WACCM / CCSM4 differences in CMIP5 simulations

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NESL

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Outline

- Model differences between WACCM & CCSM4 used for CMIP5
    - Describe CCSM4-WSET (CCSM4 with WACCM settings)
- ENSO variability
- Stratospheric sudden warmings and blocking
- SH stratospheric polar temperature trends
- Comparison of regional climate change in N.Atlantic / Europe

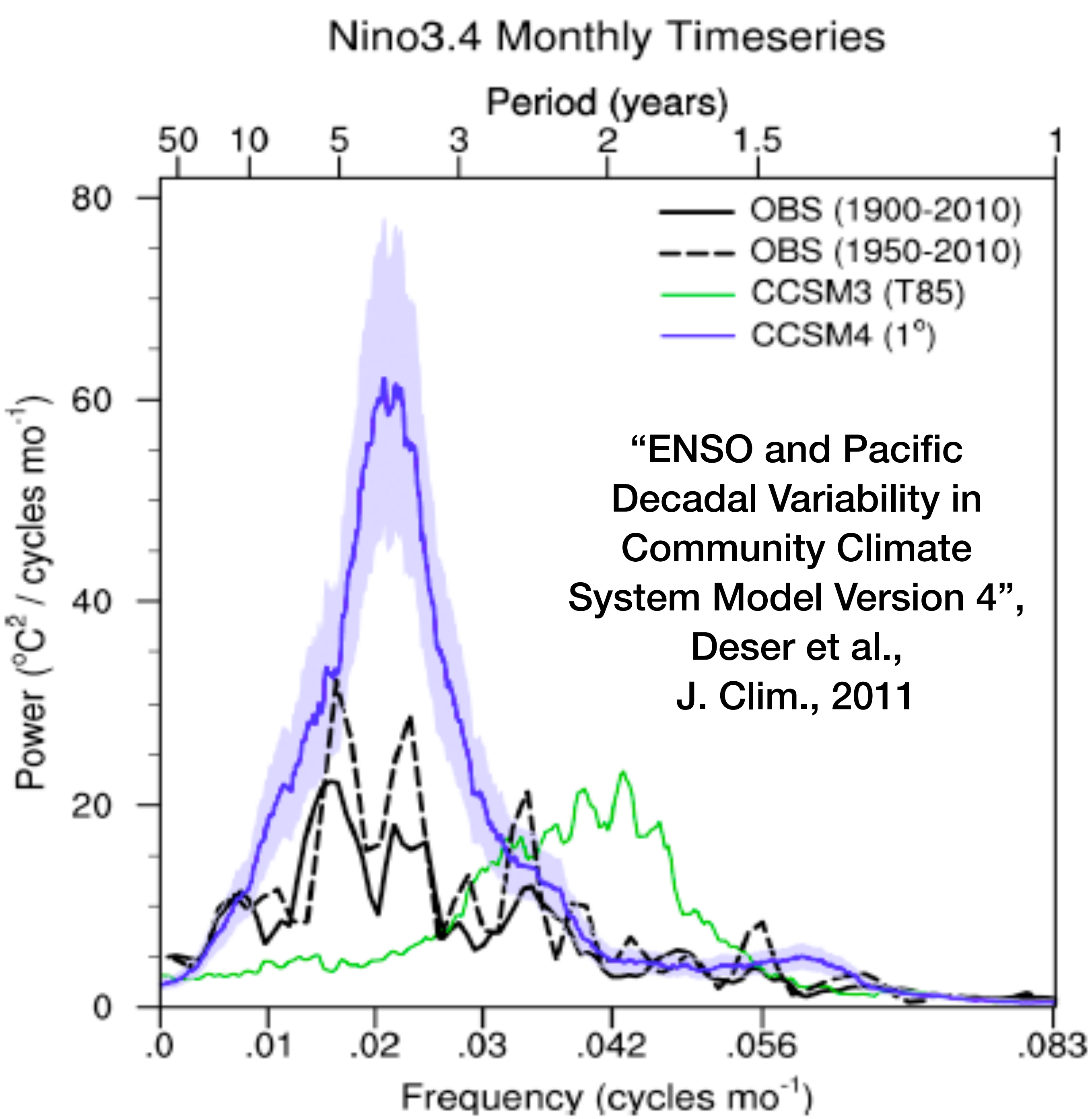
Important differences from CCSM4 used for CMIP5

- Model top at ~140 km (66 levels) vs. ~40 km (26 levels)
- Horizontal (lat x lon) resolution: 1.9° x 2.5° vs. 0.94° x 1.25°
- Fully-interactive chemistry
- Nudged Quasi-Biennial Oscillation (QBO)
- Forced with daily varying spectral irradiance rather than annual mean TSI
- Thermospheric processes - aurora, ion chemistry, molecular diffusion
- Additional parameterization for gravity waves from convection and fronts (same orographic parameterization)
- “Turbulent mountain stress” (TMS) turned on

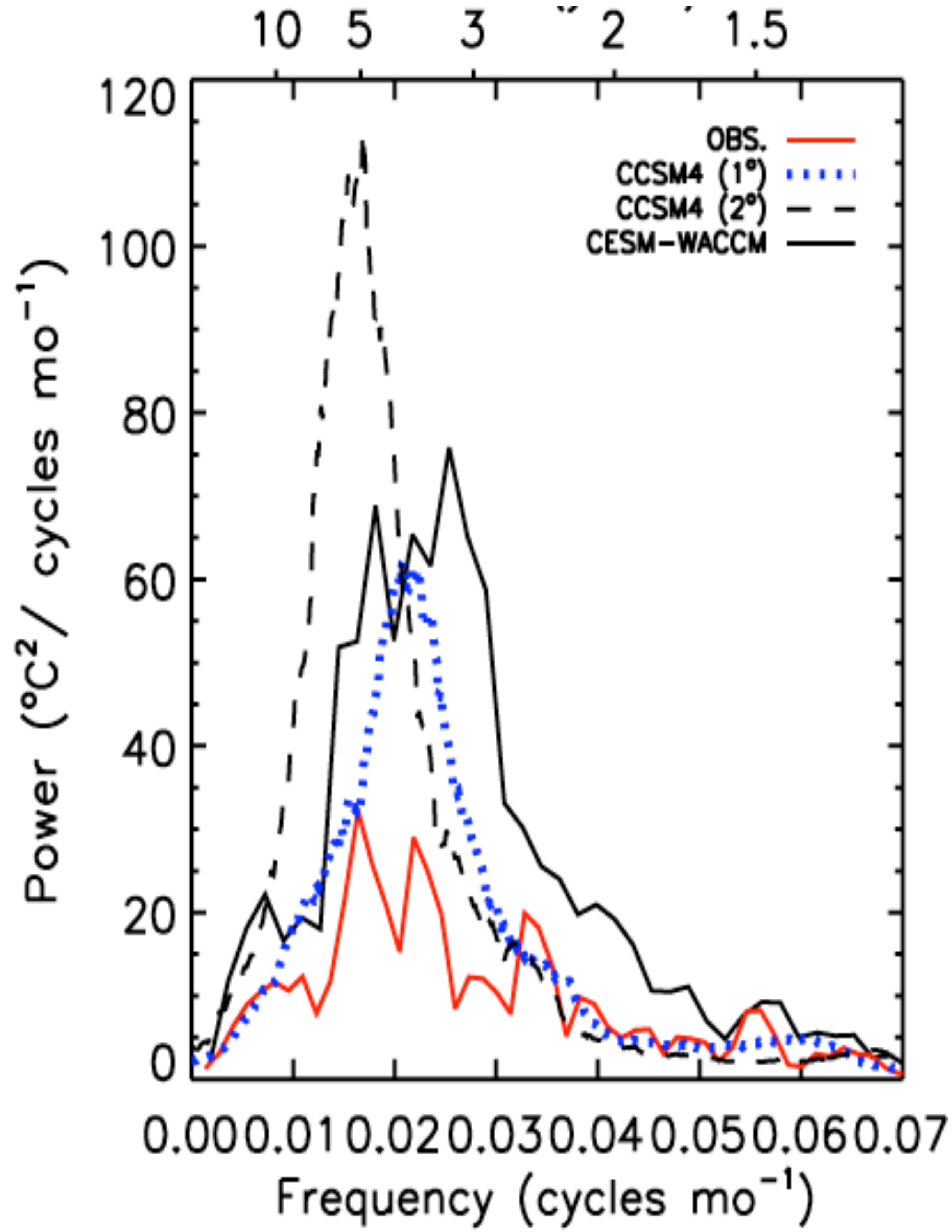
How then to investigate the influence of a ‘high-top’?

- Parallel simulations of CCSM4 configured in a similar manner to WACCM
  - Horizontal (lat x lon) resolution: 1.9° x 2.5°
  - Daily TSI
  - TMS turned on
- We term this model CCSM4-WSET
- Note: all simulations (WACCM, CCSM4 1°, and CCSM4-WSET) run with the same POP2 active ocean at 1°

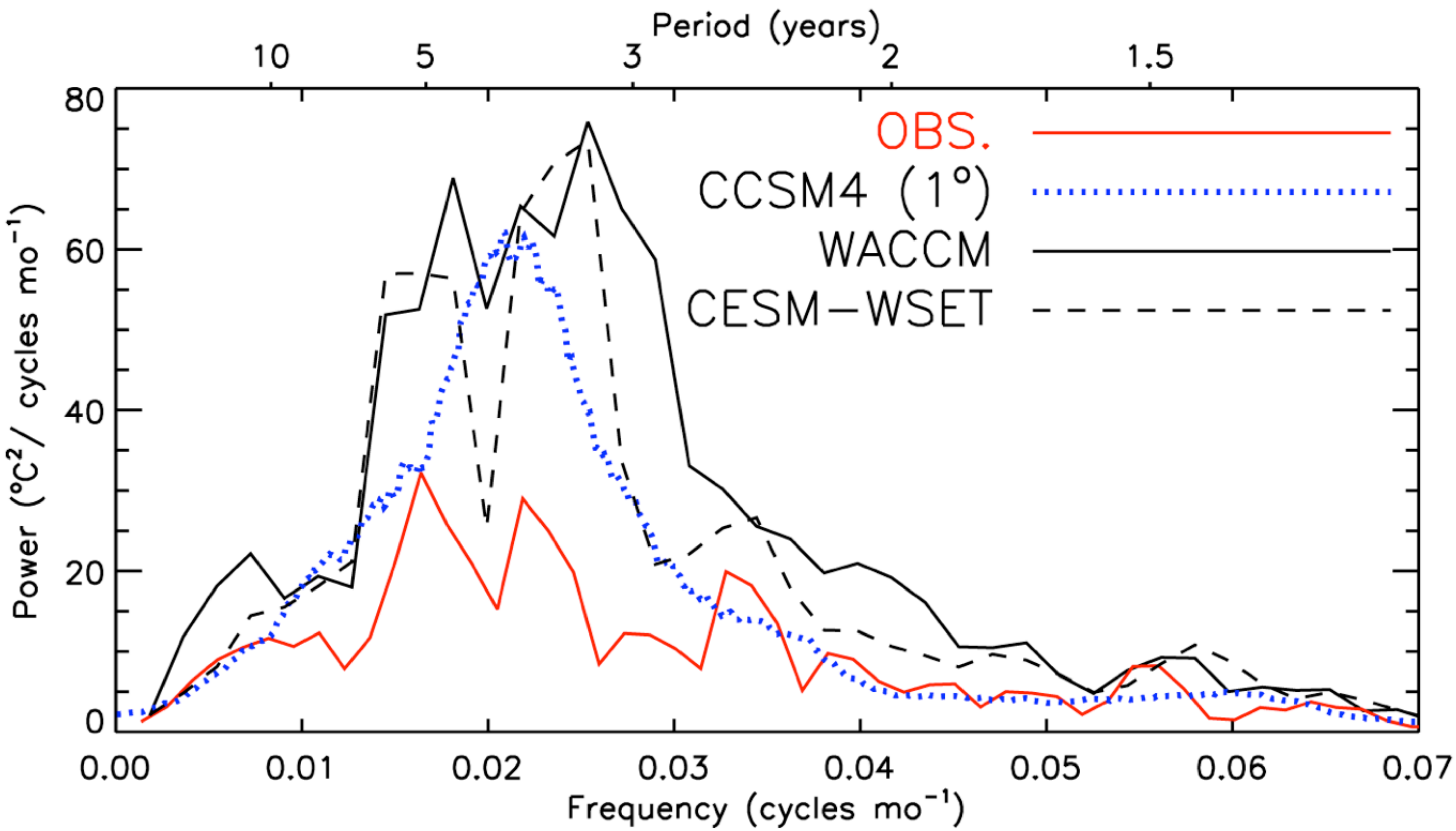
El Niño/Southern Oscillation (ENSO) in CCSM4



"ENSO and Pacific Decadal Variability in Community Climate System Model Version 4", Deser et al., J. Clim., 2011

