SC-WACCM:
a dynamics-only version of WACCM (with **S**pecified **C**hemistry)

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Thanks to: Mike Mills, Francis Vitt and Rolando Garcia, Gus Correa

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

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- 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

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  - 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 and performance

- 1.9˚ latitude x 2.5 longitude
- Same 66 levels as WACCM (fully-resolved stratosphere and mesosphere):
  - model top at 5.1×10^{-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

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  - Stratosphere: 17 levels in WACCM between 100 and 3 hPa (versus 8 in CCSM4)
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- Twice as fast WACCM (or half the cost)
- CCSM4 vs SC-WACCM: Cost scales slightly better than ratio of number of levels

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

WACCM & SC-WACCM simulations

- WACCM & SC-WACCM
  - 200 years, coupled 1850 pre-industrial control simulation
  - daily and monthly output

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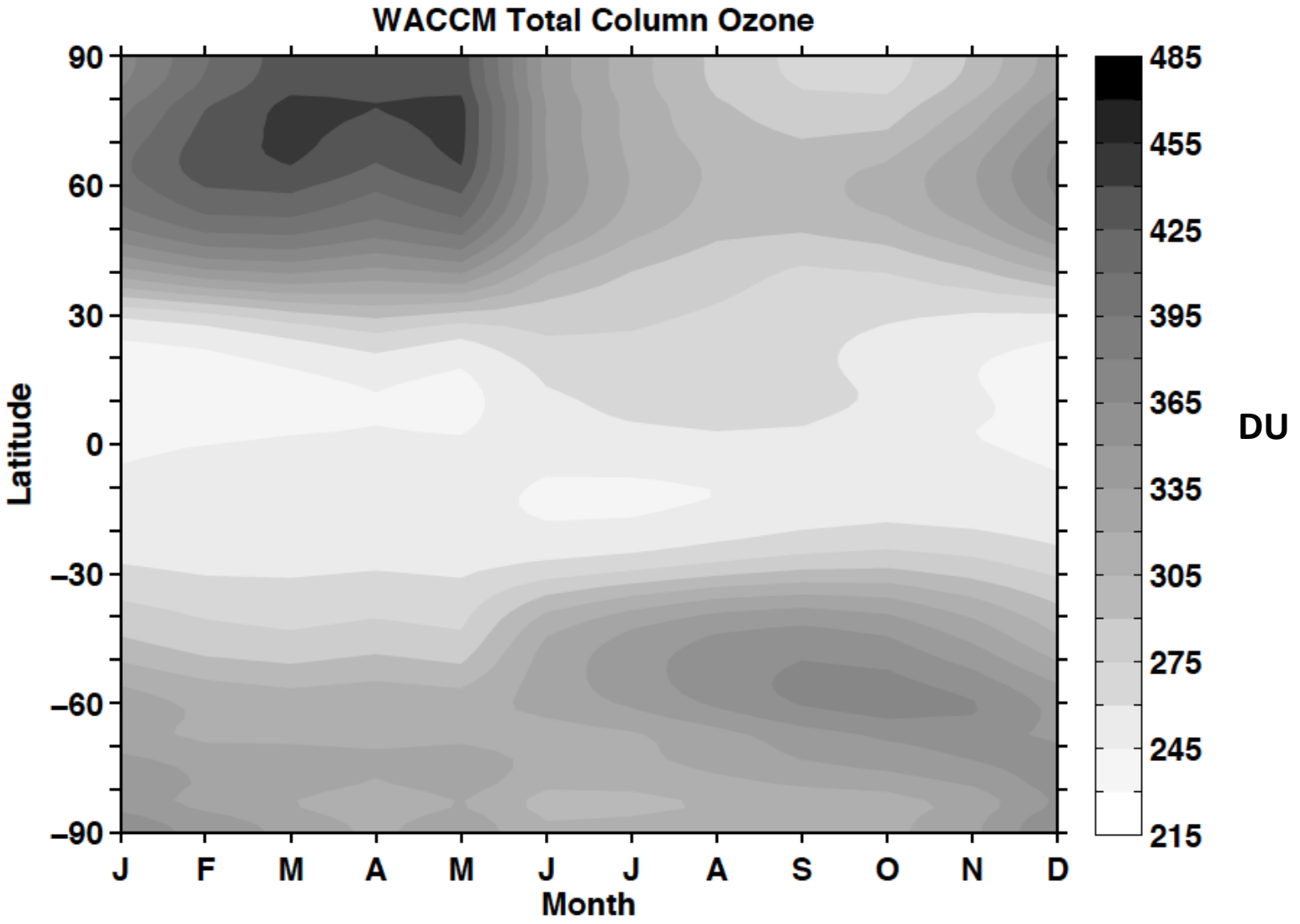
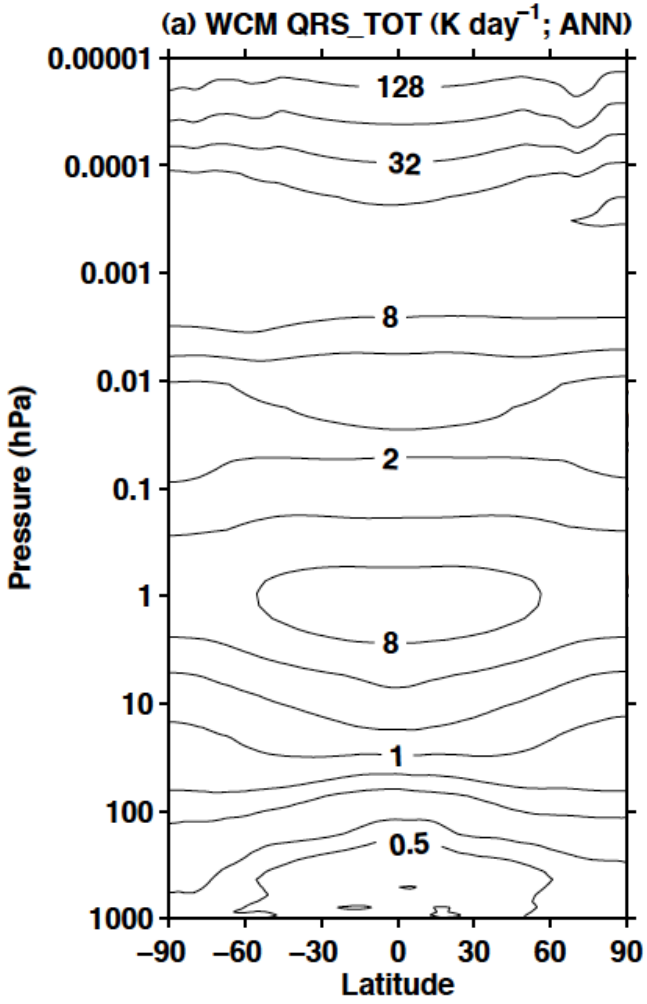
  - 200 years, coupled 1850 pre-industrial control simulation
  - daily and monthly output
- CCSM4
  - 500 years, coupled 1850 pre-industrial control simulation with monthly output
  - 54 years of daily output

