SC-WACCM
and
Problems with Specifying the Ozone Hole

R. Neely III[1], K. Smith[2], D. Marsh[1],L. Polvani[2]
[1]NCAR, [2]Columbia

Thanks to: Mike Mills, Francis Vitt and Sean Santos

Motivation

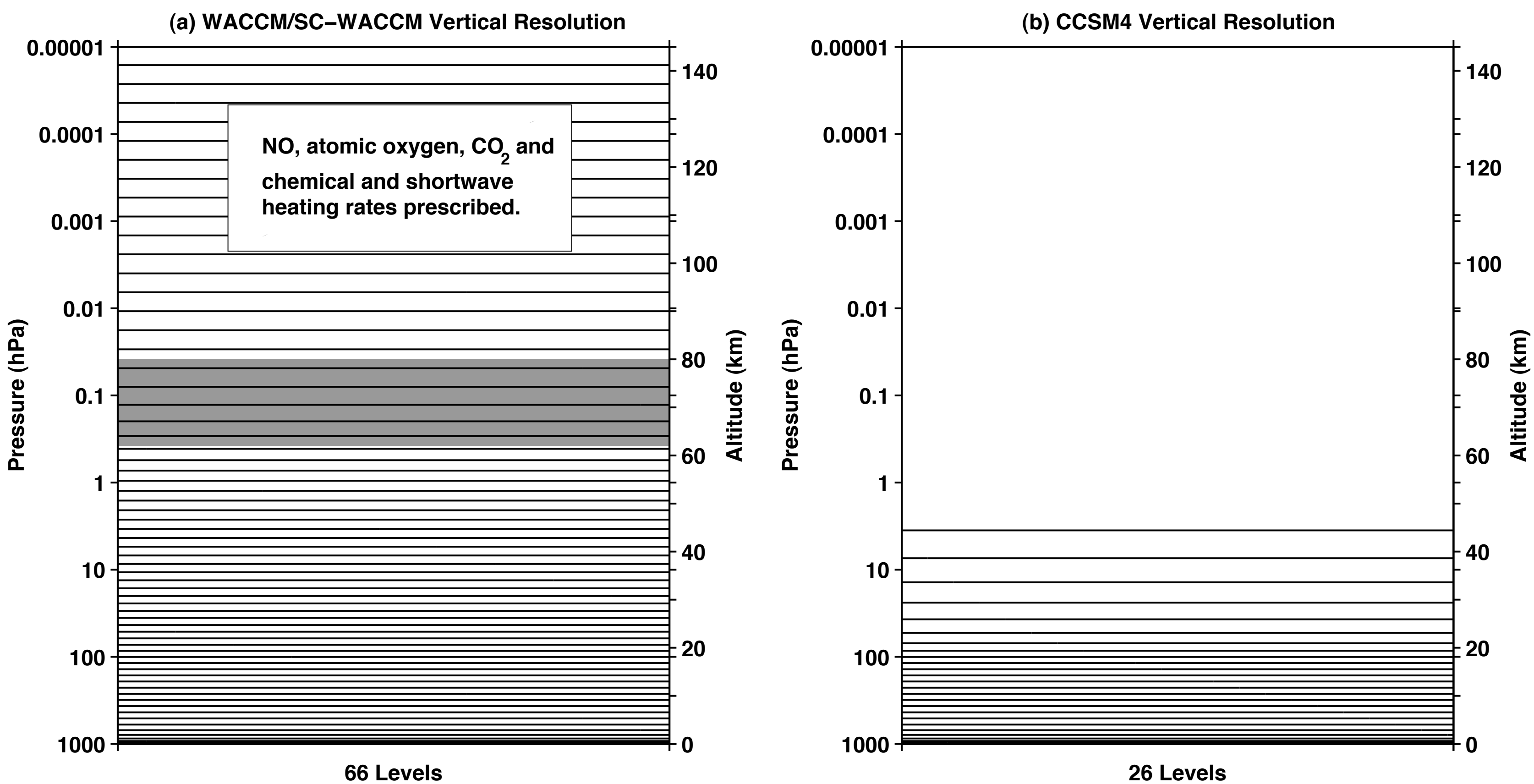
To design a stratosphere-resolving model that can be used for studies of middle atmosphere dynamics without the expense of running interactive chemistry.

SC-WACCM Physics

- Based on CESM1(WACCM)
- Ozone and CO_2 specified from prior fully-interactive WACCM simulations
- Excludes comprehensive chemistry - solves only for H_2O, CH_4, N_2O, CFC-11 and CFC-12
- Radiative transfer:
  - CAM-RT below ~65 km
  - Short-wave heating rates prescribed above >65 km from same 'fully-interactive' simulations
  - Non-LTE cooling calculated from model temperature and prescribed CO_2 >65km
- No auroral physics
- Parameterized non-orographic gravity waves as in WACCM
- TMS turned on

SC-WACCM Resolution

- 1.9˚ latitude x 2.5˚ longitude
- Same 66 levels as WACCM (fully-resolved stratosphere and mesosphere):
  - model top at 5.1x10-6 hPa (~140 km)
  - 18 pressure levels between the surface and 100 hPa are identical to CCSM4
  - Stratosphere: 17 levels in WACCM between 100 and 3 hPa (versus 8 in CCSM4)
  - 9 levels above 100 km



SC-WACCM Performance

Model	# cores	simulated years/day	core-hrs/simulated year
WACCM	352	7.5	1130
SC-WACCM	352	14.8	573
CCSM4 2°	416	42.0	237

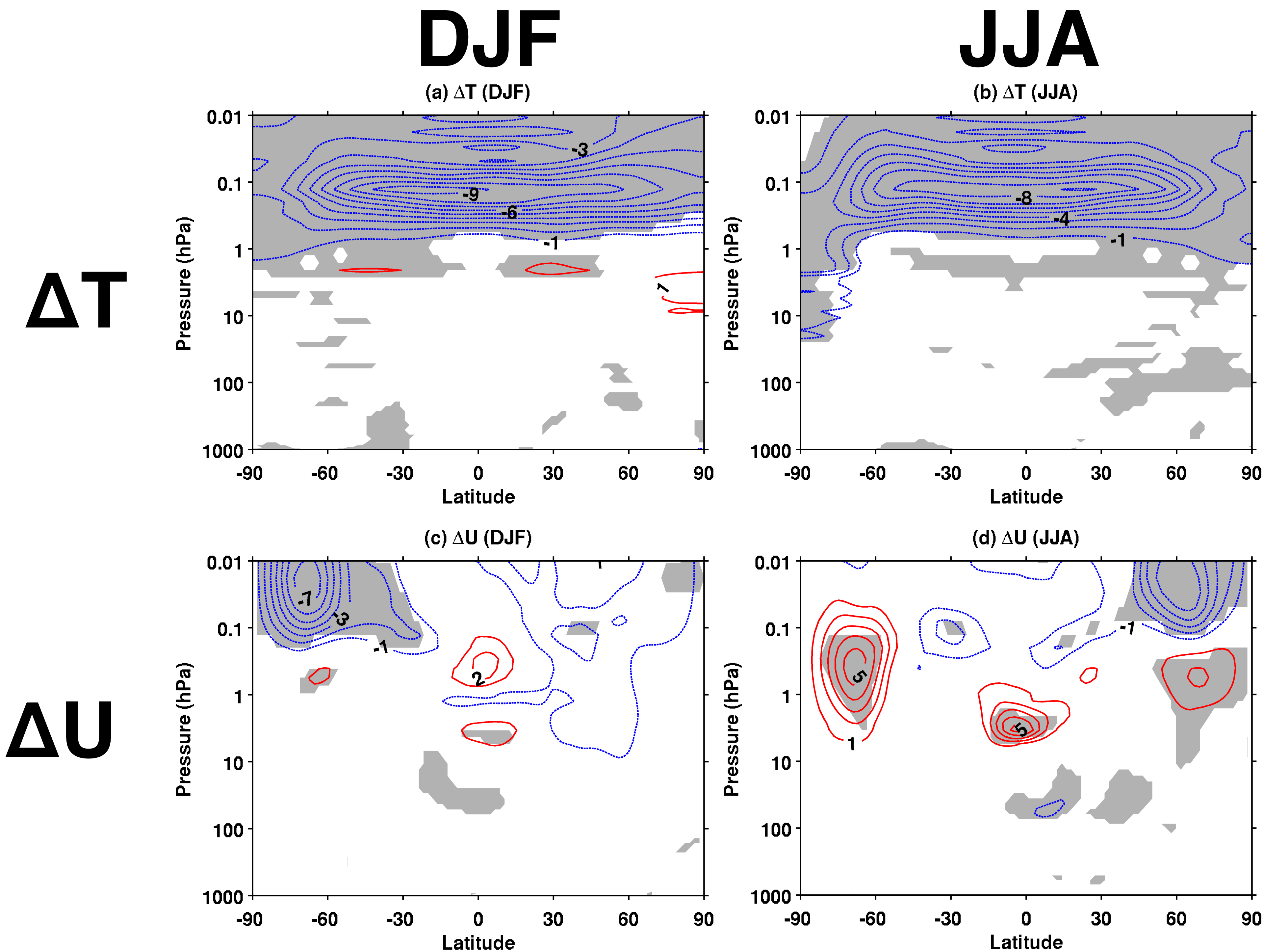
SC-WACCM is half the computational cost of WACCM

Pre-Industrial WACCM and SC-WACCM Simulations

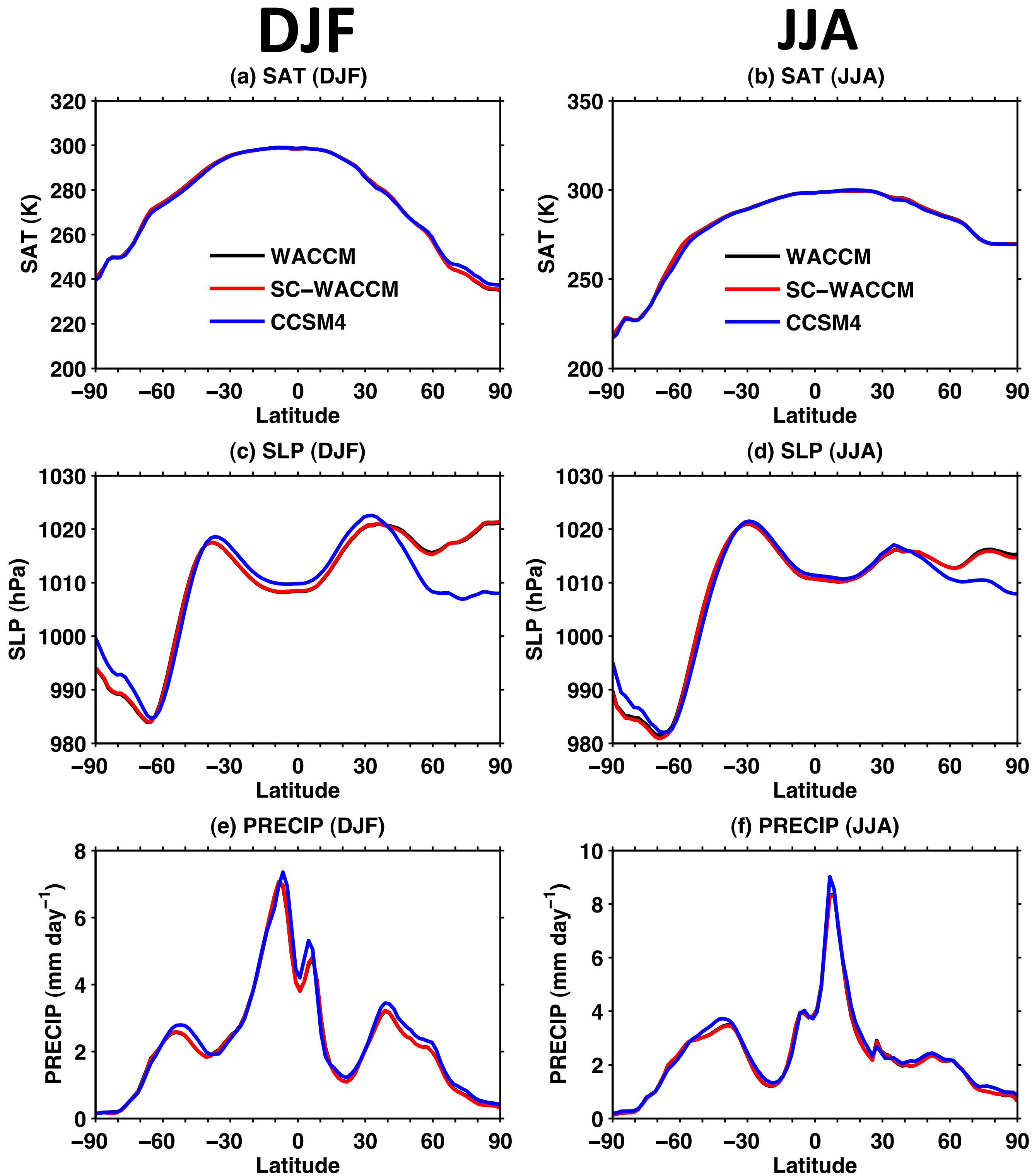
- **WACCM & SC-WACCM**
  - **200 years, coupled 1850 pre-industrial control simulation**
  - **daily and monthly output (SC-WACCM available on glade and soon on the ESG)**

- **CCSM4**
  - **500 years, coupled 1850 pre-industrial control simulation with monthly output**
  - **54 years of daily output**

Zonal Mean Differences in Wind and Temperature



Surface climate



Problems with Specifying an Ozone Hole

GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L07806, doi:10.1029/2007GL032698, 2008

Sensitivity of Southern Hemisphere climate to zonal asymmetry in ozone

Julia A. Crook,[1] Nathan P. Gillett,[1] and Sarah P. E. Keeley[1,2]

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GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L10809, doi:10.1029/2009GL037246, 2009

Sensitivity of climate to dynamically-consistent zonal asymmetries in ozone

N. P. Gillett,[1] J. F. Scinocca,[1] D. A. Plummer,[1] and M. C. Reader[1]

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GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L18701, doi:10.1029/2009GL040419, 2009

Effect of zonal asymmetries in stratospheric ozone on simulated Southern Hemisphere climate trends