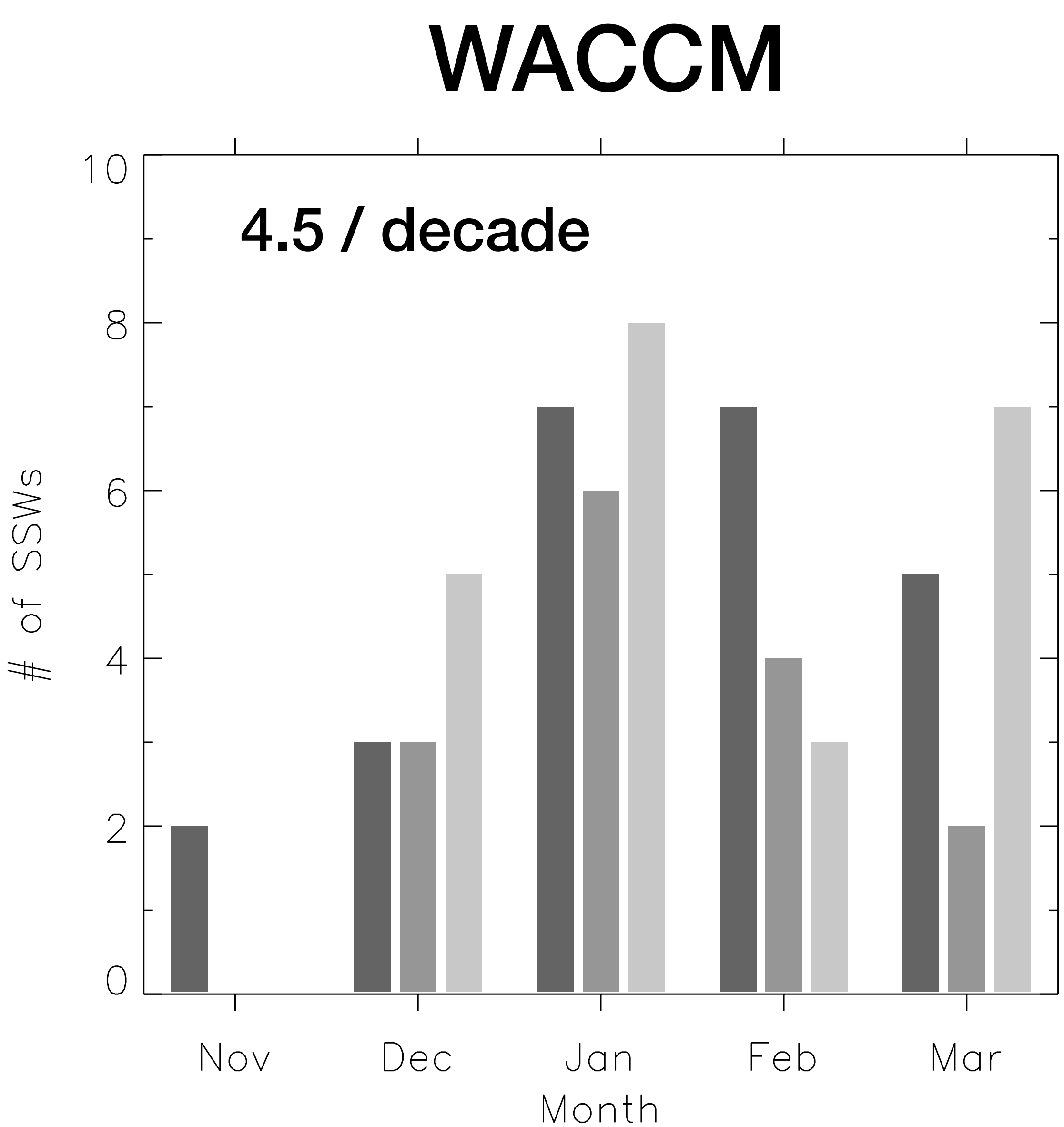


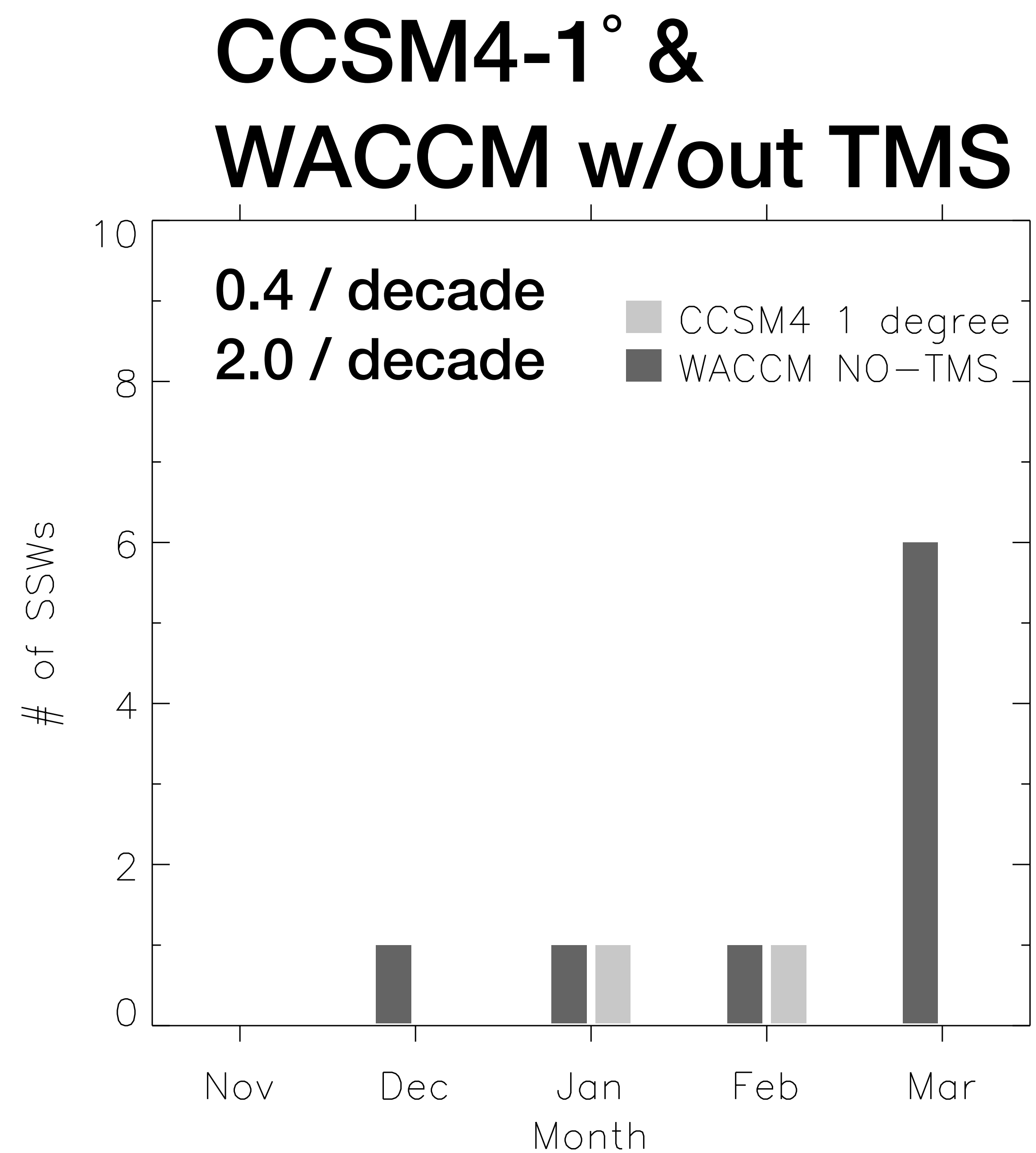
ENSO SST anomalies (Niño-3.4) 1960-2005



What is the role of TMS in setting the amplitude of ENSO?

Stratospheric Sudden Warmings (1960-2005)

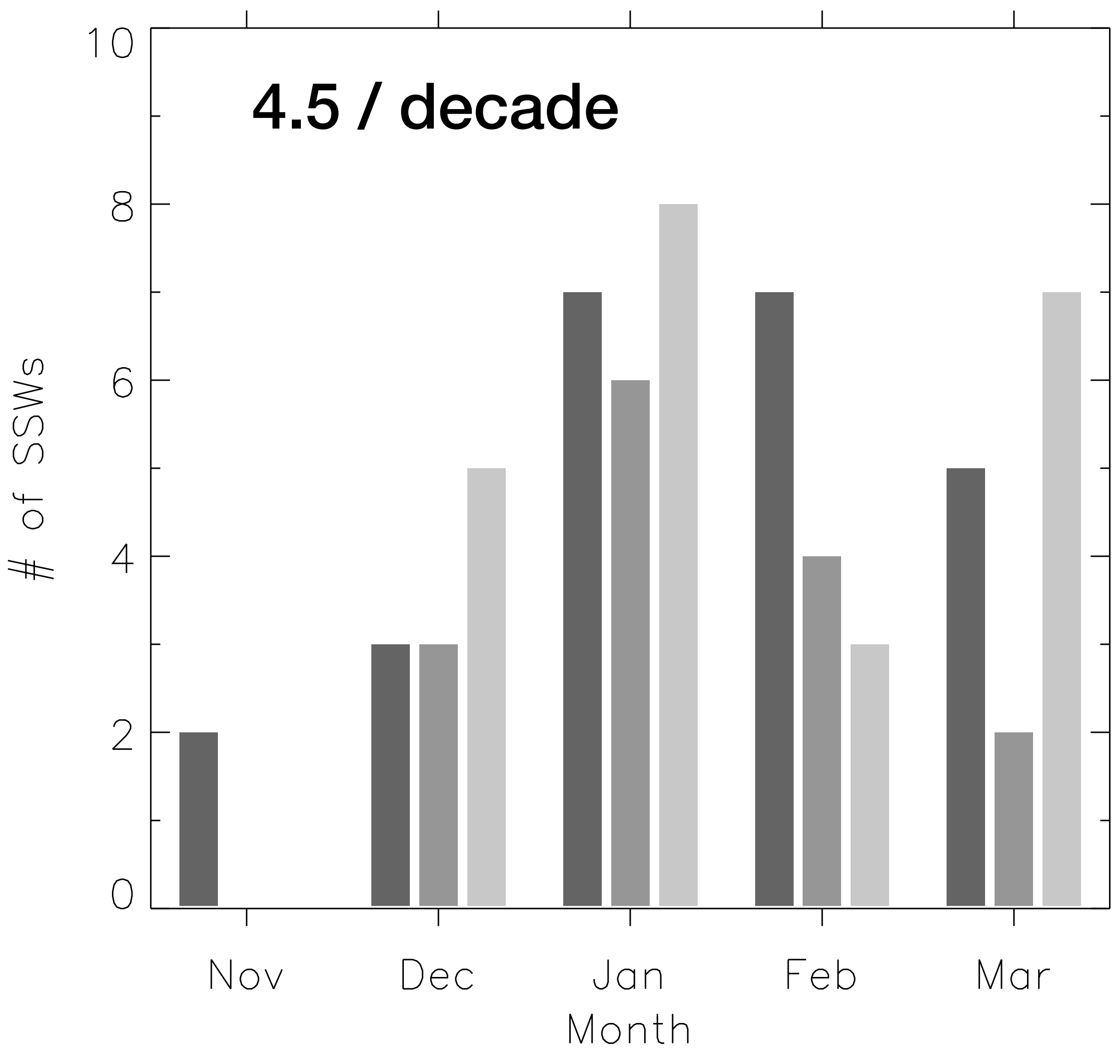




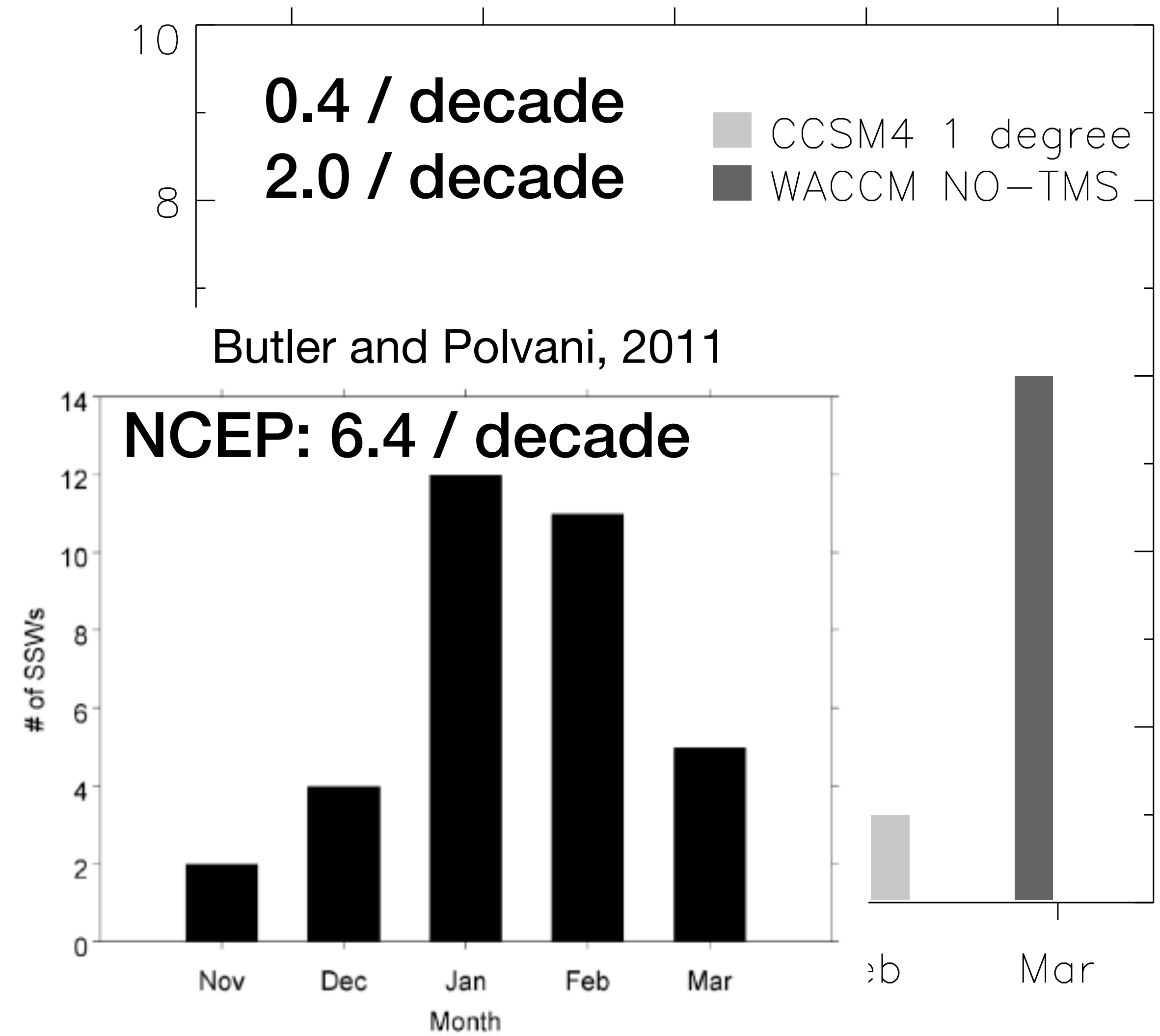
SSWs: "a major midwinter warming occurs when the zonal mean zonal winds at 60N and 10 hPa become easterly during winter, defined here as November-March (NDJFM)" - Charlton and Polvani, J. Clim. 2007