1850 Control Simulations

Climatological ozone from WACCM is prescribed in SC-WACCM



Short-wave heating rates from WACCM are also prescribed



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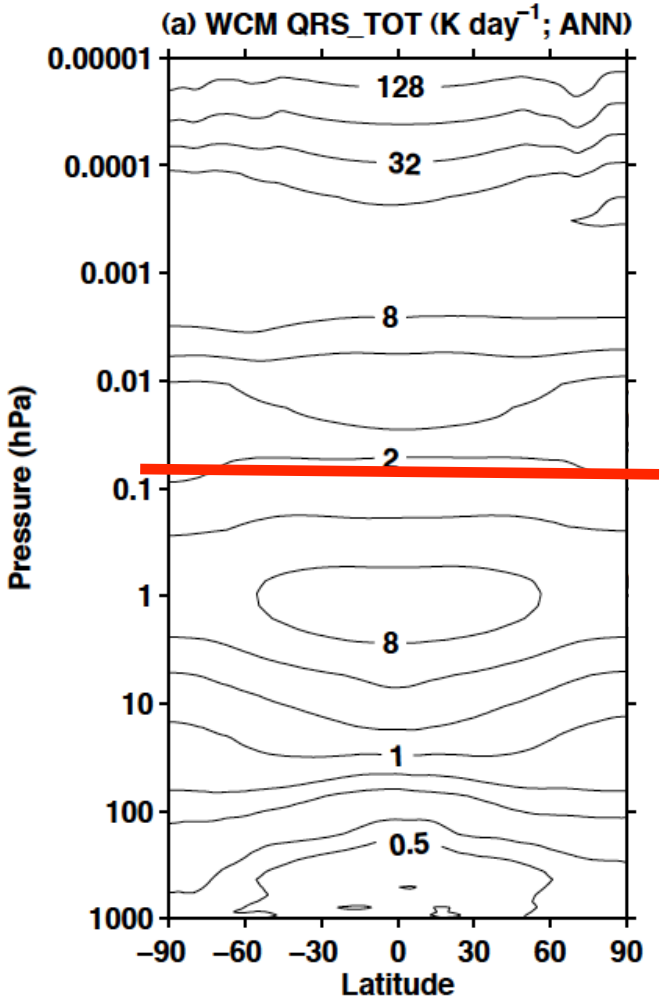

