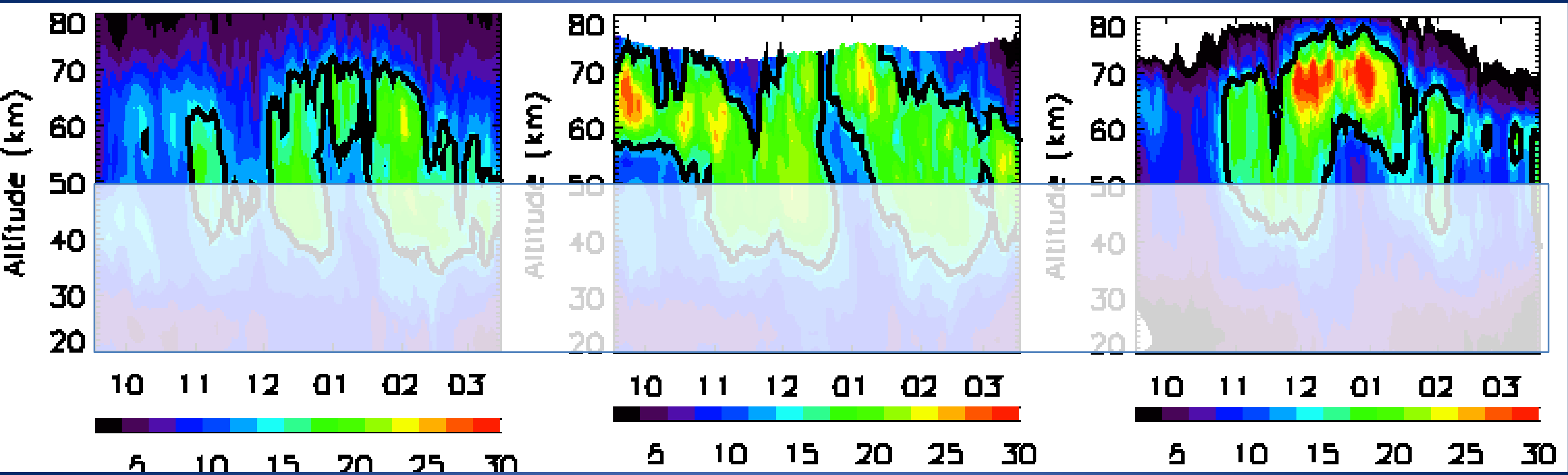
WACCM MERRA MLS



Altitude-time sections of vortex area for 2004-2014 to compare to MLS. 15% contour.
MLS geostrophic winds and vortex demarcation as in WACCM and MERRA.
“Bite out” in Jan area due to SSWs in 2006, 2009, 2010, 2012, 2013.
Extremely large in the mesosphere prior to and during SSWs.

Mesospheric vortex smallest in WACCM

WACCM MERRA MLS



Why?

Why? PWs?

A climatology of planetary wave-driven mesospheric inversion layers in the extratropical winter