Stratospheric Sudden Warmings (1960-2005)

WACCM



CCSM4-1° & WACCM w/out TMS



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Stratospheric Sudden Warmings (1960-2005)

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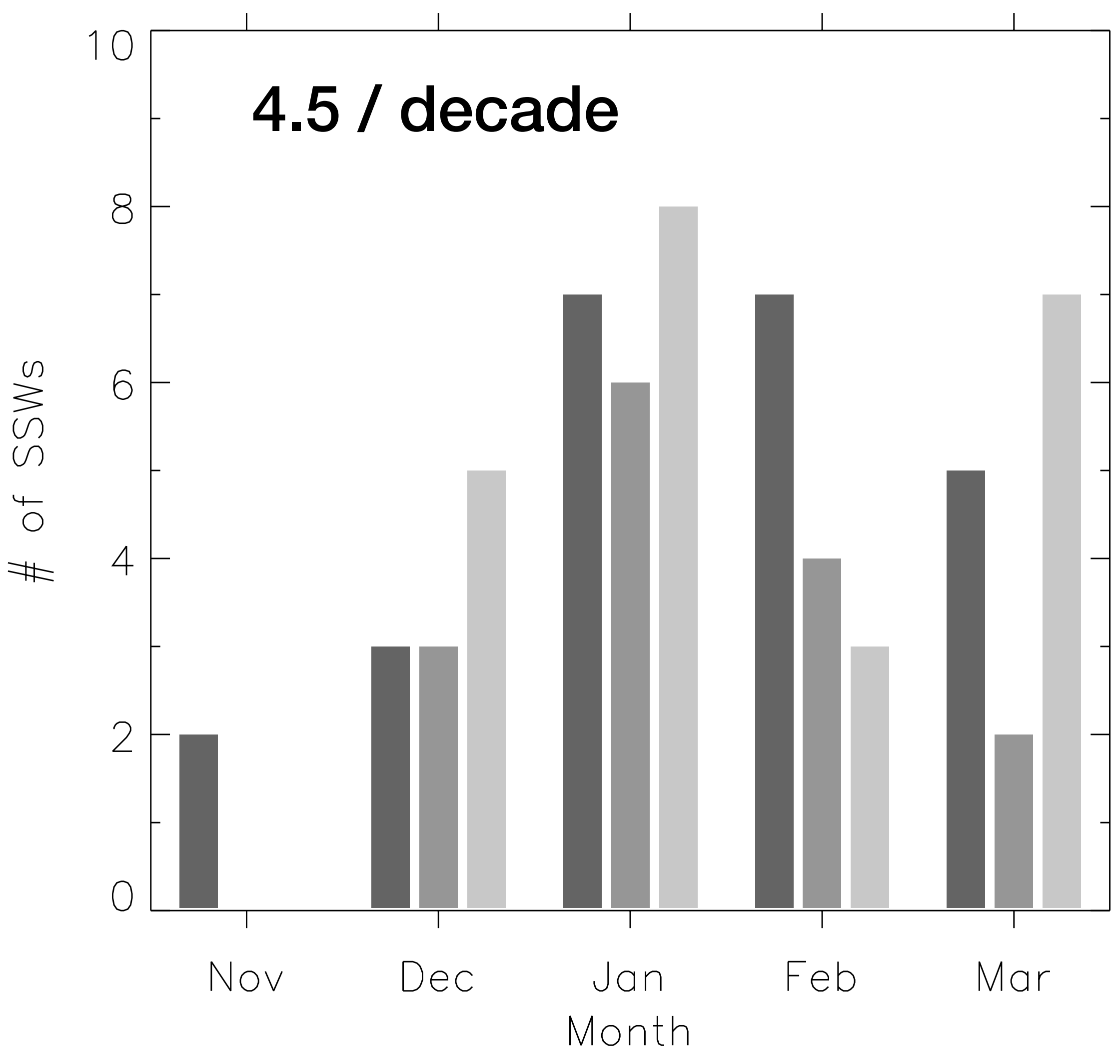
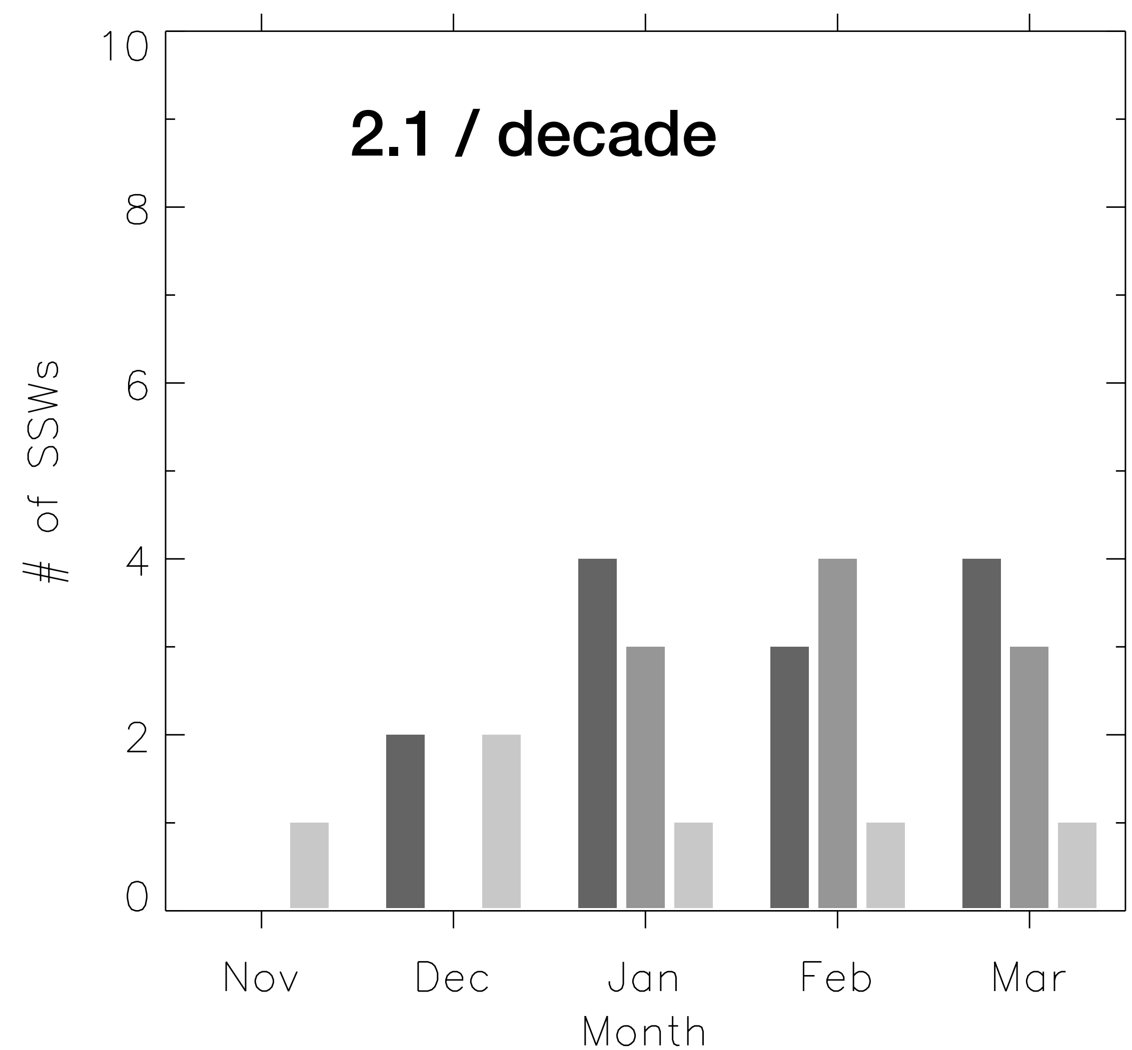


CCSM4-WSET



What is the role of TMS in triggering SSWs?

Is there are link to blocking? Is it affected by TMS?

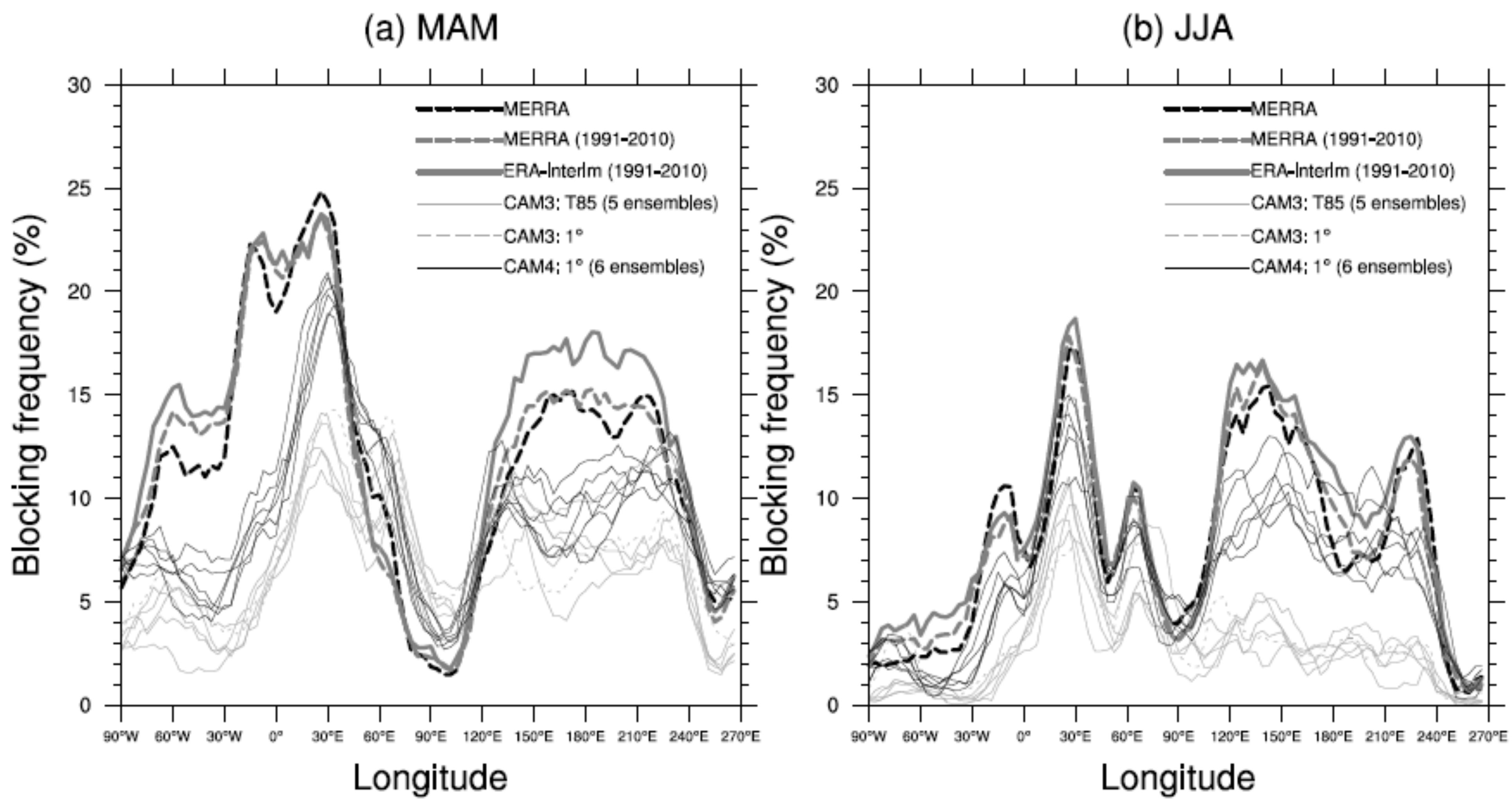
GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L14806, doi:10.1029/2009GL038776, 2009