65 km

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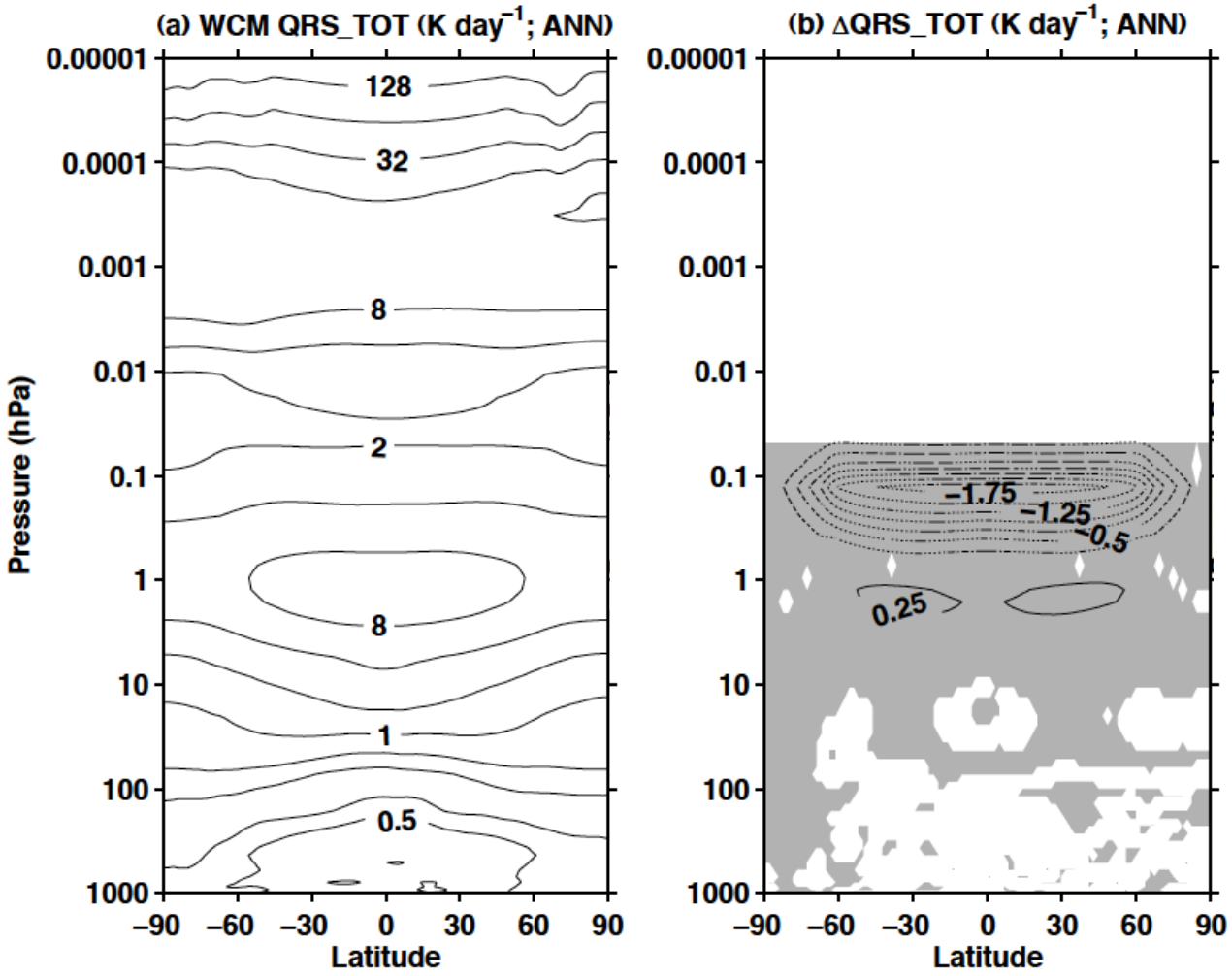
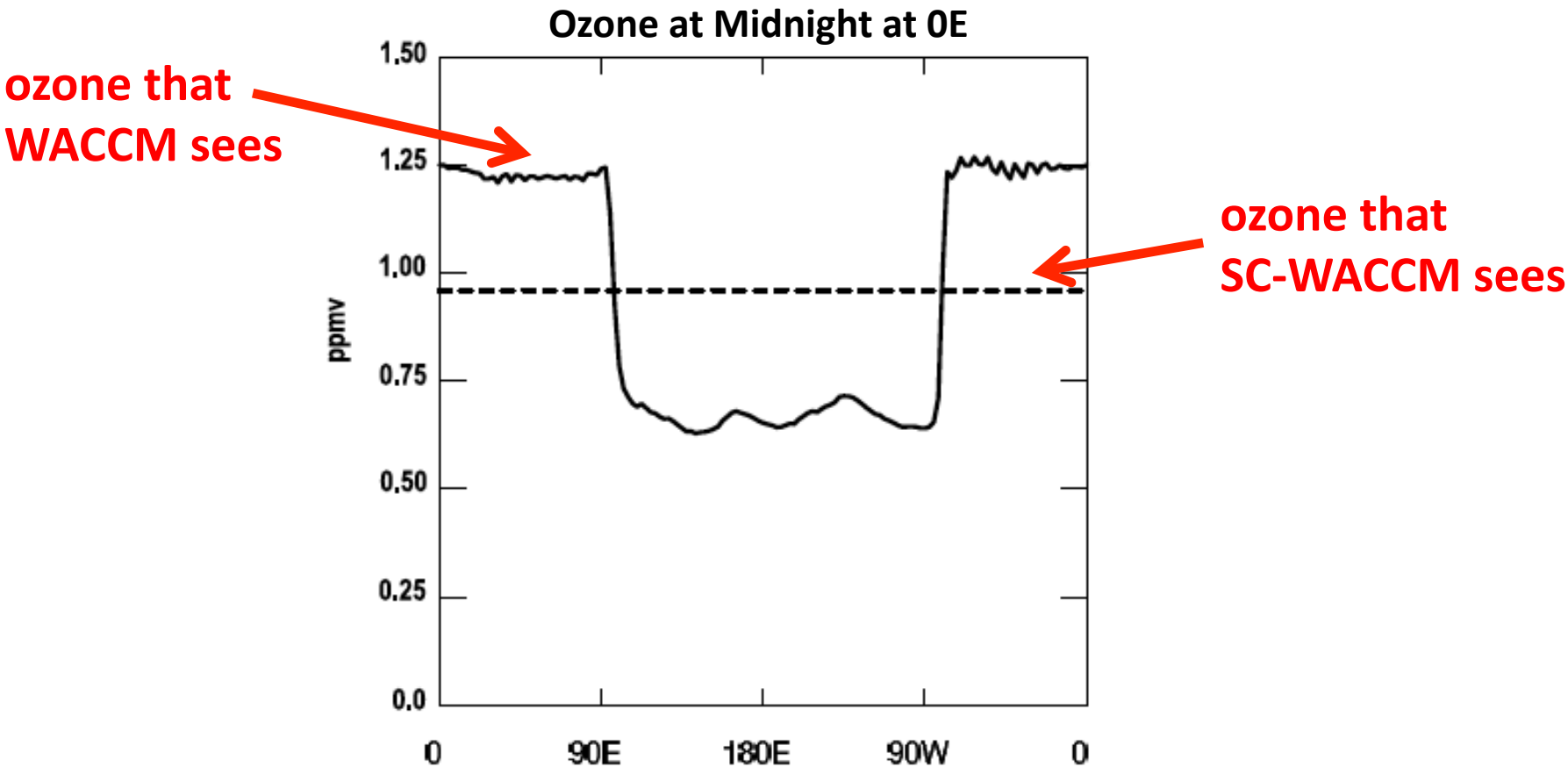