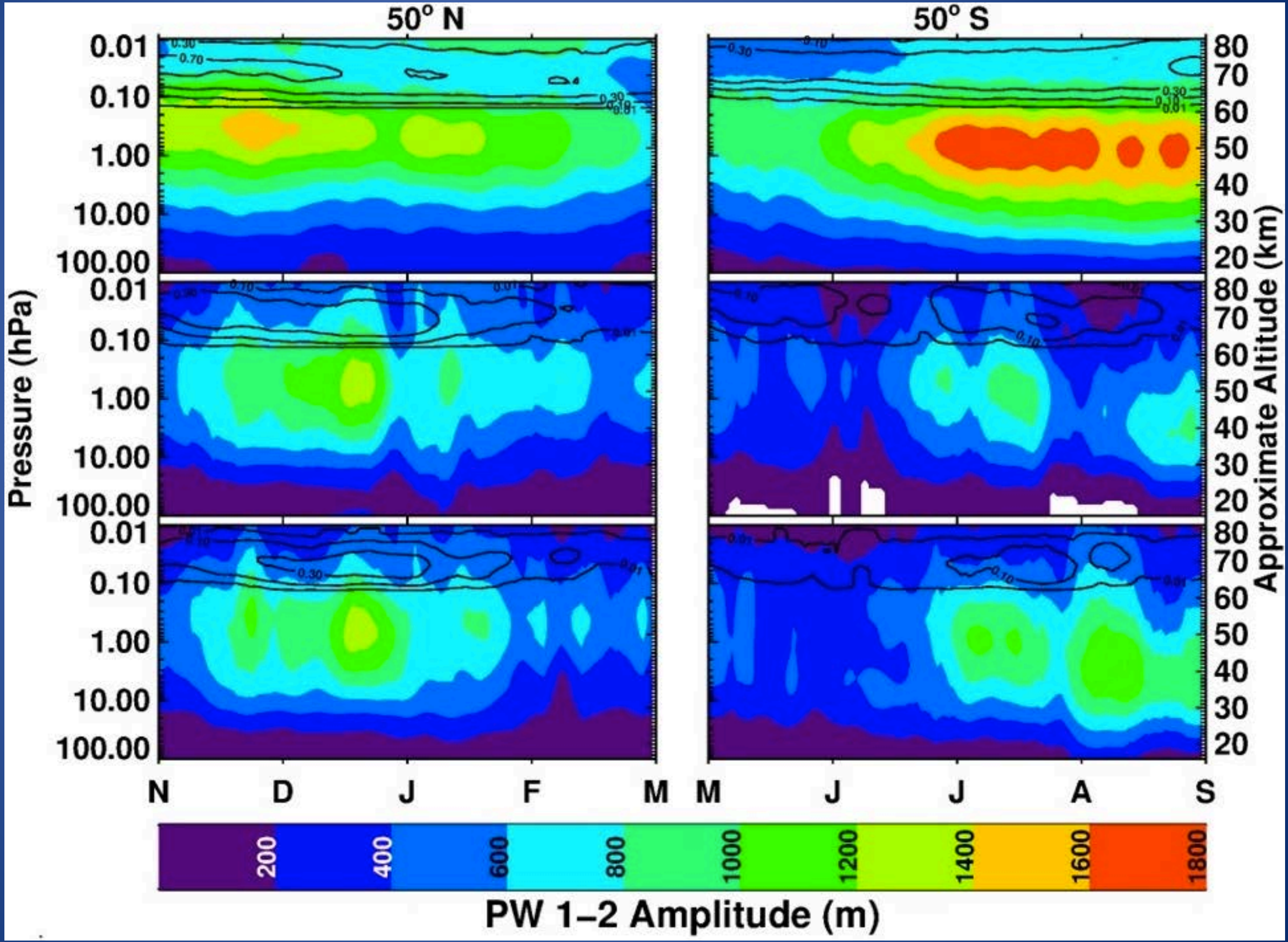
JGR, in press.