Blocking precursors to stratospheric sudden warming events

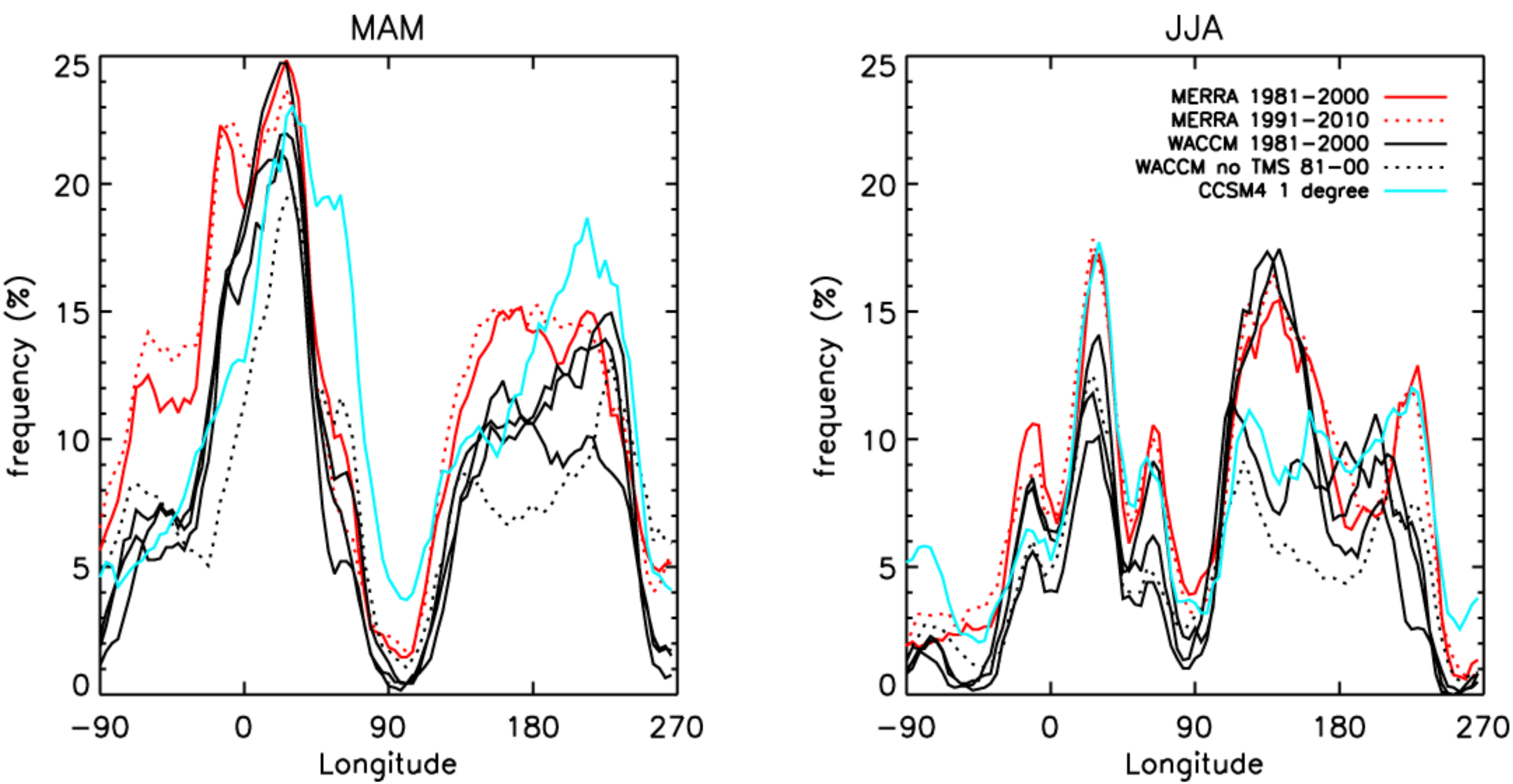
O. Martius,[1] L. M. Polvani,[2] and H. C. Davies[1]

"25 of the 27 events objectively identified in the ERA-40 dataset for the period 1957–2001 are preceded by blocking patterns in the troposphere."

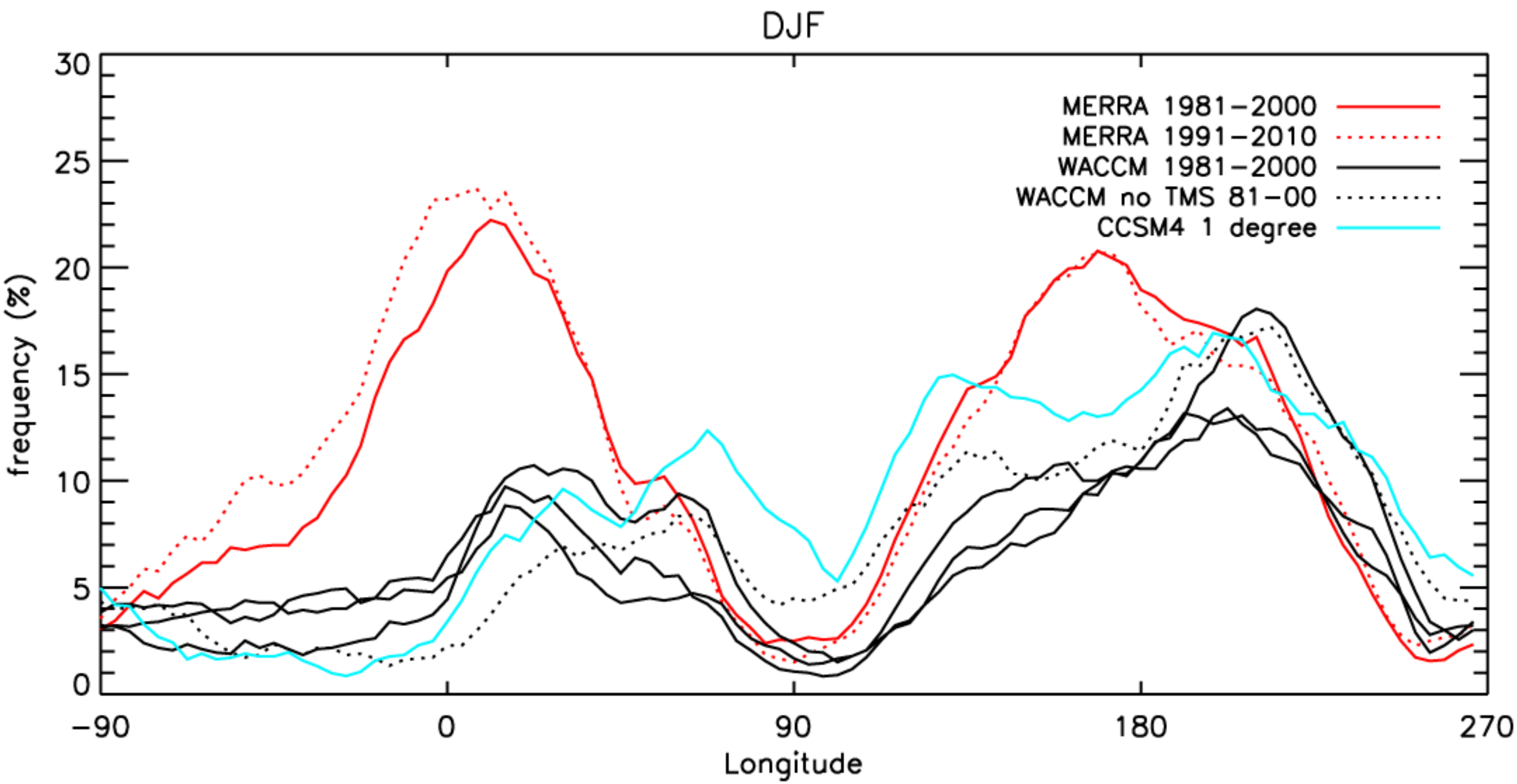
R.Neale et al., CCSM4, J. Clim., 2012



Blocking frequency MAM / JJA



Blocking frequency MAM / JJA



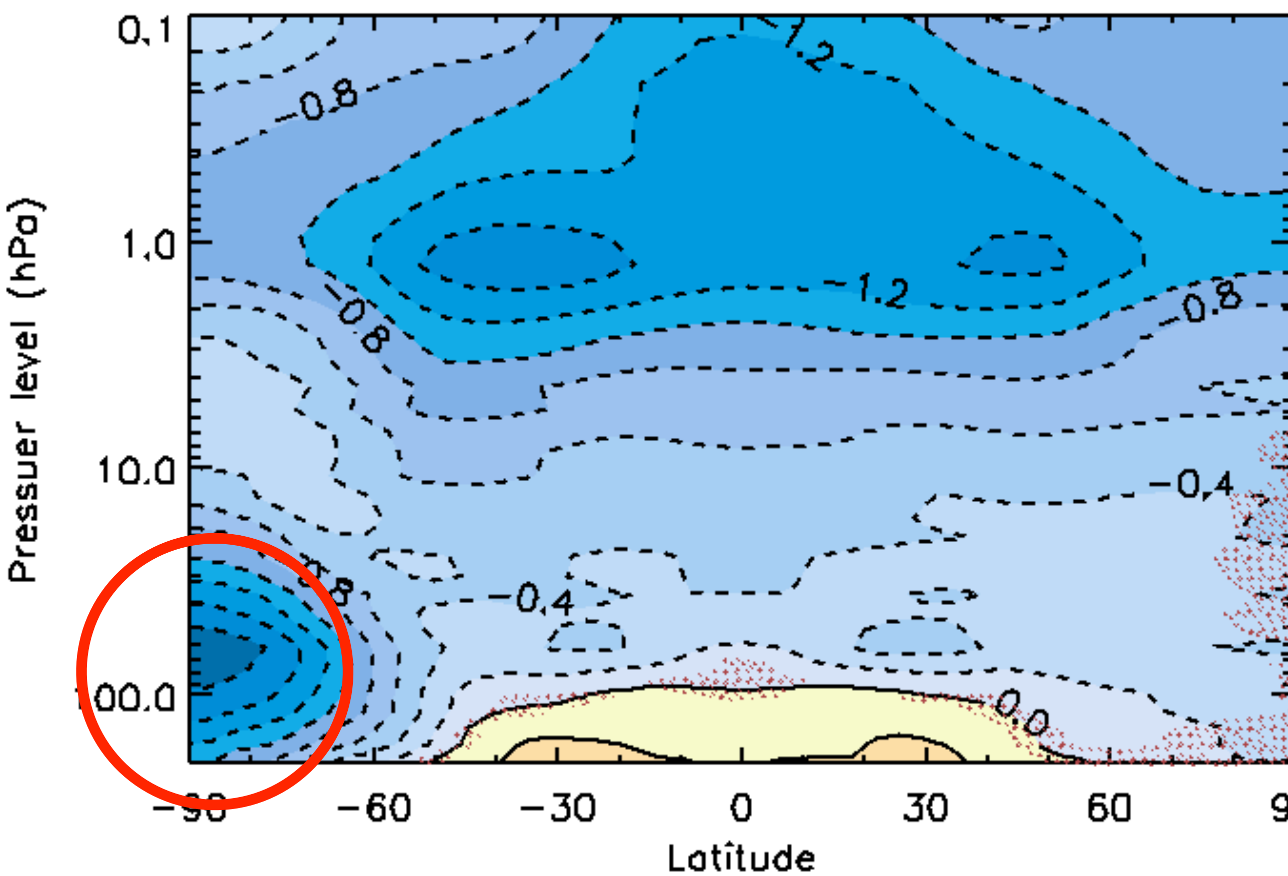
Does not appear blocking difference can account for difference in SSWs

