

Effects of Various Vertical Grids in CAM/WACCM

*Jadwiga (Yaga) Richter,
J. Bacmeister, C. Chen, L. Sun, C. Deser*

Motivation

I. Horizontal resolution of CAM/WACCM has increased, while vertical resolution has not:

2004: T42 ~ 300 km CAM3: **26** levels WACCM3: 66 levels

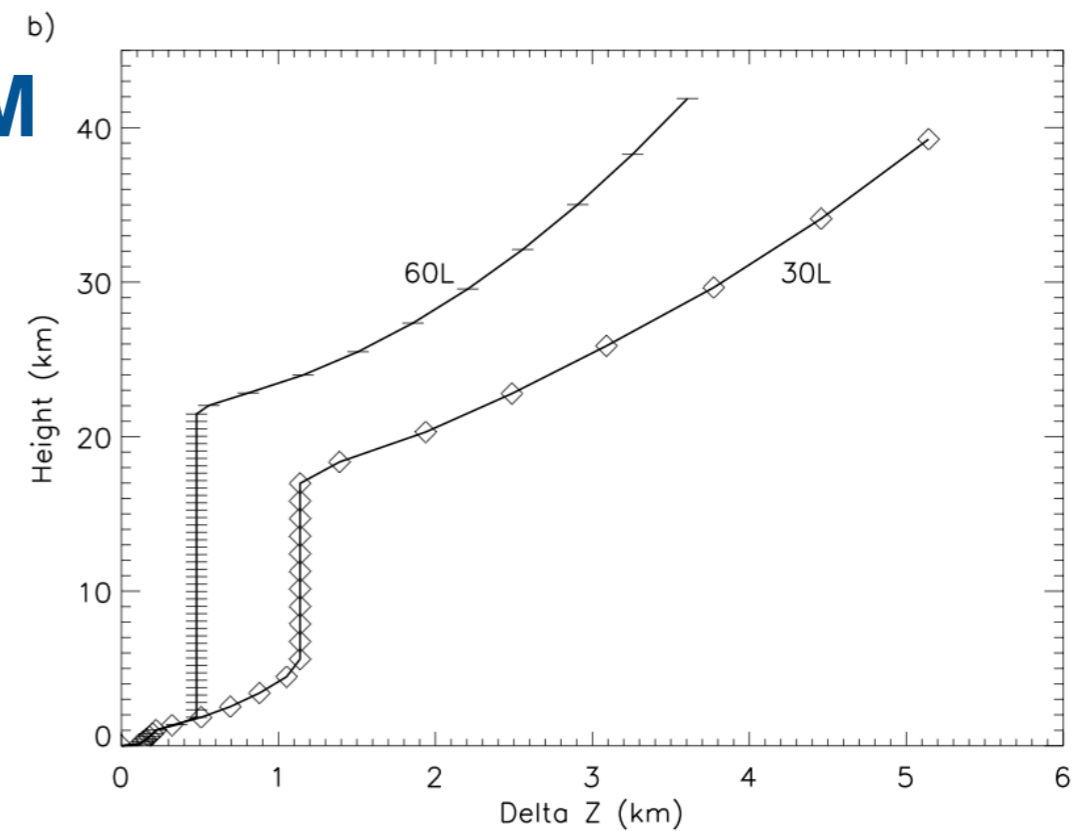
2014: 1° ~ 100 km CAM5: **30** levels WACCM5: 70 levels

II. Tropical Kelvin & Rossby-Gravity waves have wavelengths between 2 and 8 km

III. Last 20 years of middle atmospheric research have shown that the stratosphere is important to tropospheric climate

In 2013: 60L CAM

- **Doubled vertical resolution: 60L CAM**
(keeping model lid the same)
- Improved near-tropopause T biases
- Improved Kelvin & Mixed Rossby Gravity waves
- First internally generated QBO in CAM



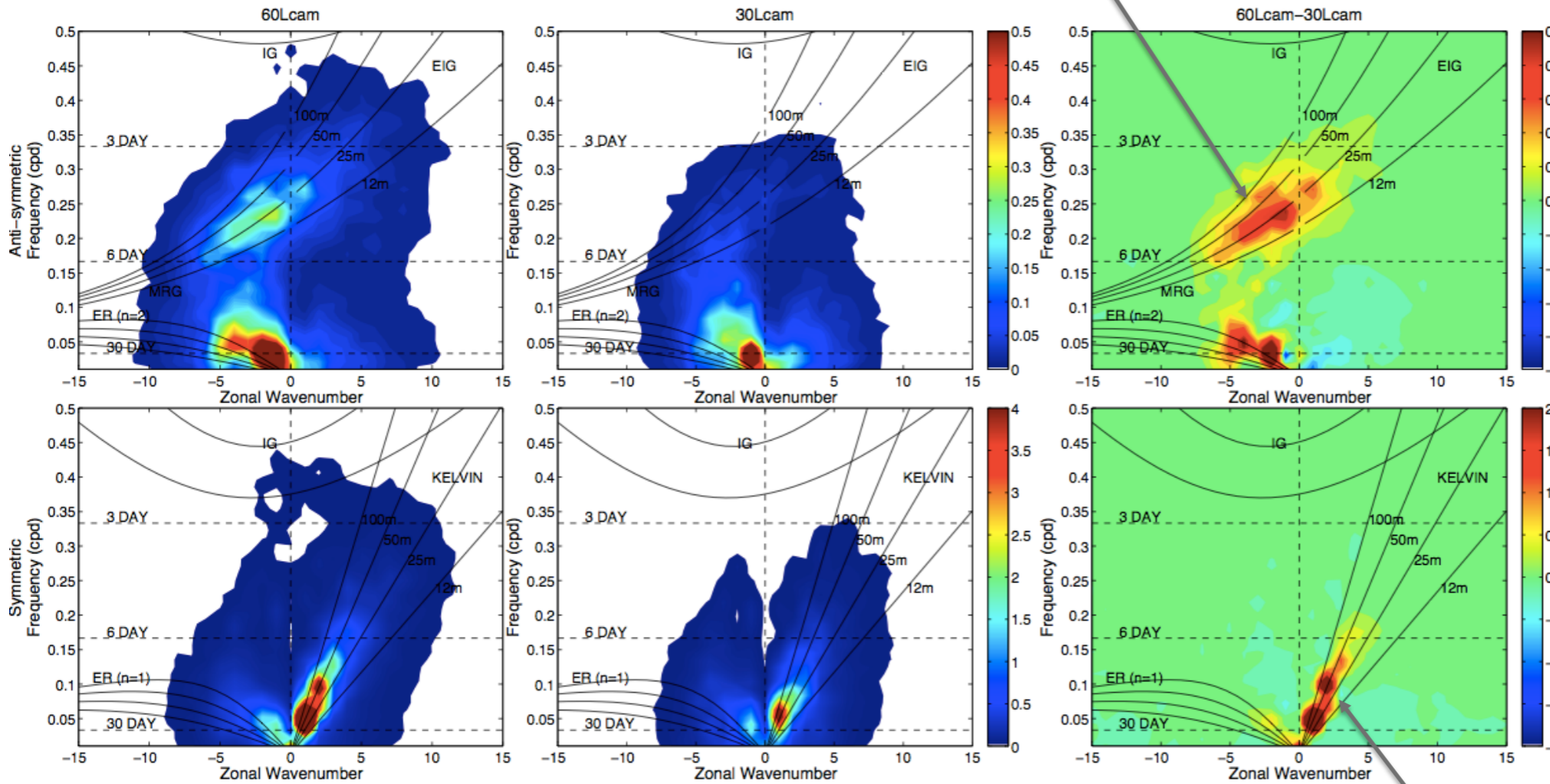
Wave Spectra:

MR-GWs

60L

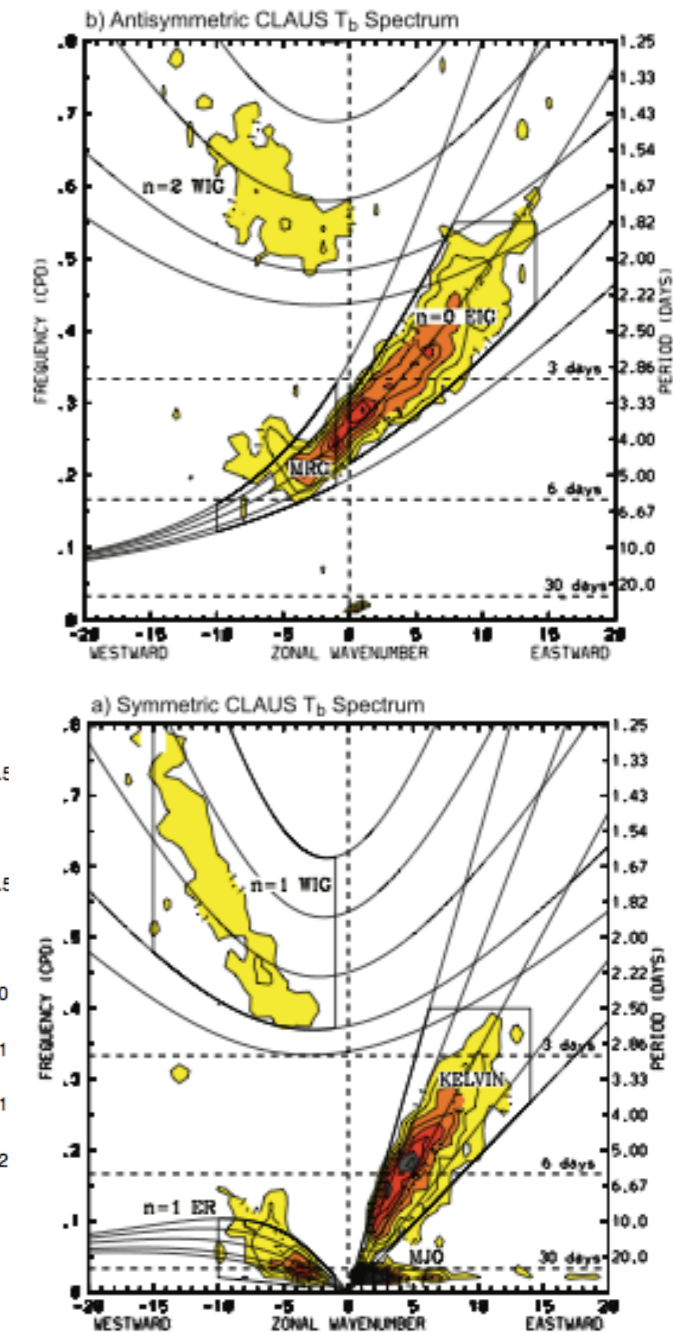
30L

60L - 30L



Richter et al. 2014, JGR

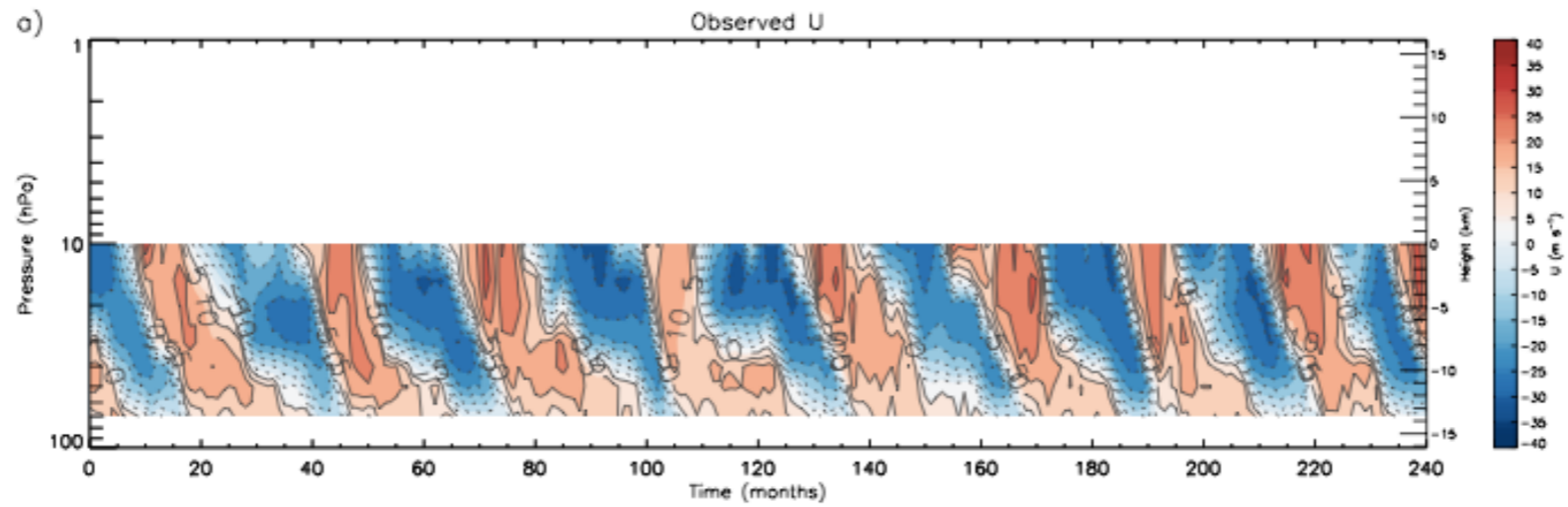
Kelvin Waves



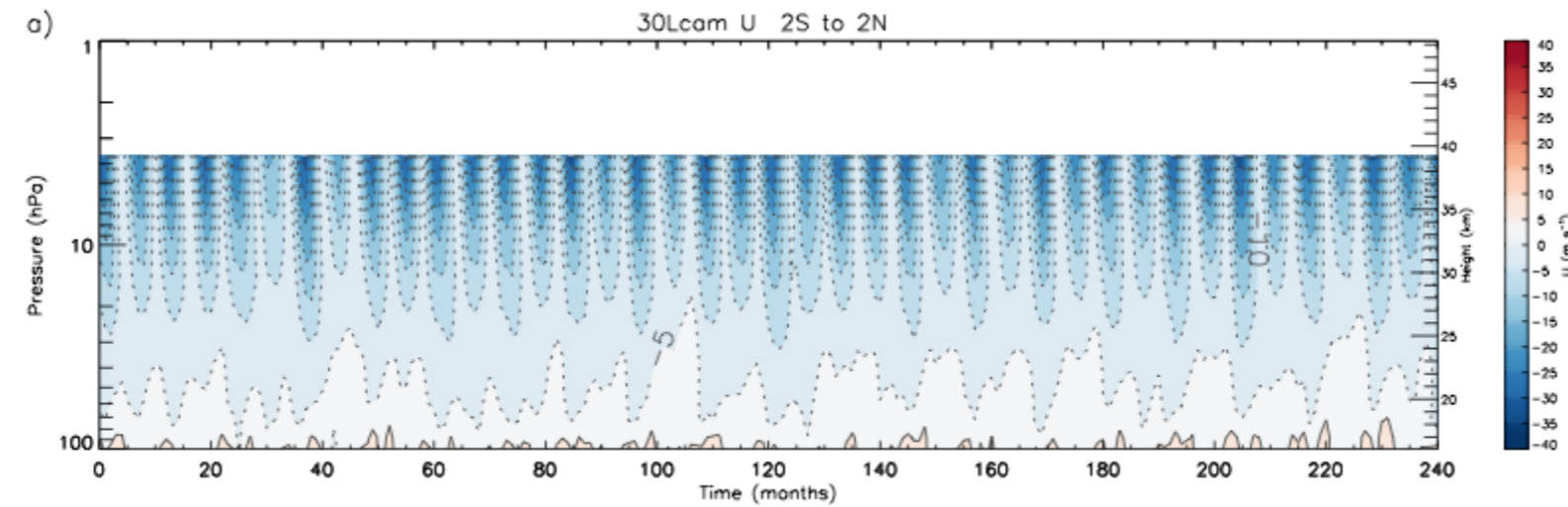
Kiladis et al. 2009

60L Tropical Winds

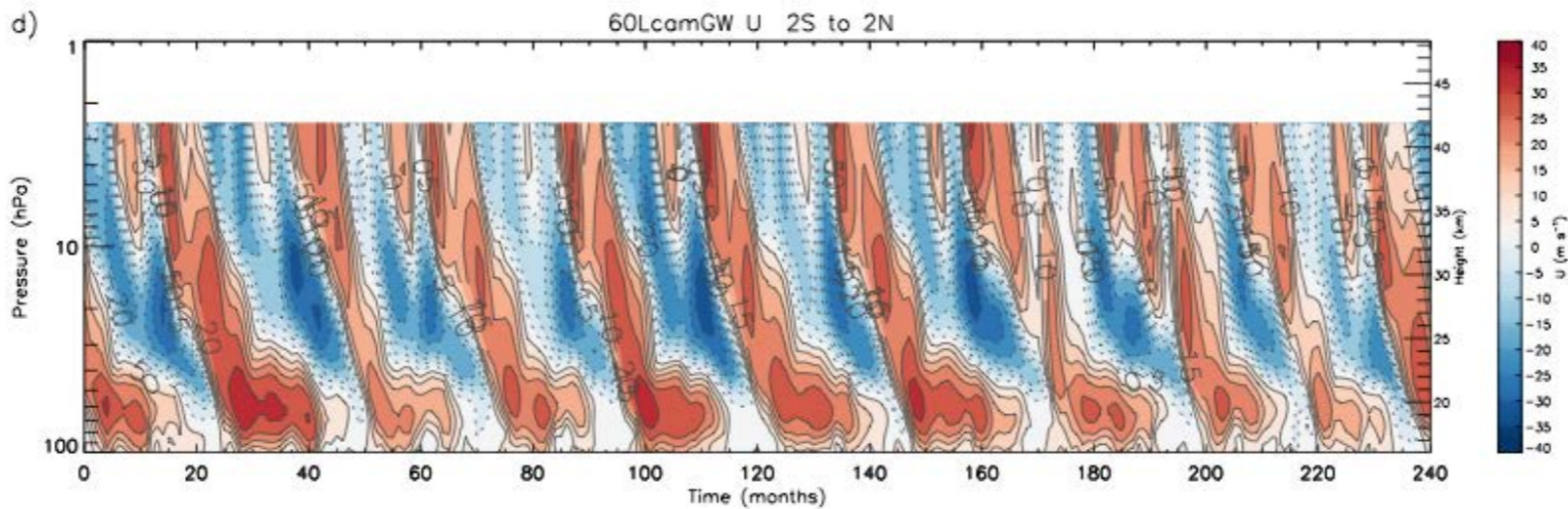
OBS



30L

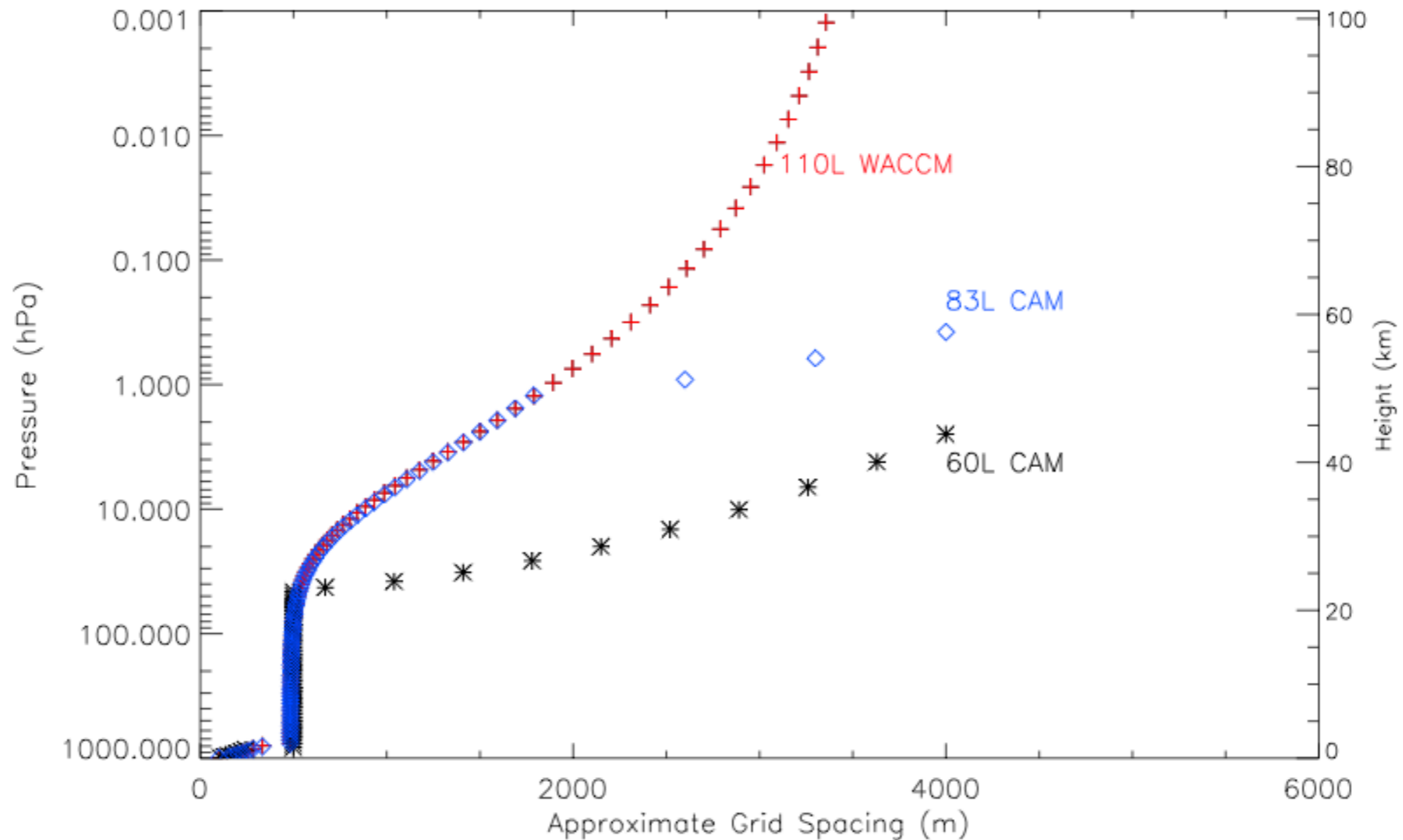


60L



Richter et al.
2014, JGR

60/83/110L Grids

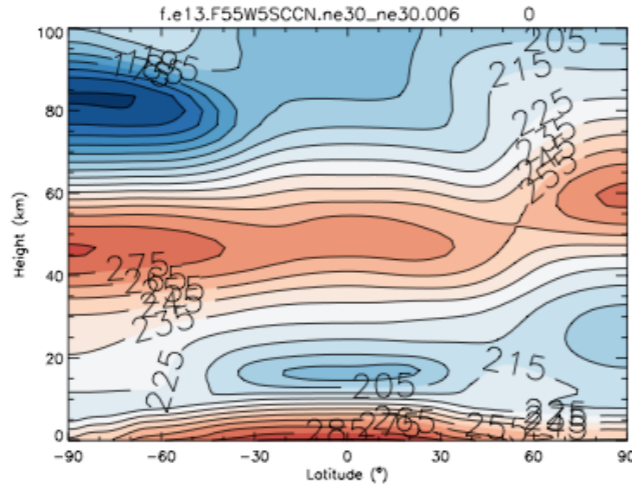


- 83L CAM: 1 50-yr AMIP run
- 110L WACCM: 12 yr AMIP run
- All SE ne30 runs (~ 1x)

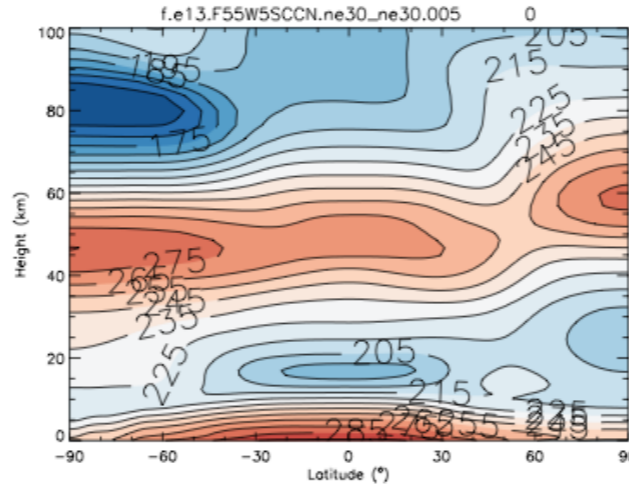
Mean T: 110 vs 70L WACCM

Jan

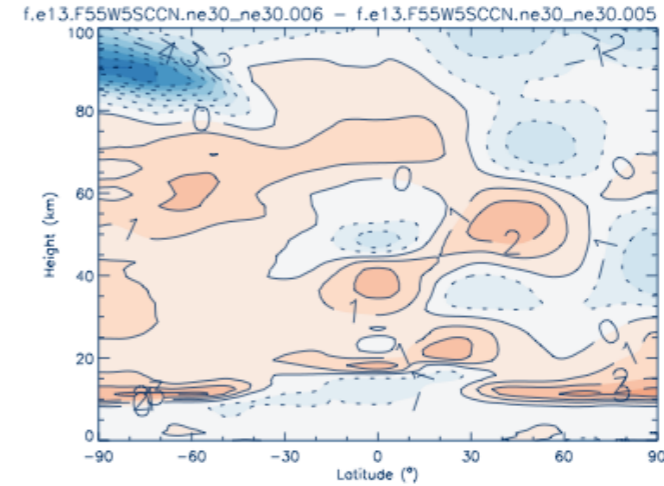
110L WACCM



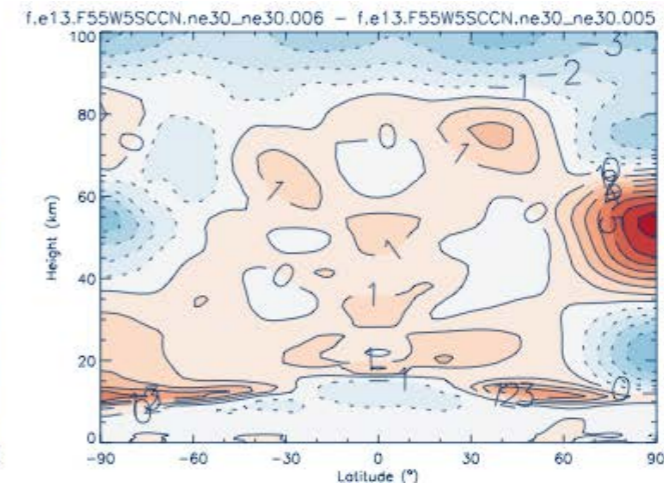
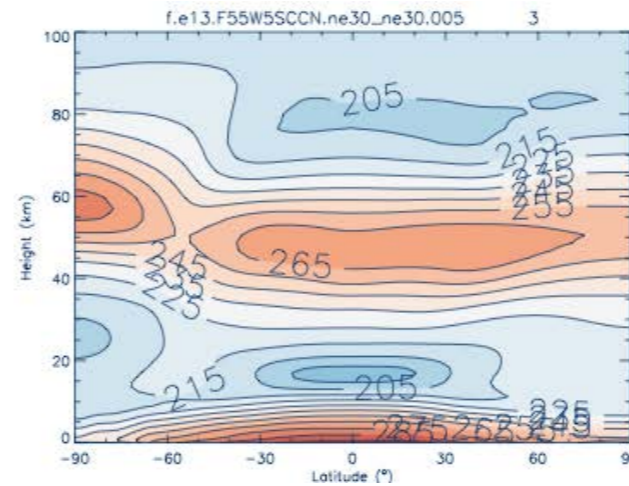
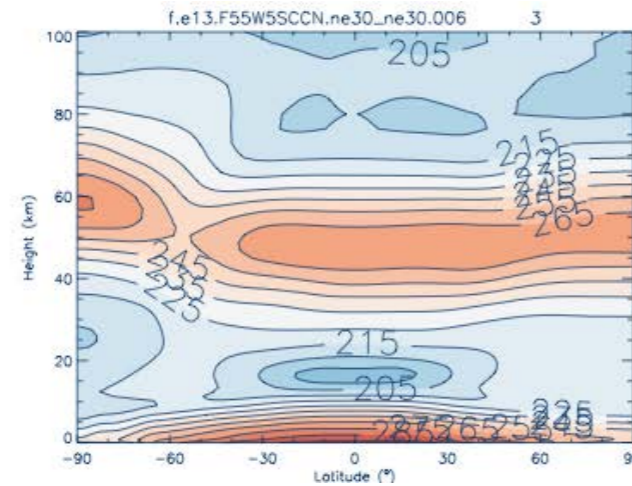
70L WACCM



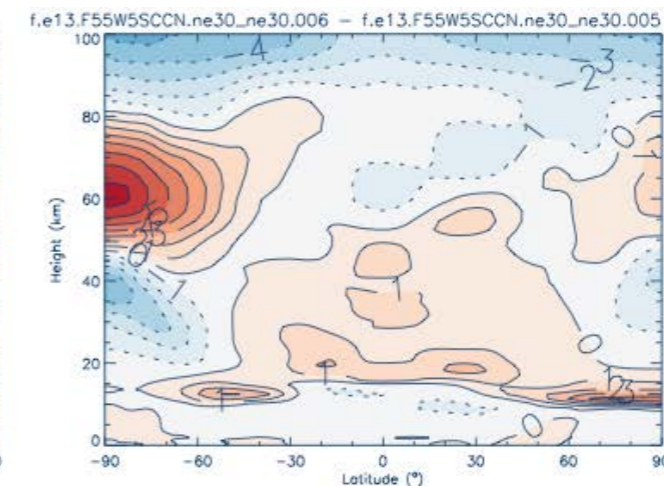
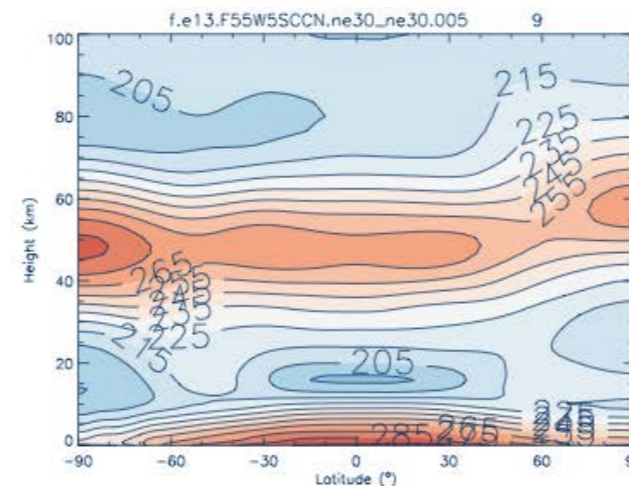
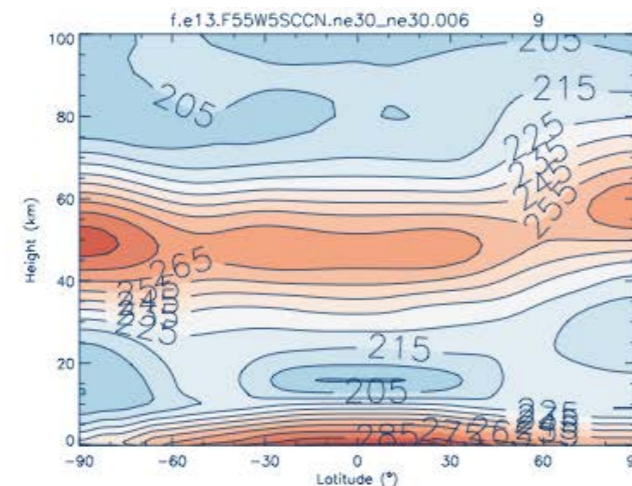
110 - 70L WACCM