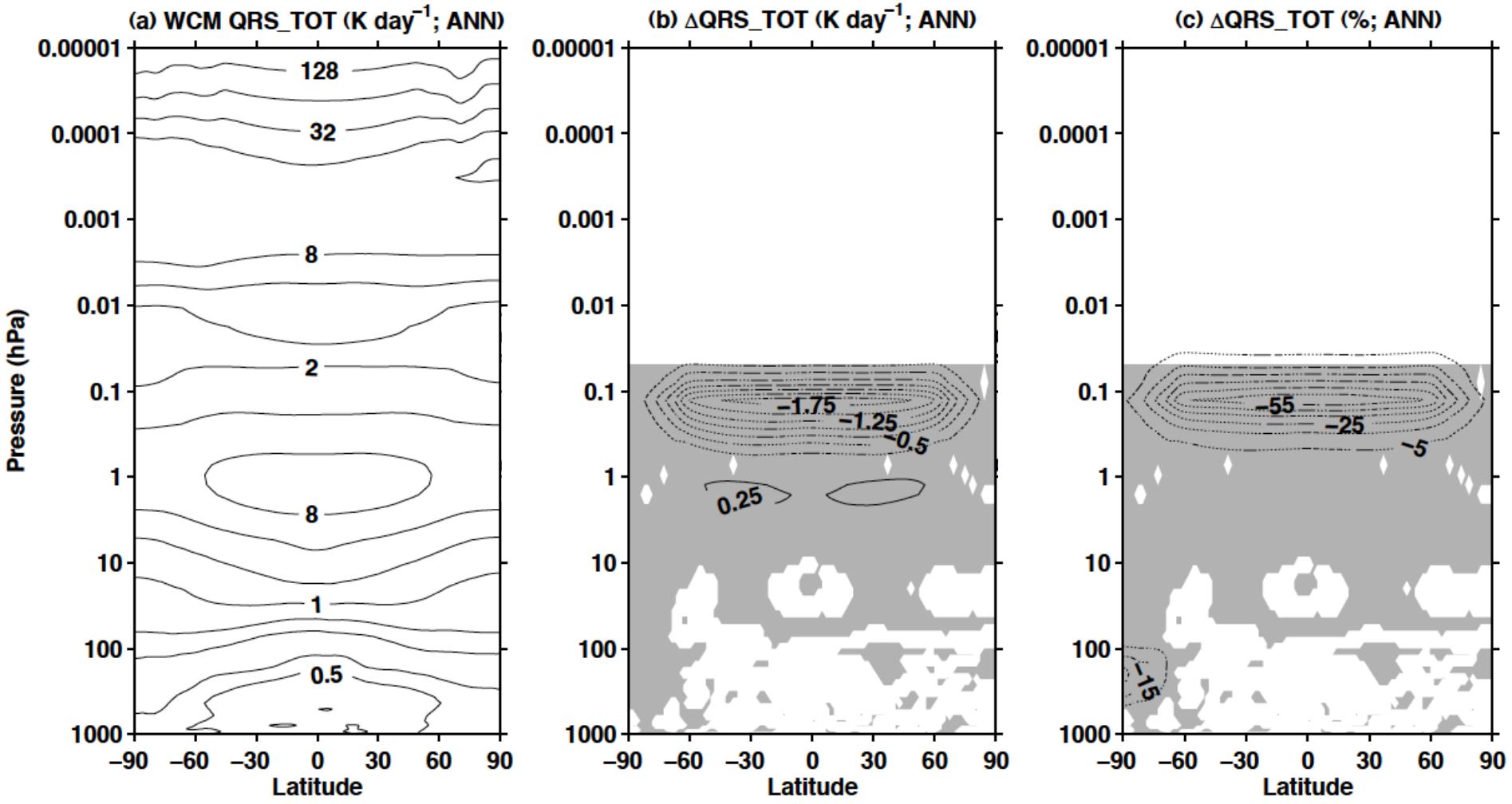
Gray shading indicates regions that are significantly different at the 95% level

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*).

Percentage differences due to diurnal cycle are large



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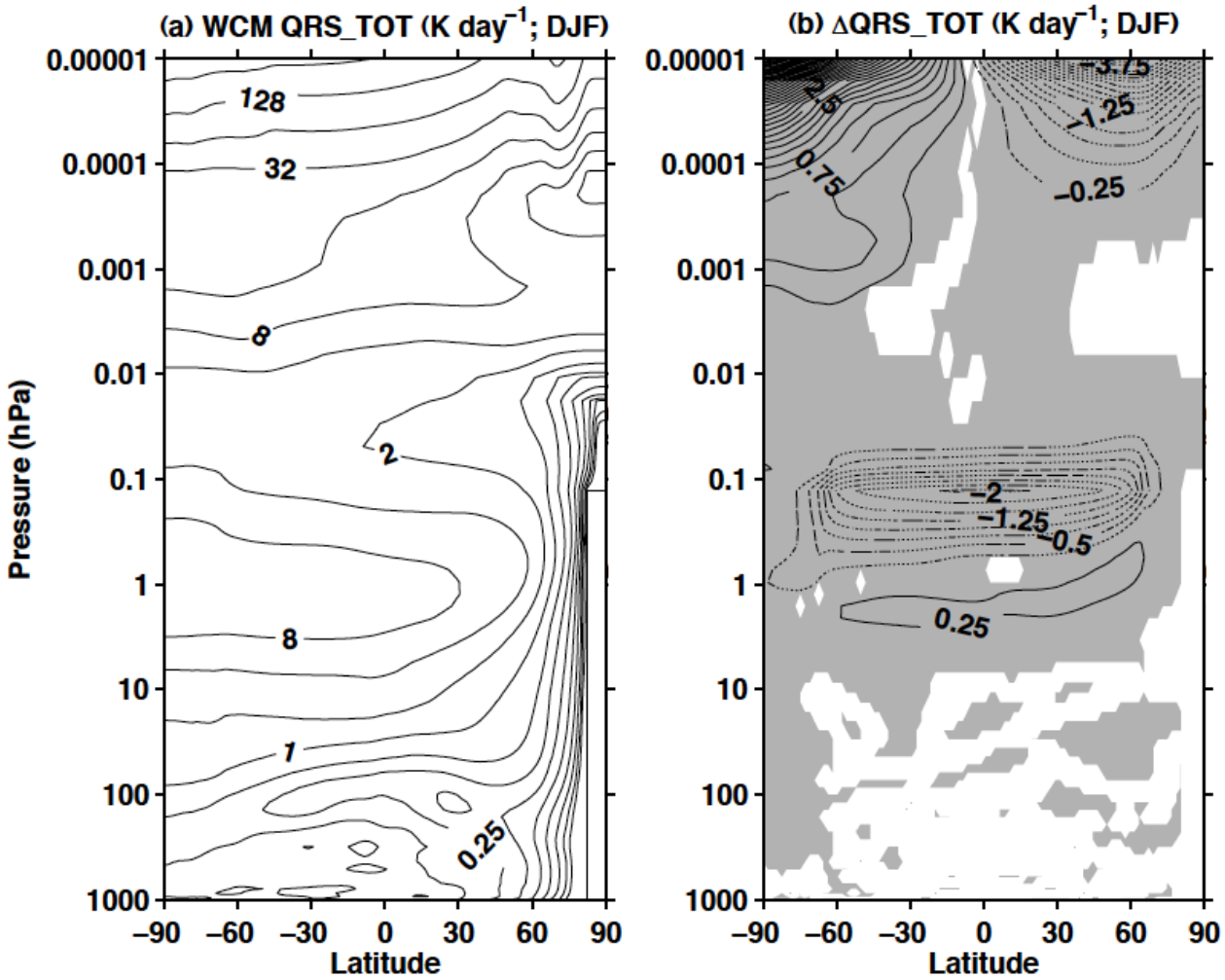
Interpolation of monthly QRS_TOT onto model time-step causes seasonal biases