WACCM Whole Atmosphere Community Climate Model

WACCM Stratospheric T and Ozone

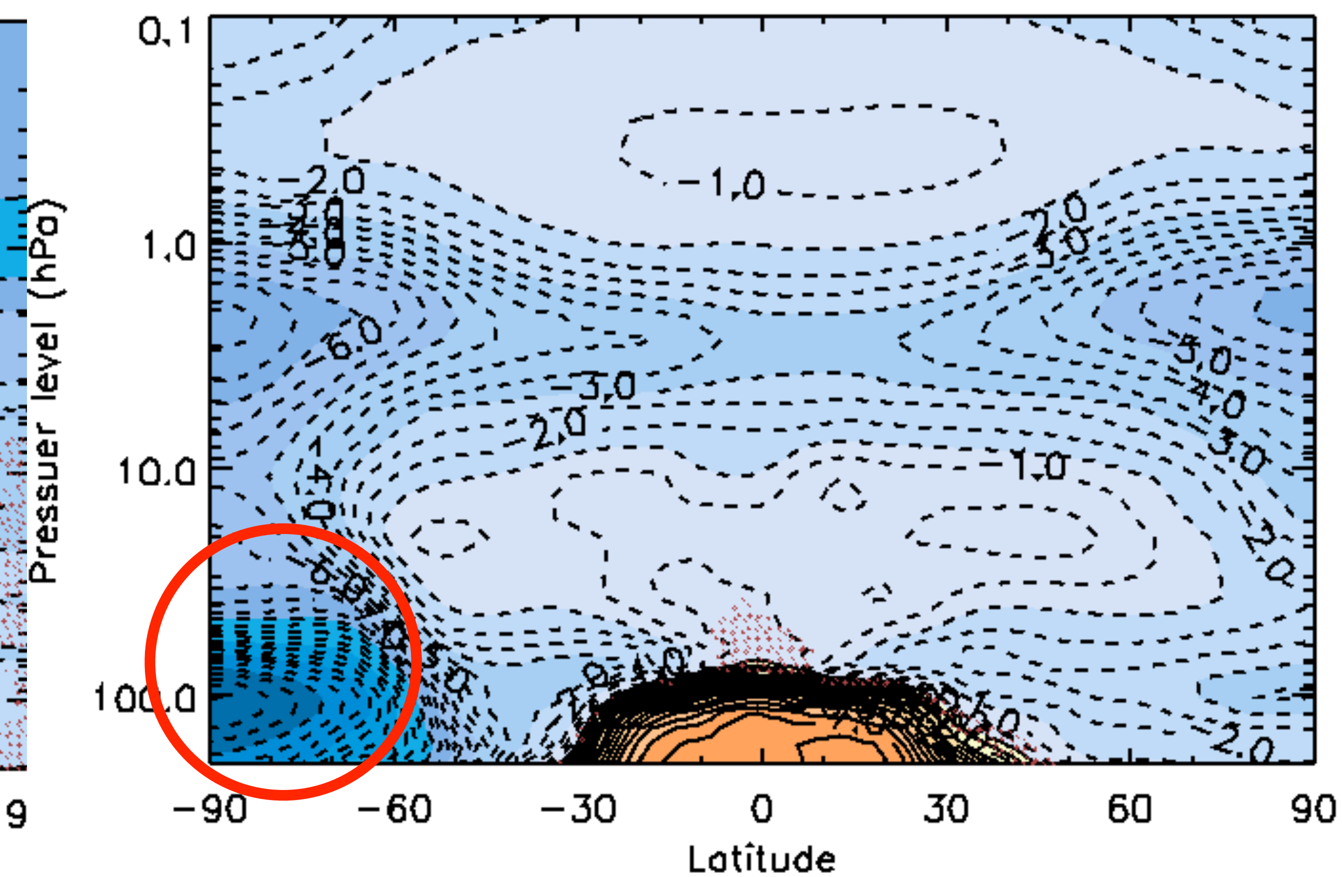
annual mean trends 1960-2005

Temperature K/decade



1 to 1.4 K/decade cooling at the stratopause

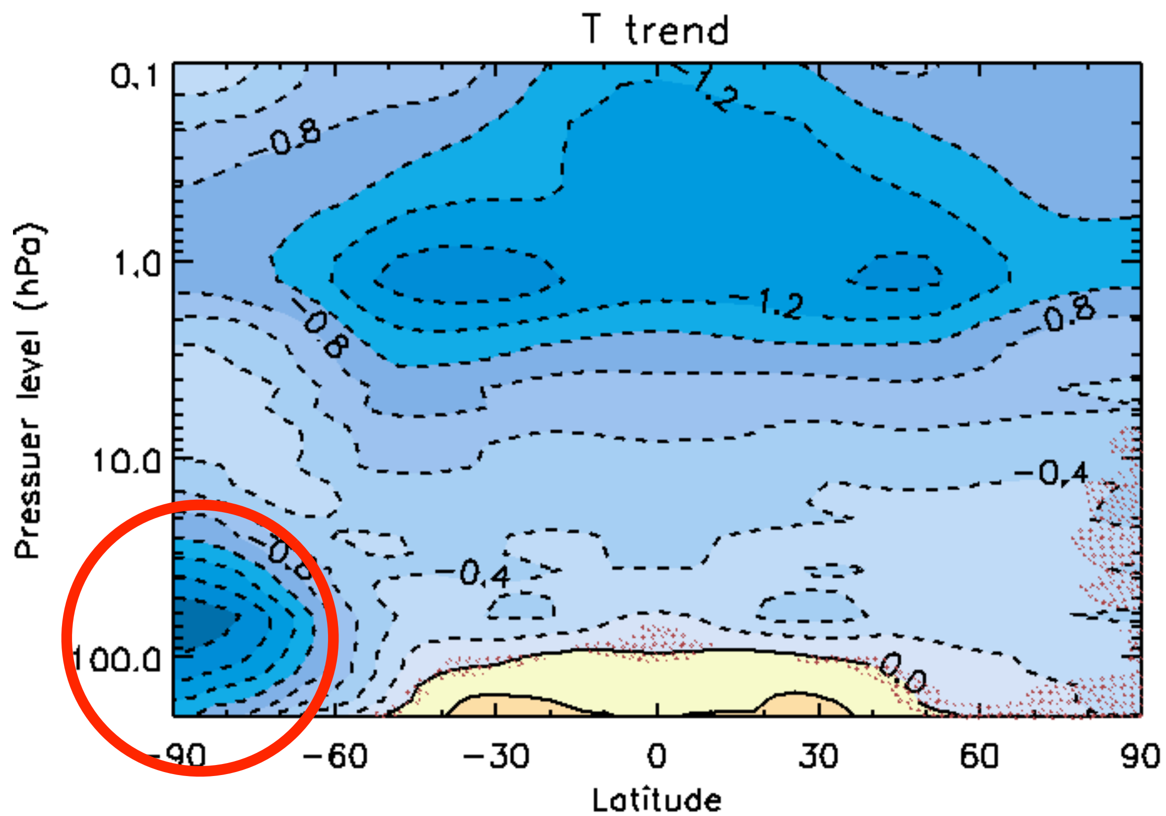
Ozone %/decade



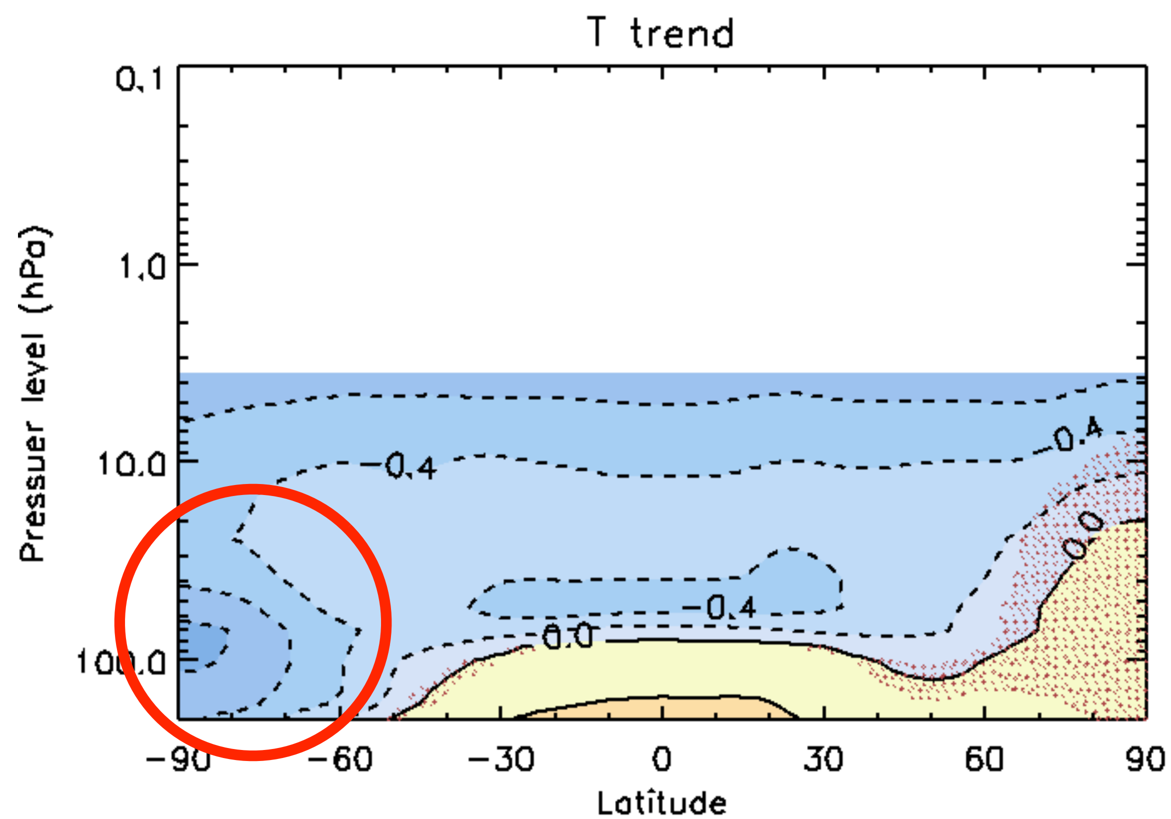
-3 to -8 %/decade decrease in the upper stratosphere

WACCM vs 'low-top' CCSM4 temperature changes

annual mean trends 1960-2005



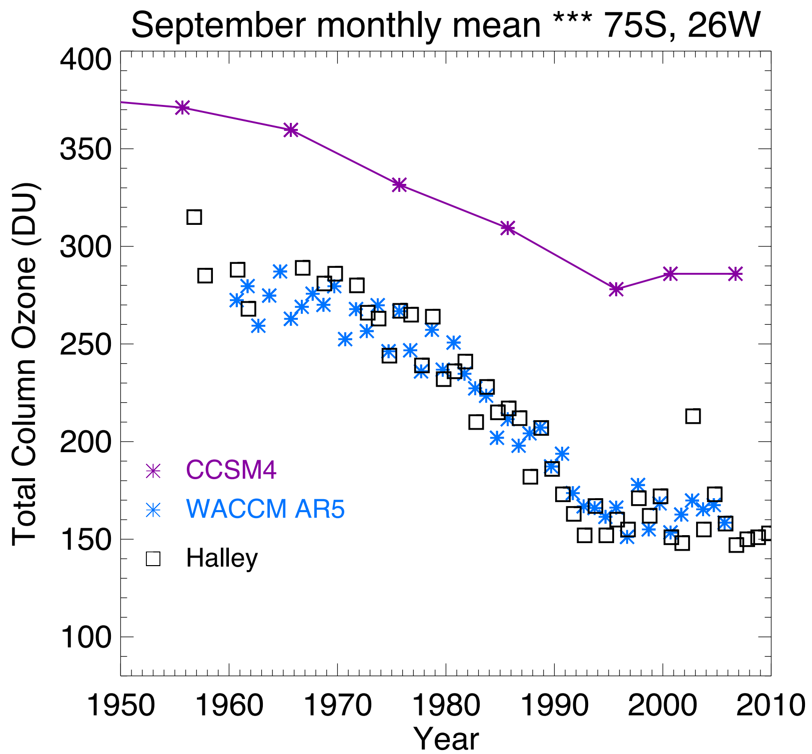
WACCM ensemble member 1

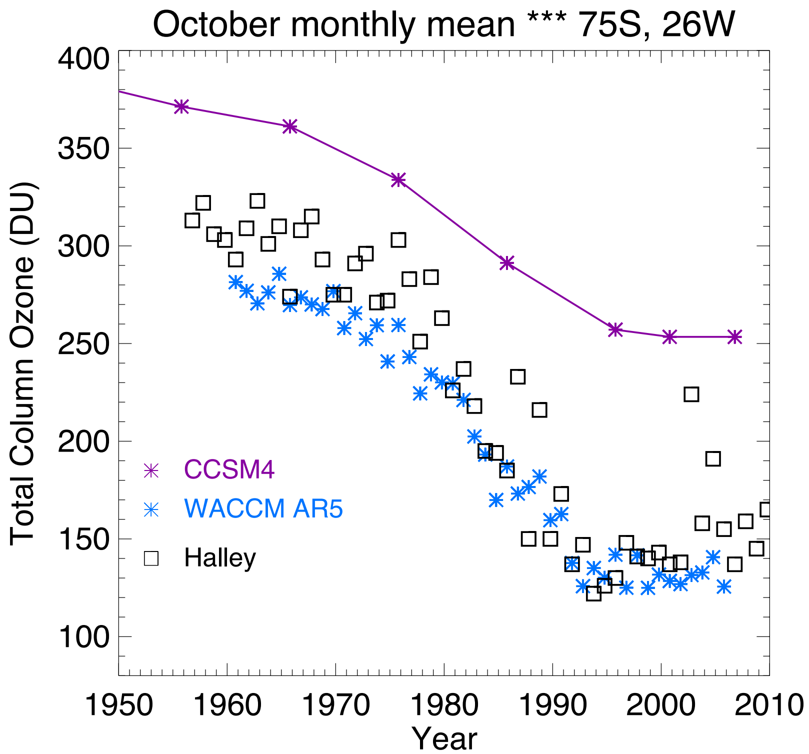


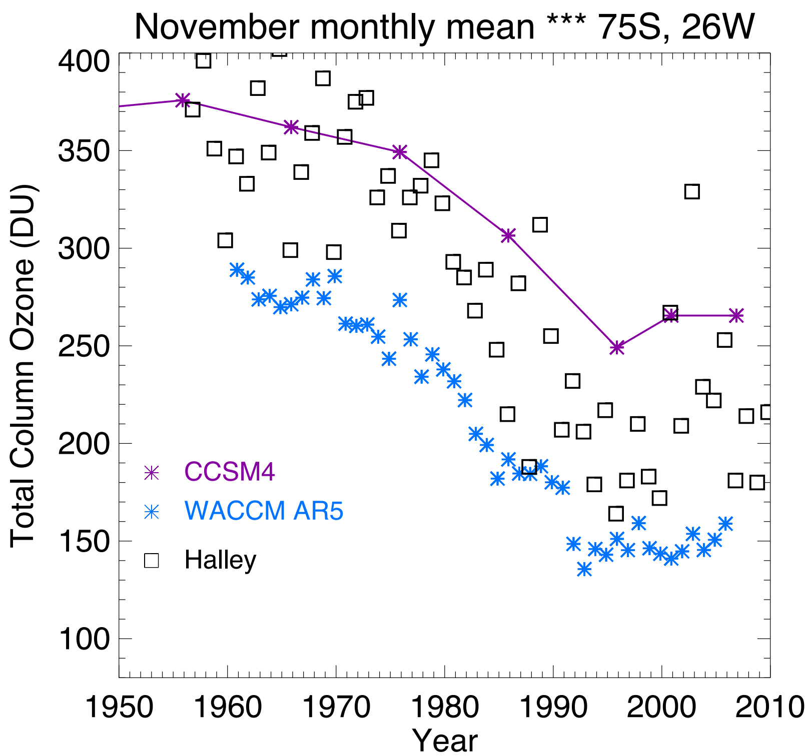
CCSM4-WSET ensemble member 1

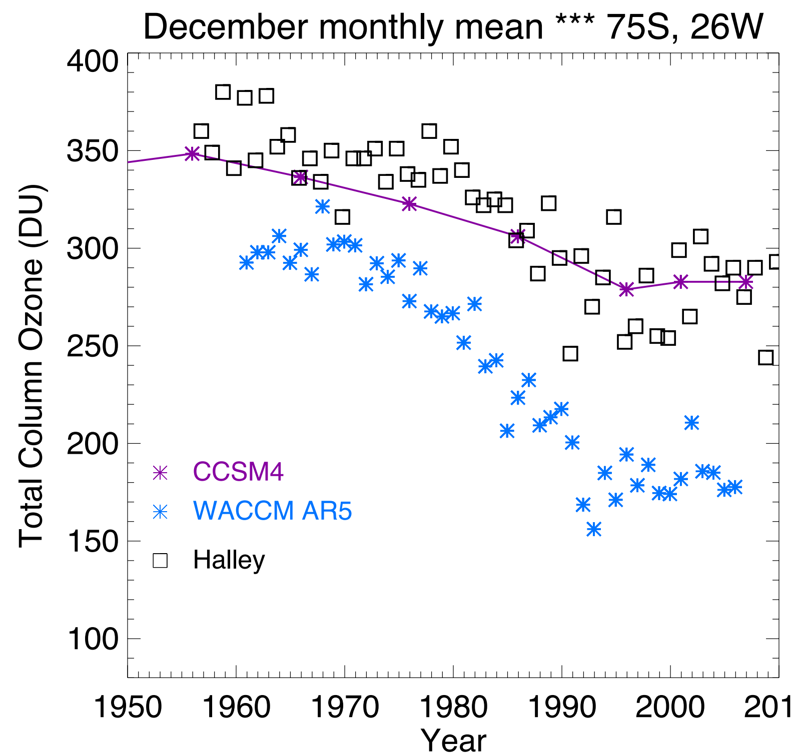
NCAR WACCM Whole Atmosphere Community Climate Model