J. A. France[1], V. L. Harvey[1,2], C. E. Randall[1,2], R. L. Collins[3], A. K. Smith[4], E. Peck[1,2], and X. Fang[1]

WACCM

SABER

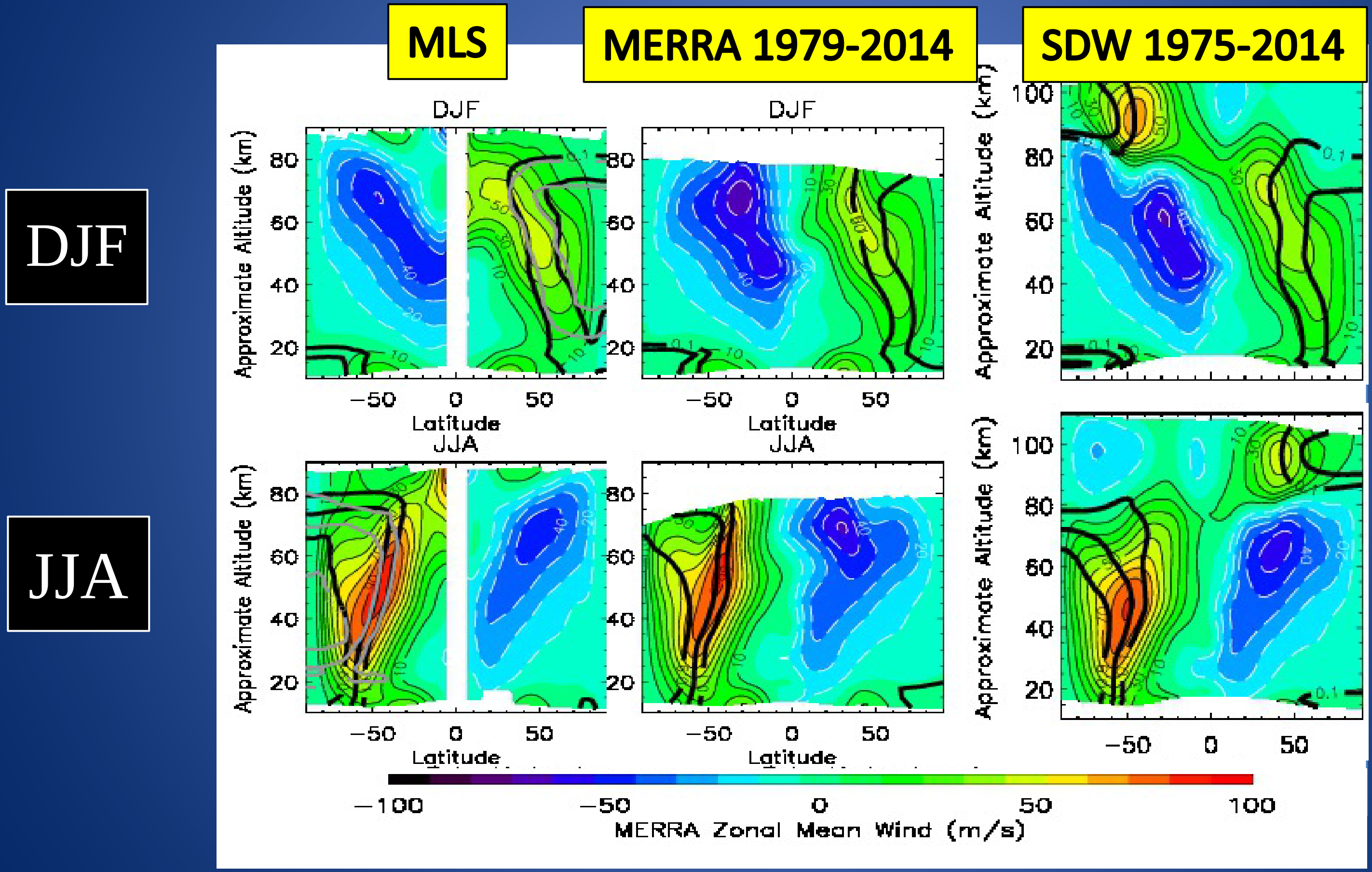
MLS



40 years of WACCM output, 12 years of SABER (2002–2014), and 10 years of MLS (2004–2014)

Larger PWs in WACCM result in smaller, displaced, elongated mesospheric vortex.

MLS stronger Arctic PNJ tilts further equatorward. Extends higher in SH.