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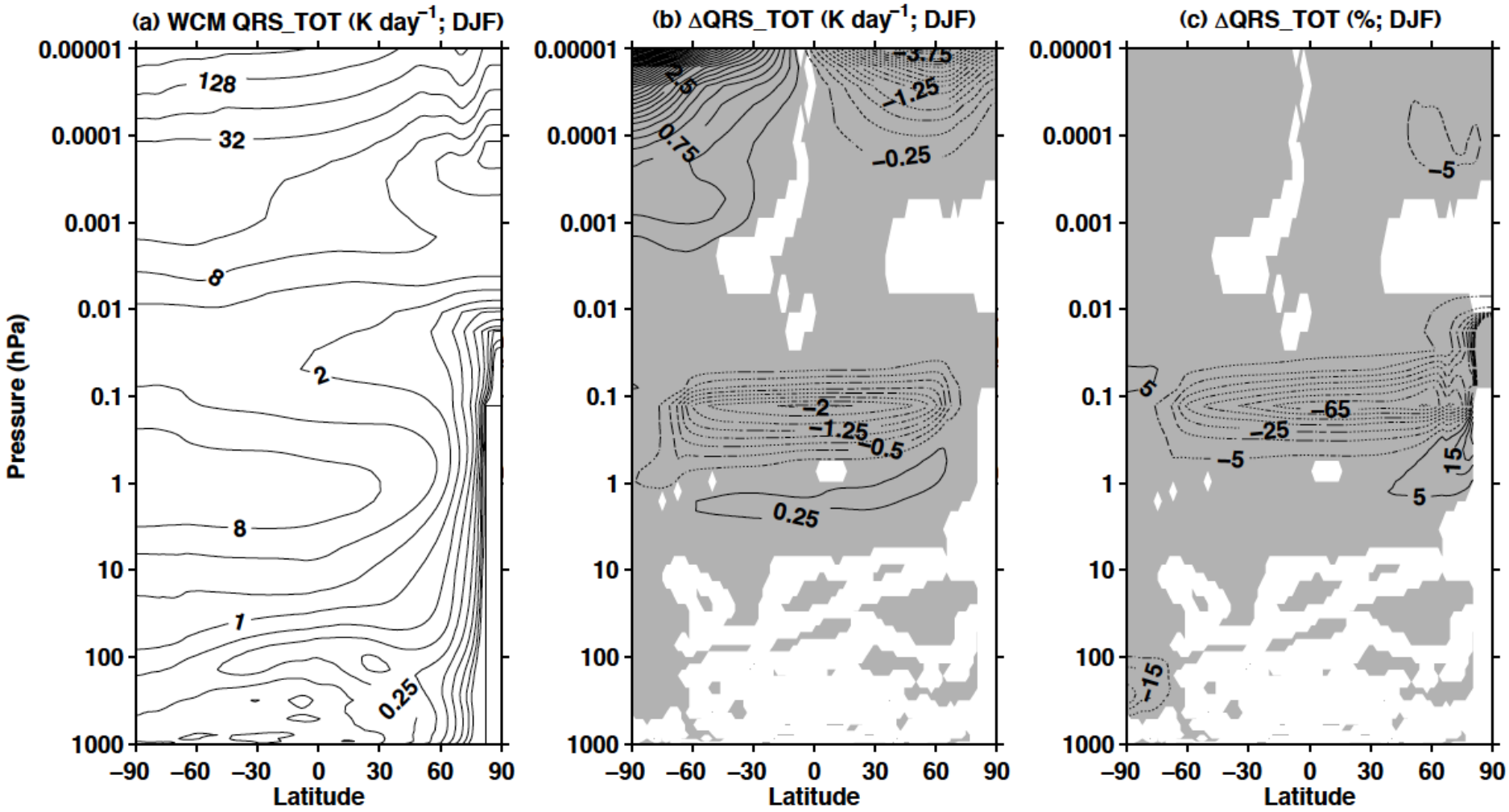
Percentage differences due to time interpolation are small