Total Column Ozone - Halley Bay





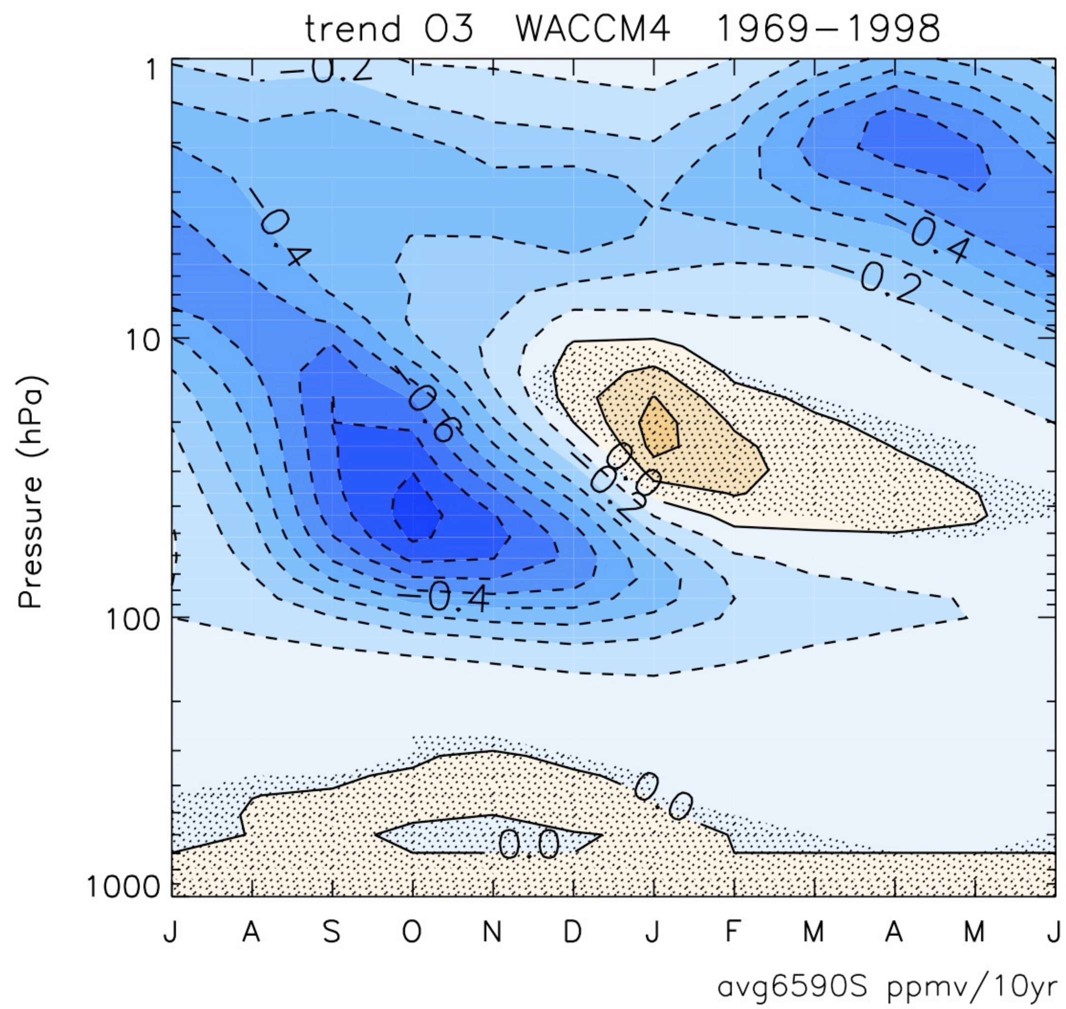




Figures courtesy D. Kinnison

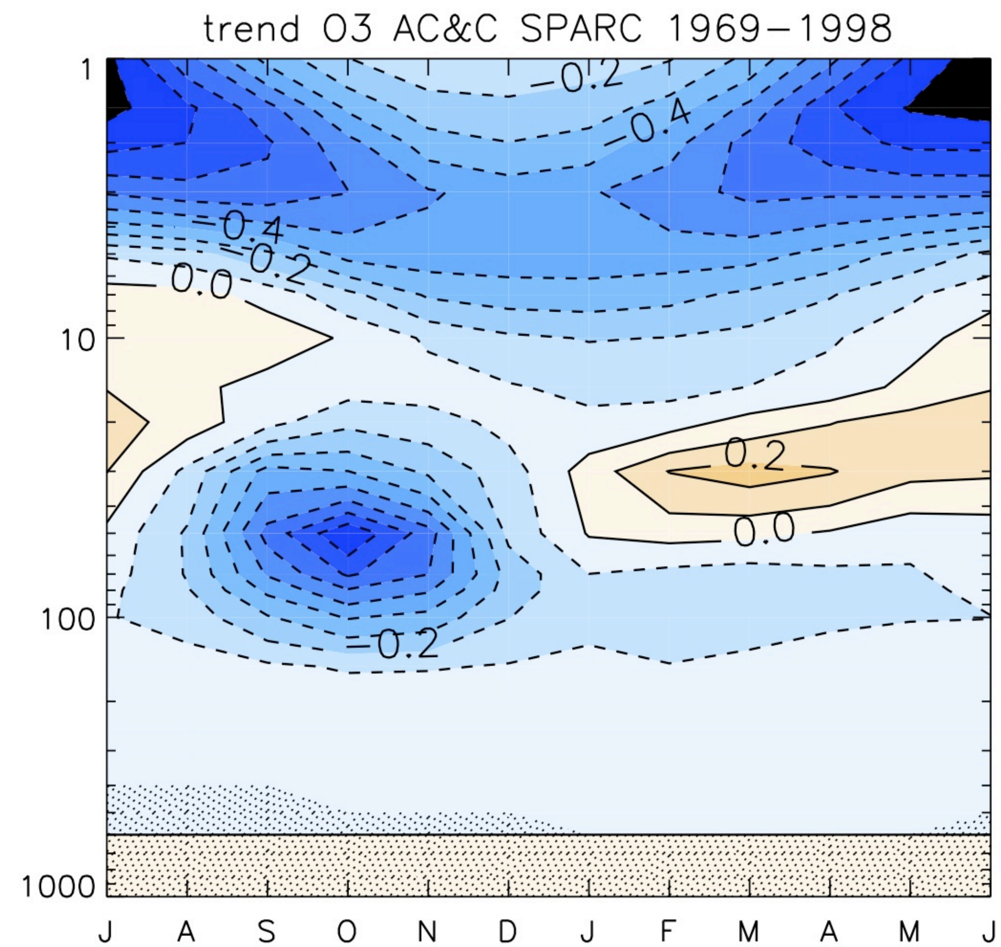
SH polar cap ozone trends

WACCM



Contours: 0.1 ppmv / decade

OBS. (SPARC)



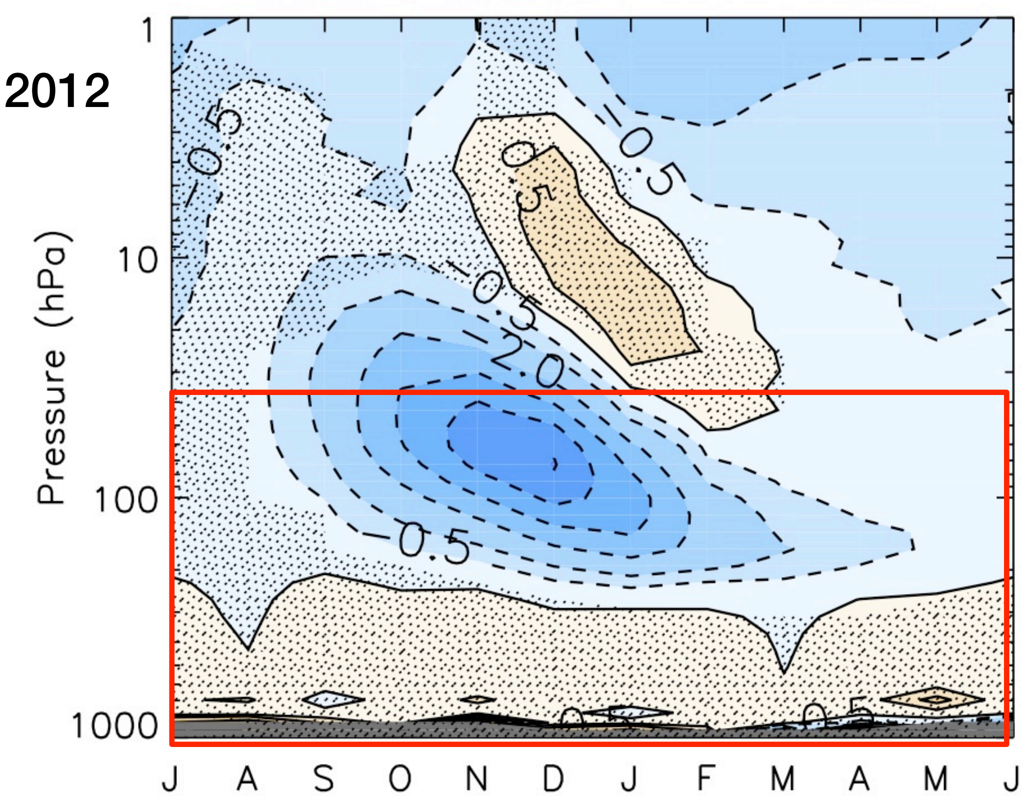
Calvo et al., 2012

NCAR WACCM Whole Atmosphere Community Climate Model

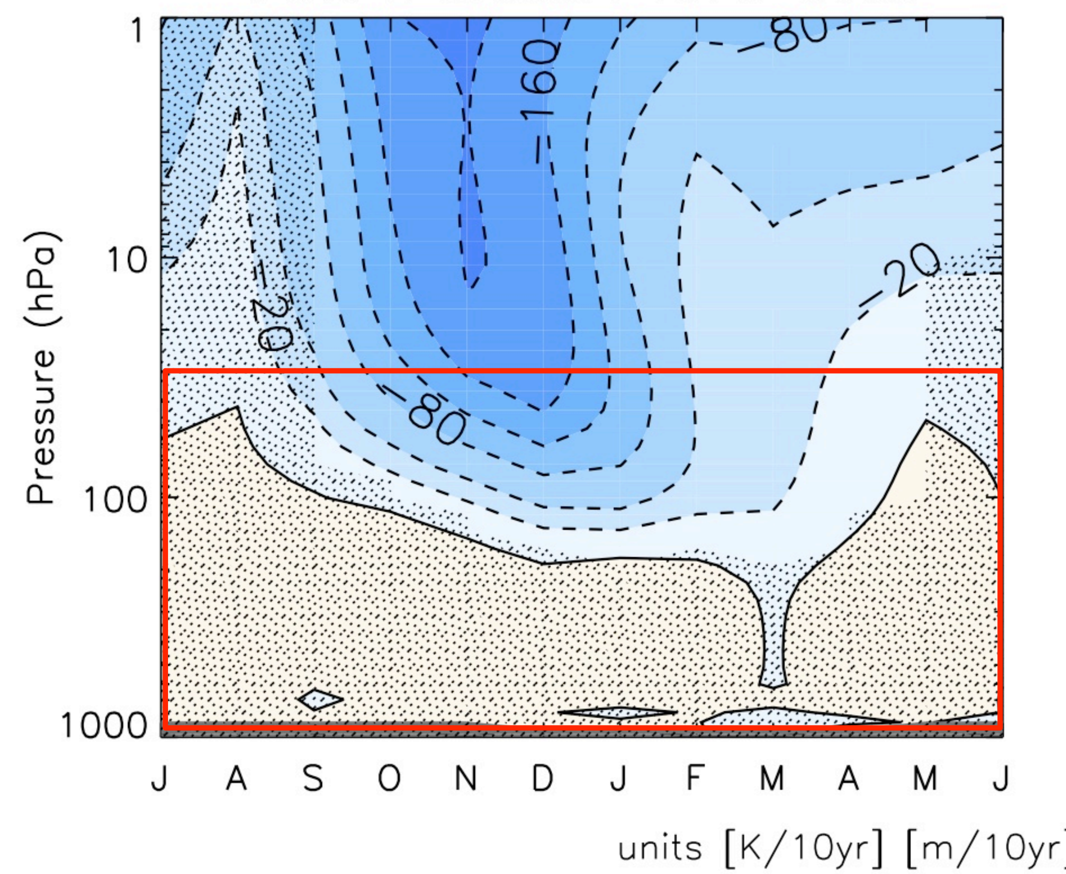
Temperature & geopotential height trends 1979-2003