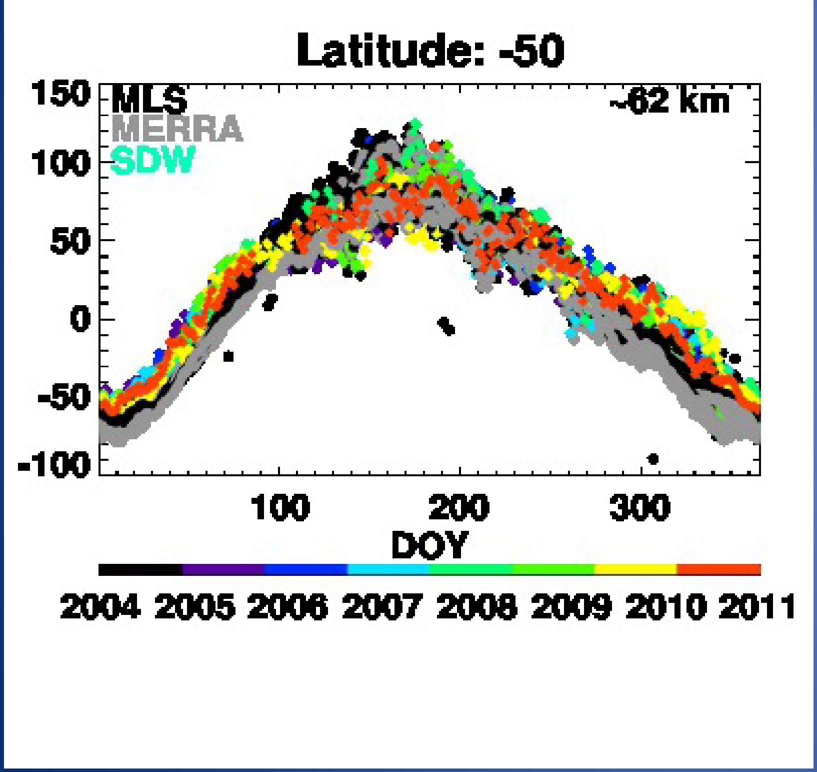


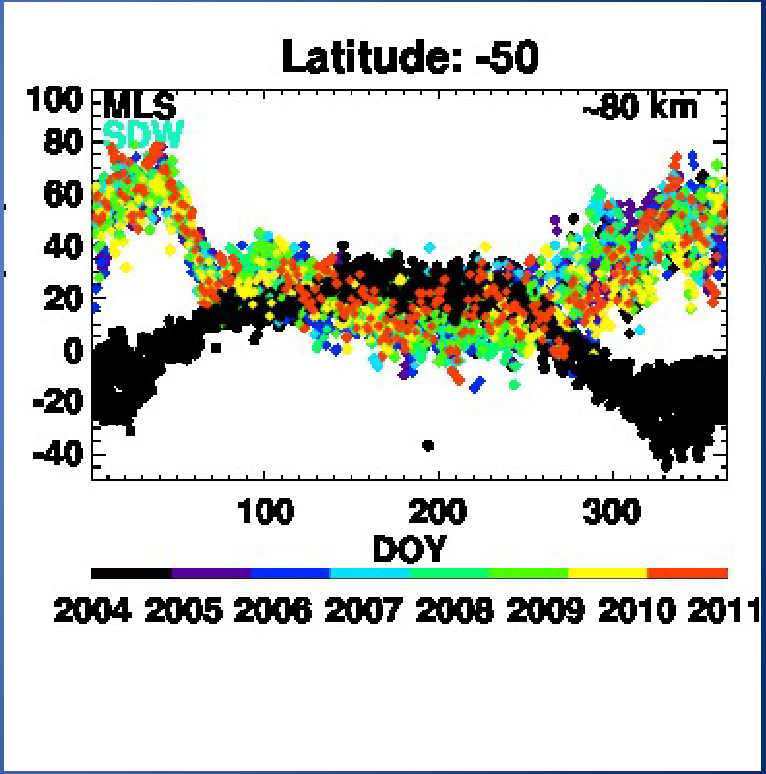
Closure of WACCM PNJ points to GWs

Differences in the mesospheric jets result in differences in the vortex.

Annual cycle at 50S 60 km, 80 km.