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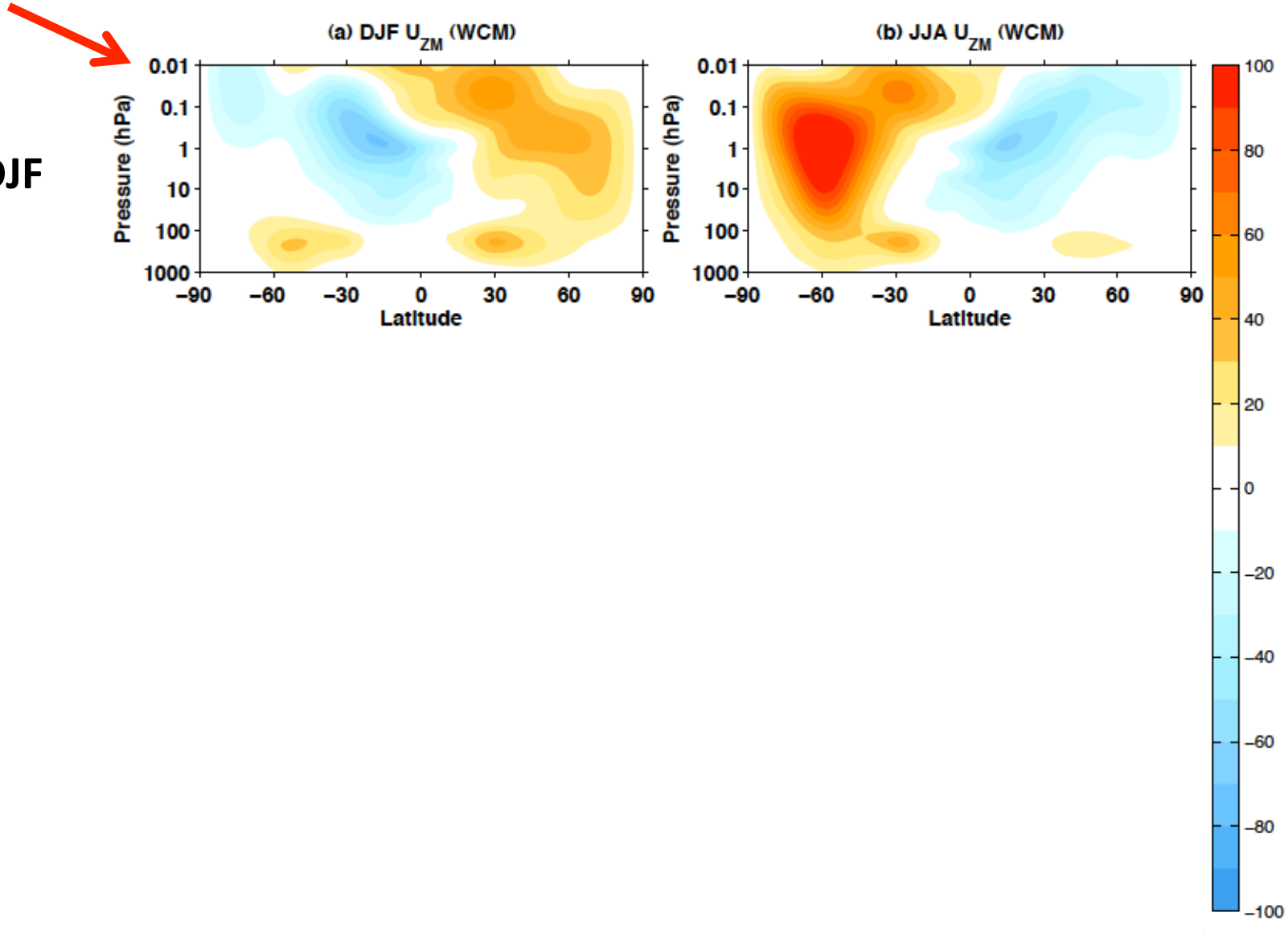
Zonal mean zonal wind climatology