D. W. Waugh,[1] L. Oman,[1] P. A. Newman,[2] R. S. Stolarski,[2] S. Pawson,[3] J. E. Nielsen,[3] and J. Perlwitz[4]

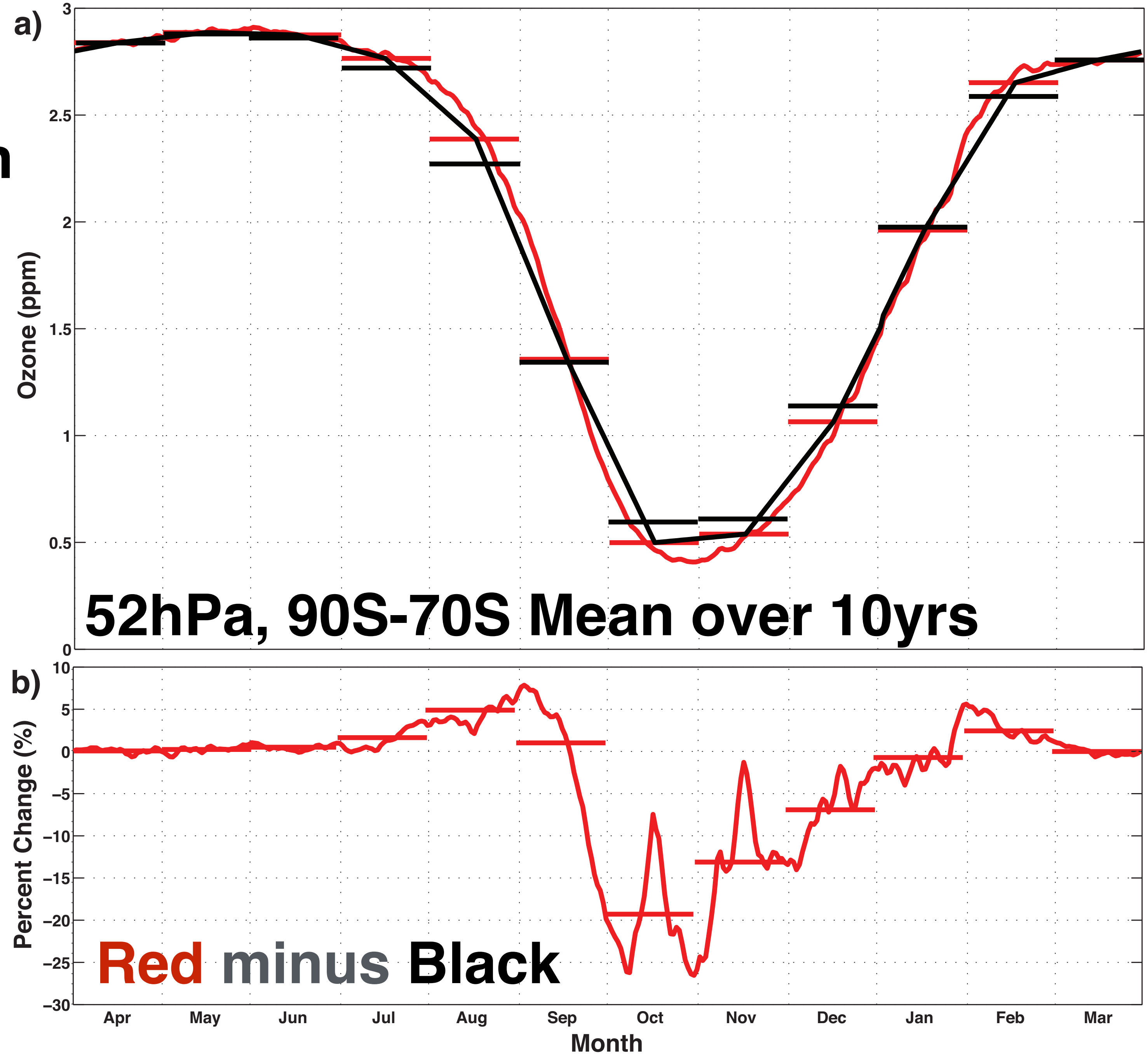
Received 6 August 2009; revised 21 August 2009; accepted 27 August 2009; published 22 September 2009.

Effect of Specifying Monthly Mean Ozone

Monthly Mean

Daily Mean

Percent Difference

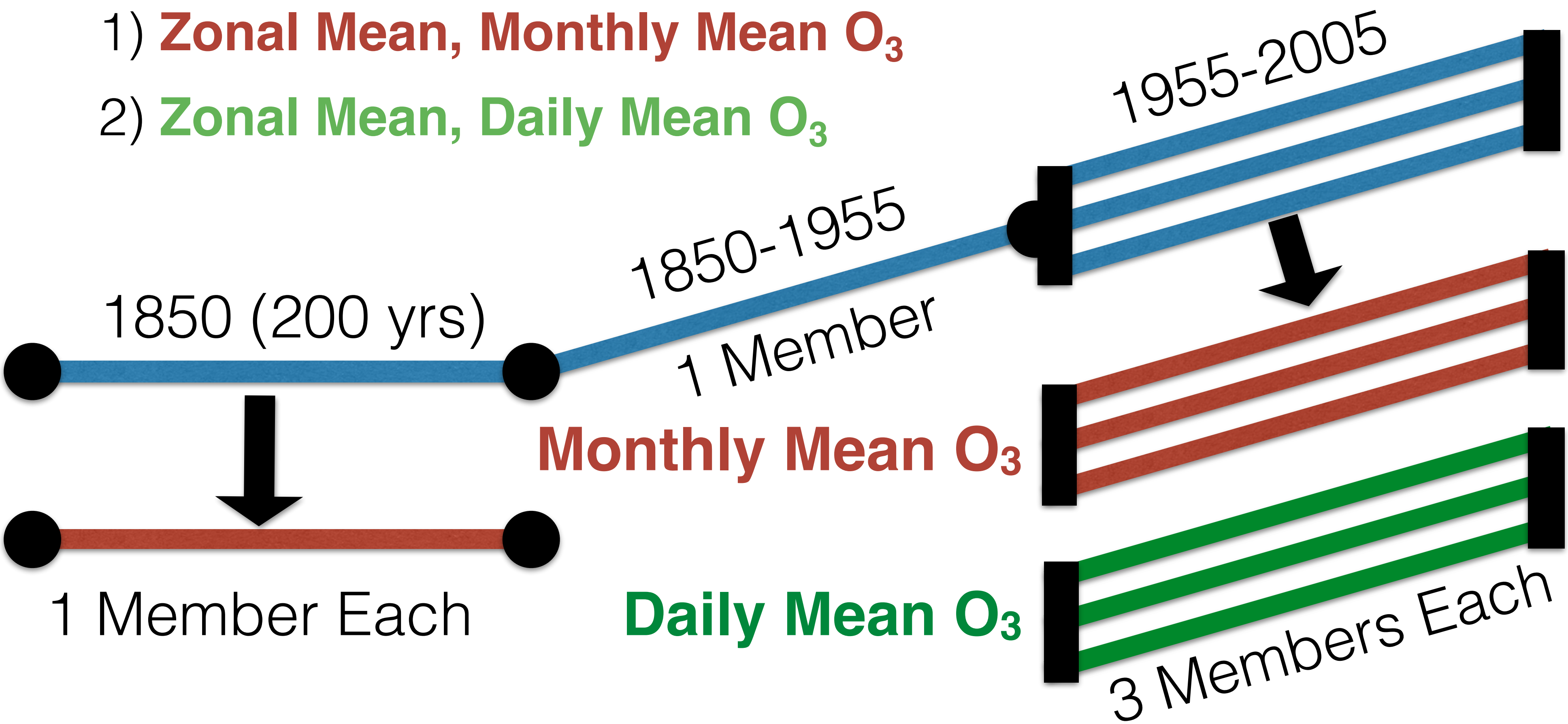


20th Century Historical Simulations

- **WACCM:** 6 (3 New) members from 1955 to 2005 (started from differing atmospheric ICs)
- **SC-WACCM**: Uses **ensemble mean values** from prior WACCM runs for prescribed values
  - 2 x1955 to 2005 ensembles:

    1) **Zonal Mean, Monthly Mean O_3**

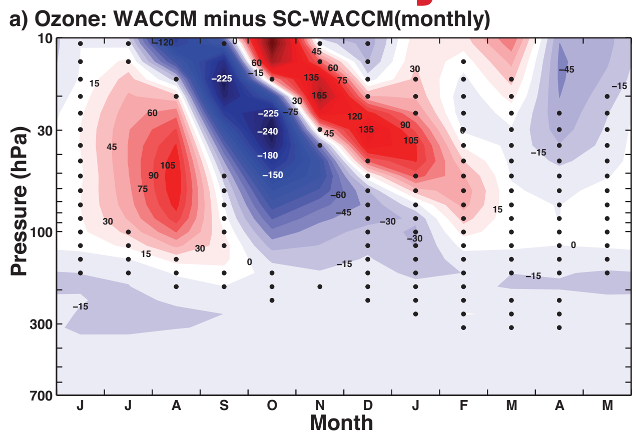
    2) **Zonal Mean, Daily Mean O_3**



Impact of a Monthly Mean Specified Ozone Hole

Monthly

Ozone

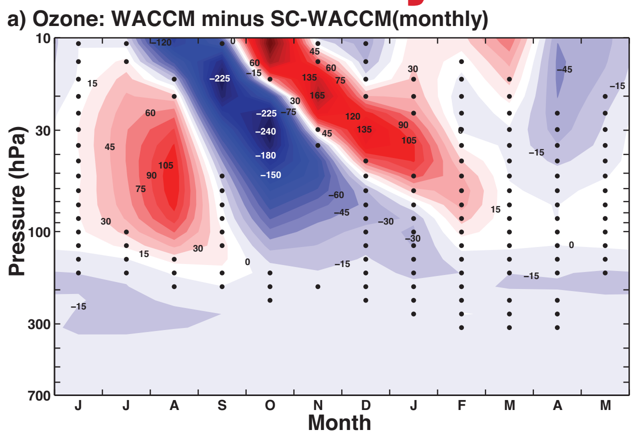


WACCM minus SC; 90S-70S Mean; Dots Cover Insignificant Areas

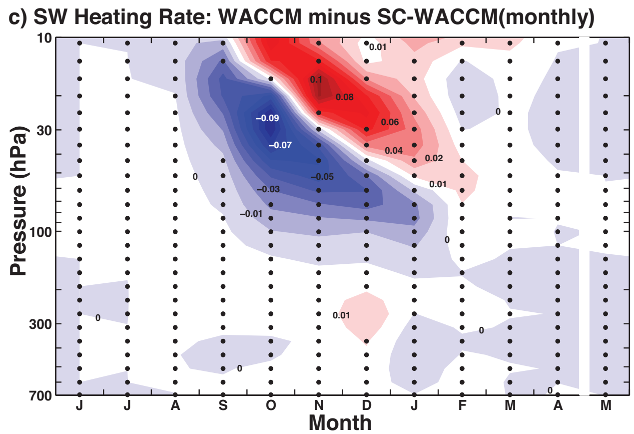
Impact of a Monthly Mean Specified Ozone Hole

Monthly

Ozone



Short Wave Heating



WACCM minus SC; 90S-70S Mean; Dots Cover Insignificant Areas

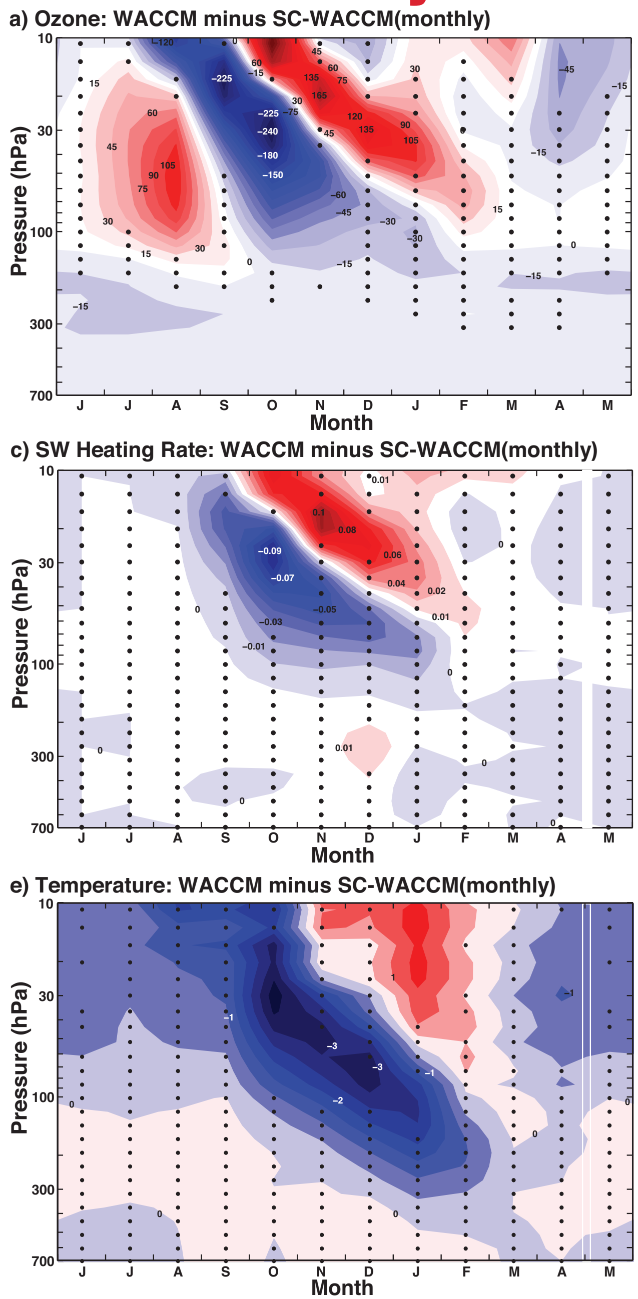
Impact of a Monthly Mean Specified Ozone Hole

Monthly

Ozone

Short Wave Heating

Temperature



WACCM minus SC; 90S-70S Mean; Dots Cover Insignificant Areas

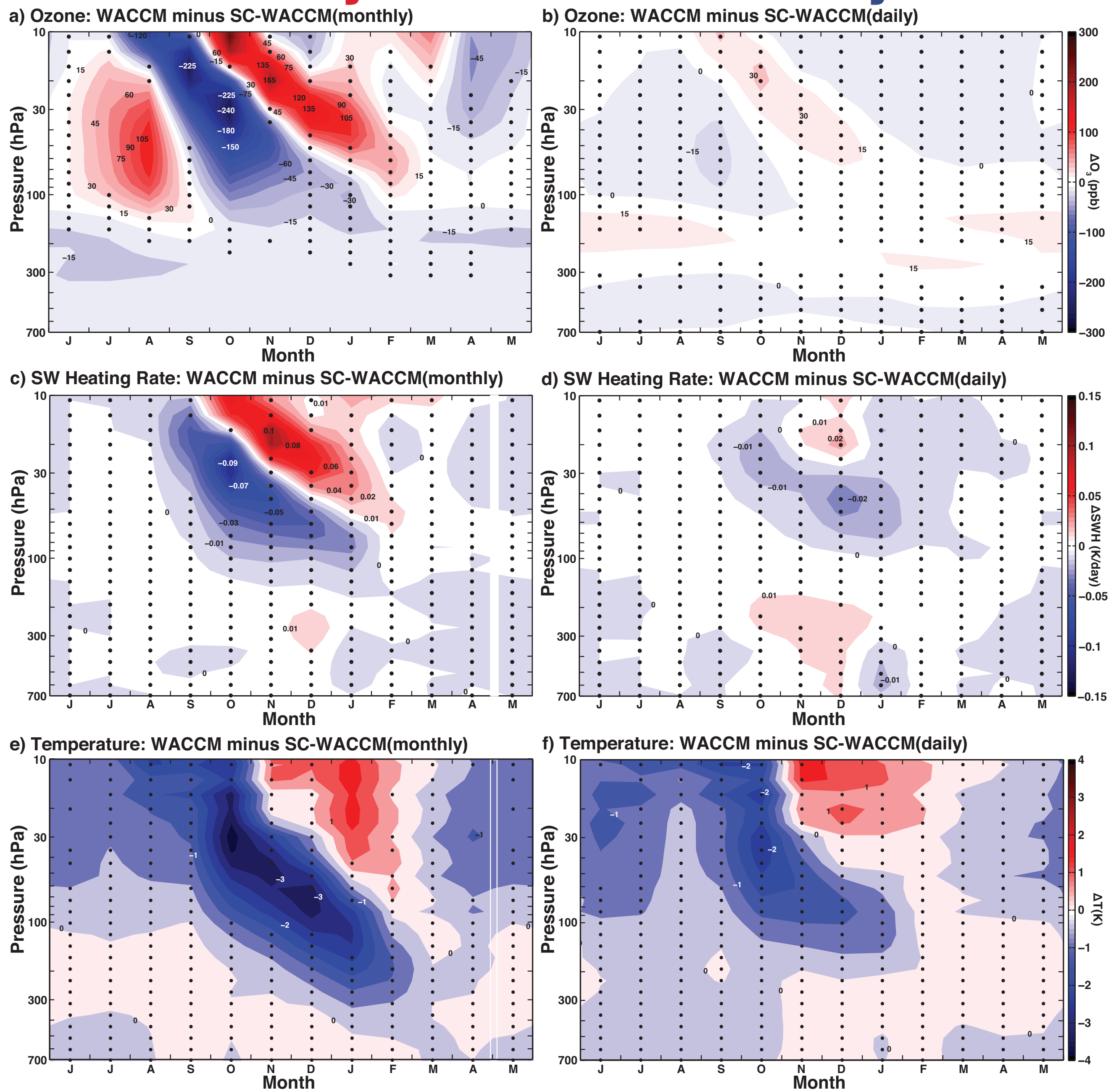
Impact of a Monthly Mean Specified Ozone Hole