SH Ubar Annual Cycle at 60 km and 80 km



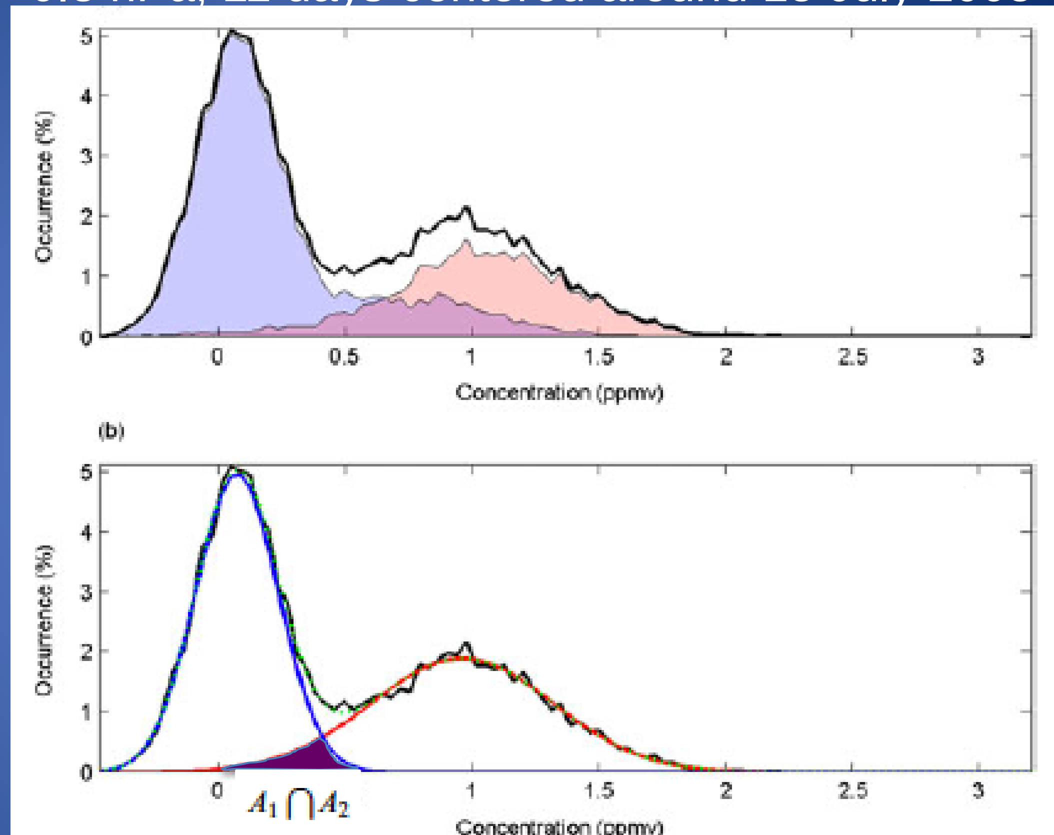


MLS extends the PNJ higher than WACCM.
Likely large differences in SH vortex.

A technique to identify vortex air using carbon monoxide observations

A. J. McDonald[1] and M. Smith[1] JGR, 2013.

0.3 hPa; 11 days centered around 15 July 2005



Black = SH CO PDF
Blue = 0-60ºS
Red = 60º-90ºS

"Simultaneous nonlinear least squares fitting of two Gaussian distributions to the hemispheric PDF"

Chemical Distinction: when intersection between the Gaussian fits is less than half the total area under the smaller Gaussian