Apr

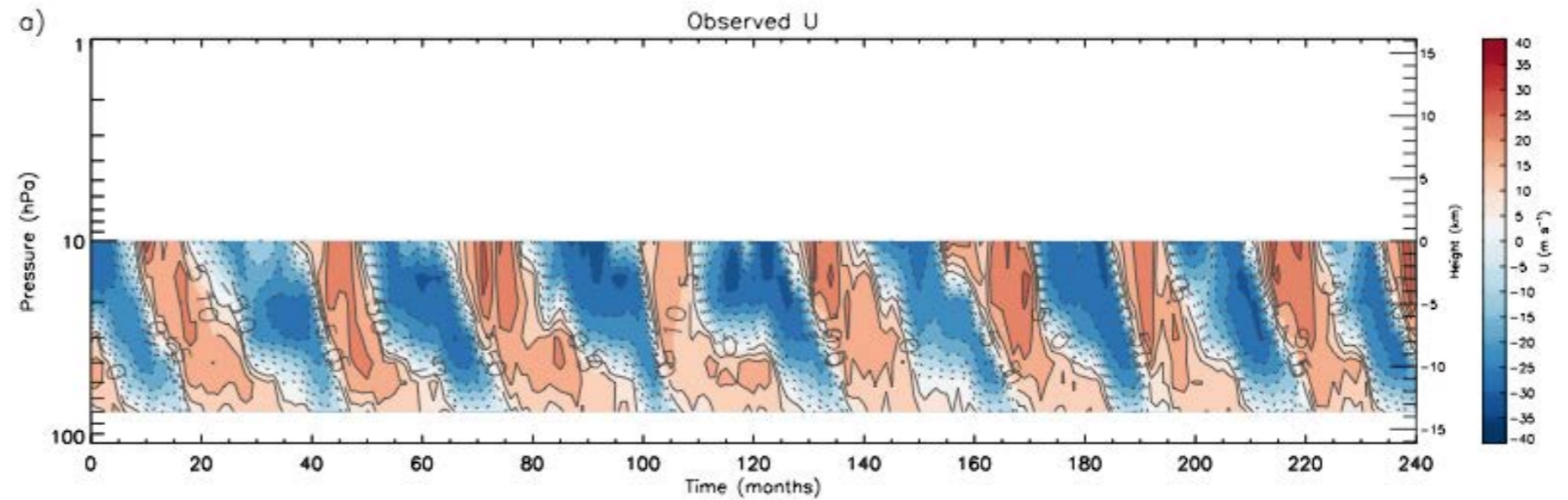


Oct

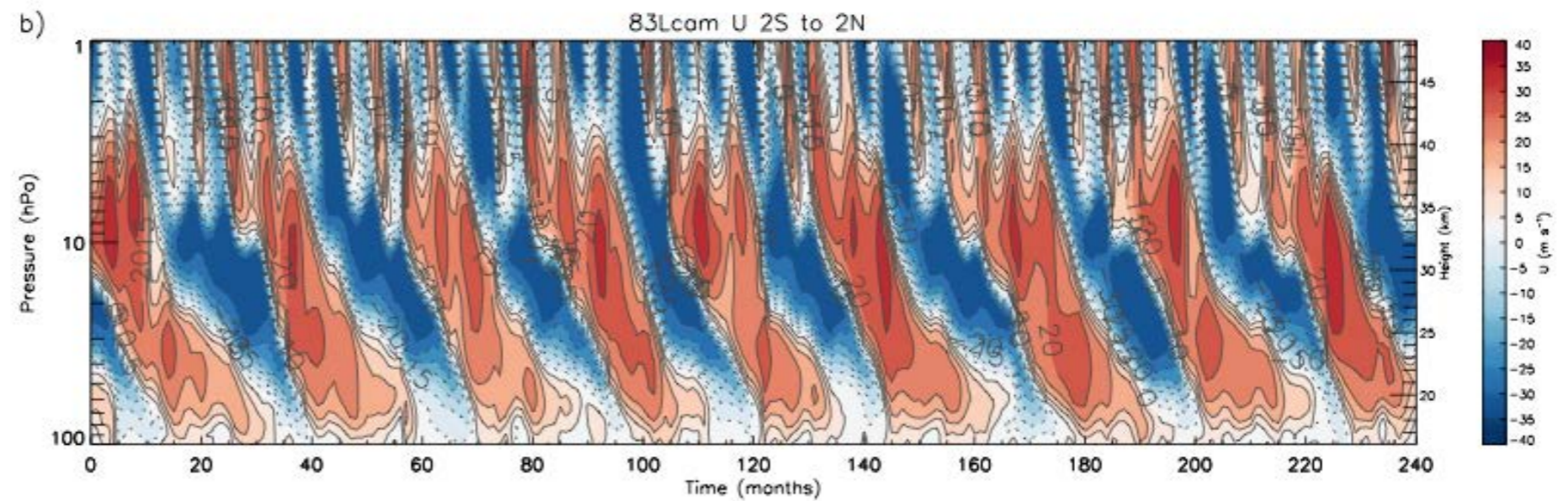


QBO

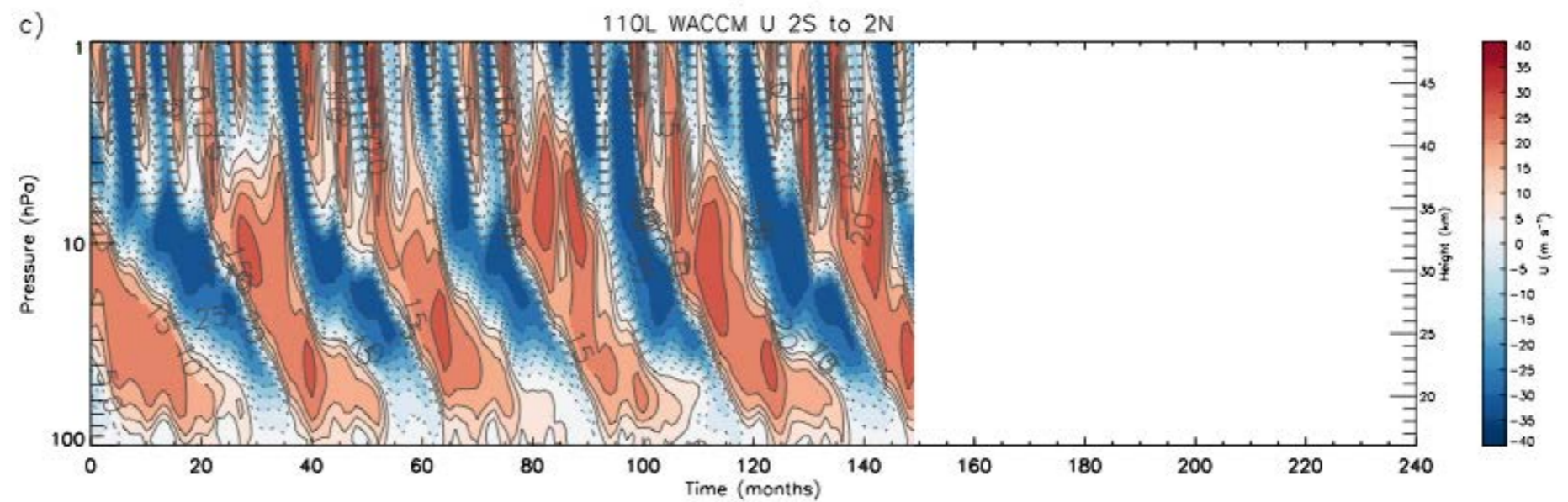
OBS



83L CAM



110L WACCM



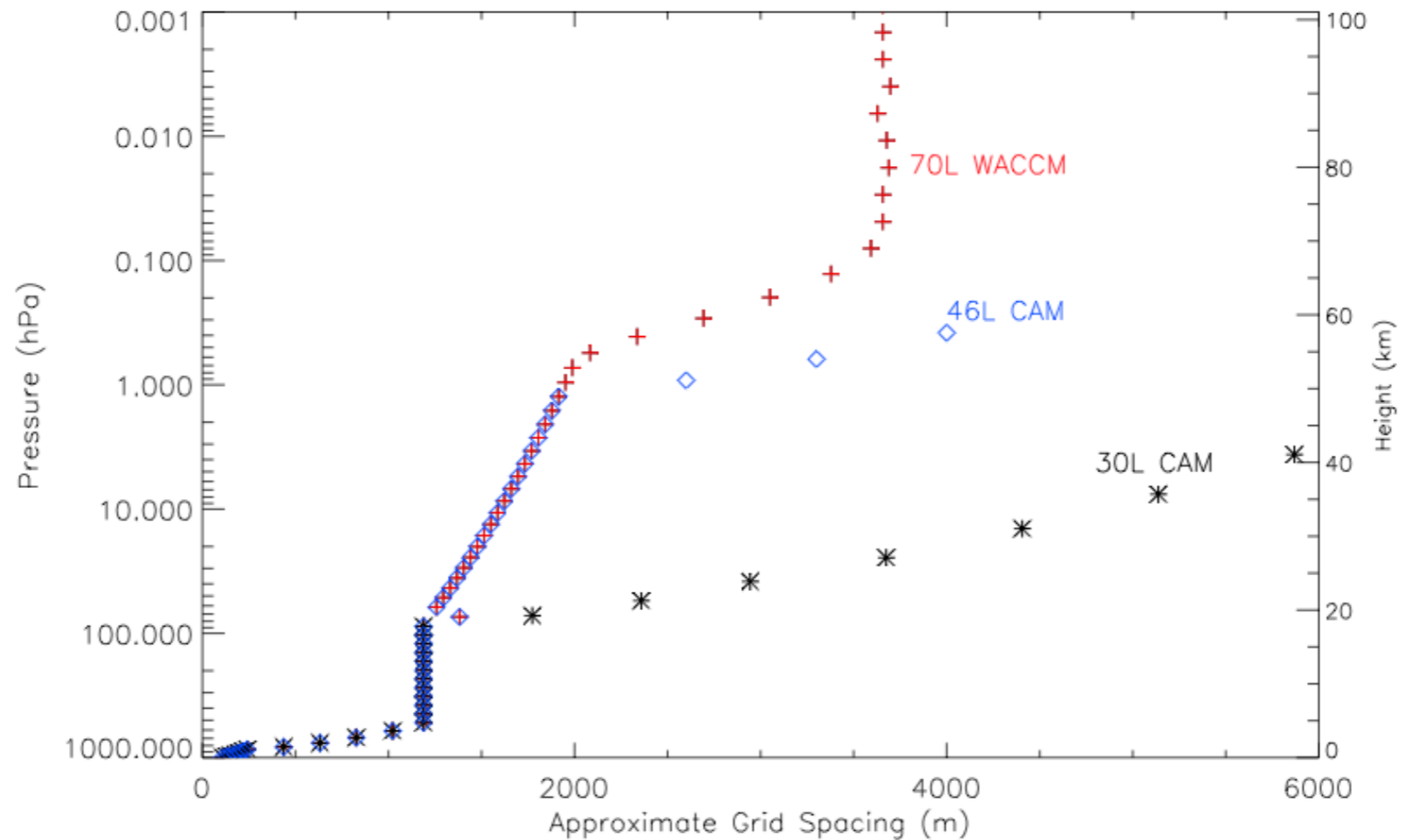
Adequate Vertical Resolution

Better representation of tropopause

More Kelvin, Mixed-Rossby GW's

An internally generated QBO

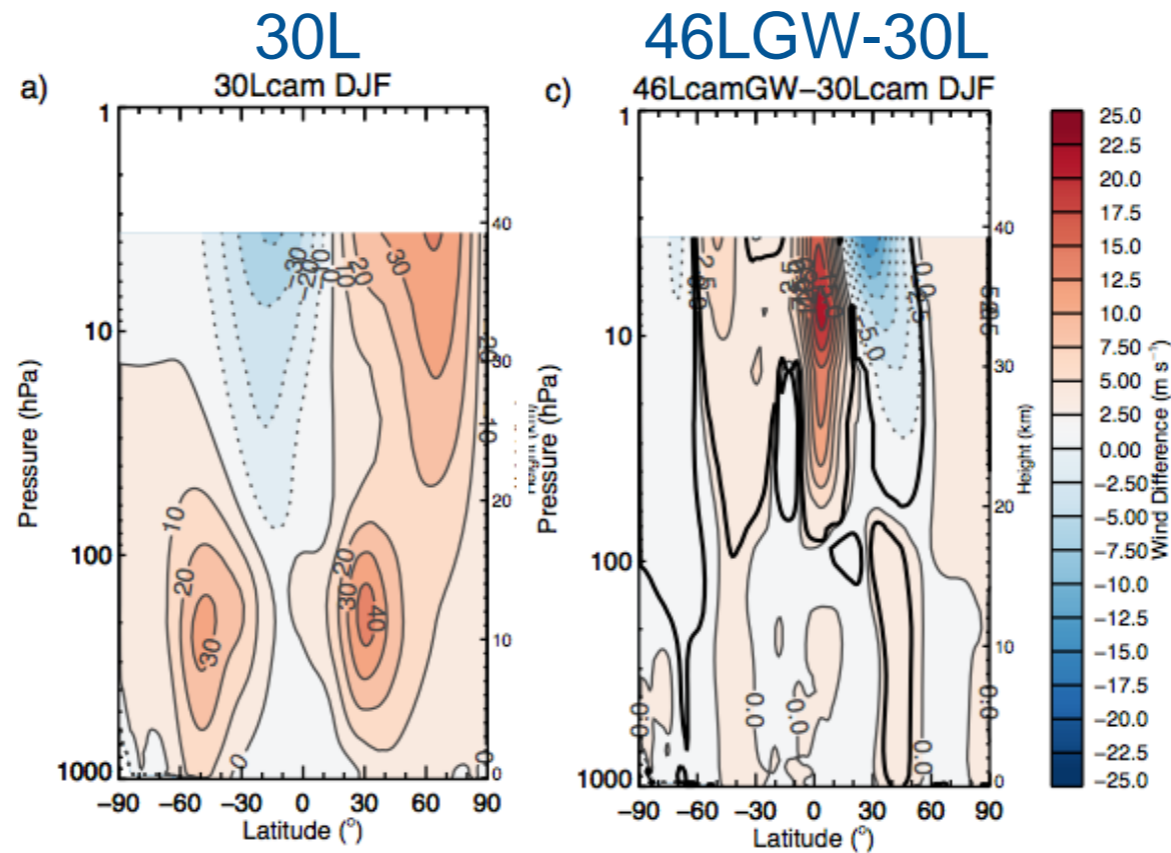
Raised Model Lid in CAM



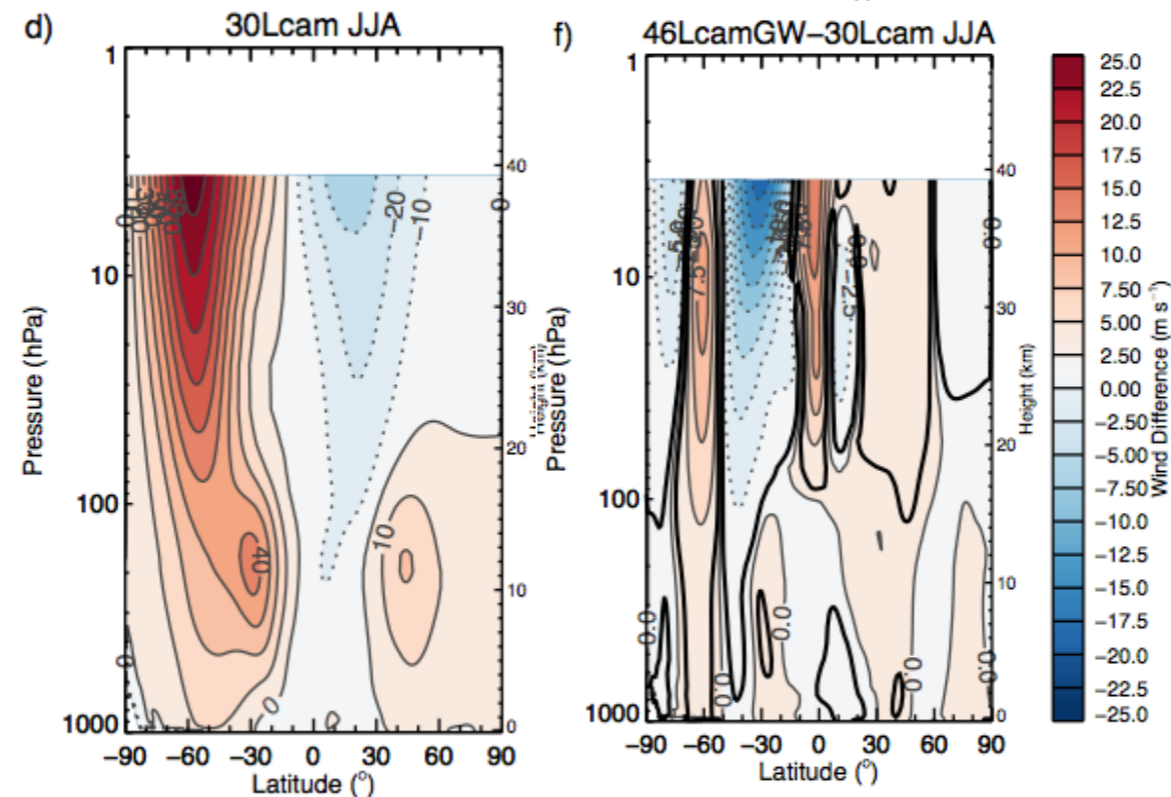
- 46L CAM: CAM+WACCM GWs
10 50-yr AMIP ensembles
- WACCM: 50-yr AMIP run