Monthly | Daily

Ozone

Short Wave Heating

Temperature



WACCM minus SC; 90S-70S Mean; Dots Cover Insignificant Areas

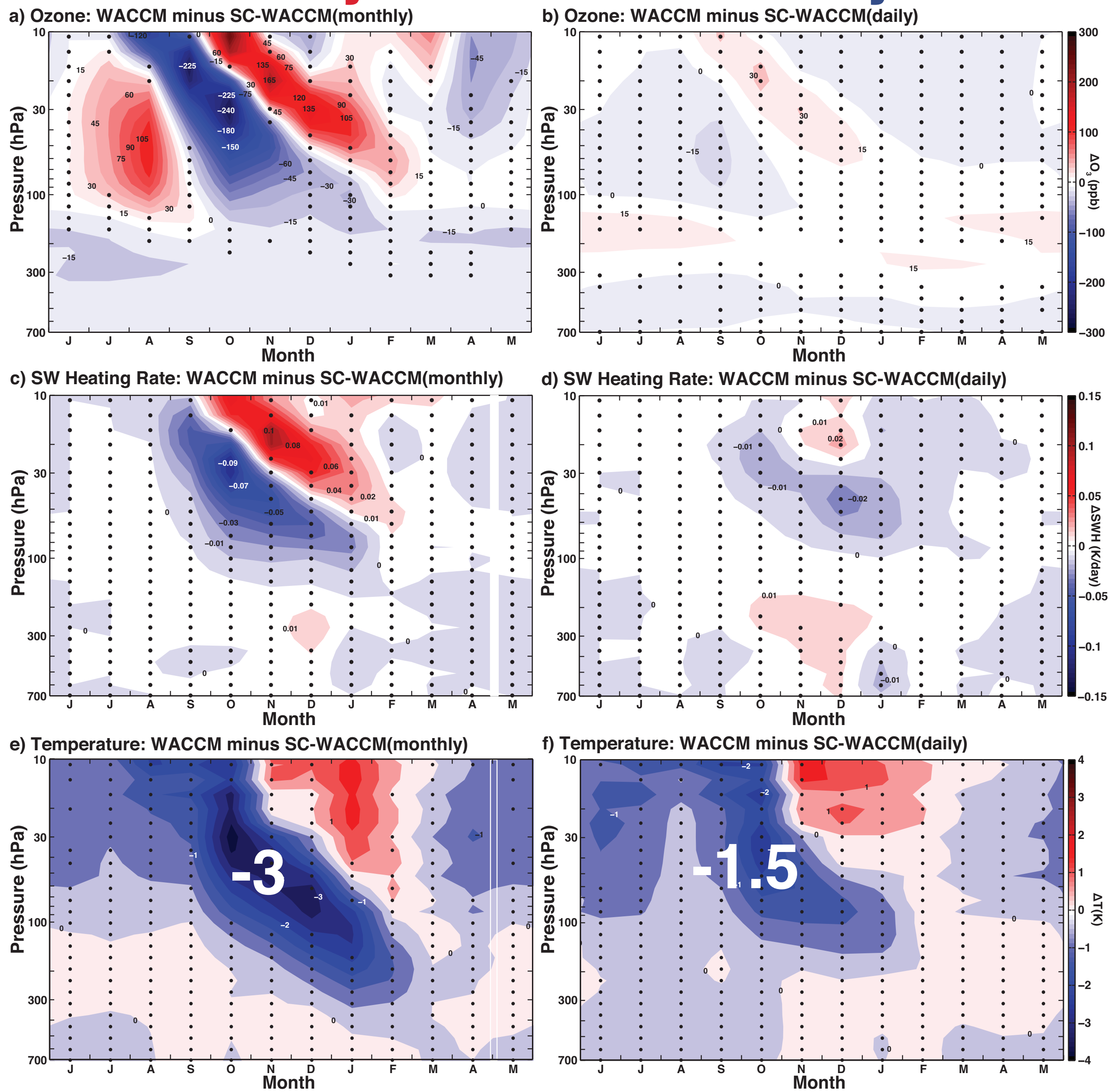
Impact of a Monthly Mean Specified Ozone Hole

Monthly **Daily**

Ozone

Short Wave Heating

Temperature



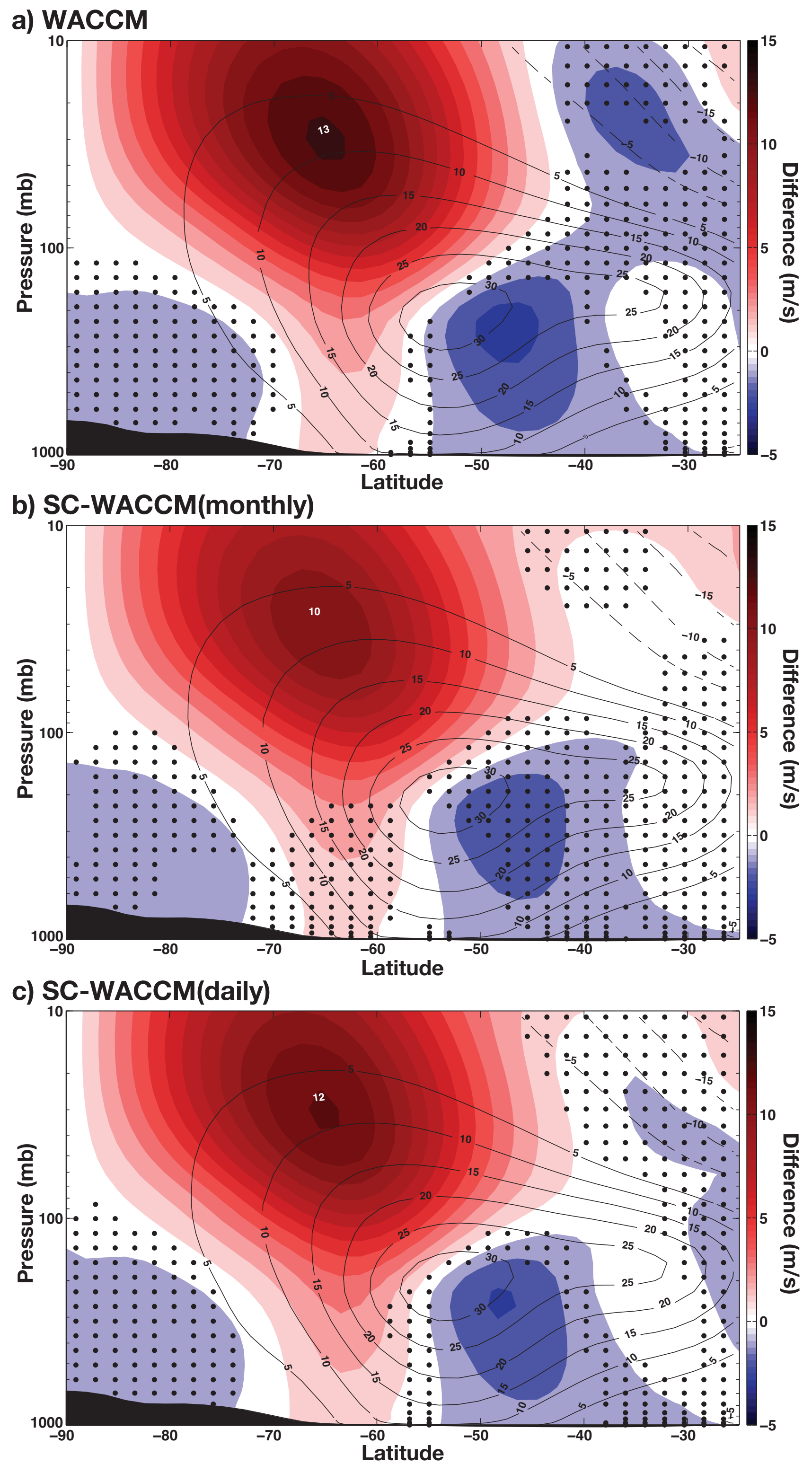
WACCM minus SC; 90S-70S Mean; Dots Cover Insignificant Areas

Changes in the DJF Zonal Mean Winds
(1995-2005 mean minus 1960-1969 mean)

WACCM Peak = 13 m/s

SC-Monthly Peak = 10 m/s

SC-Daily Peak = 12 m/s



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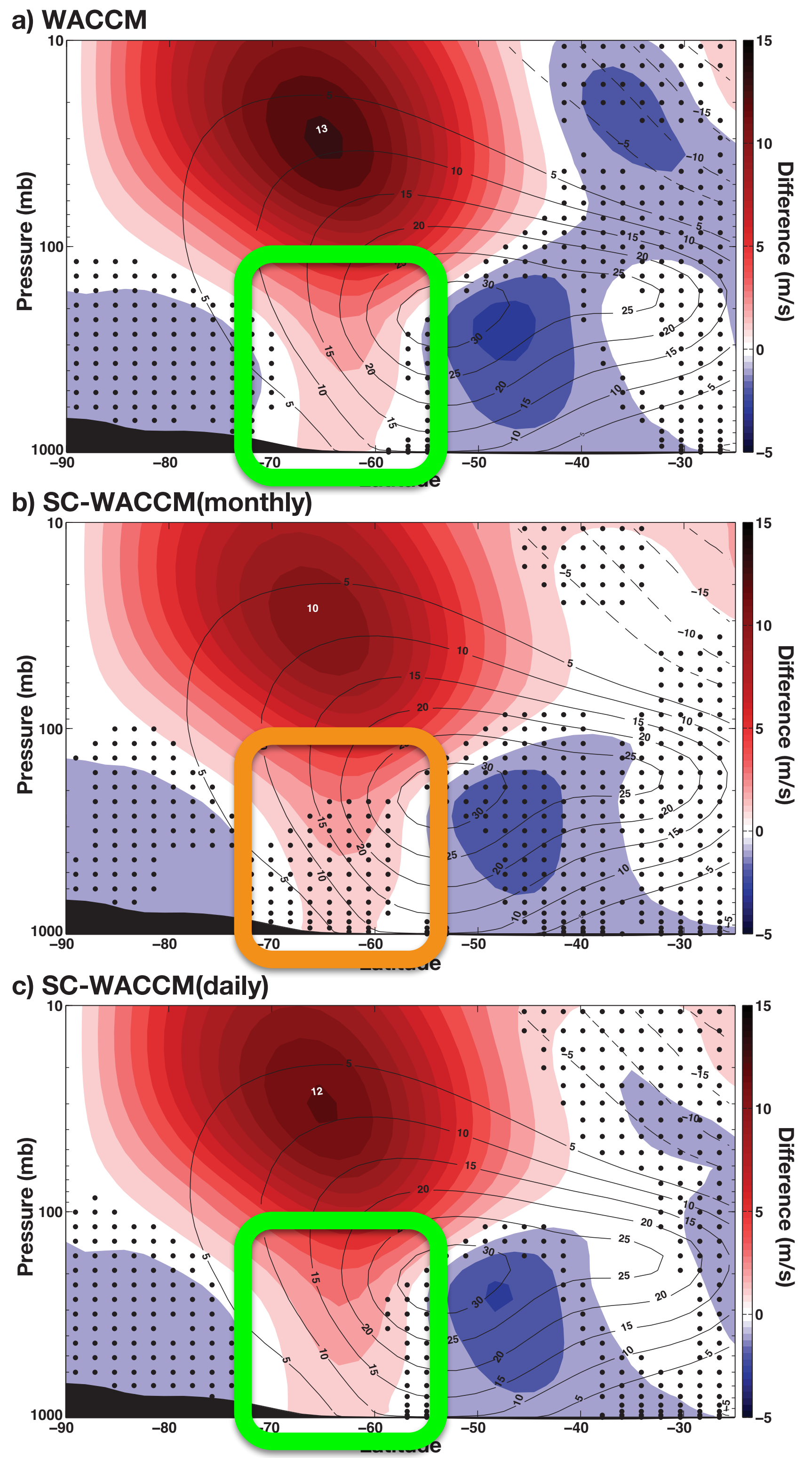
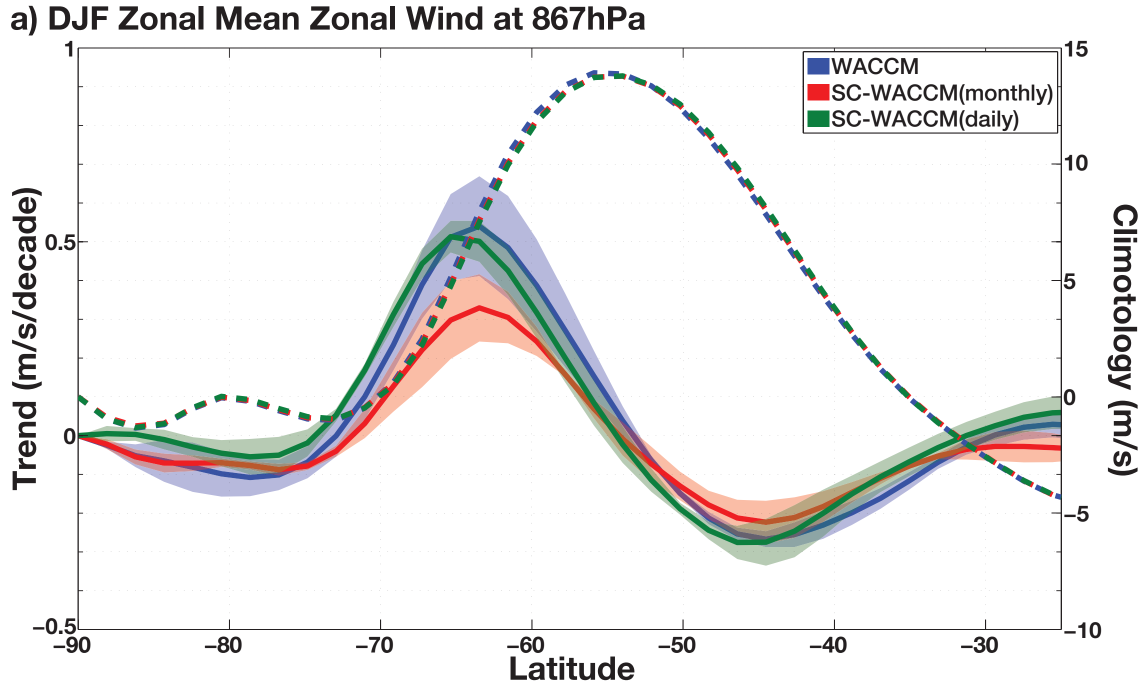
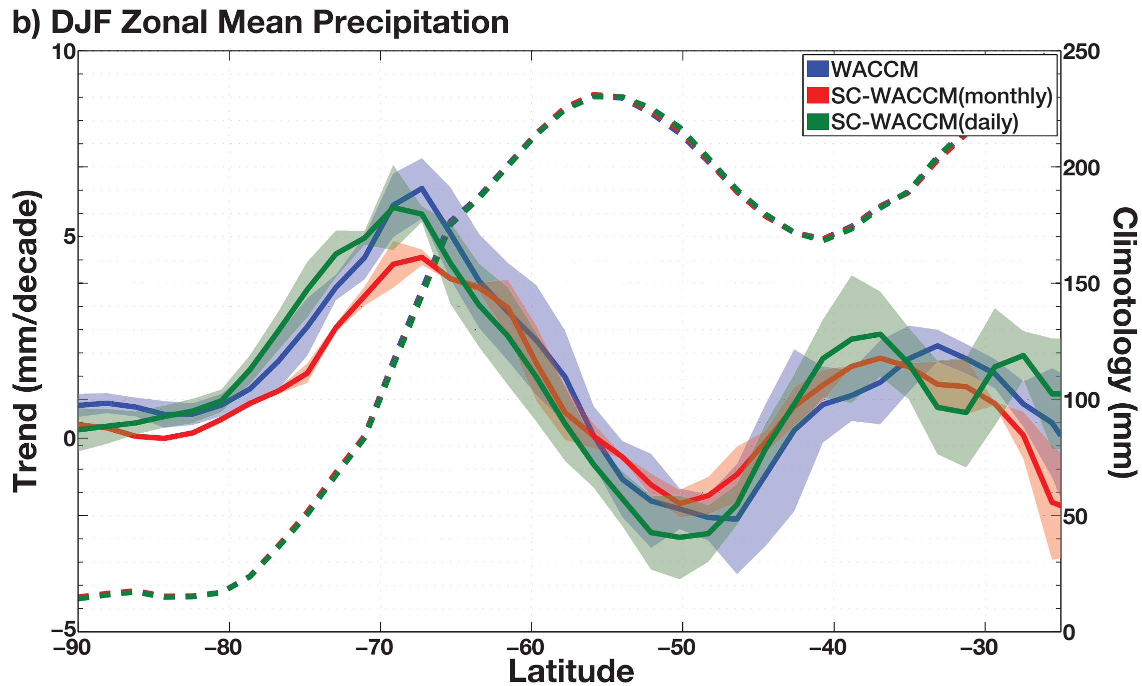