Vortex Interior: when chemically distinct, CO > mean of A_2

$$d = \frac{A_1 \bigcap A_2}{\min(A_1, A_2)} < 0.5$$

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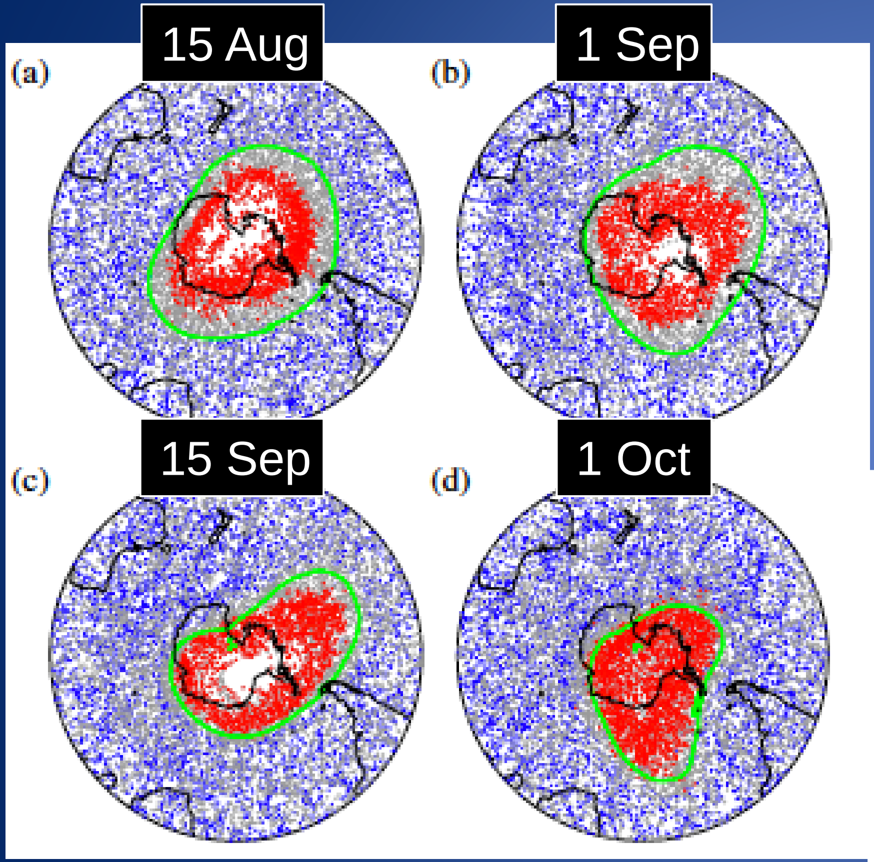


900 K; 2005; SH
Chemically Distinct
Red: Vortex Interior, trajectory mapped MLS +/- 5 days
Blue: CO < mean of A_1
: mean A_1 < CO < mean A_2
Green: Nash Vortex Edge

Table 1. Statistics Based on the Percentages of CO Observations With Concentrations Above the Mean of the High Concentration Gaussian Fit (CO_{thresh}), That Are Within the Vortex Edge as Defined By the *Nash et al.* [1996] Method[a]

Year	Isentropic Level	Mean (%)	Standard Deviation (%)	Lower Decile (%)	Upper Decile (%)
2005	700	99.7	0.4	98.9	100
2005	900	99.1	1.2	97.4	100
2005	1250	98.1	2.5	93.6	99.9
2009	700	98.6	0.5	98.0	99.5
2009	900	97.8	2.6	95.0	100
2009	1250	86.8	11.1	75.0	94.8
2010	700	98.3	2.5	93.4	99.9
2010	900	98.5	1.3	96.6	100
2010	1250	94.4	5.4	85.8	99.9

[a]These are calculated for each day within the AVP for which the chemical distinction is below 0.33. The mean and standard deviation of these percentages are shown here for a number of different years and isentropic levels. The percentage of CO observations above CO_{thresh} for the upper and lower deciles over these periods is also displayed.