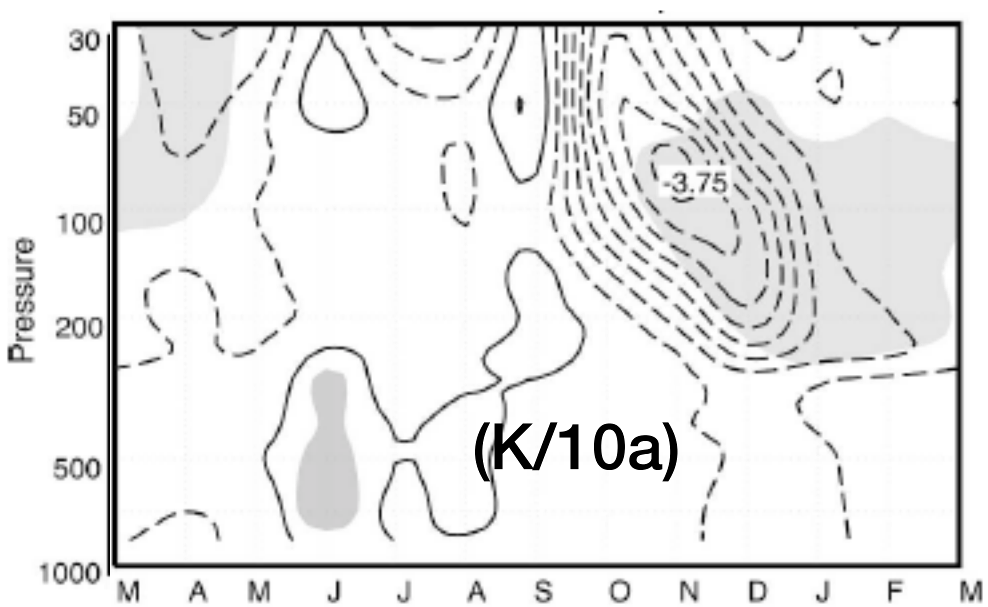
Calvo et al., 2012

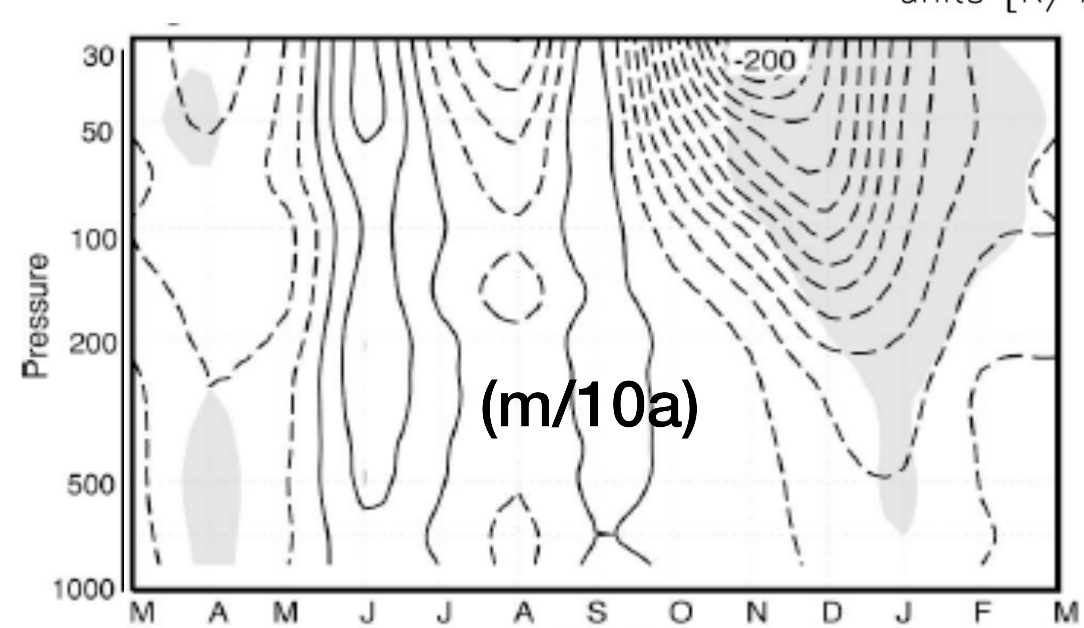
Temperature (K/decade)



Geopotential (m/decade)

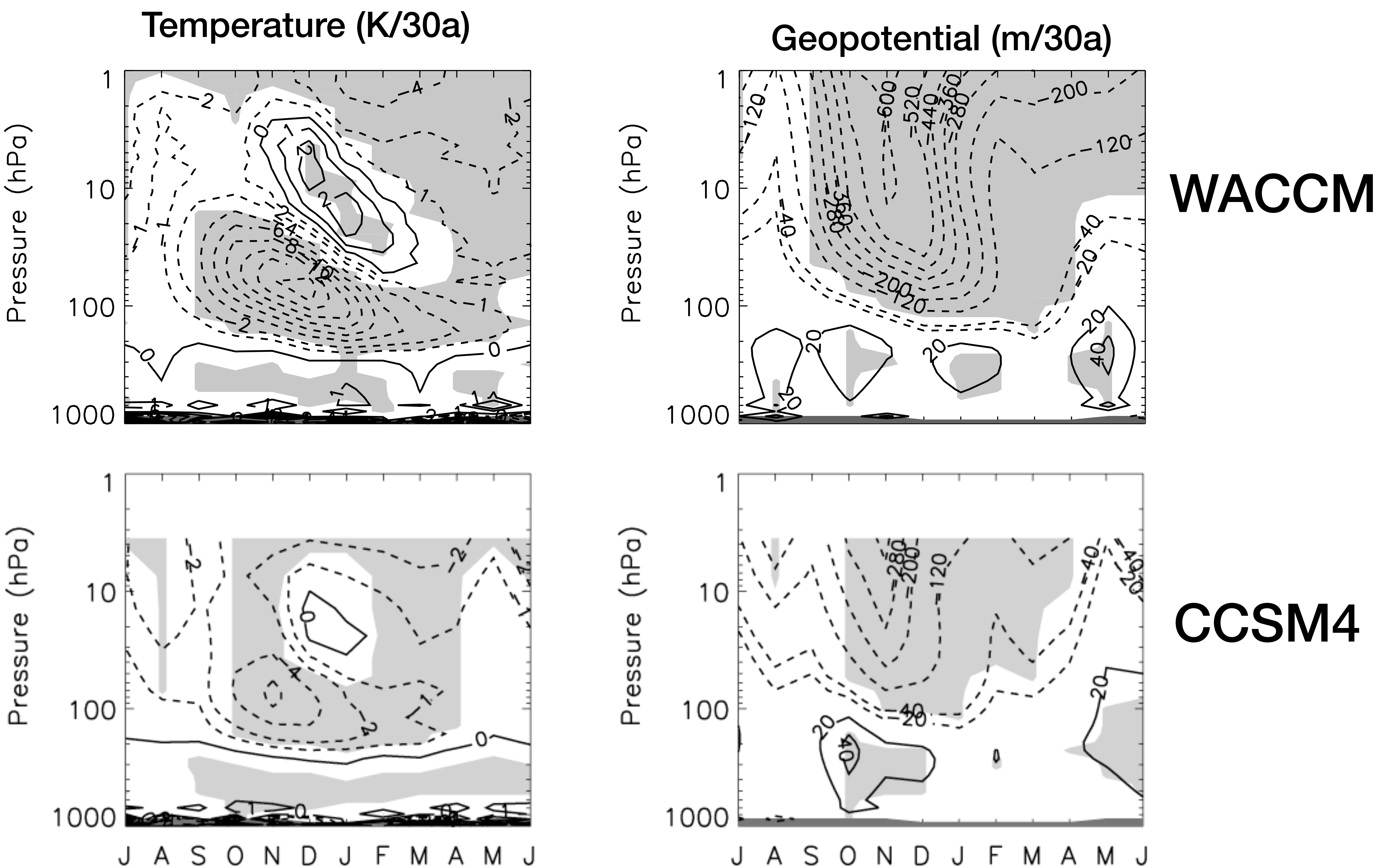






Thompson & Solomon, 2005

1979-2003 Trends 3x weaker in CCSM4



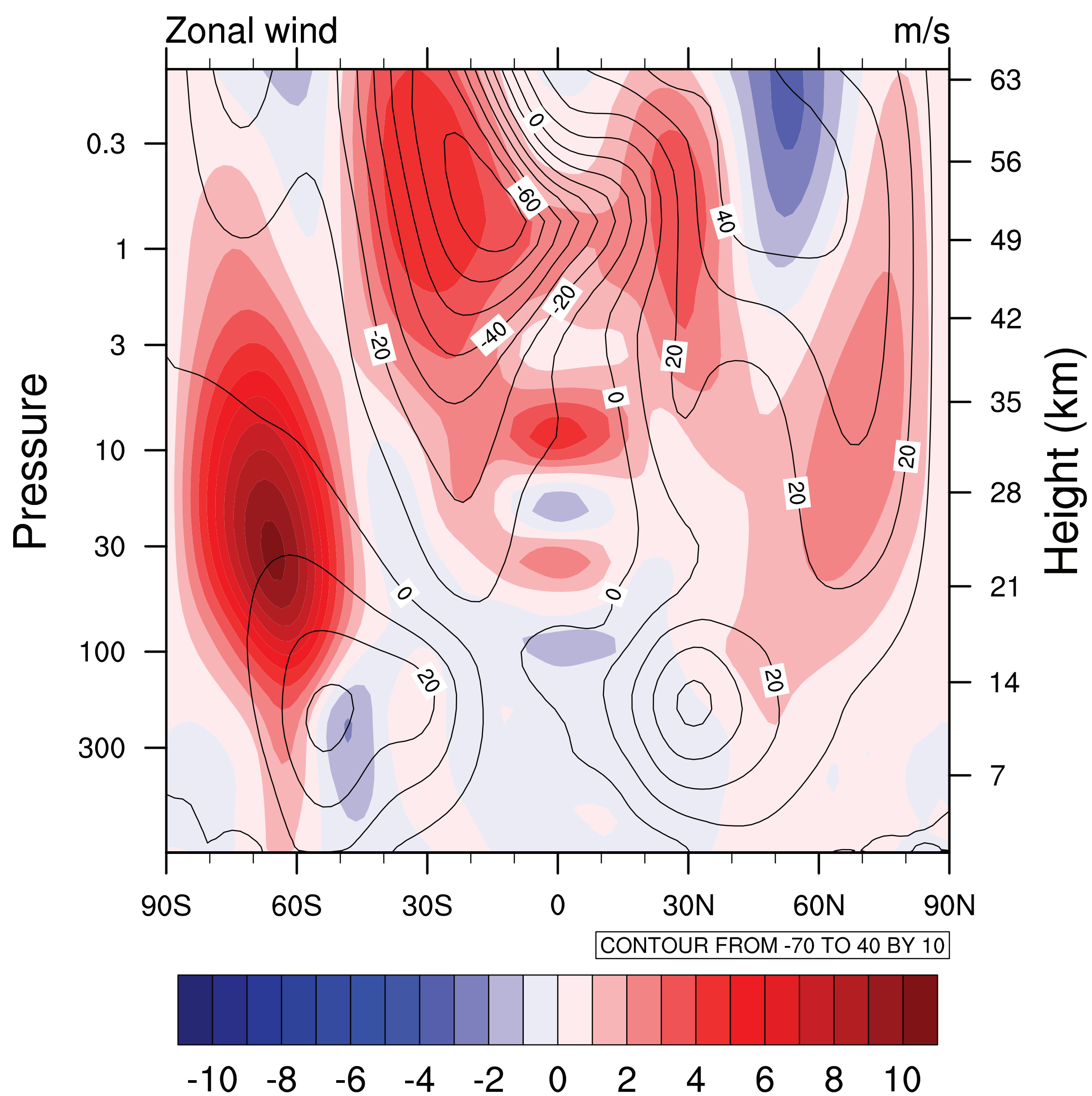
SH polar cap maximum trends

Case	T (K per decade)	Geopotential (m per decade)	Source
TS02, 1969-1998	–2.2	–110	*Thompson and Solomon* [2002]
WACCM4, 1969-1998, 65-90S	–6.2 ± 2.5	–290 ± 130	CMIP5
CCMVal2 ensemble, 1969-1998, 65-90S	–3.7	-166	*SPARC CCMVal* [2010]
TS05, 1979-2003, 60-90S	–3.75	–200	*Thompson and Solomon* [2005]
WACCM4, 1979-2003, 60-90S	–4.6 ±3.2	–200 ±150	CMIP5

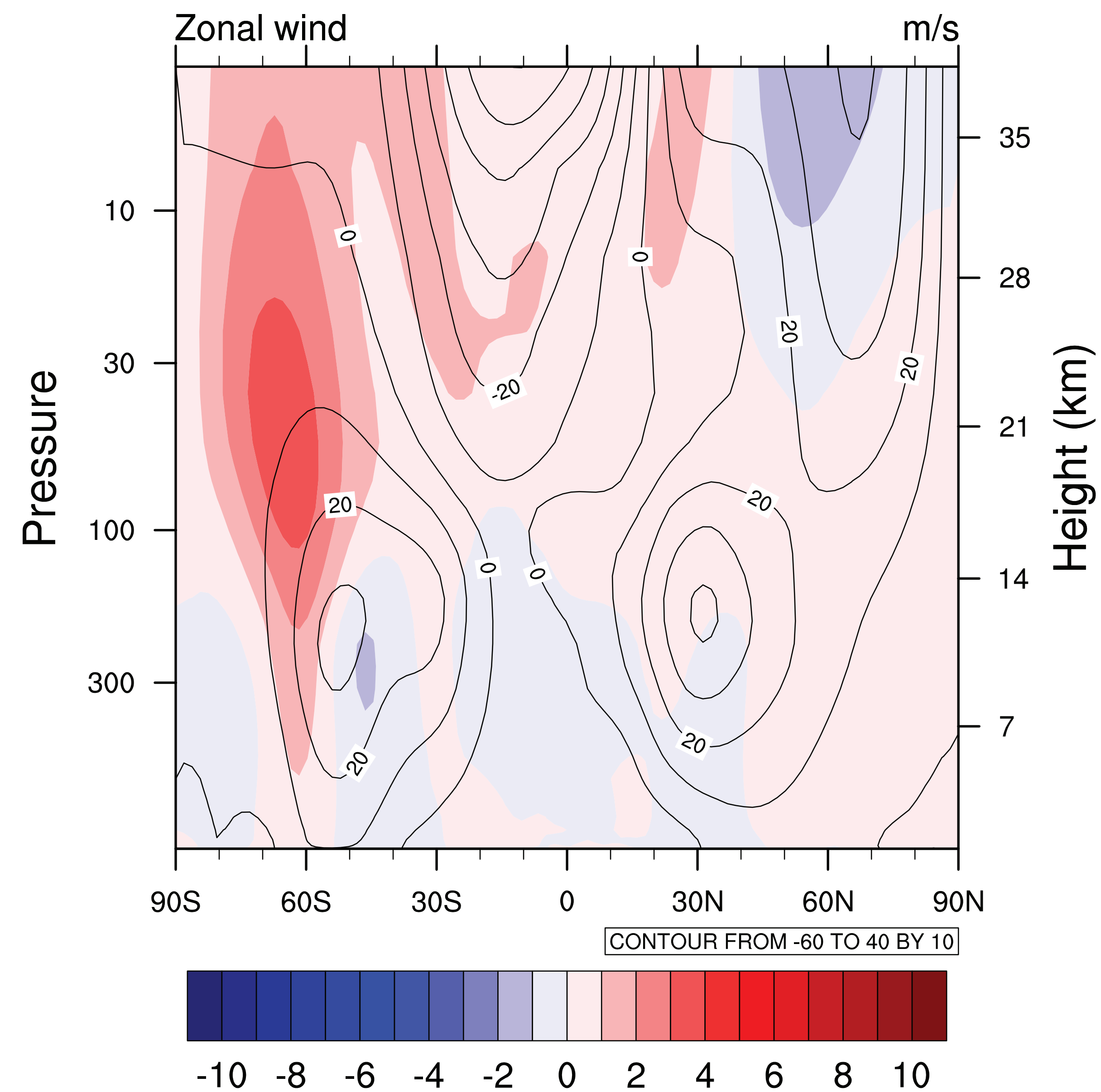
Calvo et al., 2012

DJF zonal wind (m/s)