Impact on Surface Climate Trends

DJF Zonal Mean Wind at 867hPa



DJF Zonal Mean Precipitation

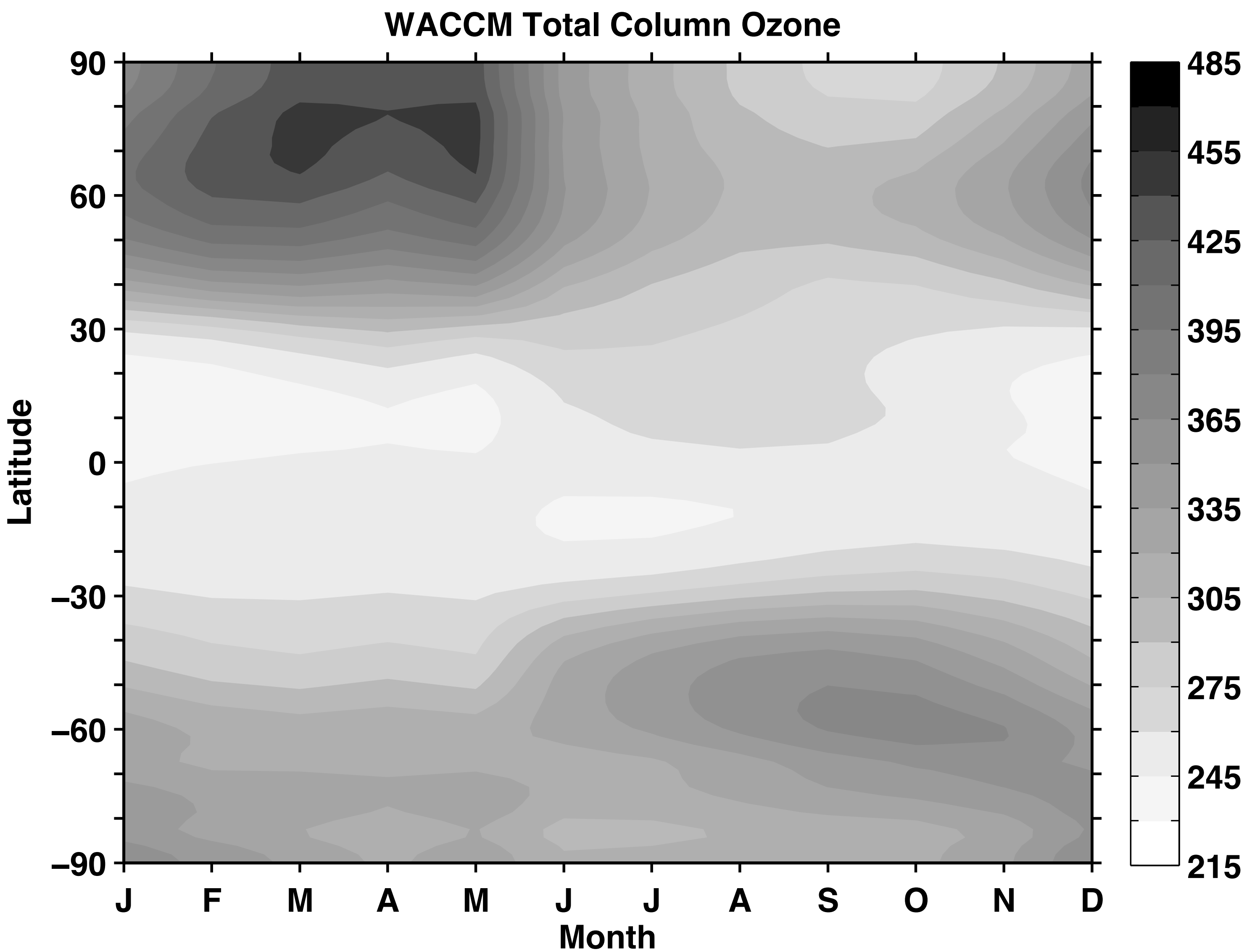


Summary

- SC-WACCM's climatology in the troposphere and stratosphere are indistinguishable from WACCM.
- 1/2 Cost Of WACCM (with Chemistry)
- Temporal smoothing of the specified ozone forcing file leads to significant changes in southern hemispheric trends from 1955 to 2005.

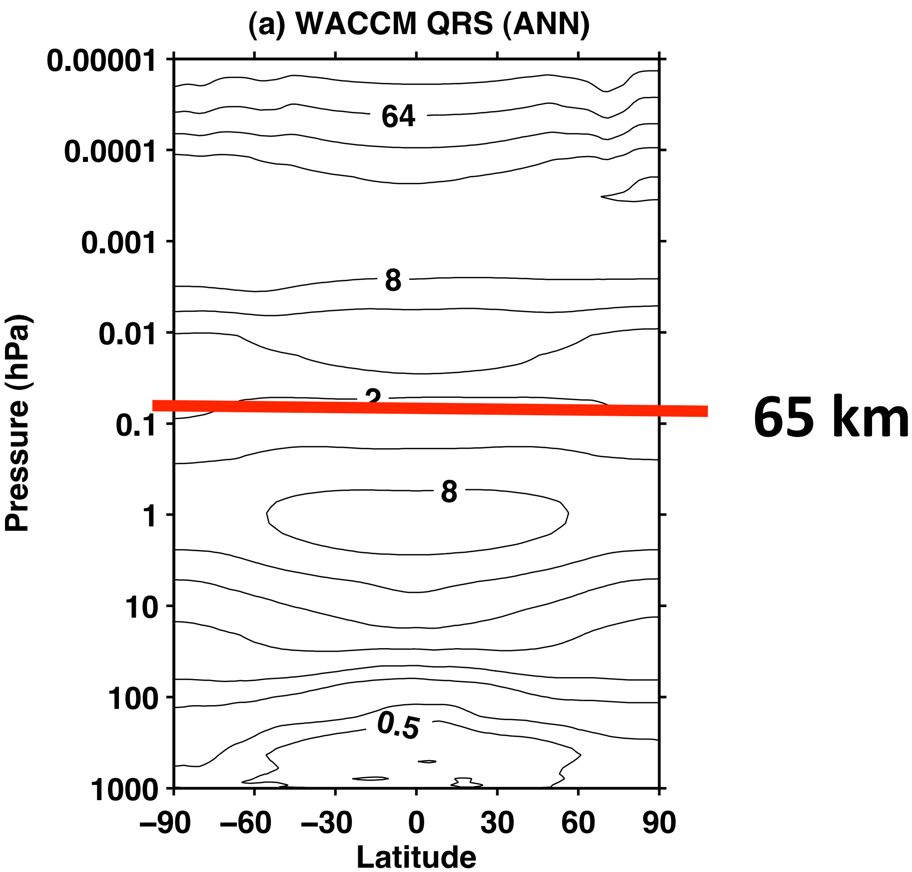
Back Up Slides and Extra Info

SC-WACCM (1850) Ozone



Annual Short-Wave Heating Rate Differences

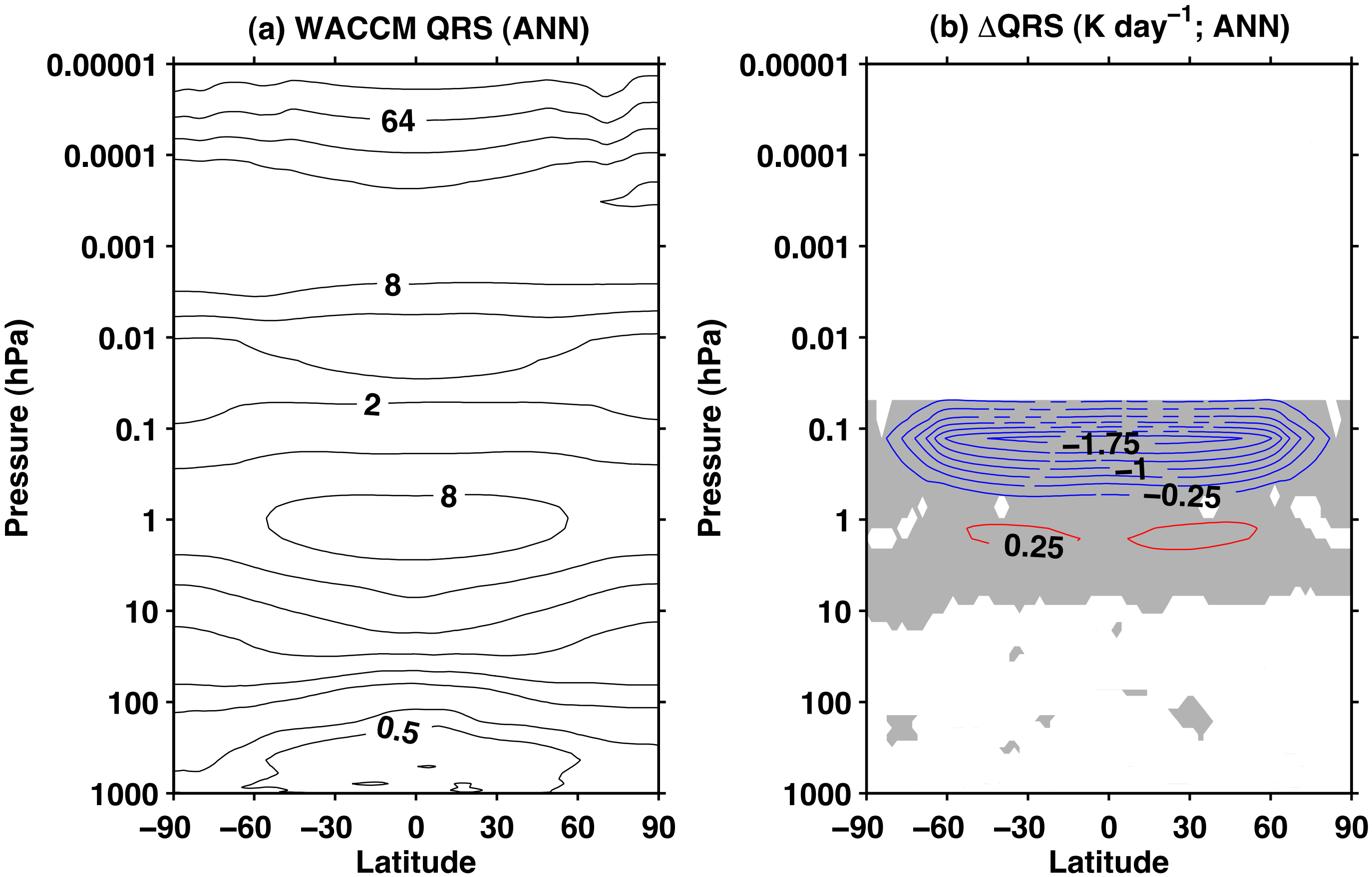
WACCM



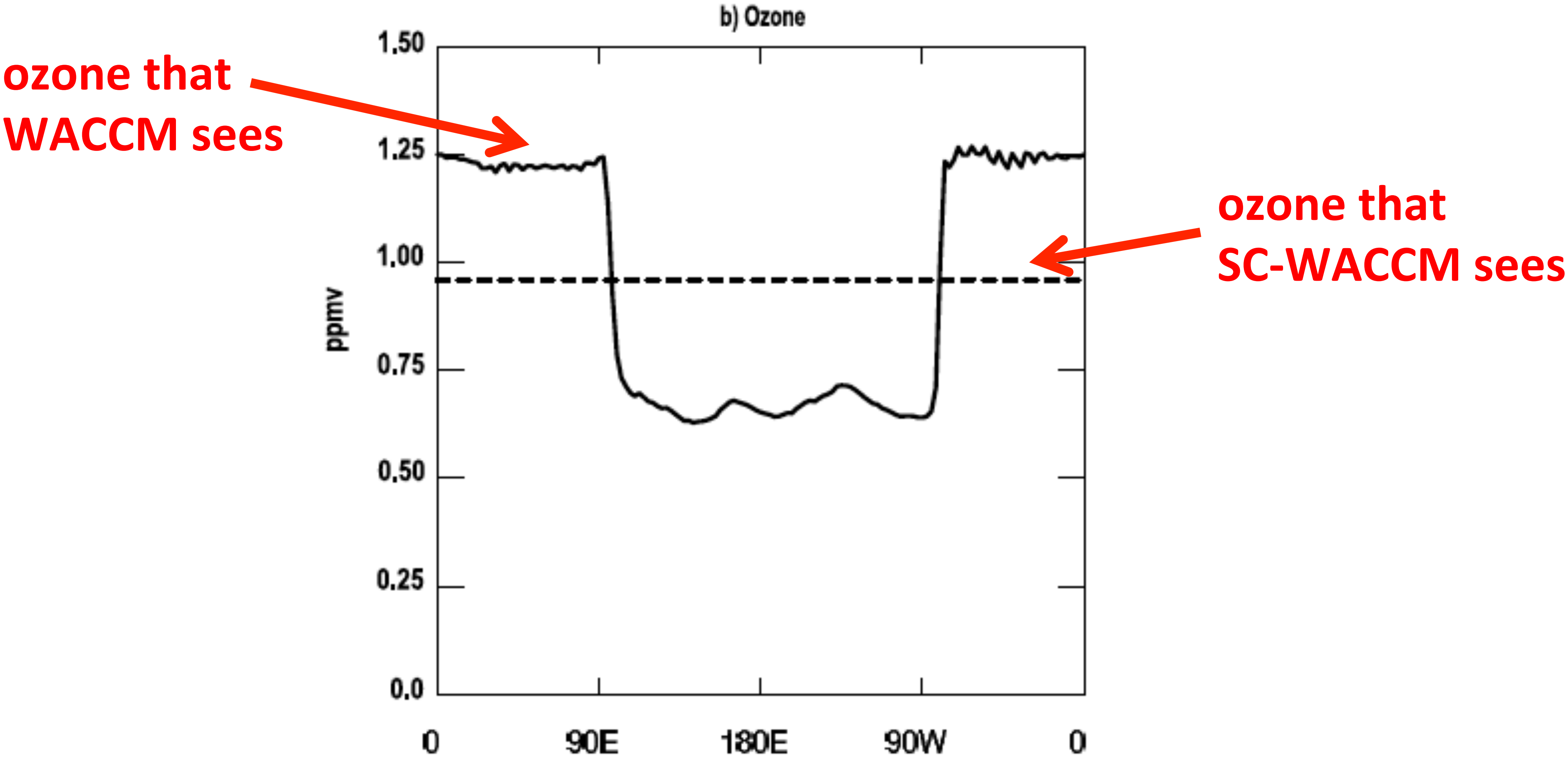
Annual Short-Wave Heating Rate Differences