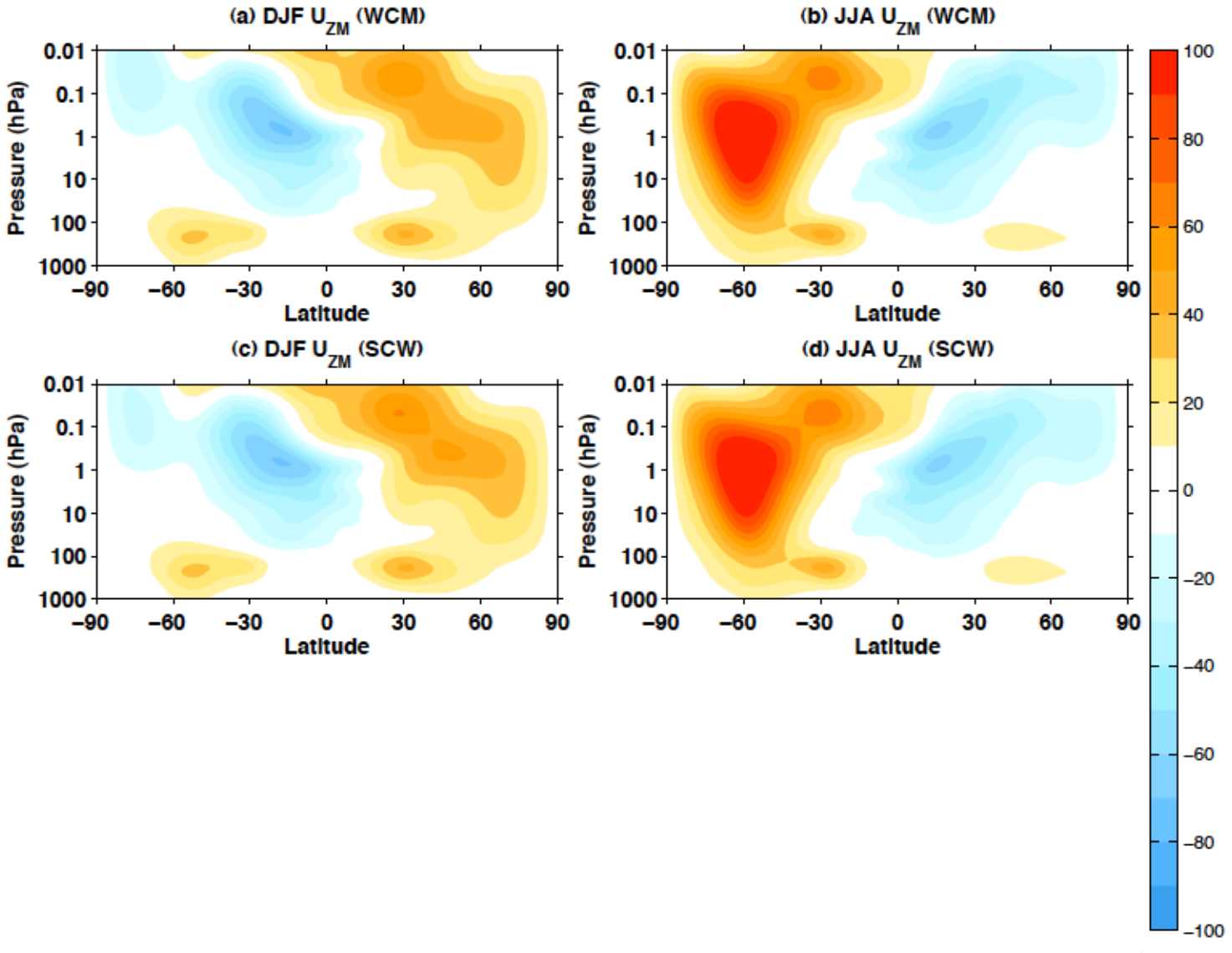
DJF



JJA

Zonal mean zonal wind climatology

DJF



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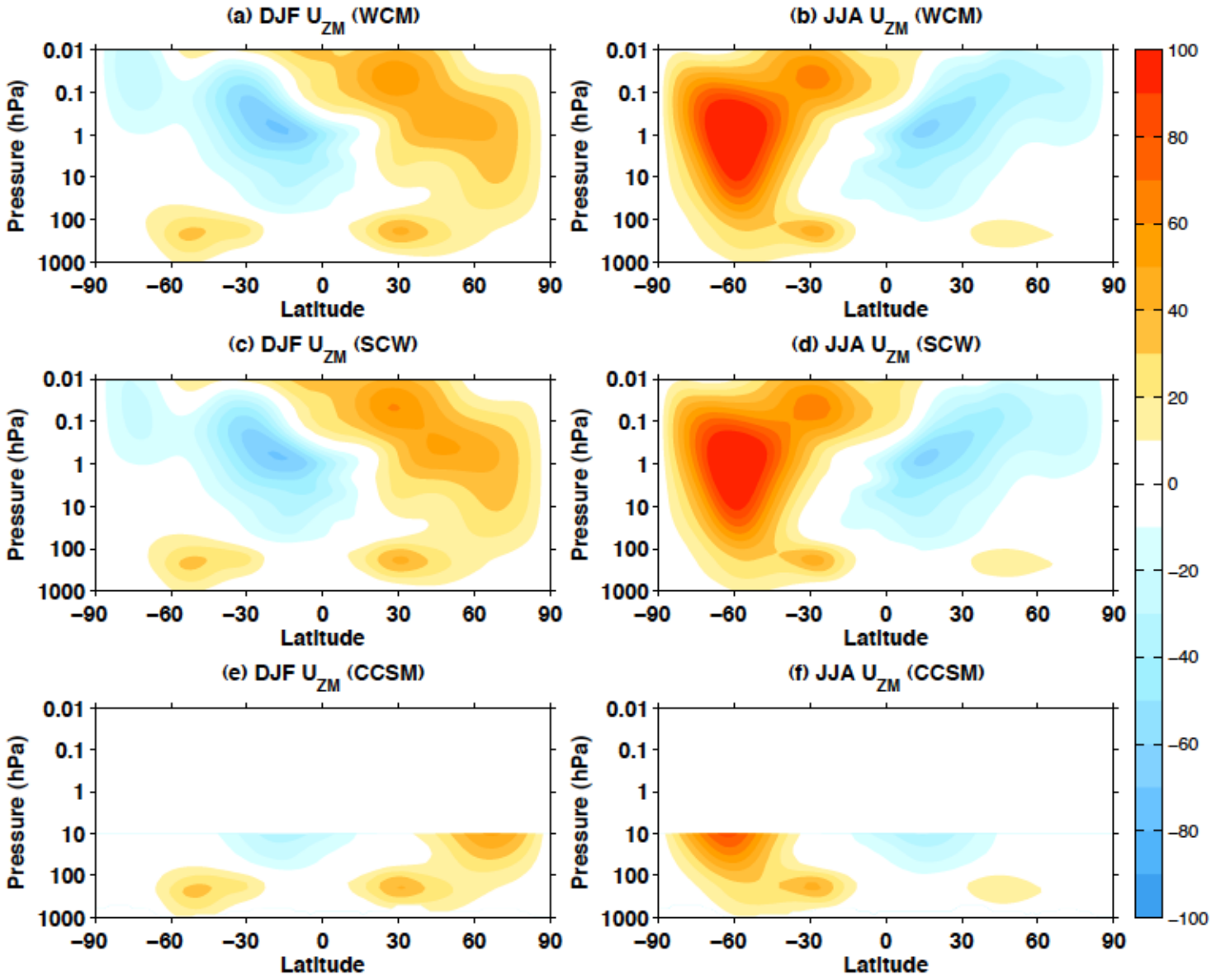

JJA

Temperature differences are large due to ozone diurnal cycle

DJF

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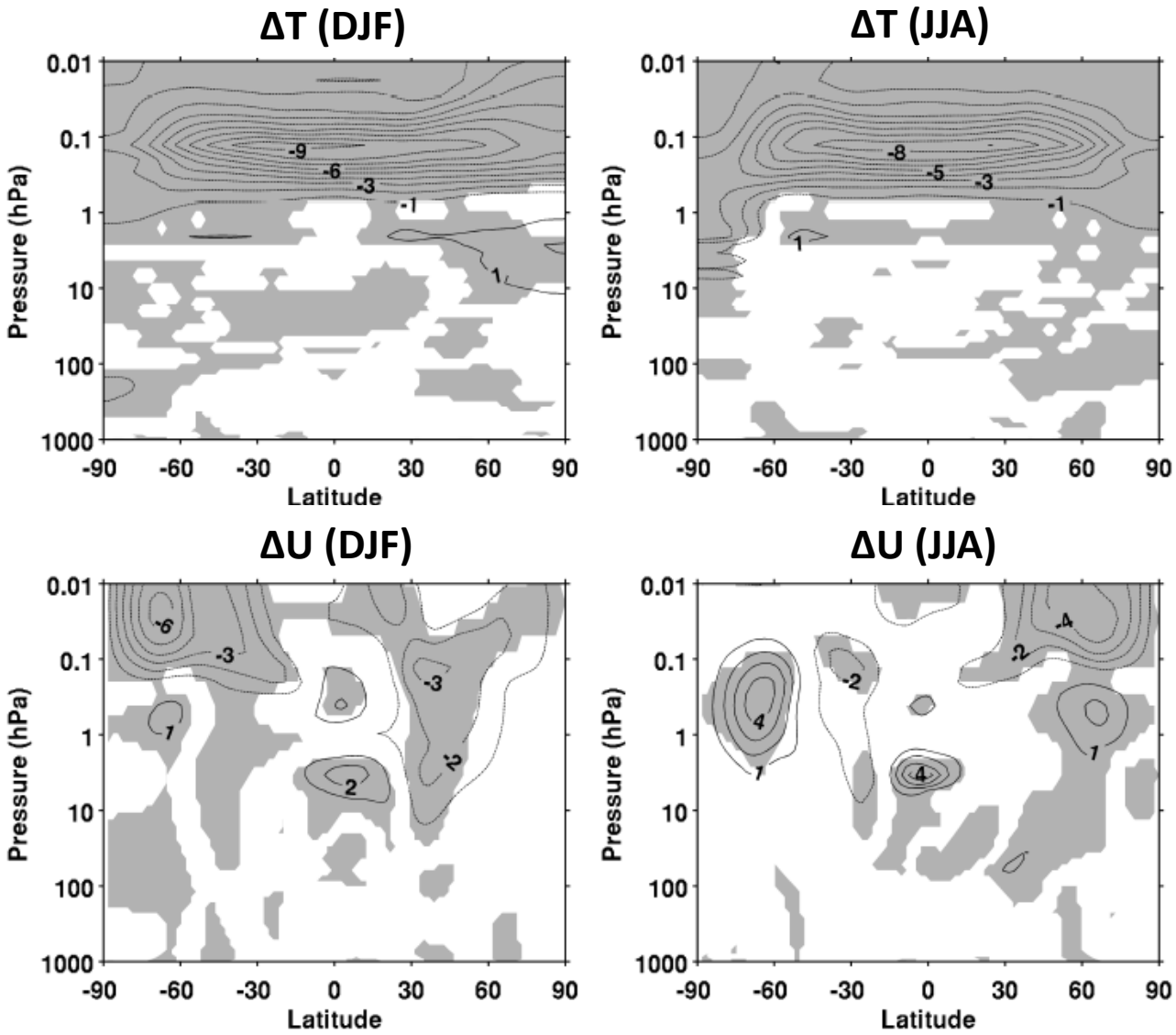
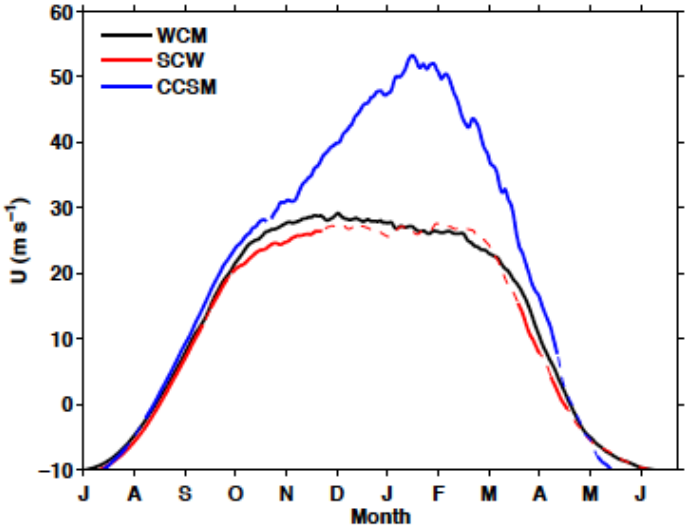