46L Mean Climate

DJF

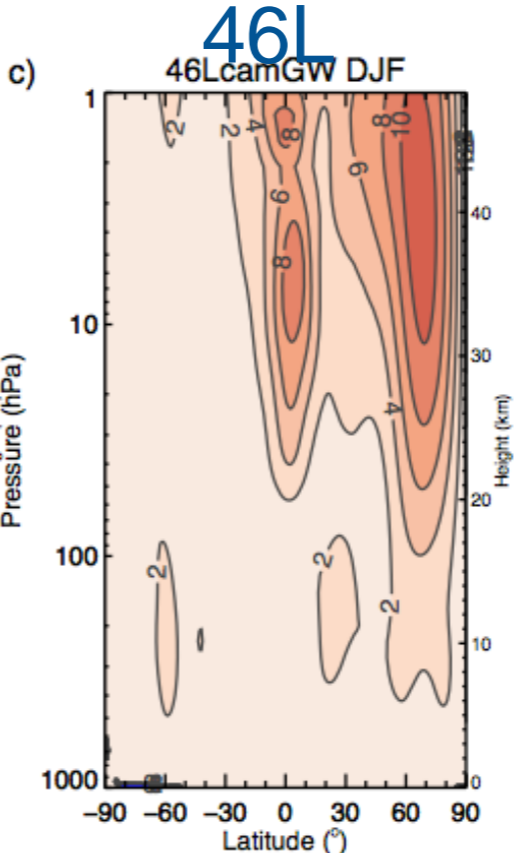
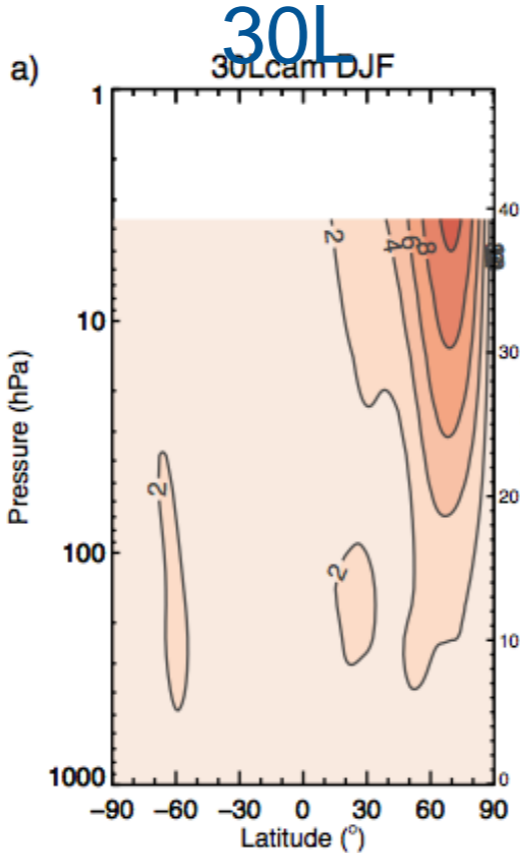


JJA

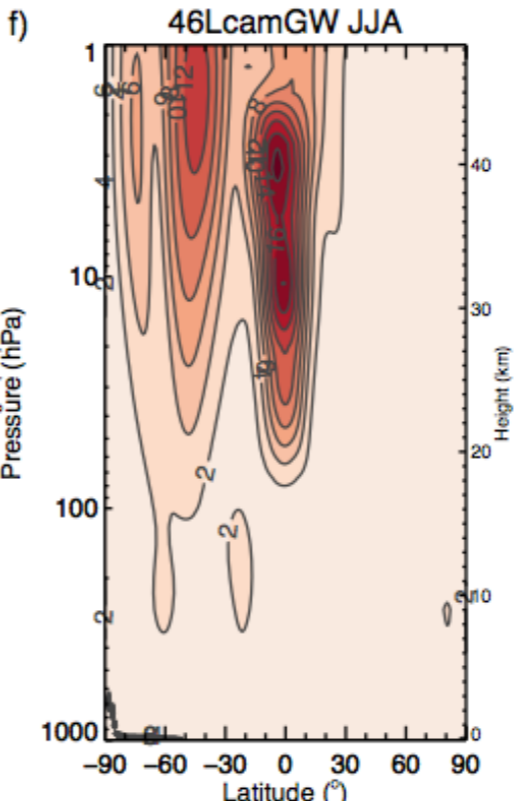
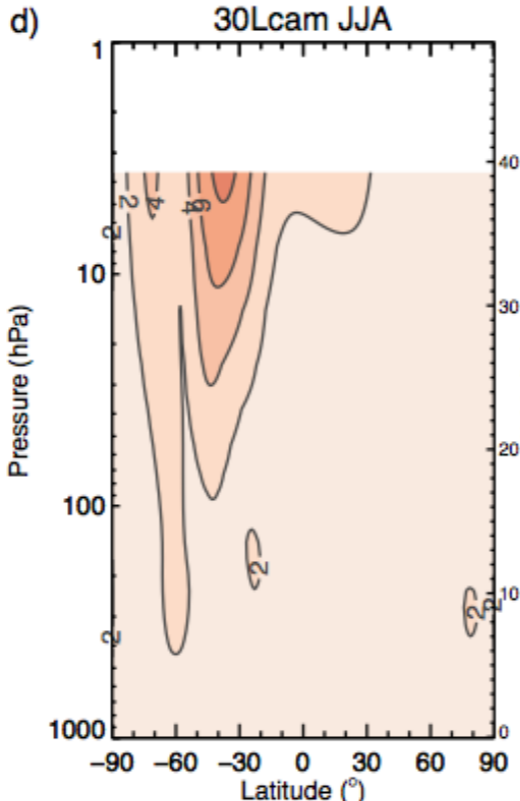


46L Variability:

DJF

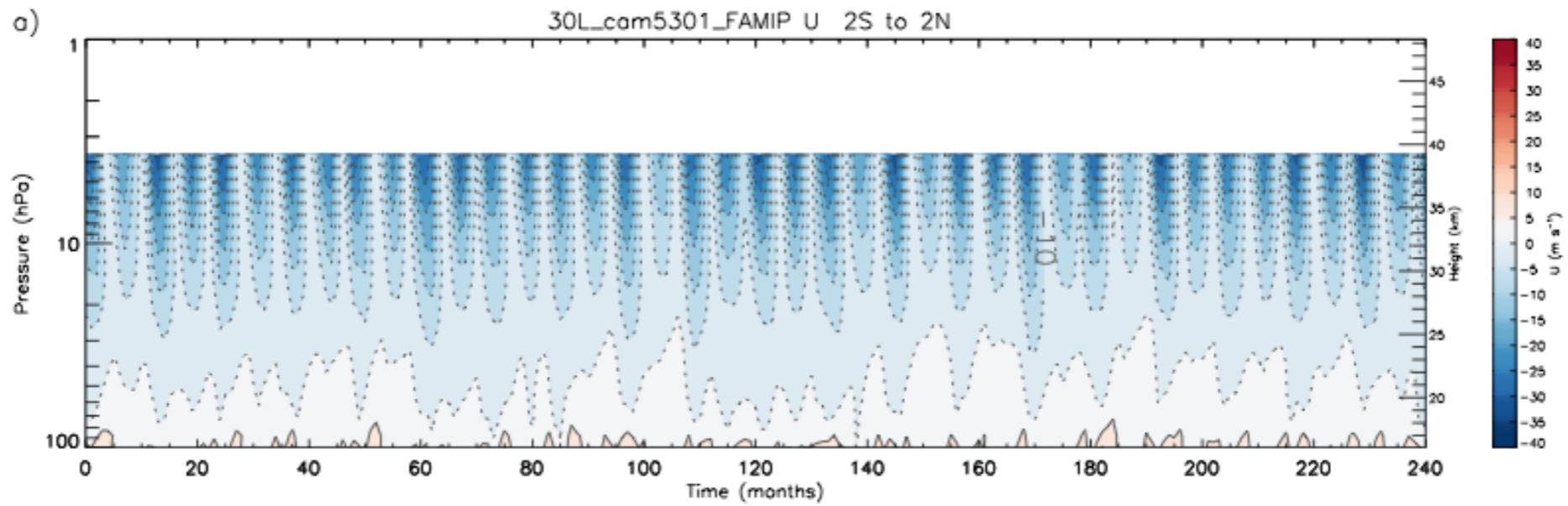


JJA

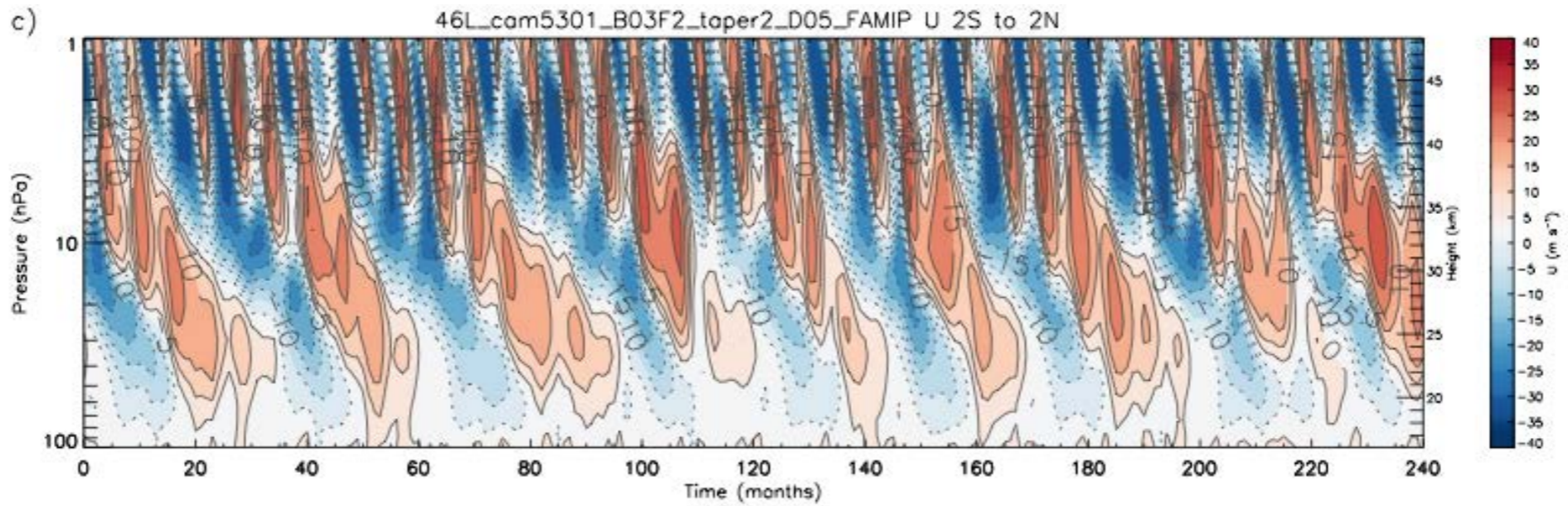


46L Model:

30L



46L



El Nino Response

El nino Anomaly

Std. El nino Anomaly

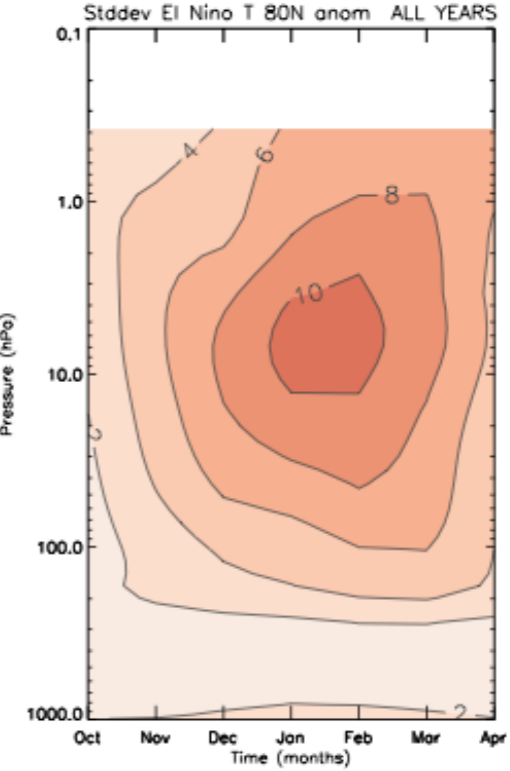
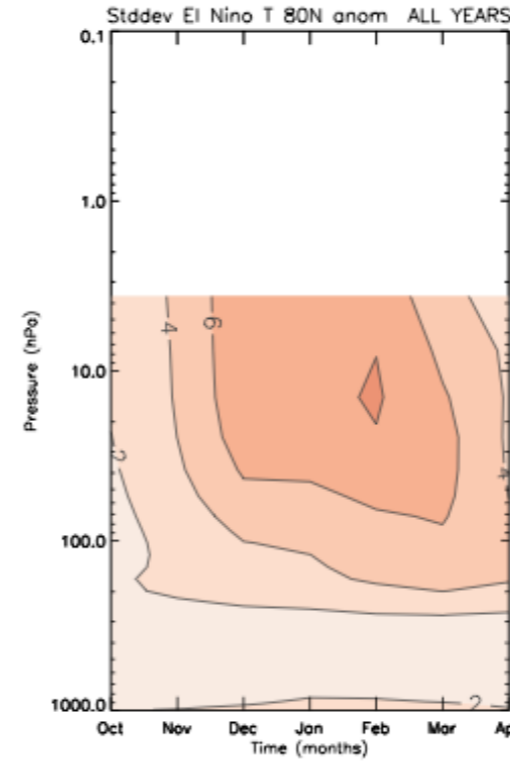
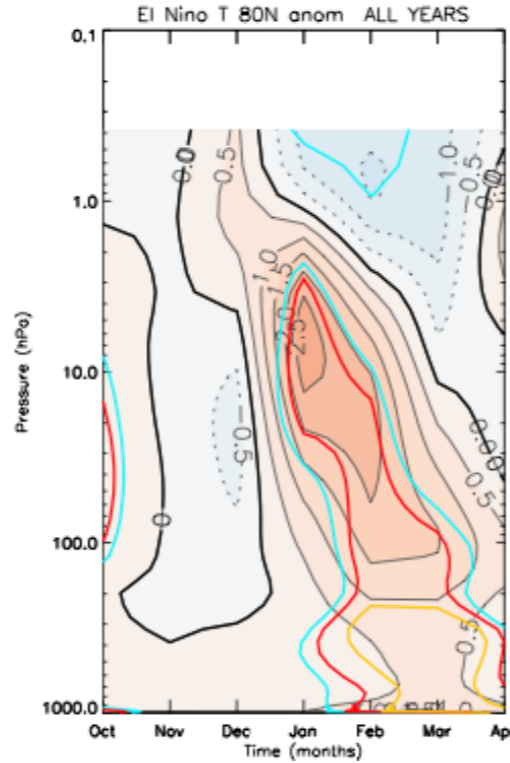
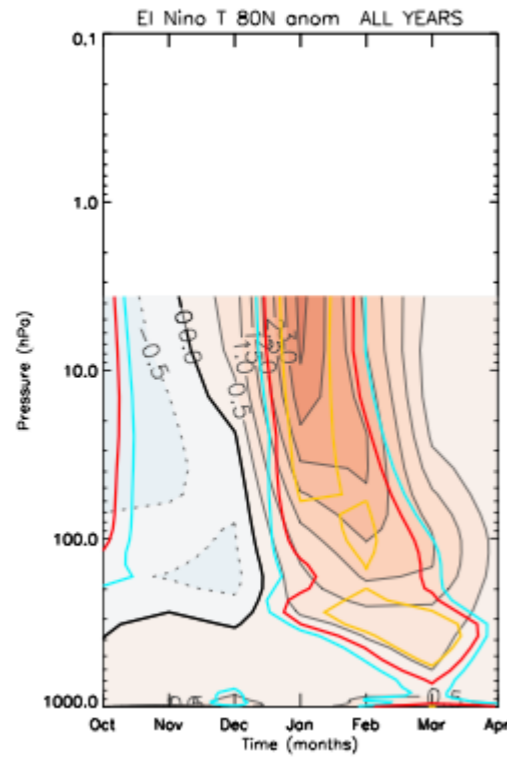
30L