WACCM

WACCM minus SC-WACCM



Ozone has a diurnal cycle in WACCM but not SC-WACCM



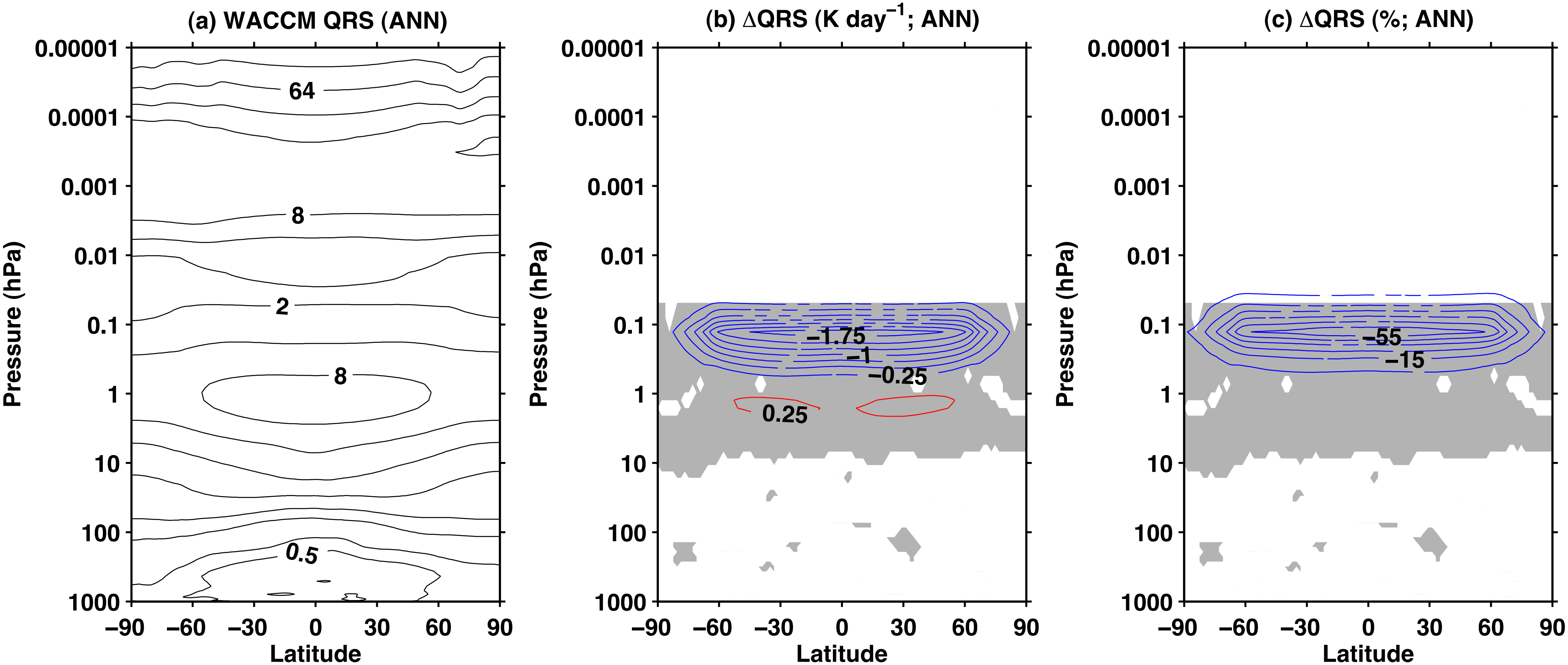
Instantaneous zonal profile of ozone (ppmv) for a day in January at the equator, at 60km, and at 12 midnight 0E. Solid in WACCM ozone and dashed is SC-WACCM ozone (*Sassi and Garcia, 2005*).

Annual Short-Wave Heating Rate Differences

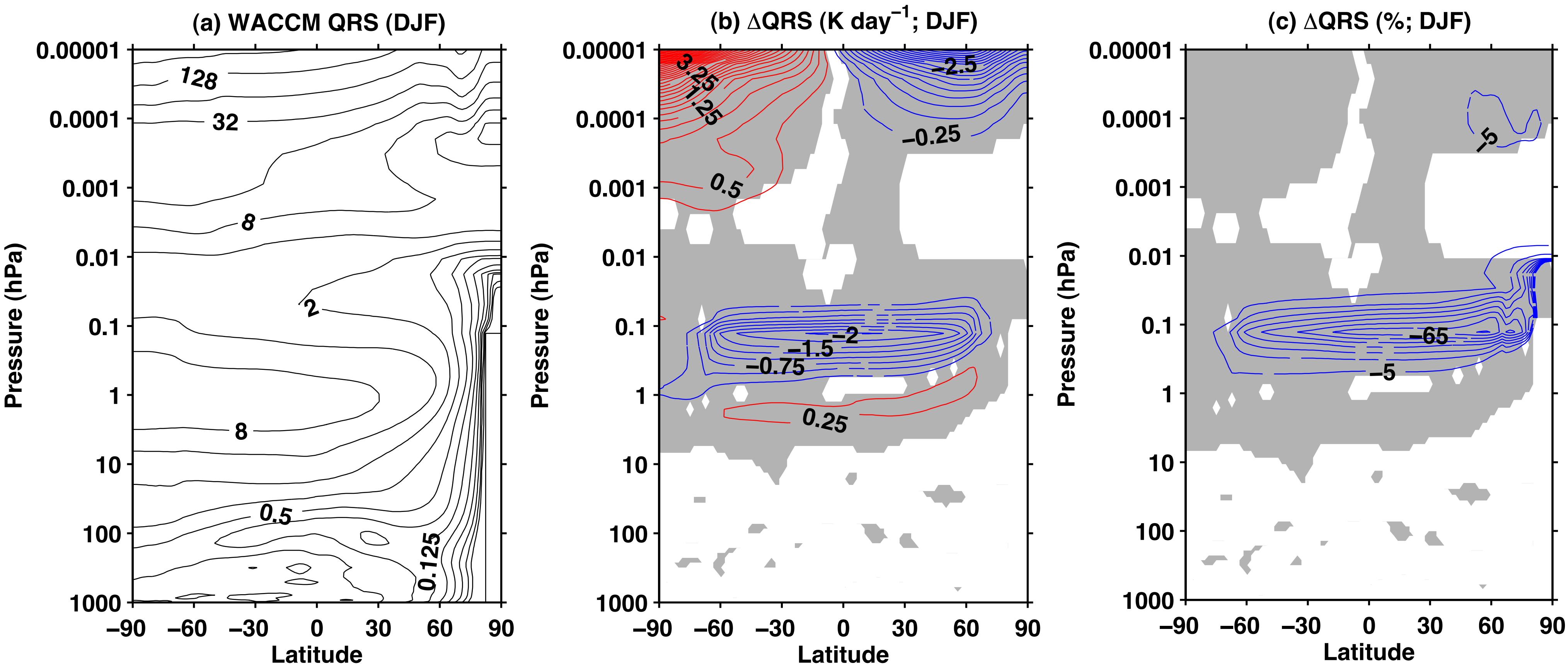
WACCM

WACCM minus SC-WACCM

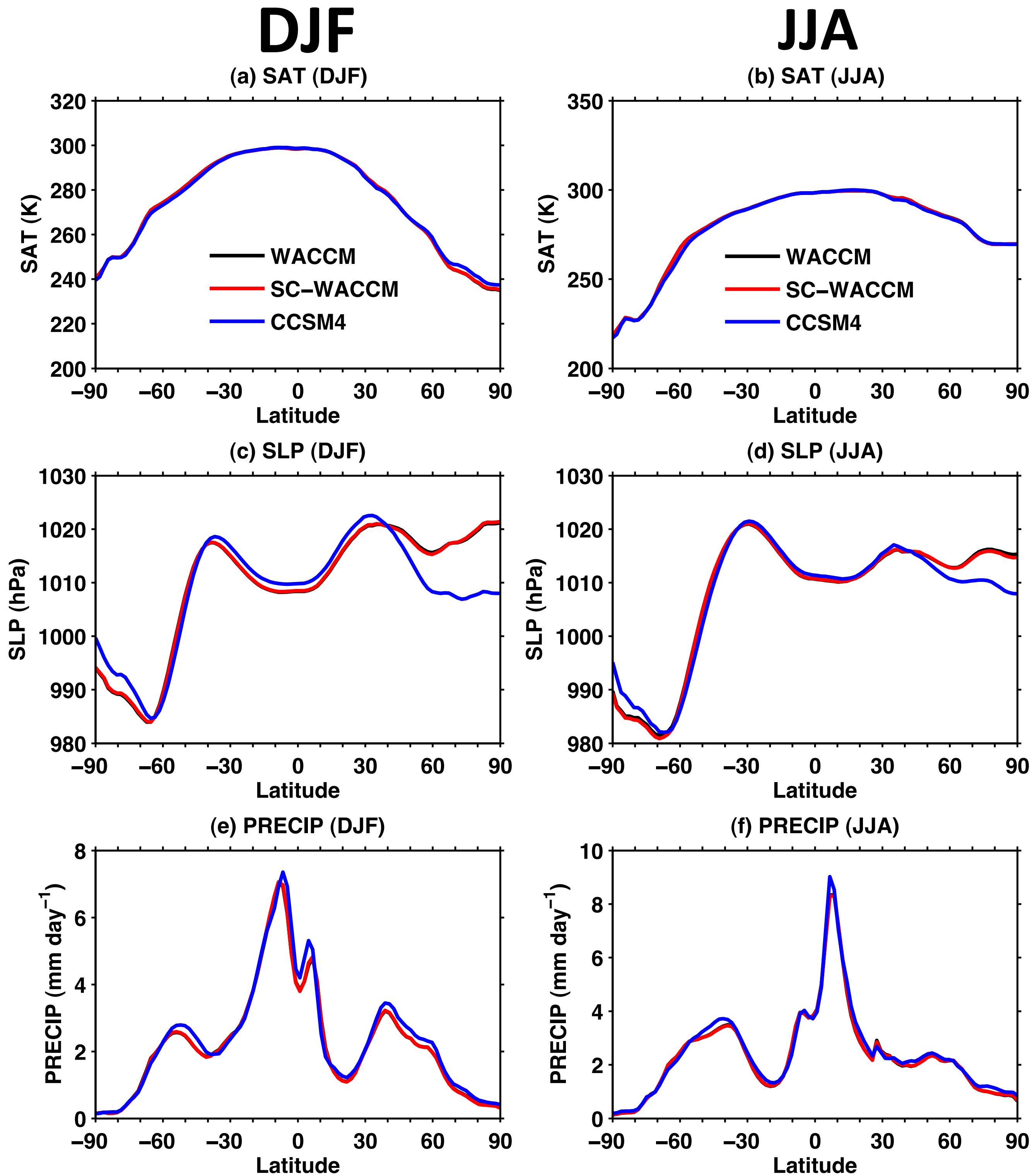
WACCM minus SC-WACCM (%)



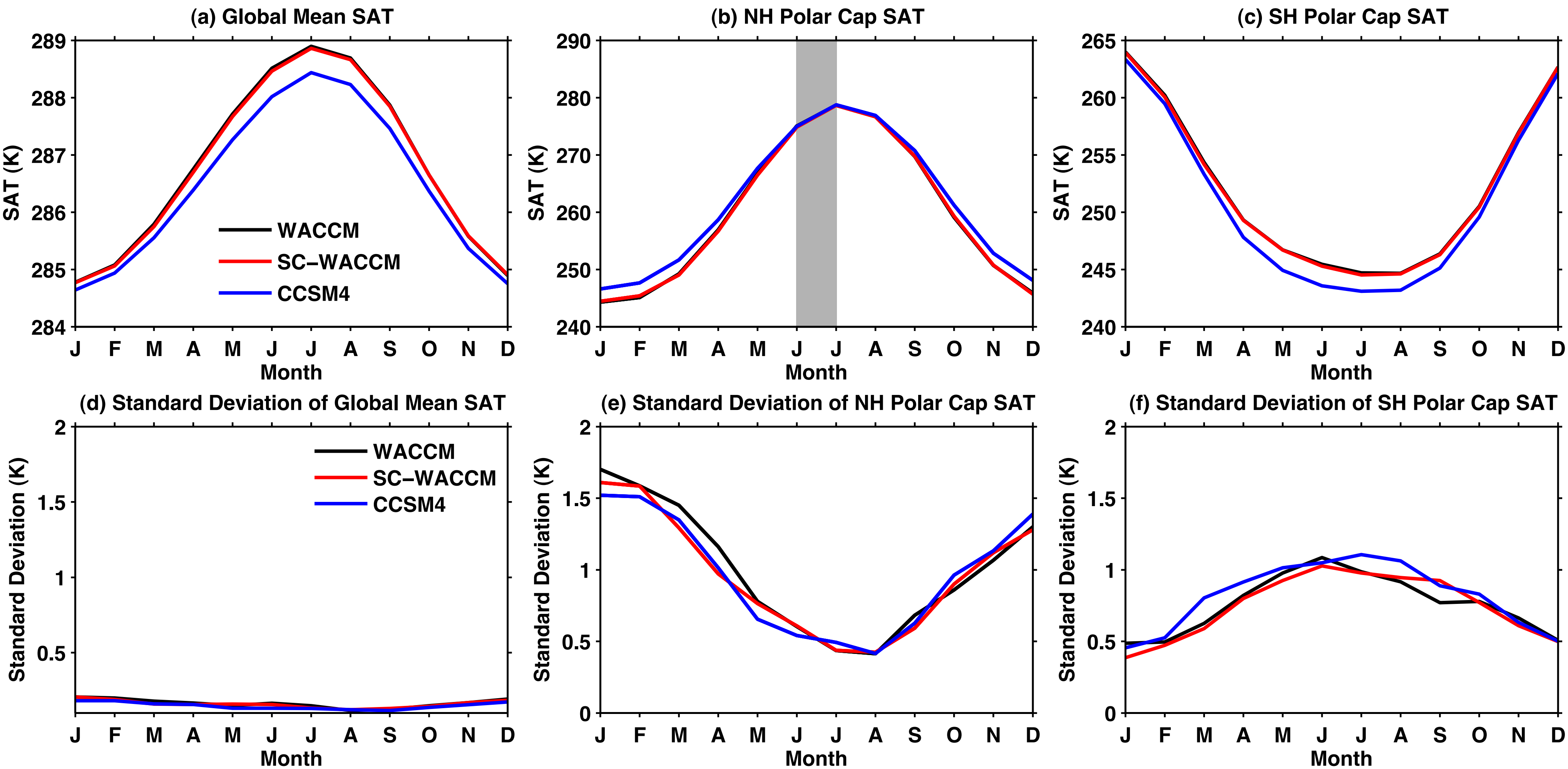
Interpolation of monthly QRS onto model time-step causes seasonal biases