WACCM



CCSM4-WSET



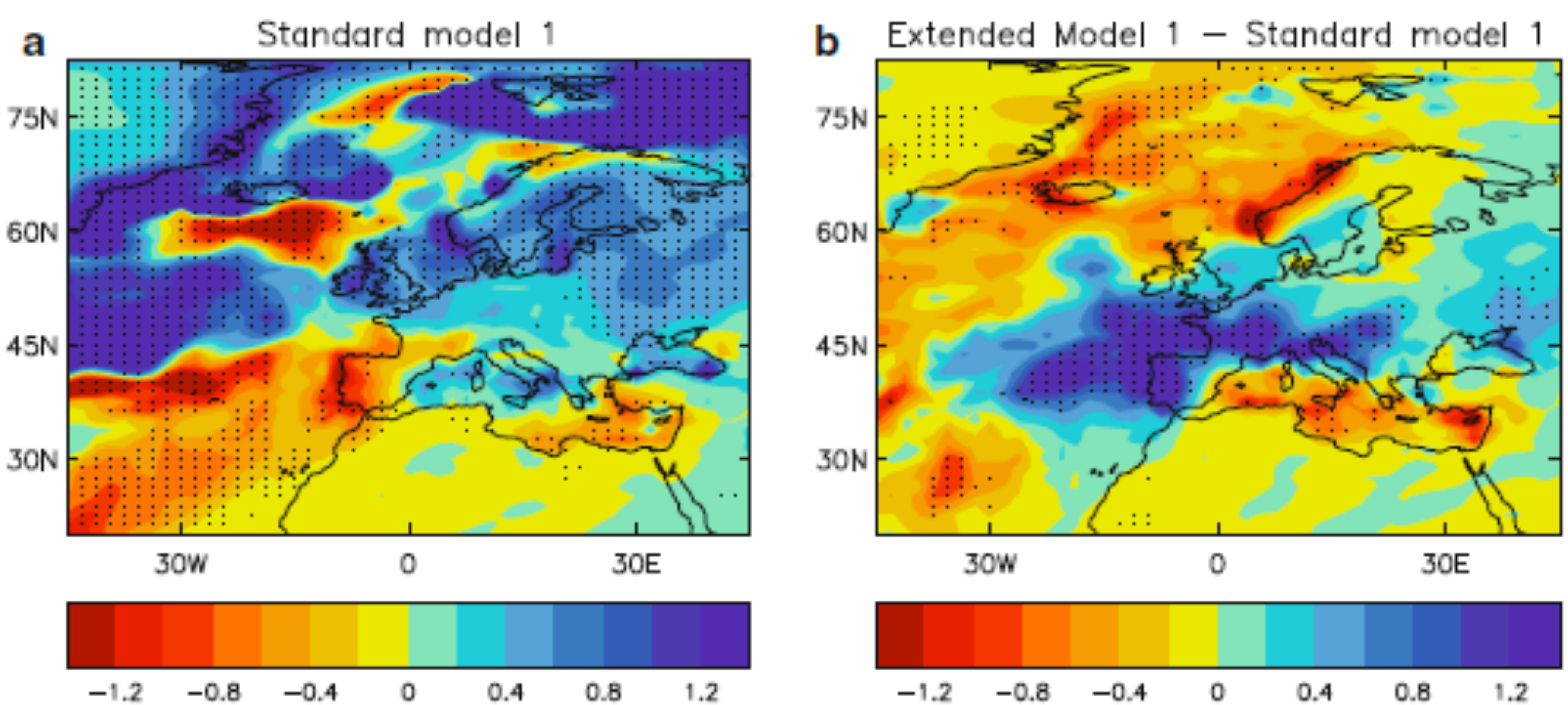
Colors: 1986-2005 average minus 1960-79 average.
Lines: 1960-79 average.

NH surface response

Clim Dyn
DOI 10.1007/s00382-011-1080-7

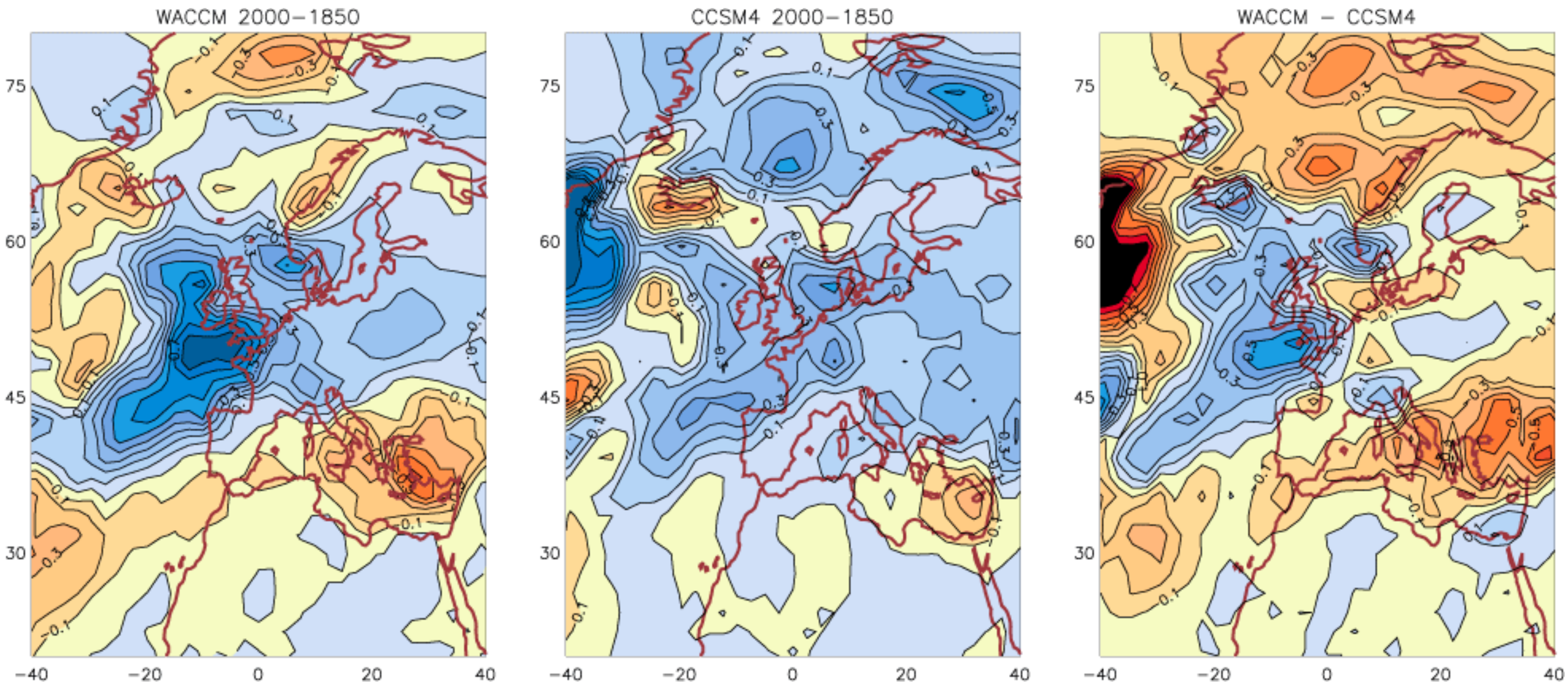
Climate change projections and stratosphere–troposphere interaction

Adam A. Scaife · Thomas Spangehl · David R. Fereday · Ulrich Cubasch · Ulrike Langematz · Hideharu Akiyoshi · Slimane Bekki · Peter Braesicke · Neal Butchart · Martyn P. Chipperfield · Andrew Gettelman · Steven C. Hardiman · Martine Michou · Eugene Rozanov · Theodore G. Shepherd

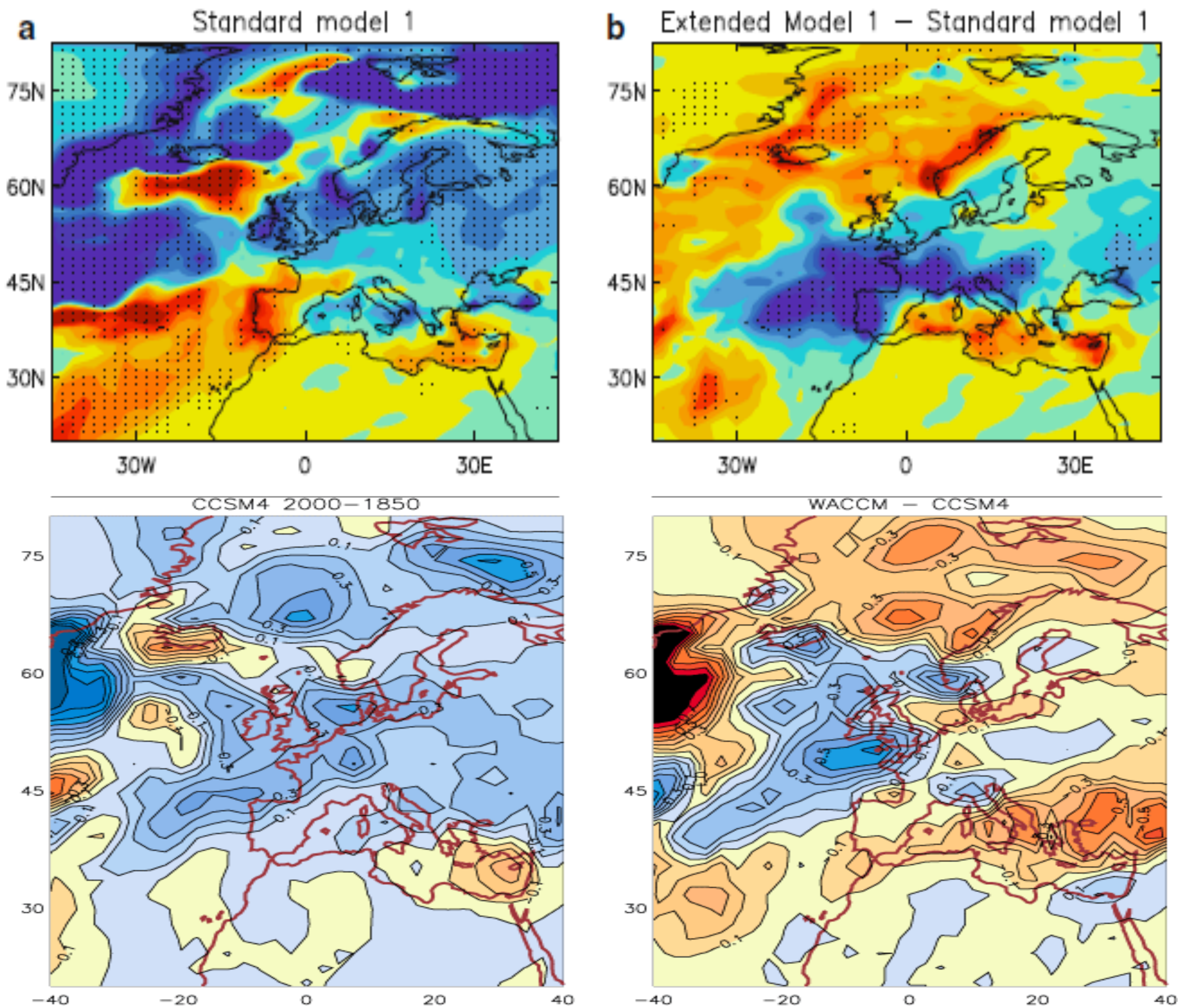


Winter Mean Rainfall
$(4 \times CO_2)$-$(1 \times CO_2)$

Change in winter mean rainfall (mm/day)



Change in winter mean rainfall (mm/day)



Summary I

- N3.4 period and amplitude of WACCM & CCSM4-WSET 2° comparable to CCSM4 1° and half the amplitude of CCSM4 2° (role of TMS?)
- Almost all NH winter stratospheric variability and its propagation into the troposphere are absent in CCSM4 CMIP5 integrations
  - Switching on TMS in CCSM4 increases SSW counts to ~50% of WACCM
  - NAM signal (not shown) is weaker and similarly less frequent
  - Blocking frequency seems consistent across models - a necessary but not sufficient condition for SSWs?

Summary II

- New CMIP-5 CCSM4 and WACCM simulations allow investigation of the role of the stratosphere-troposphere coupling in climate change
  - Signals related to the development of the ozone hole propagate into the troposphere and appear to be more realistic in WACCM.
  - Mid-latitude NH SLP/precipitation changes in wintertime strongly dependent on whether there is a resolved stratosphere - systematic error not captured in ensemble variance
  - Representation of stratosphere-troposphere coupling could be a major source of uncertainty in regional climate change projections.

Acknowledgements

- @NCAR - Mike Mills, Natalia Calvo, Doug Kinnison, Francis Vitt, Rolando Garcia, Jean-Francois Lamarque, Andrew Conley, Rich Neale, CESM Working group co-chairs and liaisons ...
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- CSEG, particularly Mariana Vertenstein and Chris Fischer
- Substantial computing resources were provided by the Climate Simulation Laboratory at NCAR's Computational and Information Systems Laboratory
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Thank you

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