d<0.33
AVP=18 July to 30 November as defined in *Huck et al. [2005]*

>95% of vortex interior points are inside the Nash vortex

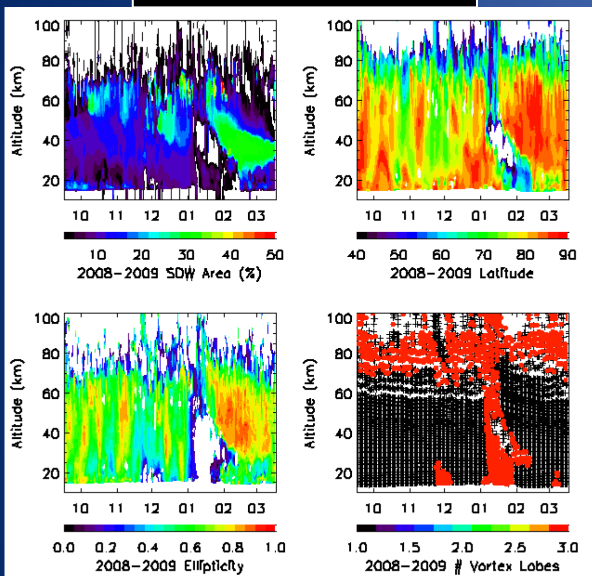
Summary

- SD-WACCM and MERRA vortex differences in the mesosphere
  - WACCM vortex is smaller, at lower latitudes, more elongated
- Vortex in MLS sanity check
- PWs larger in WACCM
- WACCM GWs close the PNJs too fast.
- Differences in the mesospheric jets lead to significant differences in the vortex.
- Chemical definition

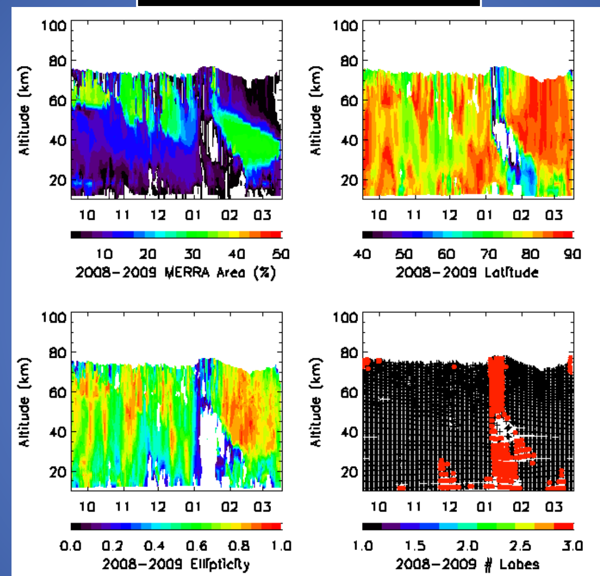
Thank You

2009 Arctic Vortex Split

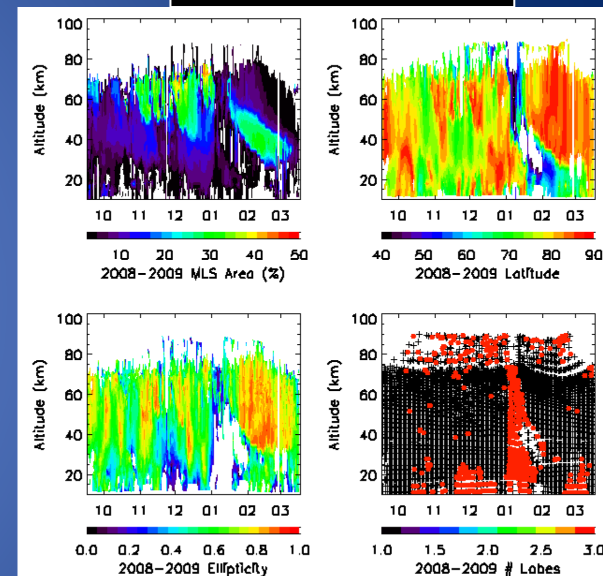
WACCM



MERRA



MLS



Low latitude center, elliptic, and small during SSW.
Pole centered, circular, and large during ES.
Multiple vortex lobes above ~80 km.