46L

30L

46L

T 80N

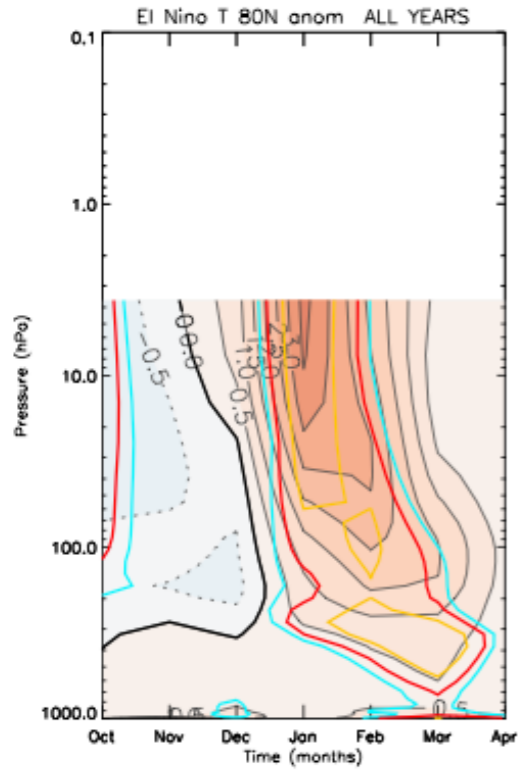


El Nino Response

T 80N

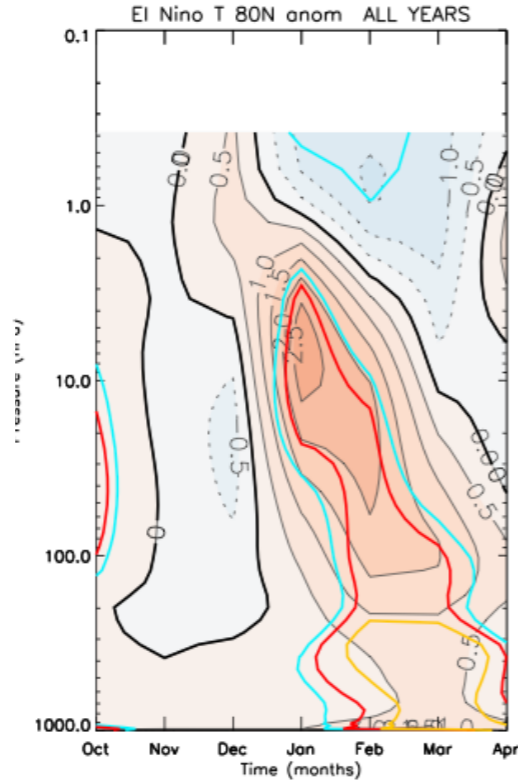
30L

All El Nino



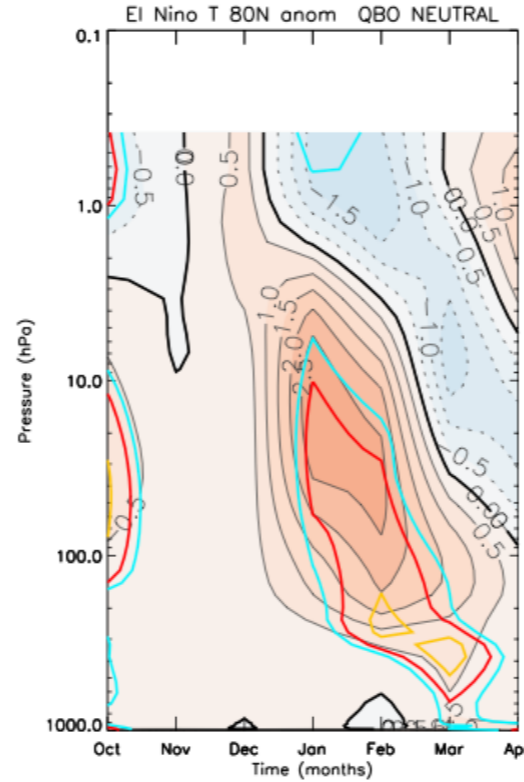
46L

All El Nino



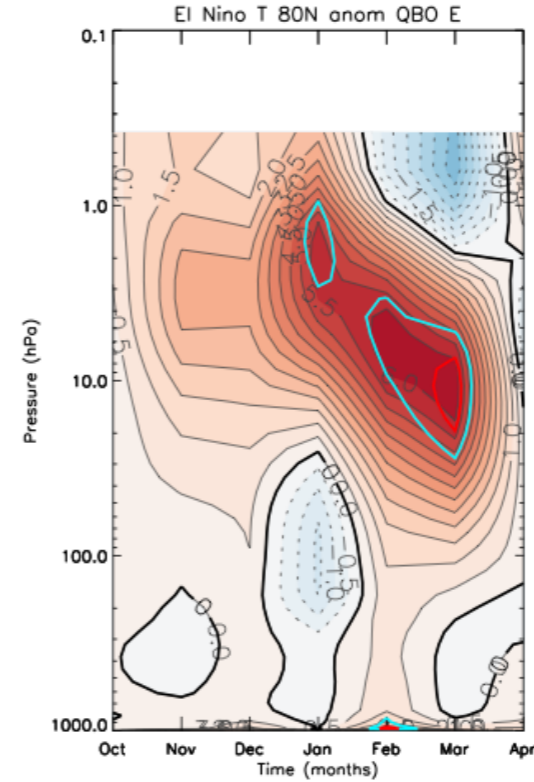
El Nino

QBO NEU (43)



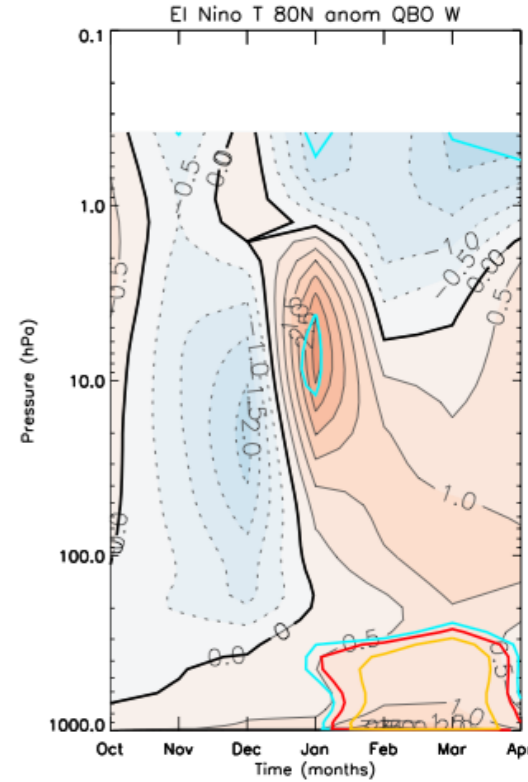
El Nino

QBO E (7)



El Nino

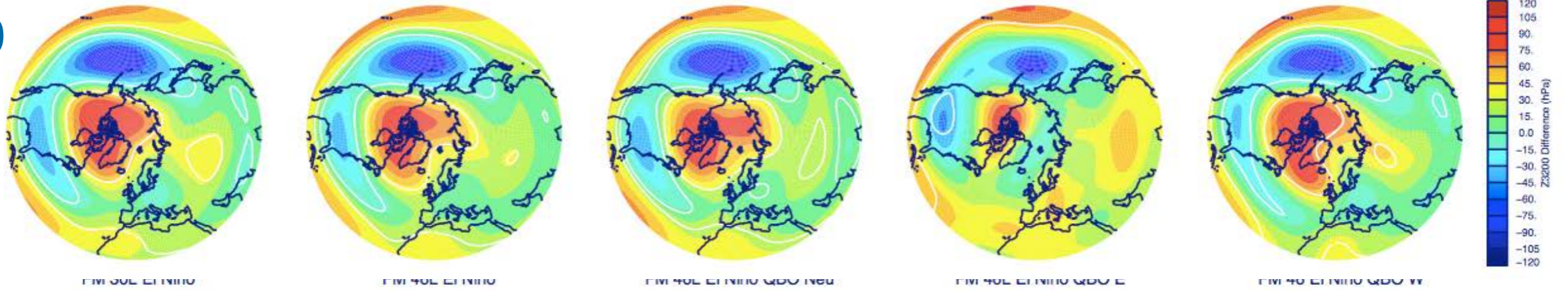
QBO W (30)



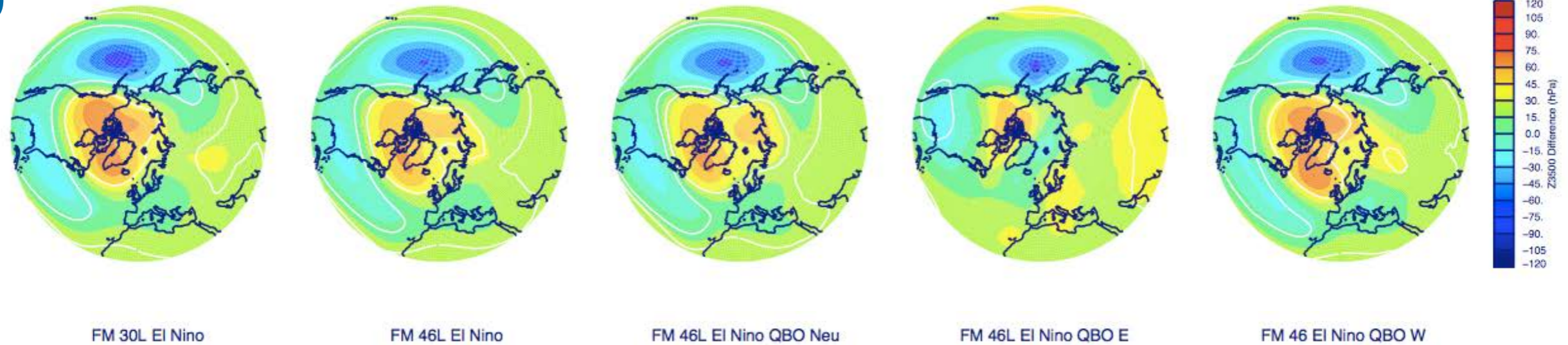
El Nino Response

30L 46L 46L 46L 46L
El Nino Anom (48) El Nino Anom (80) El Nino /QBO NEU (43) El Nino /QBO E (7) El Nino /QBO W (30)
FM 30L El Nino FM 46L El Nino FM 46L El Nino QBO Neu FM 46L El Nino QBO E FM 46 El Nino QBO W

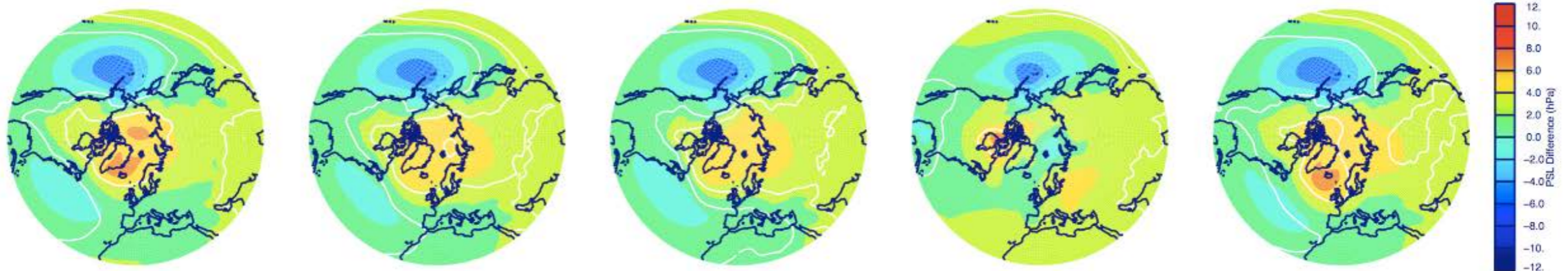
Z200



Z500



PSL



Mechanism?

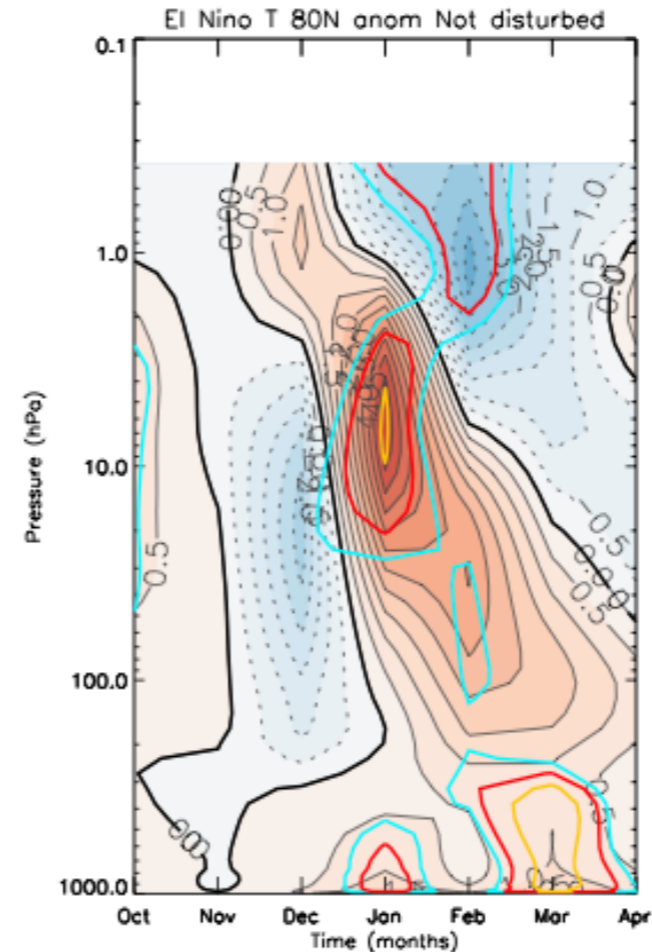
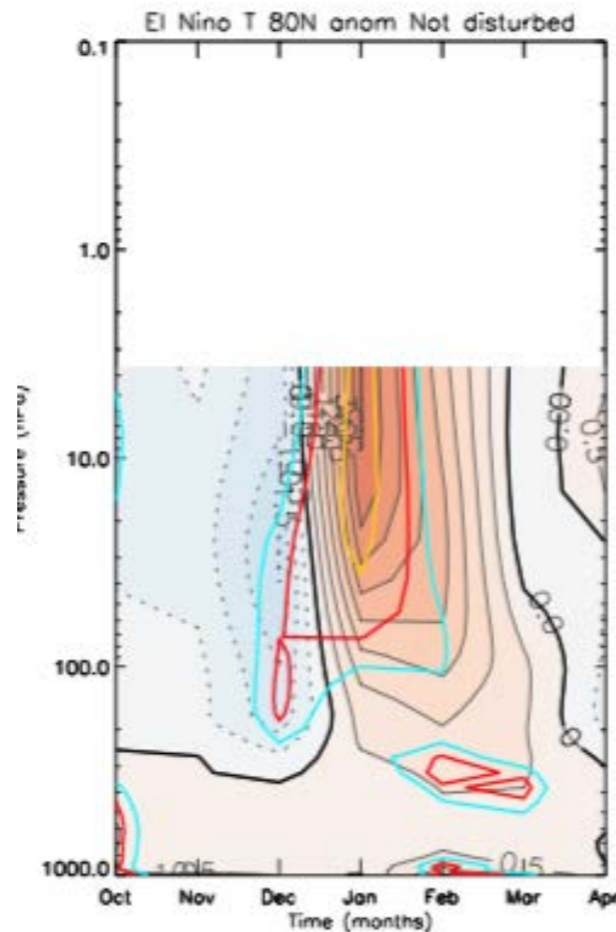
is the Stratospheric Pathway via SSWs?