Surface climate



Surface Climate

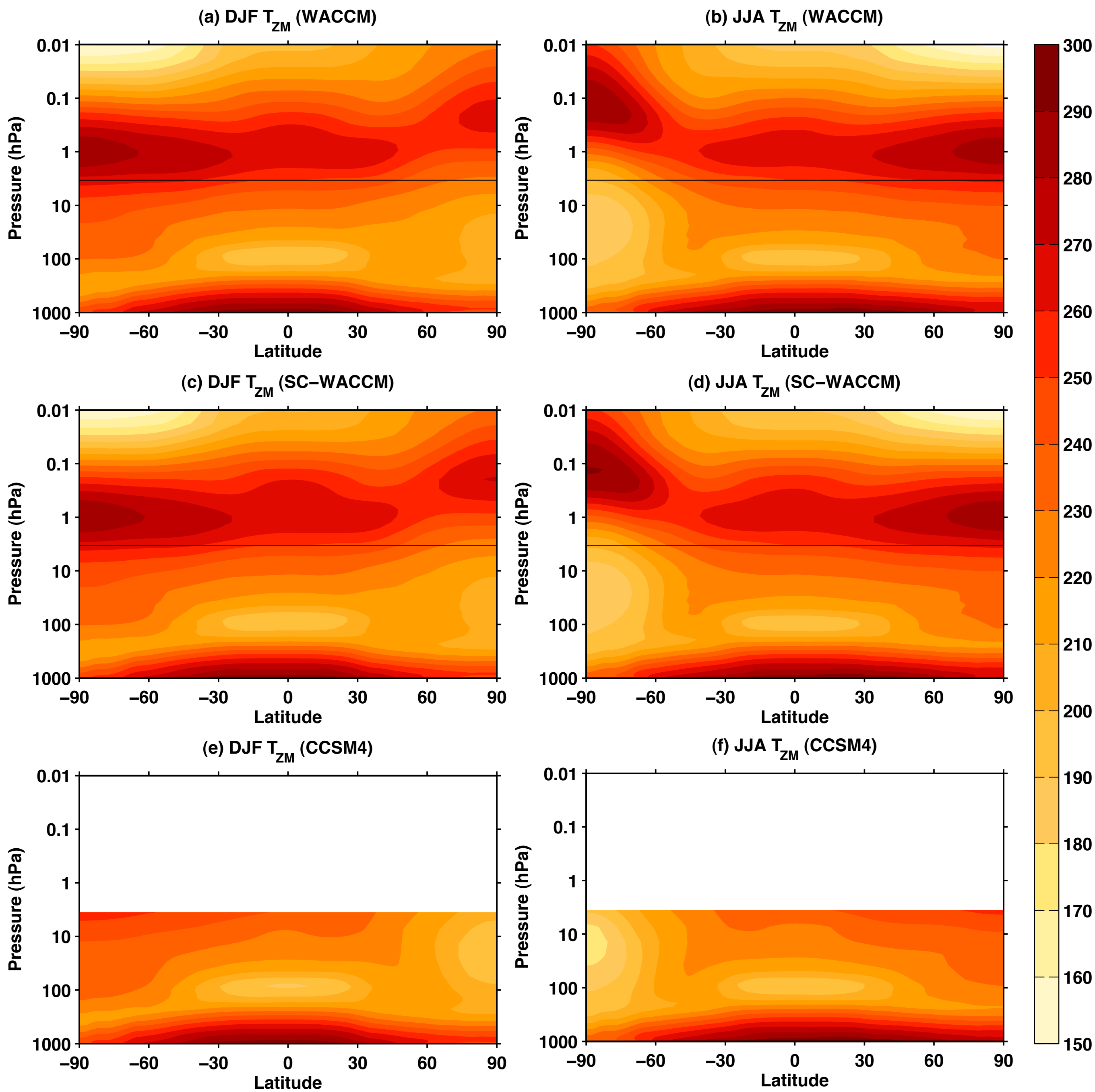


Surface Climate

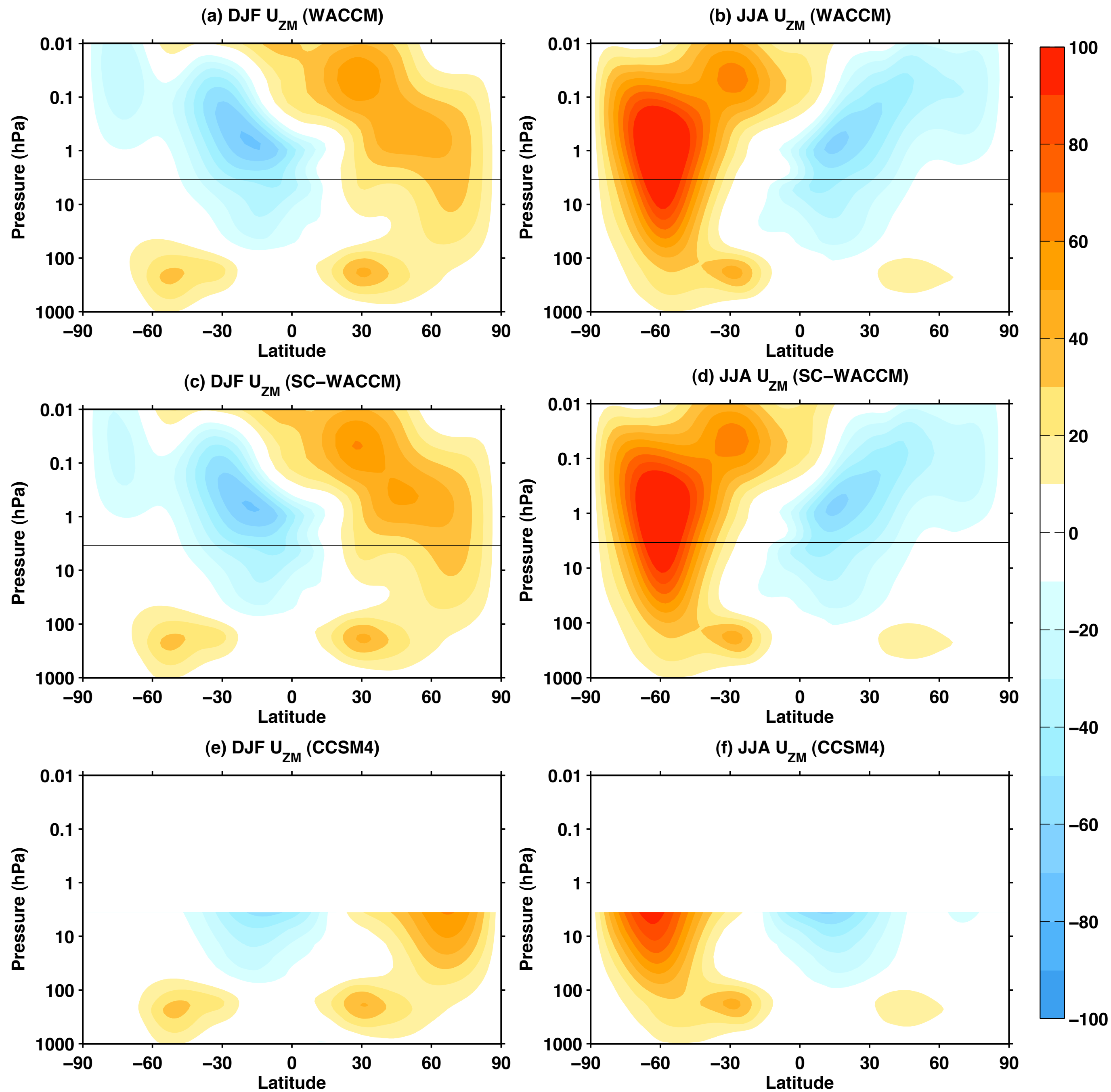
	Model	$SAT(K)$	$P(mmday^{-1})$	$SLP(hPa)$	$SIE(10^6km^2)$
Global	WACCM	286.8 (0.2)	2.83 (0.03)	1011.3 (0.05)	–
	SC-WACCM	286.7 (0.2)	2.83 (0.03)	1011.4 (0.05)	–
	CCSM4	286.5 (0.2)	2.93 (0.02)	1011.2 (0.04)	–
21°-90°N	WACCM	281.1 (0.3)	2.00 (0.04)	1016.9 (0.4)	14.0 (0.6)
	SC-WACCM	281.0 (0.3)	1.99 (0.05)	1016.9 (0.4)	14.0 (0.5)
	CCSM4	281.0 (0.3)	2.13 (0.04)	1014.9 (0.5)	13.3 (0.5)
21°S-21°N	WACCM	298.2 (0.4)	4.10 (0.08)	1010.6 (0.4)	–
	SC-WACCM	298.2 (0.5)	4.10 (0.08)	1010.7 (0.4)	–
	CCSM4	298.2 (0.4)	4.20 (0.07)	1011.9 (0.3)	–
21°-90°S	WACCM	279.9 (0.2)	2.25 (0.04)	1006.6 (0.4)	16.4 (0.9)
	SC-WACCM	279.8 (0.2)	2.25 (0.04)	1006.5 (0.4)	16.5 (0.7)
	CCSM4	279.0 (0.2)	2.33 (0.04)	1006.7 (0.4)	20.4 (1.1)

Table 1. WACCM, SC-WACCM and CCSM4 annual mean surface air temperature (SAT), precipitation (P), sea-level pressure (SLP), and sea ice extent (SIE) for preindustrial conditions. Climatological means are calculated over 200 years for WACCM, 195 years for SC-WACCM and 501 years for CCSM4. The 2σ uncertainties in the means are listed in parentheses.

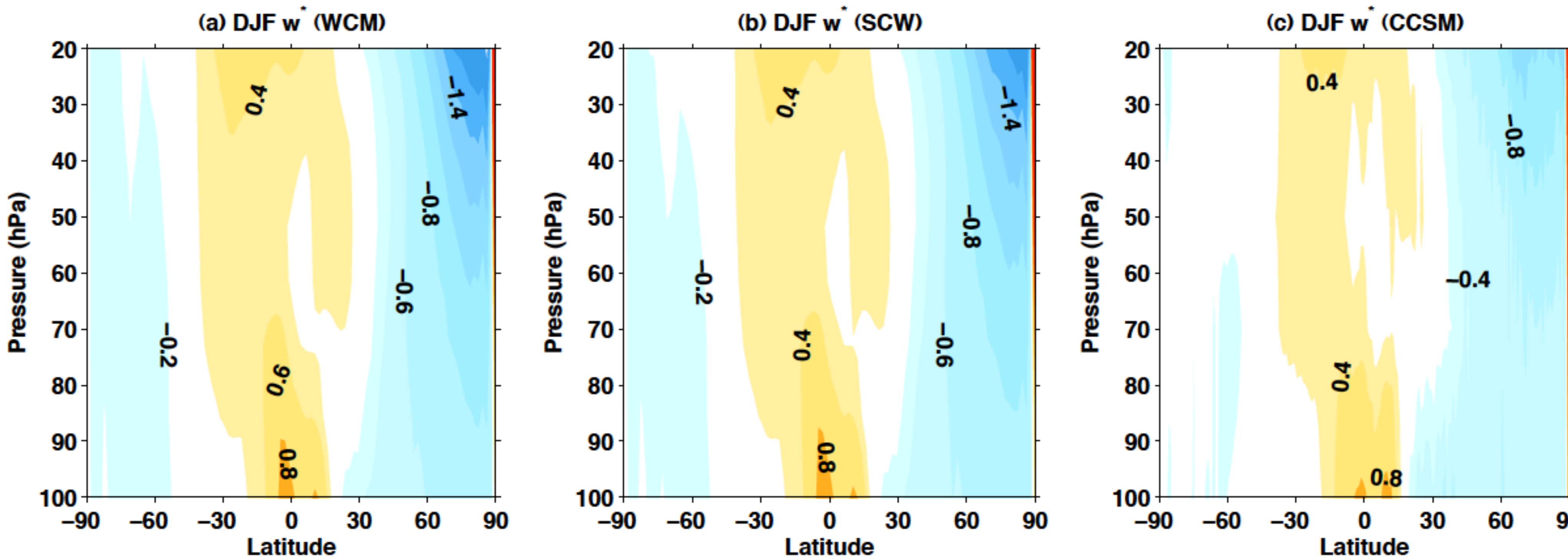
Zonal Mean Temperature Comparison



Zonal Mean Wind Comparison



The residual circulation is also well represented in SC-WACCM



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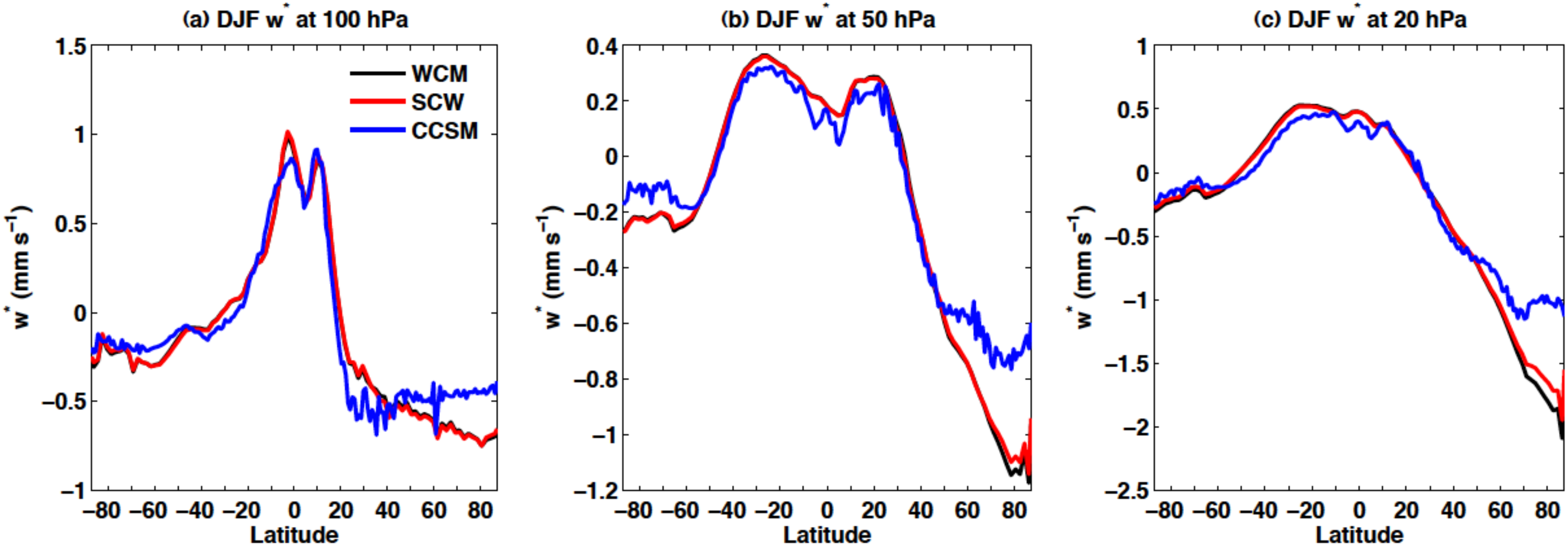
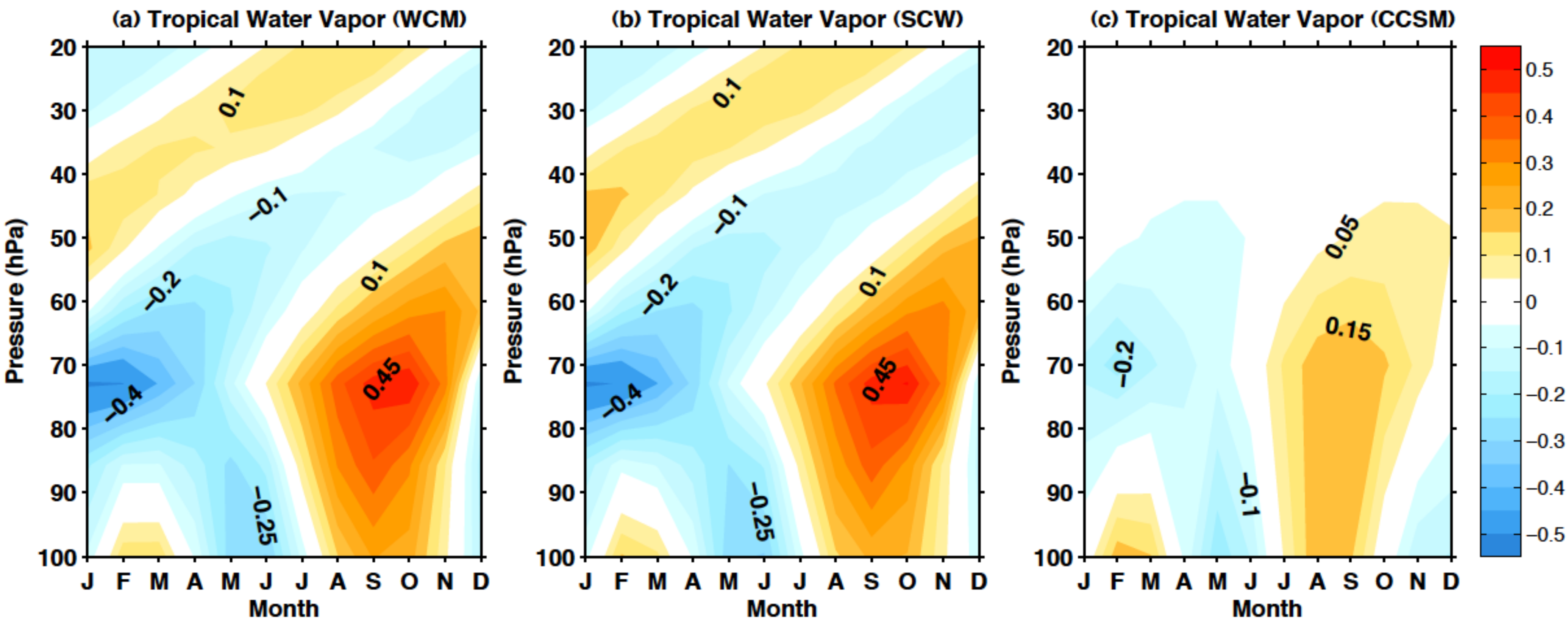
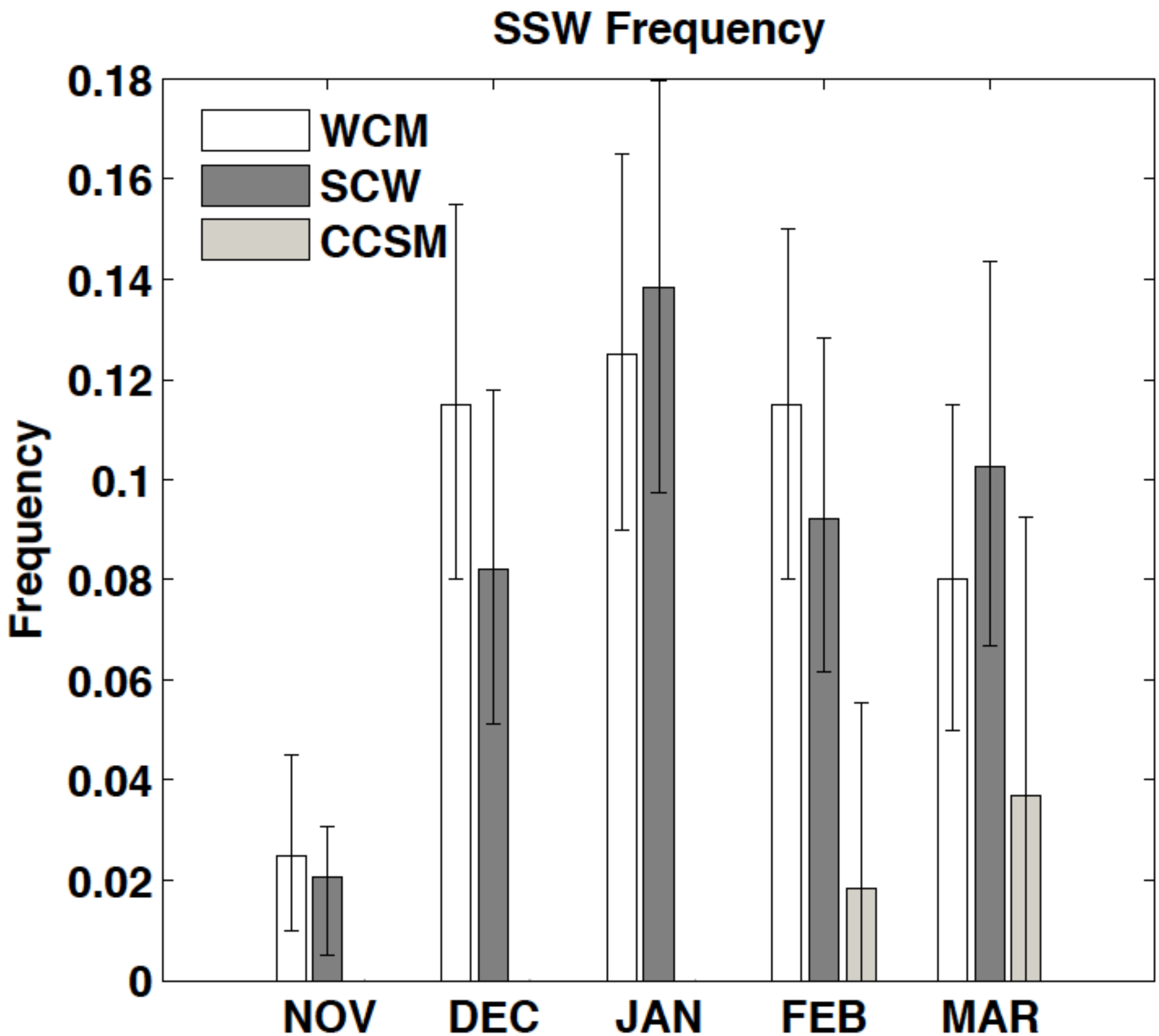


The tropical water vapor tape recorder



Plots show the deviation in water vapor mixing ratio (ppmv) from the time-mean average profile averaged over 10°N-10°S.

Sudden stratospheric warming (SSW) frequency



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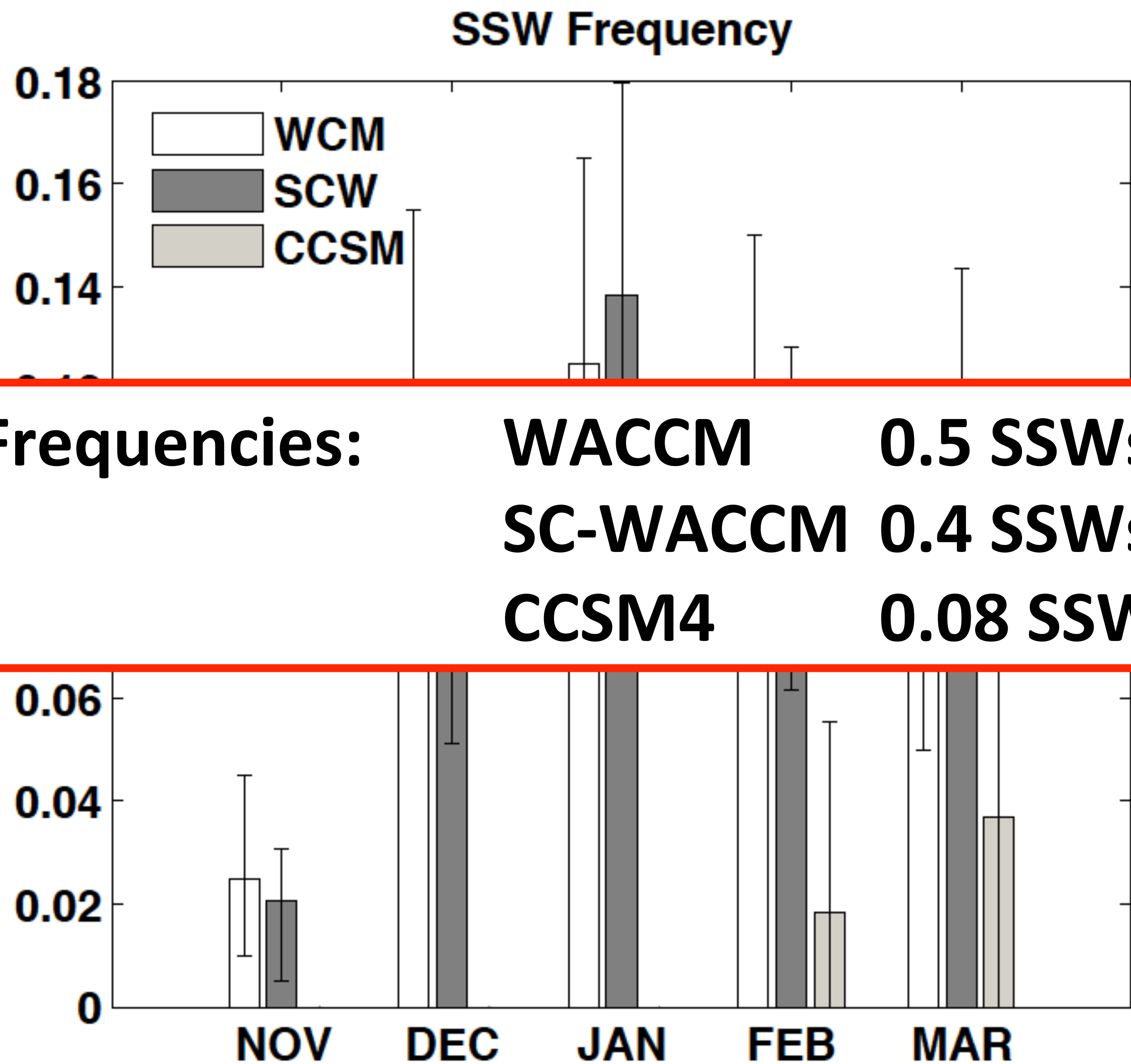
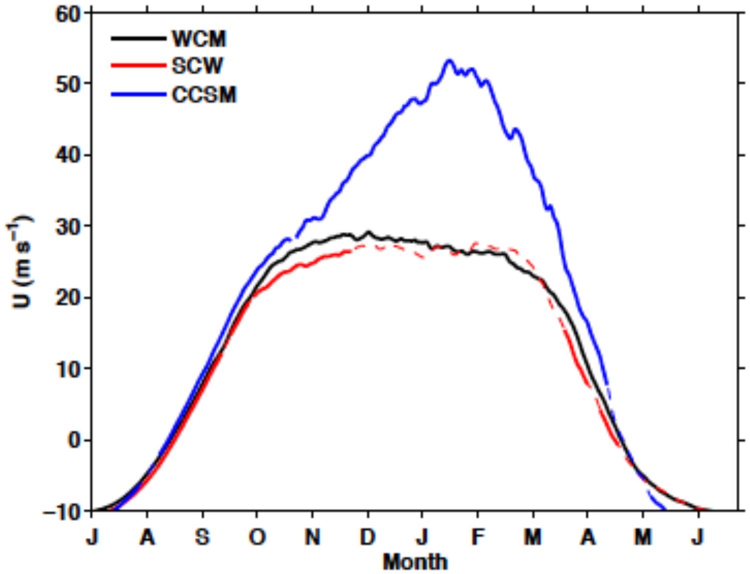


Winter Frequencies:	WACCM	0.5 SSWs yr^{-1}
	SC-WACCM	0.4 SSWs yr^{-1}
	CCSM4	0.08 SSWs yr^{-1}