Non-Disturbed years:

El Nino Years with No SSW Events:

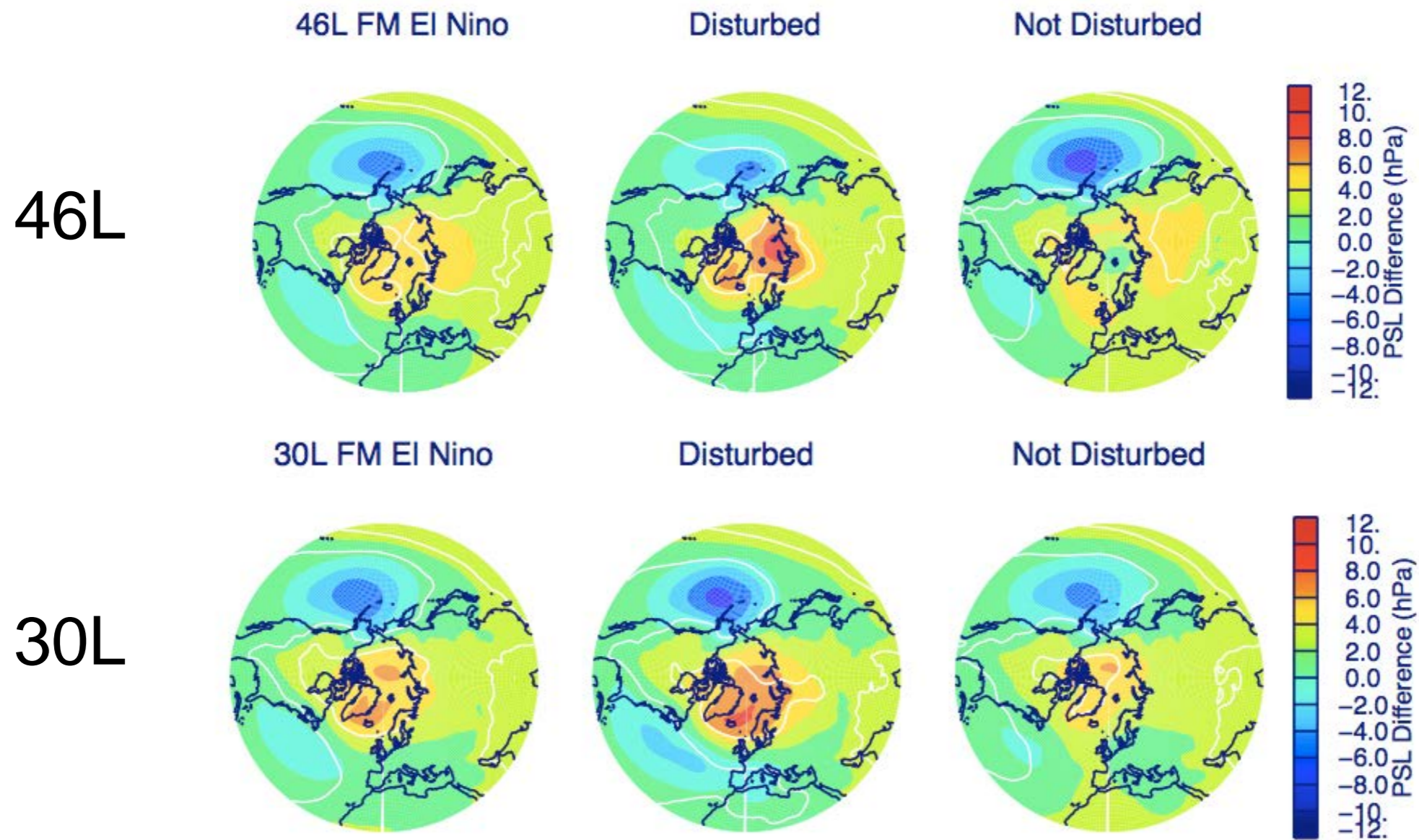
T80N 30L

T80N 46L



El Nino response reaches the surface in Spring even when there are no SSWs suggesting that stratospheric pathway exists with or without SSWs

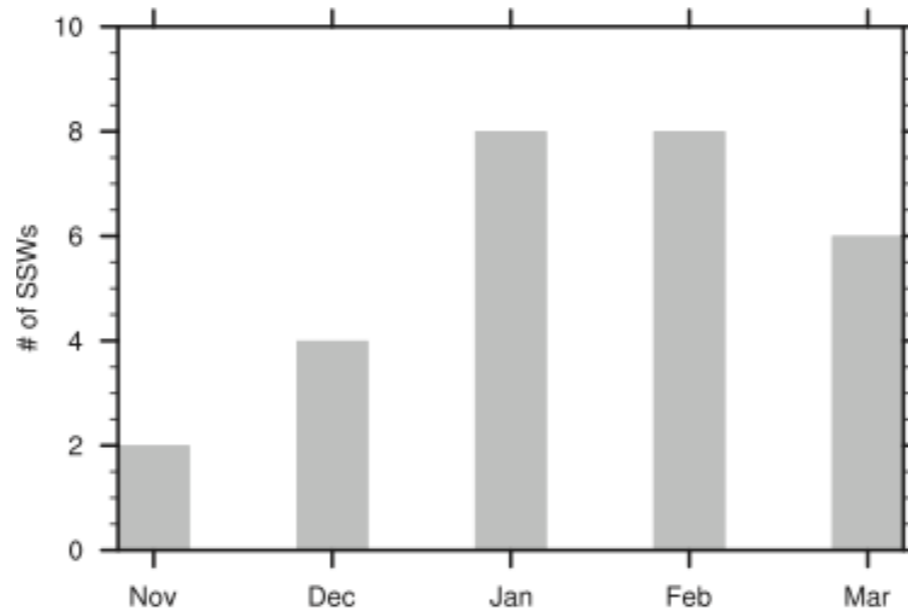
However....



Stronger PSL response over NP during winters with SSWs suggesting **STRONGER** stratospheric pathway when SSWs are present

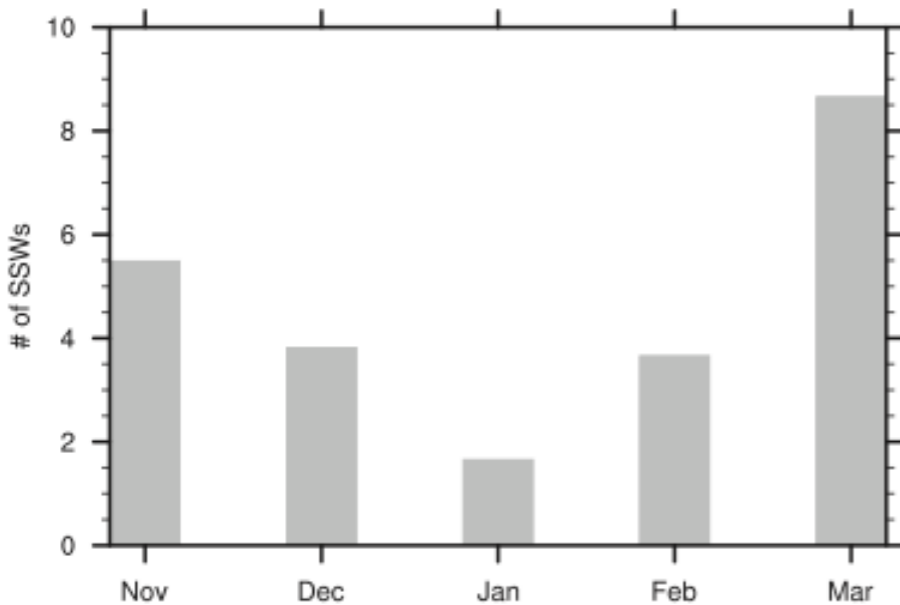
SSWs

NCEP Reanalysis:



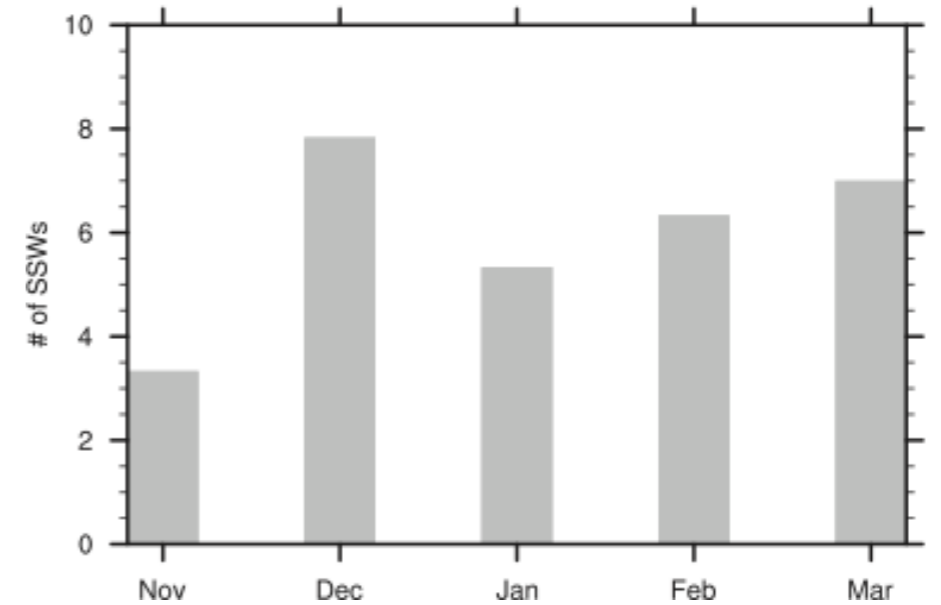
28 SSWs / 50 yrs
0.6 SSWs/ yr

30L 6-ensembles:



23 SSWs / 50 yrs
0.5 SSWs/ yr

46L GW 6-ensembles:



29 SSWs / 50 yrs
0.6 SSWs/ yr

Increased Model Lid

No Changes to mean climate

Increased Stratospheric Variability

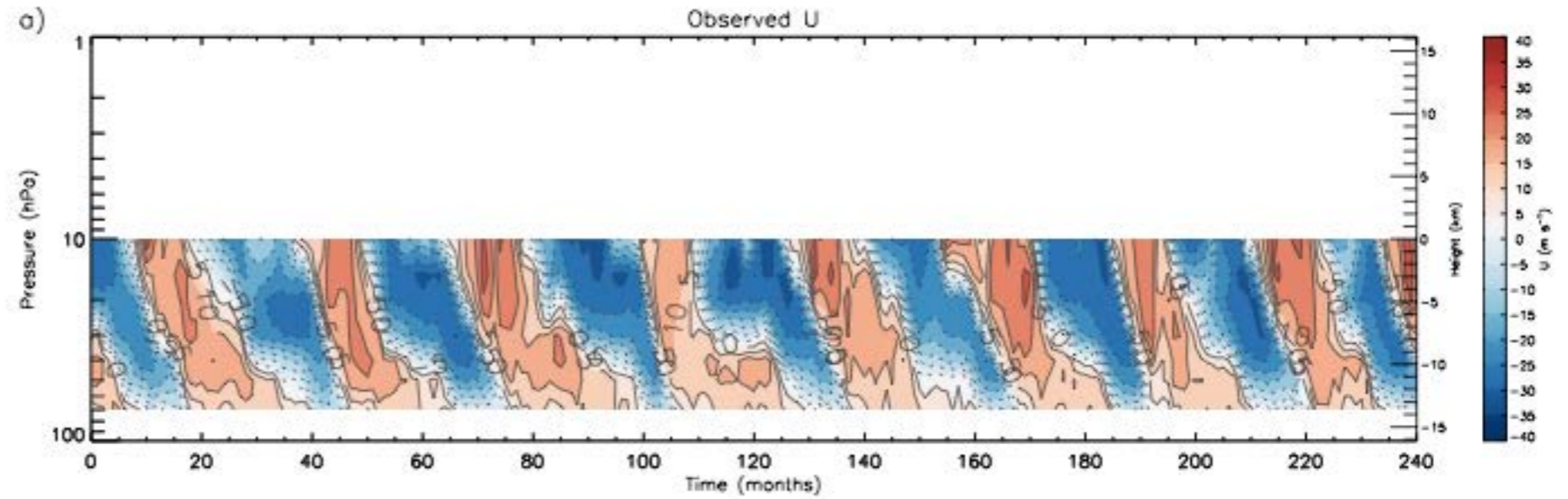
An internally generated QBO

Significant Impacts to ENSO response

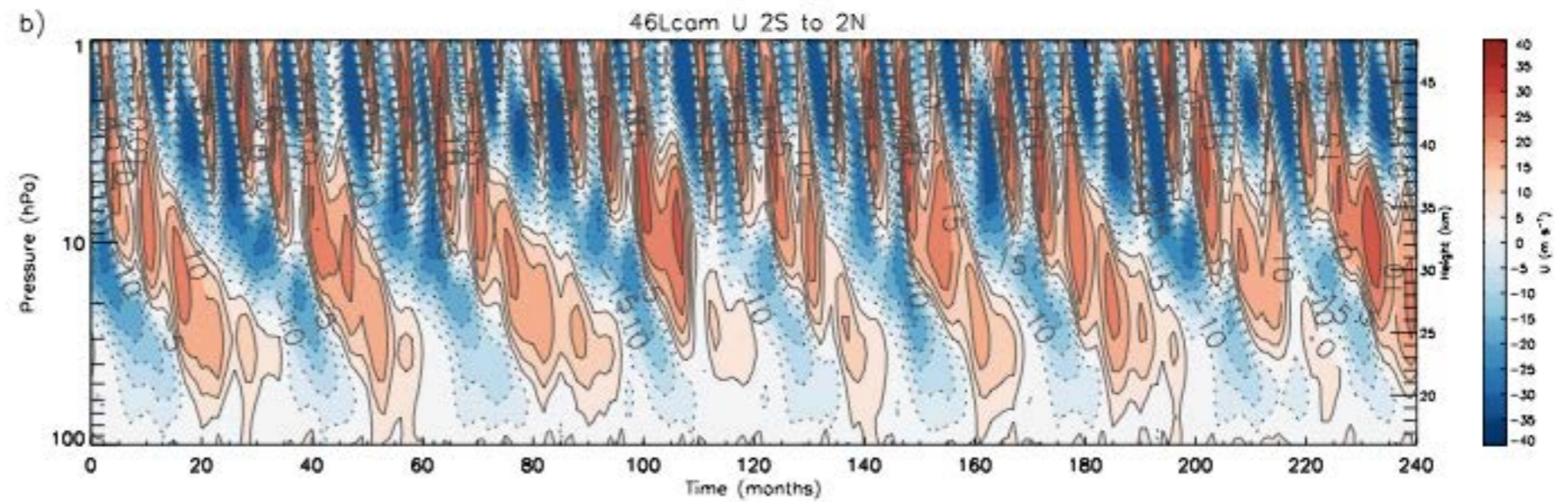
Better SSWs

QBO

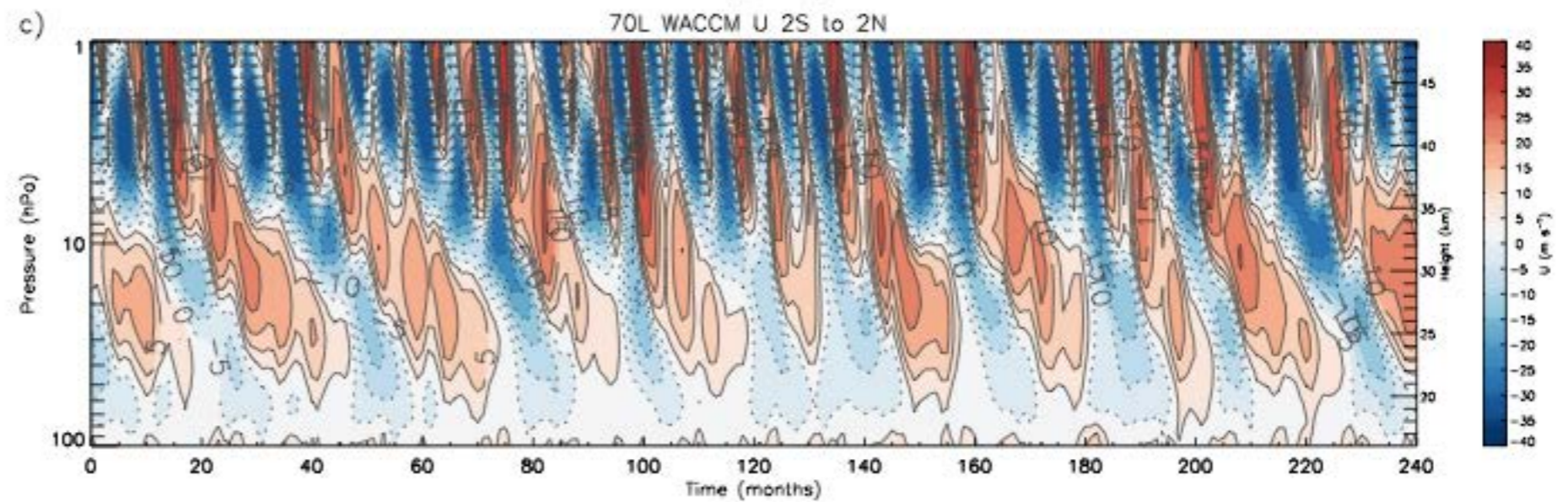
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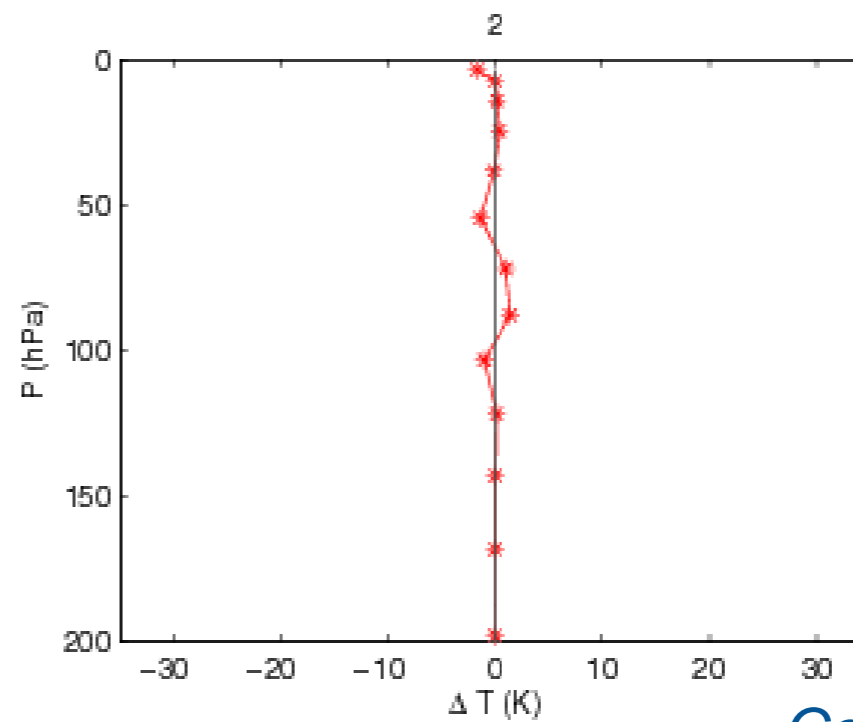
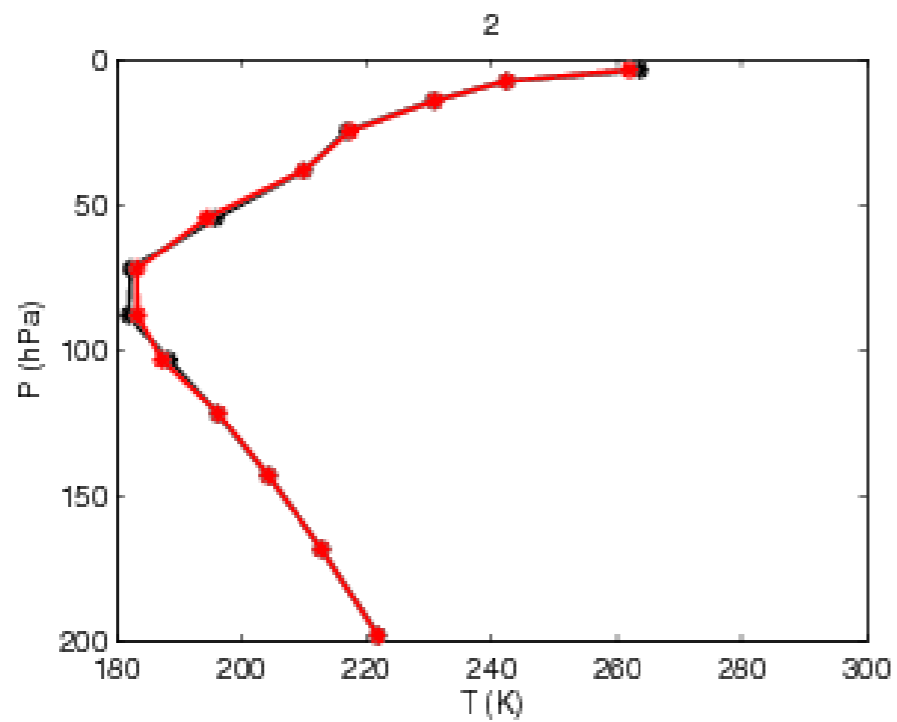
46L CAM



70L WACCM



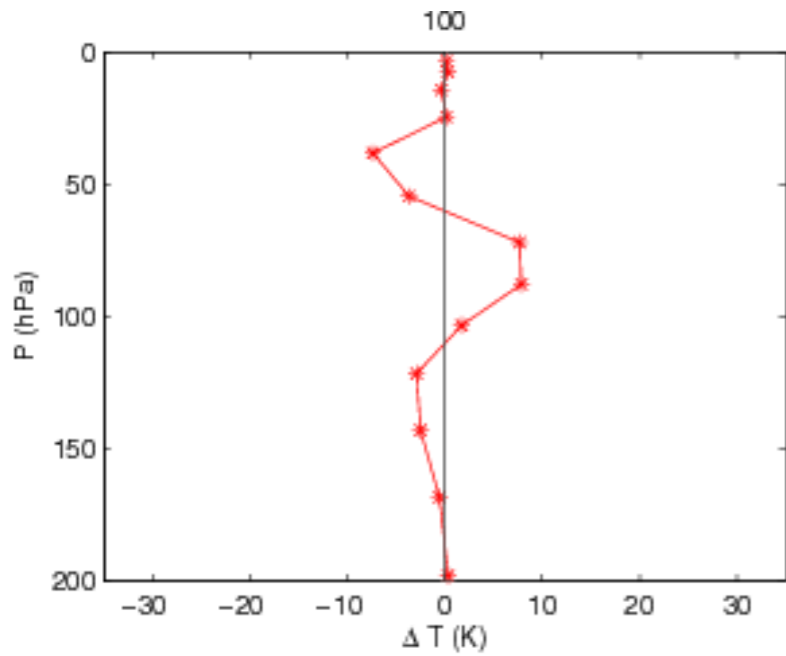
Vertical Remapping:



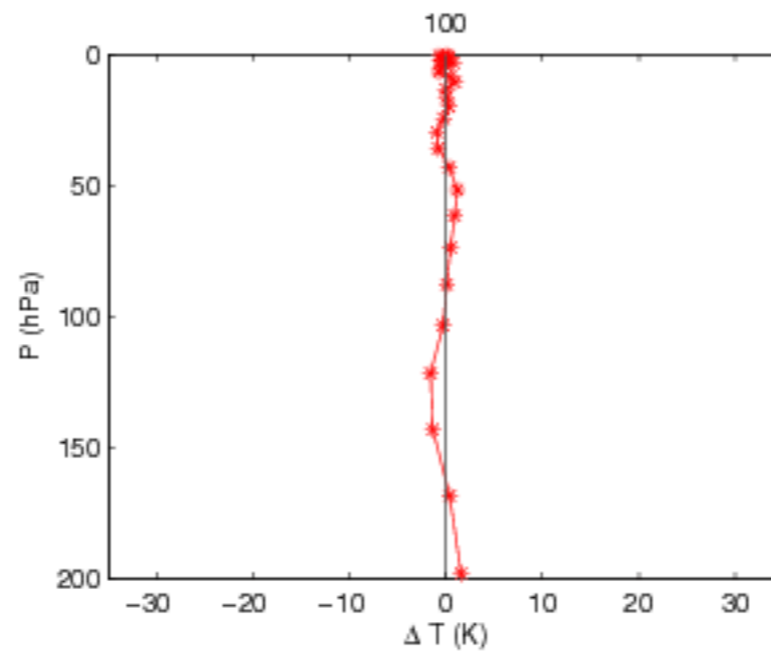
Courtesy of C. Chen

Vertical Remapping:

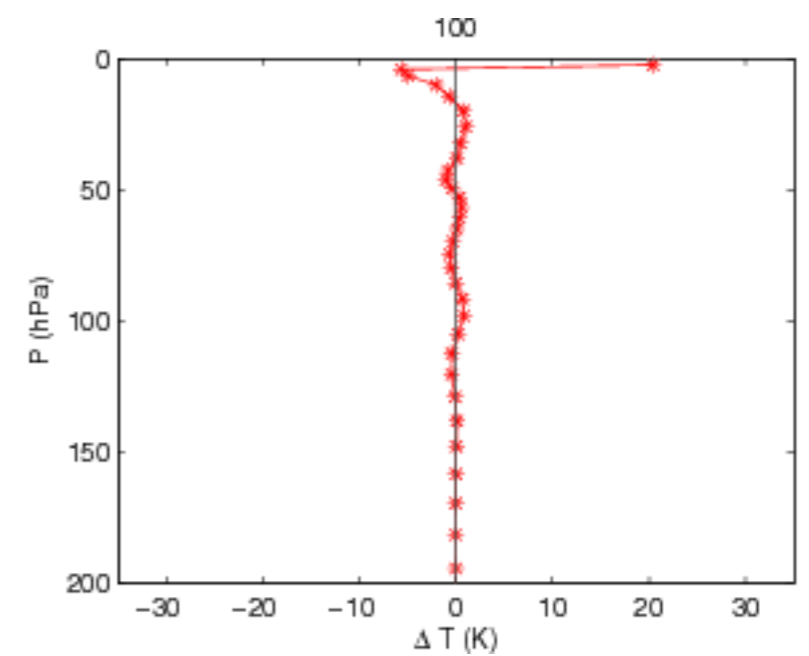
30L



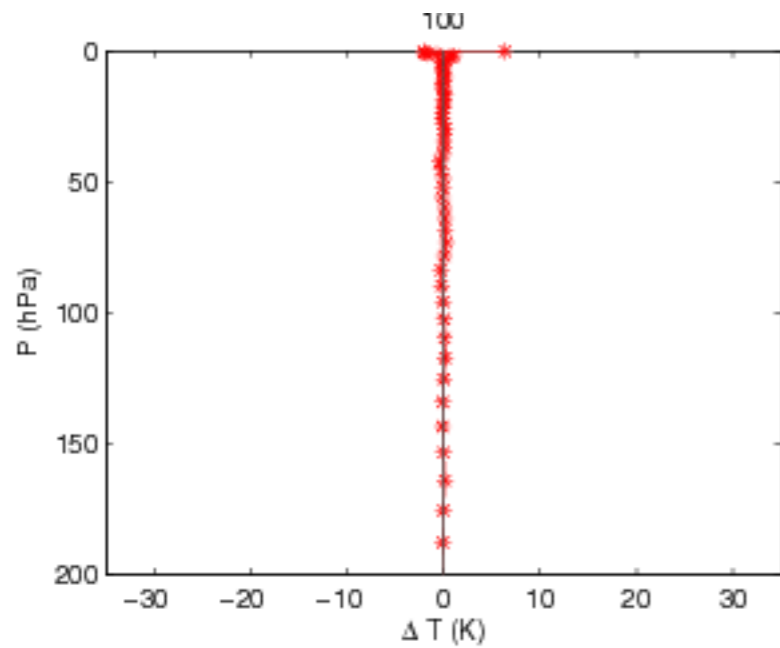
46L



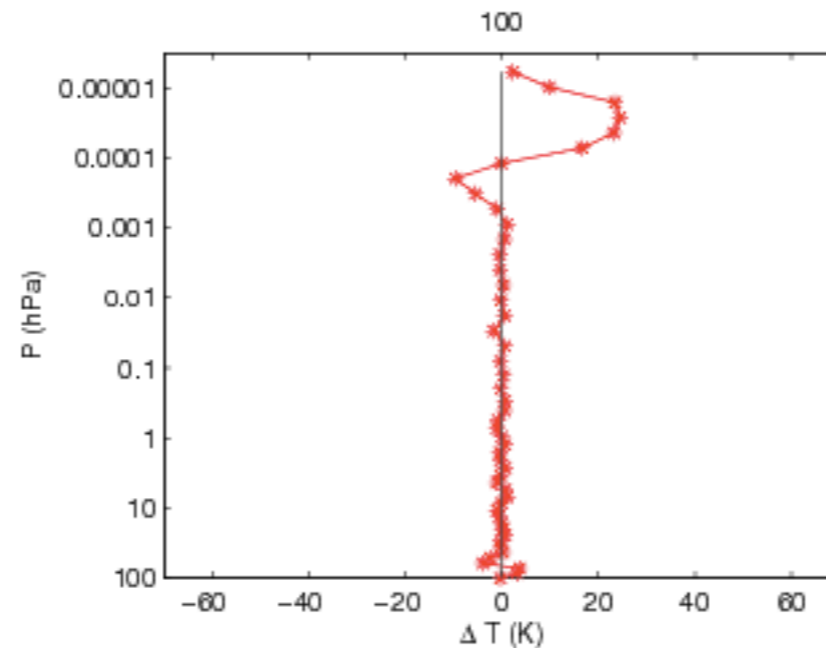
60L



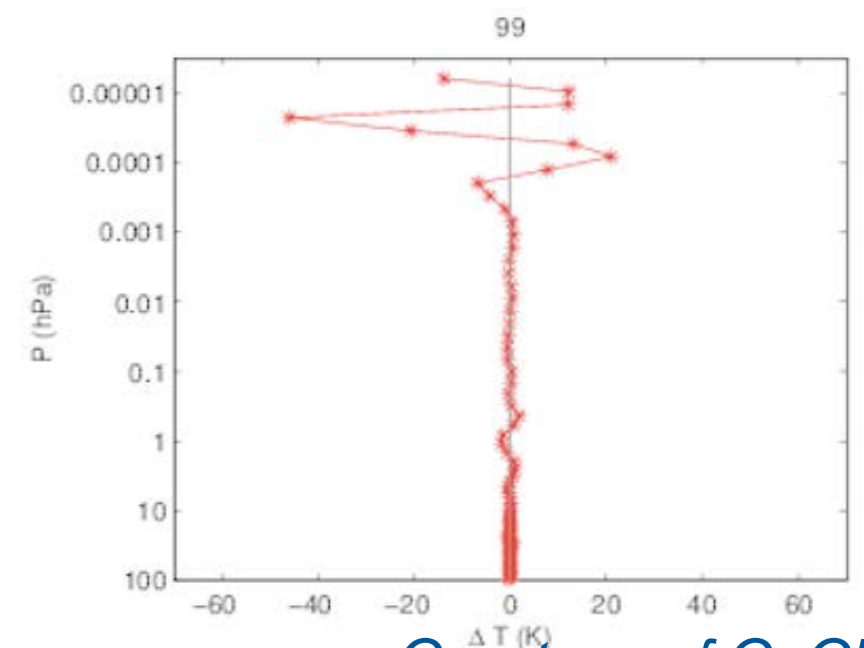
83L



70L WACCM



110L WACCM



Courtesy of C. Chen

Vertical Grid Choices:

Model	Mean Climate	Tropospheric Wave Spectrum	QBO	Vertical Remapping	Cost
30L (or 32) CAM	OK	Deficient	None	Poor	1xC
46L CAM	OK	Deficient	OK	OK	1.5C
70L WACCM	OK	Deficient	OK	OK at trop Not great at model top	1W
60L	OK + Improved Tropopause	Improved	Very Good	OK	2C
83L	OK + Improved Tropopause	Improved	Very Good	OK	3C
110L WACCM	OK + Improved Tropopause	Improved	Very Good	OK at trop Not great at model top	1.5W

Conclusions

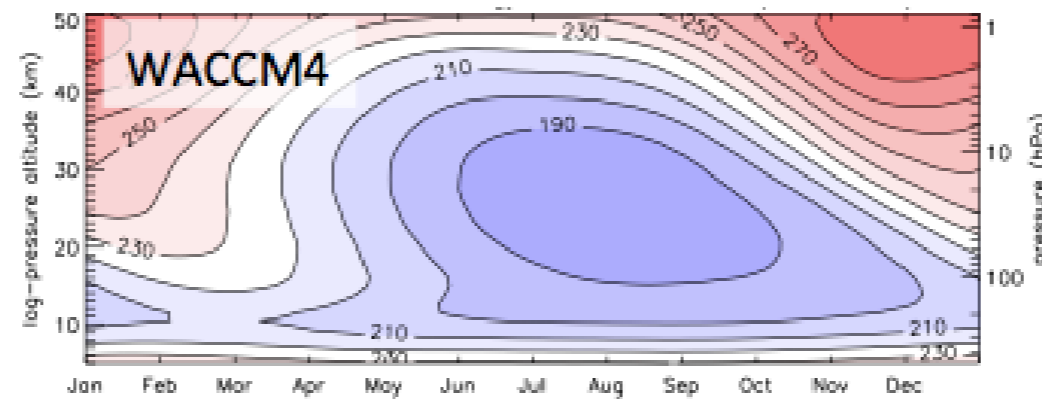
- It's time to consider changing the vertical grid structure in CAM and WACCM
- For **CAM**: the inclusion of a better resolved stratosphere would add more realistic variability & get rid of remapping issues
- For **WACCM**: higher vertical resolution clearly improves the resolved wave spectrum & provides best representation of the QBO

Vertical Grid Choices:

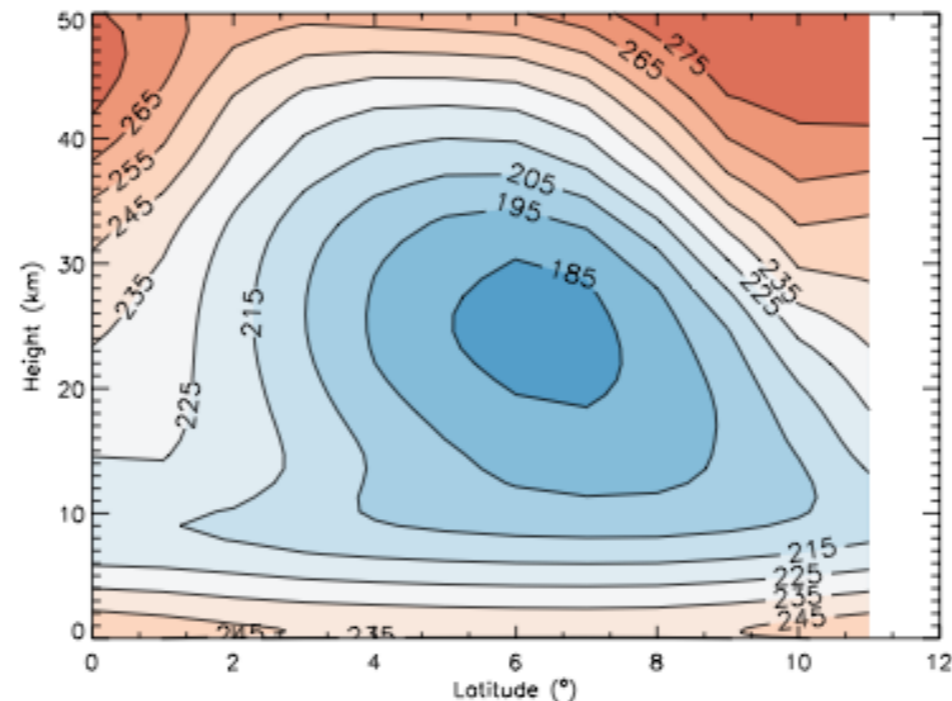
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60L	OK + Improved Tropopause	Improved	Very Good	OK	2C
83L	OK + Improved Tropopause	Improved	Very Good	OK	3C
110L WACCM	OK + Improved Tropopause	Improved	Very Good	OK at trop Not good at model top	1.5W

Cold Pole Problem in WACCM

SH polar cap T climatology: 1980-2010

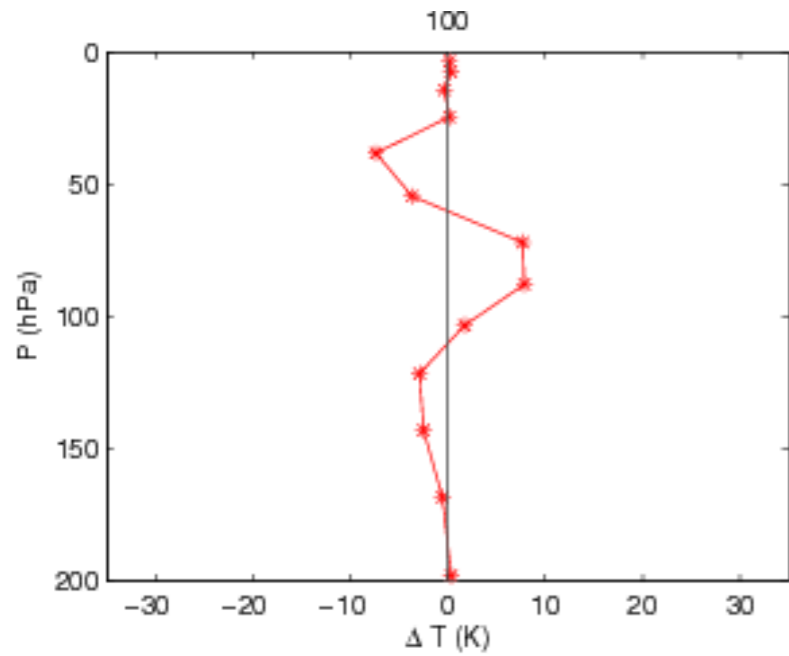


WACCM 5

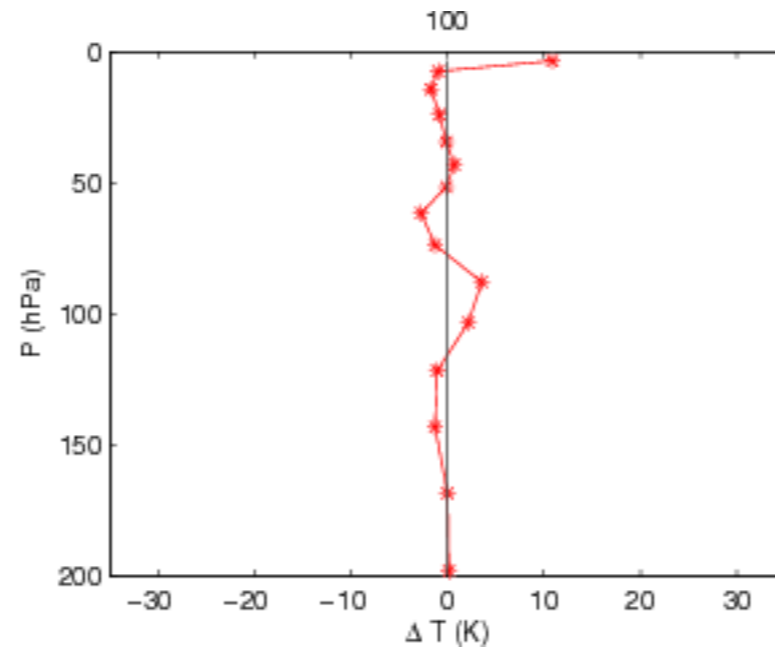


Vertical Remapping:

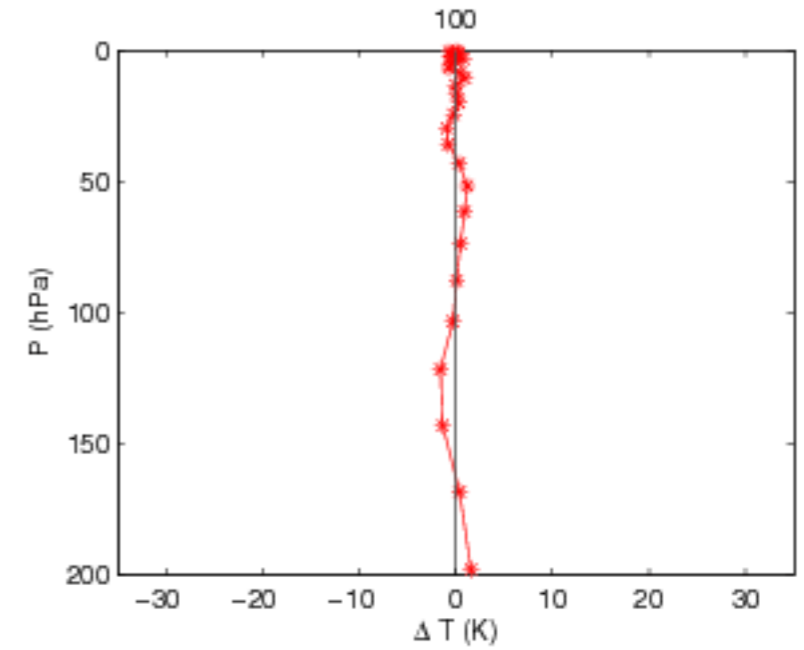
30L



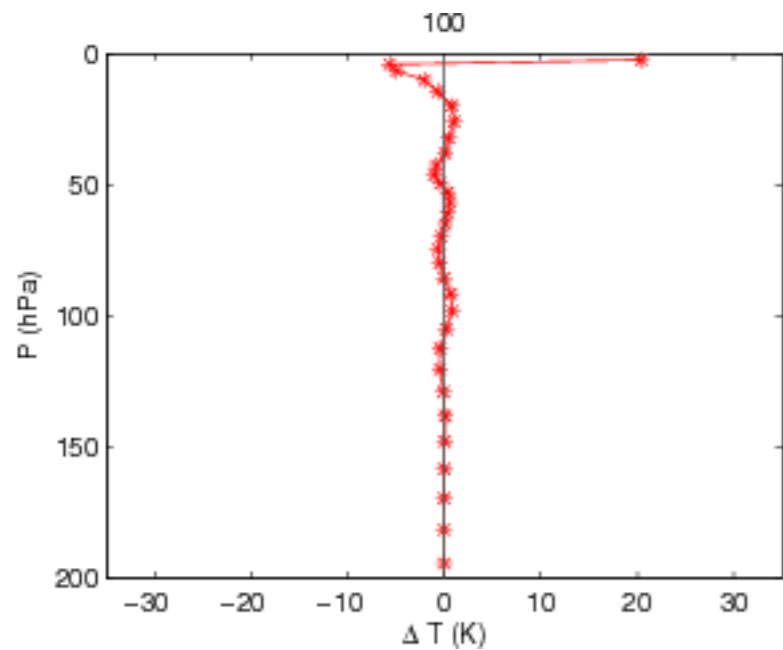
32L



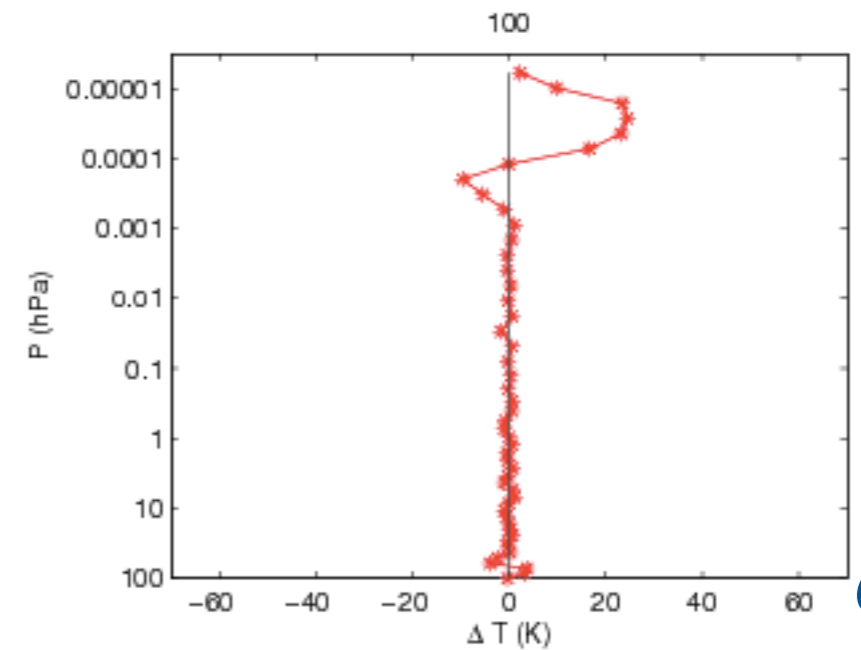
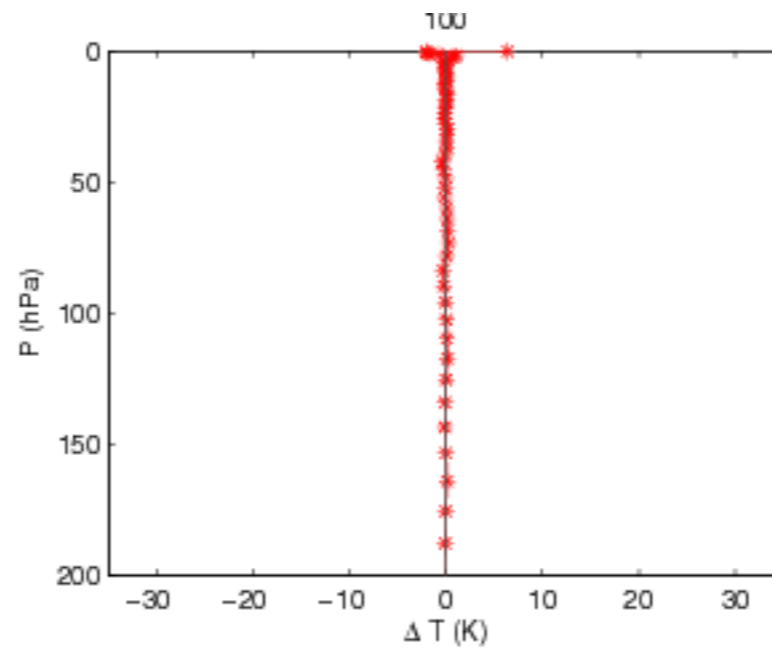
46L



60L



83L



Chen