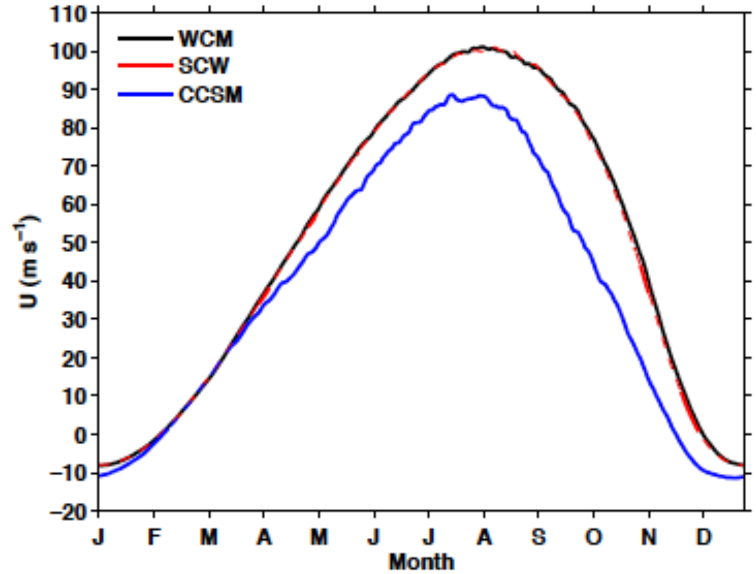
Polar vortices

NH

U at 60N, 10hPa

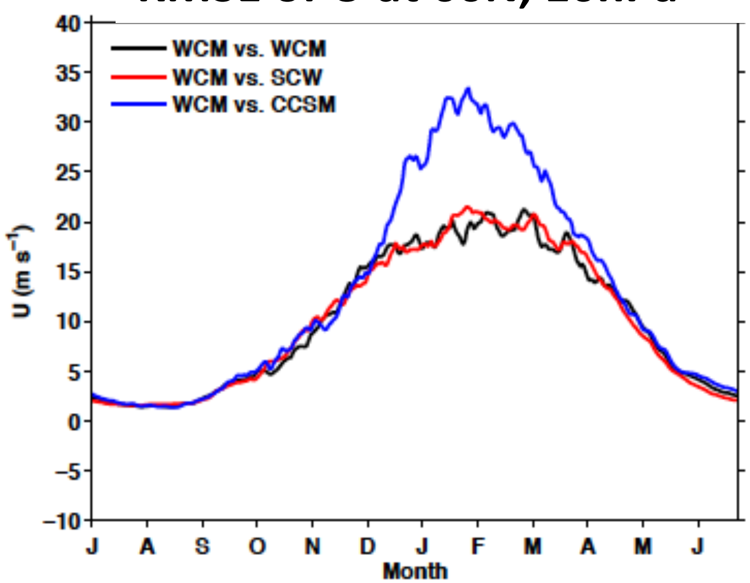


U at 60S, 10hPa

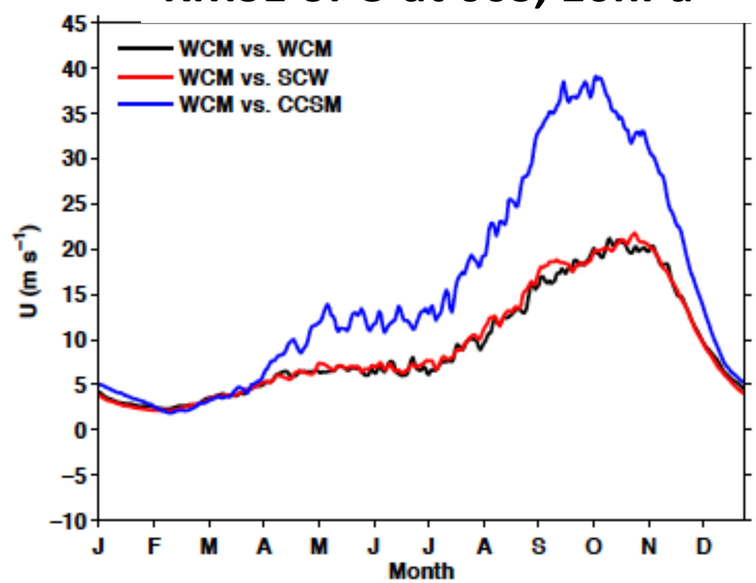


SH

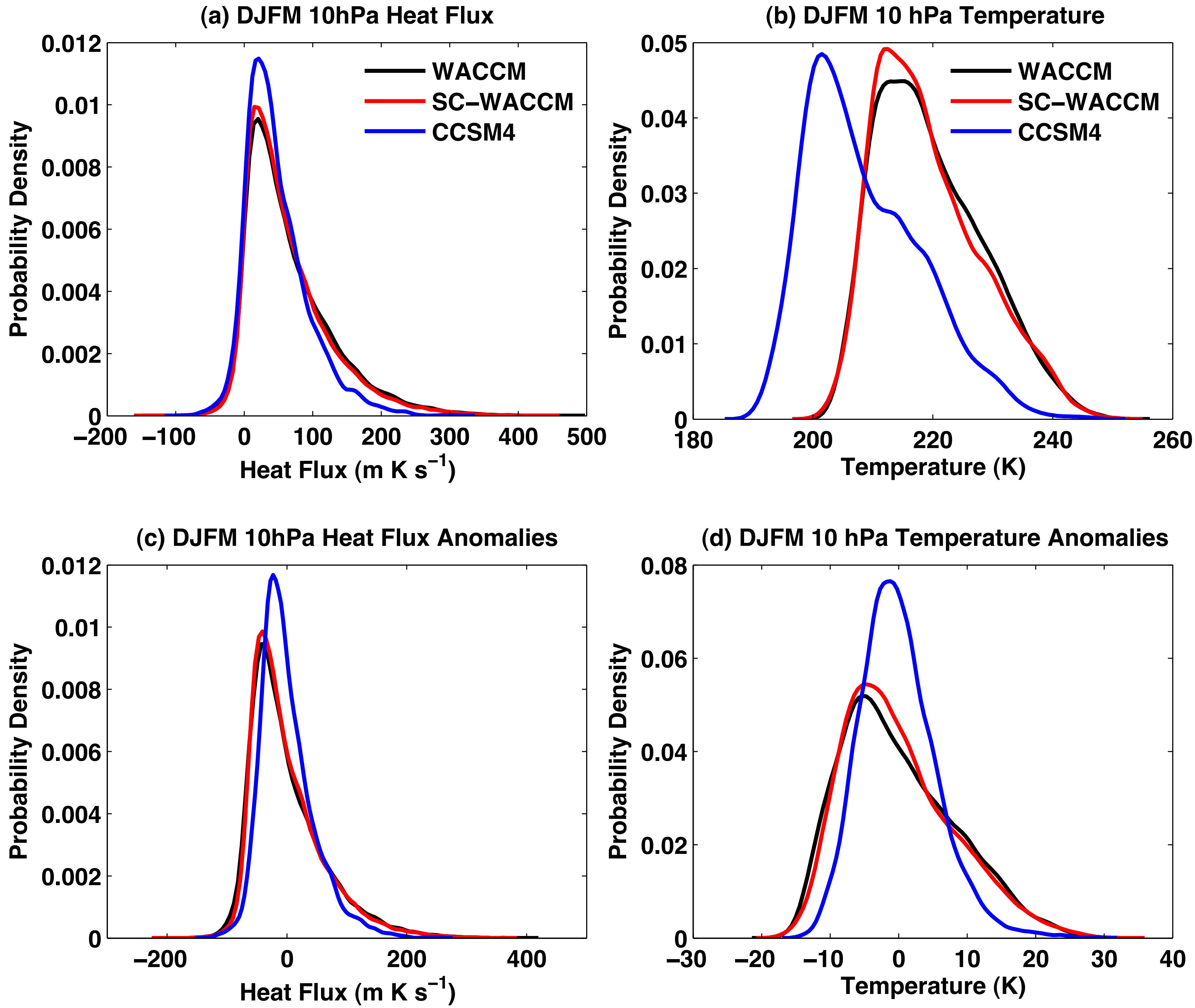
RMSE of U at 60N, 10hPa



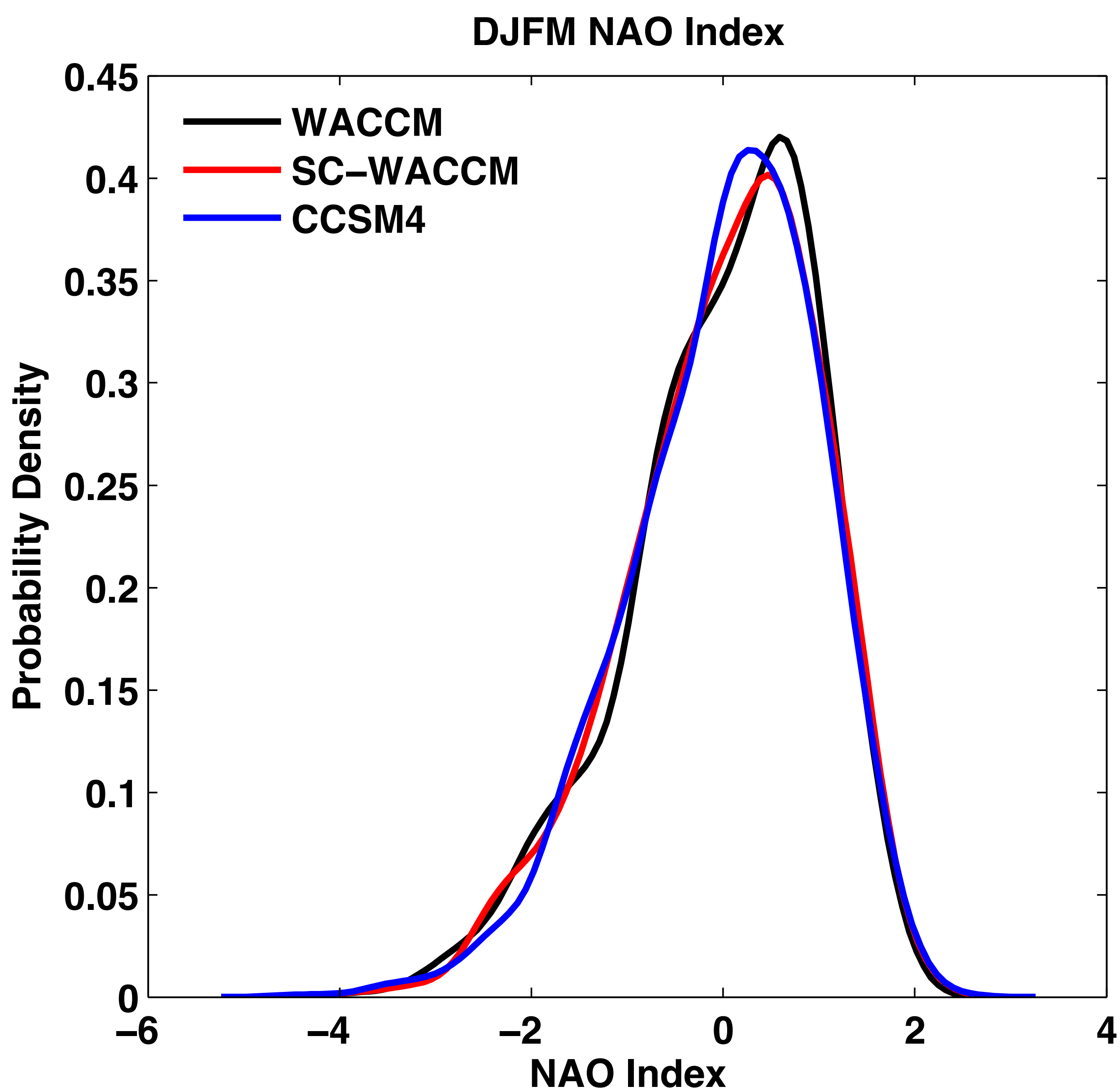
RMSE of U at 60S, 10hPa



DJFM Heat Flux and 10hPa Temperatures

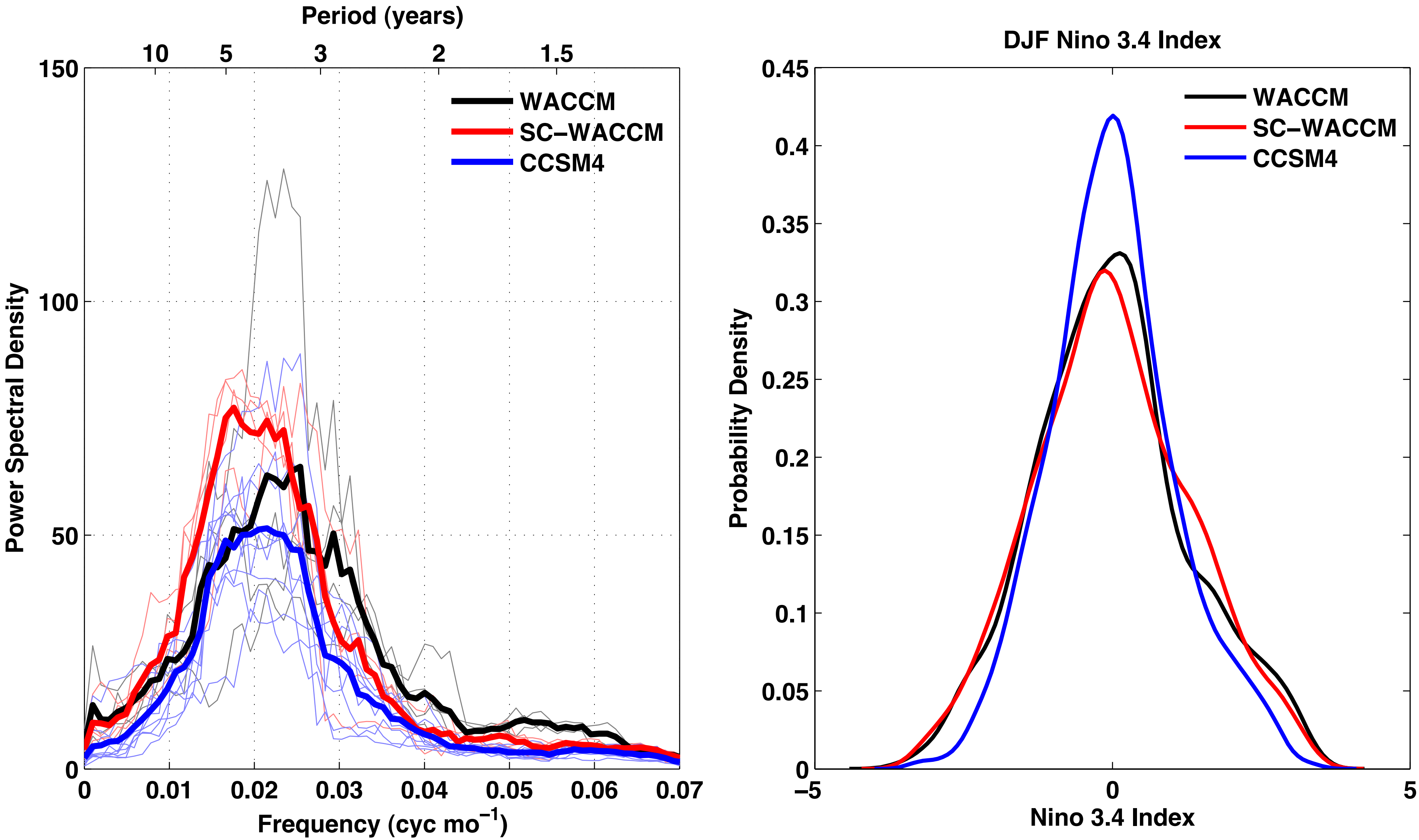


NAO



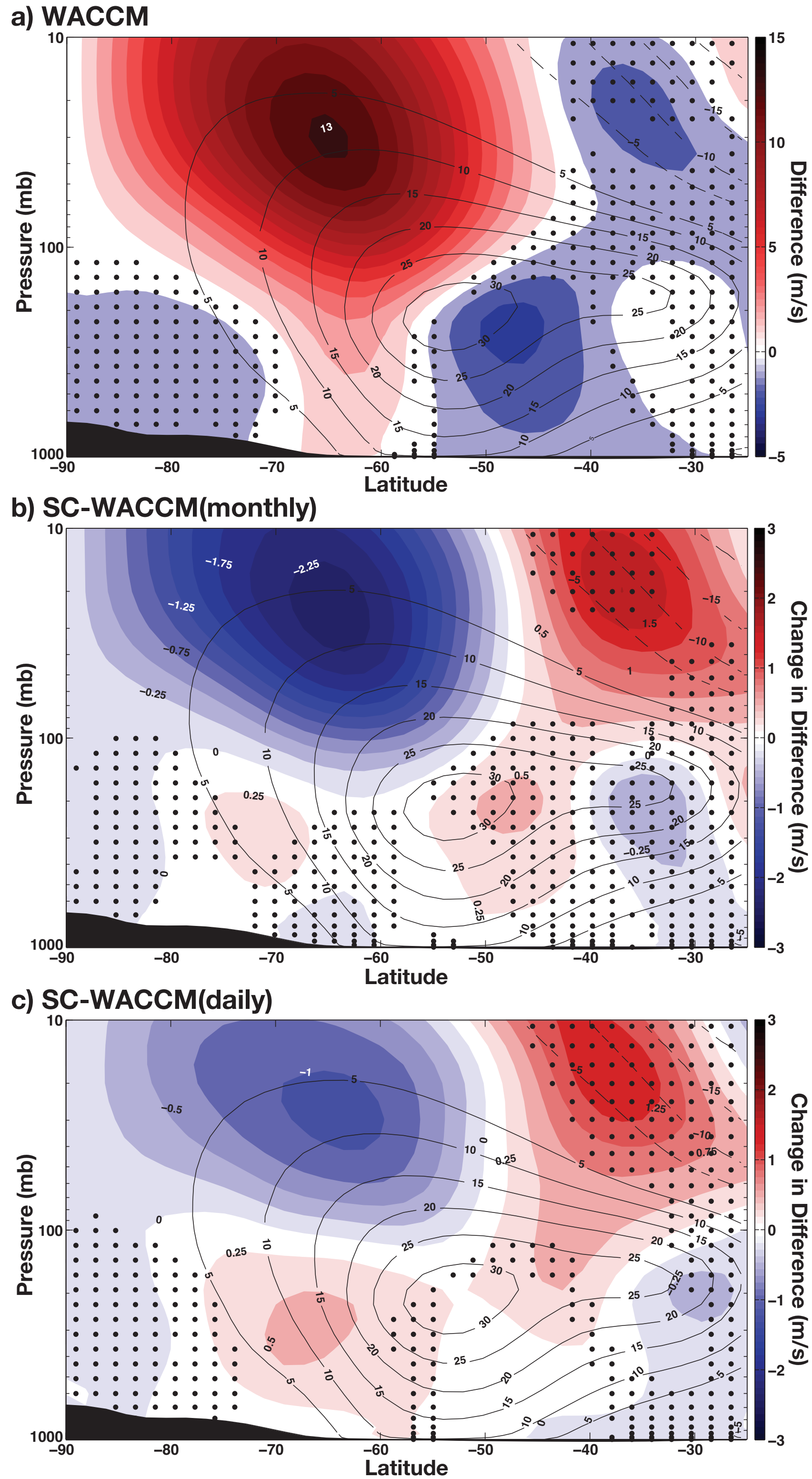
DJFM NAO Index
WACCM
SC–WACCM
CCSM4
Probability Density
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
–6
–4
–2
0
2
4
NAO Index

NINO 3.4



Period (years)
10
5
3
2
1.5
150
100
50
0
Power Spectral Density
WACCM
SC−WACCM
CCSM4
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Frequency (cyc mo^{-1})
DJF Nino 3.4 Index
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Probability Density
WACCM
SC−WACCM
CCSM4
−5
0
5
Nino 3.4 Index

Changes in the Zonal Mean Winds (1995-2005 mean minus 1960-1969 mean)



Change from WACCM Difference

Jet Changes and Temperature