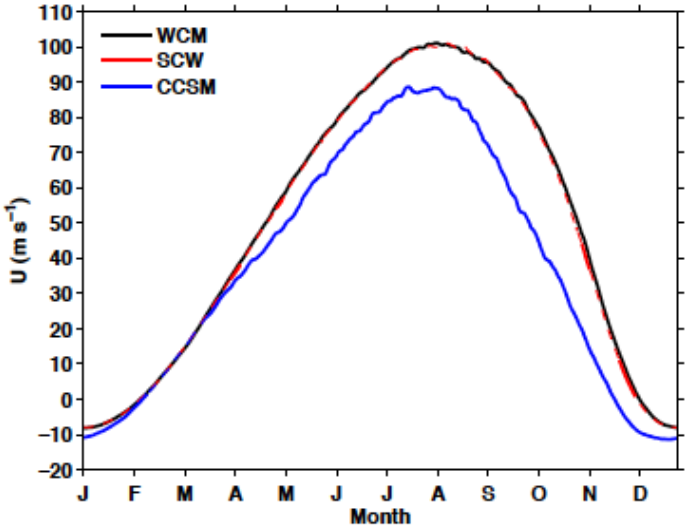
Polar vortices

NH

U at 60N, 10hPa

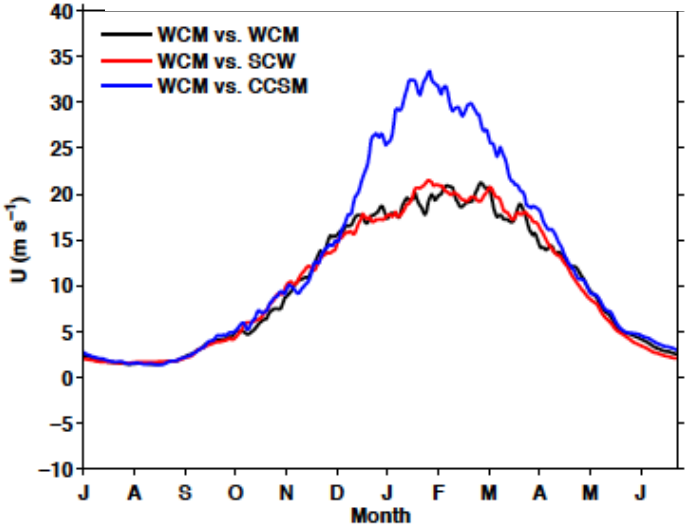


U at 60S, 10hPa

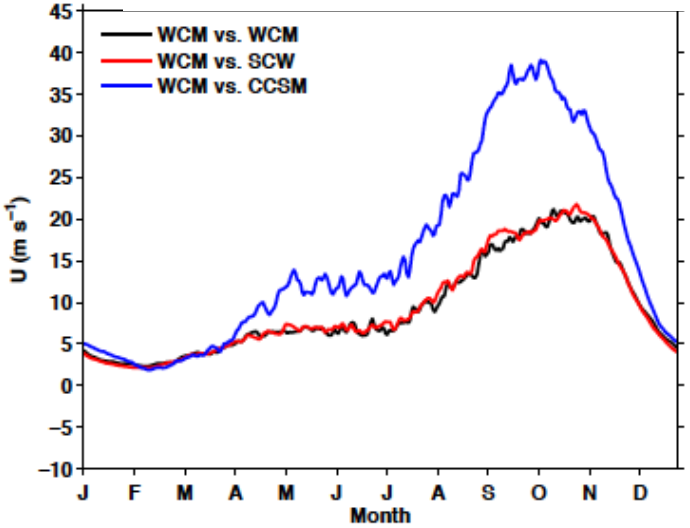


SH

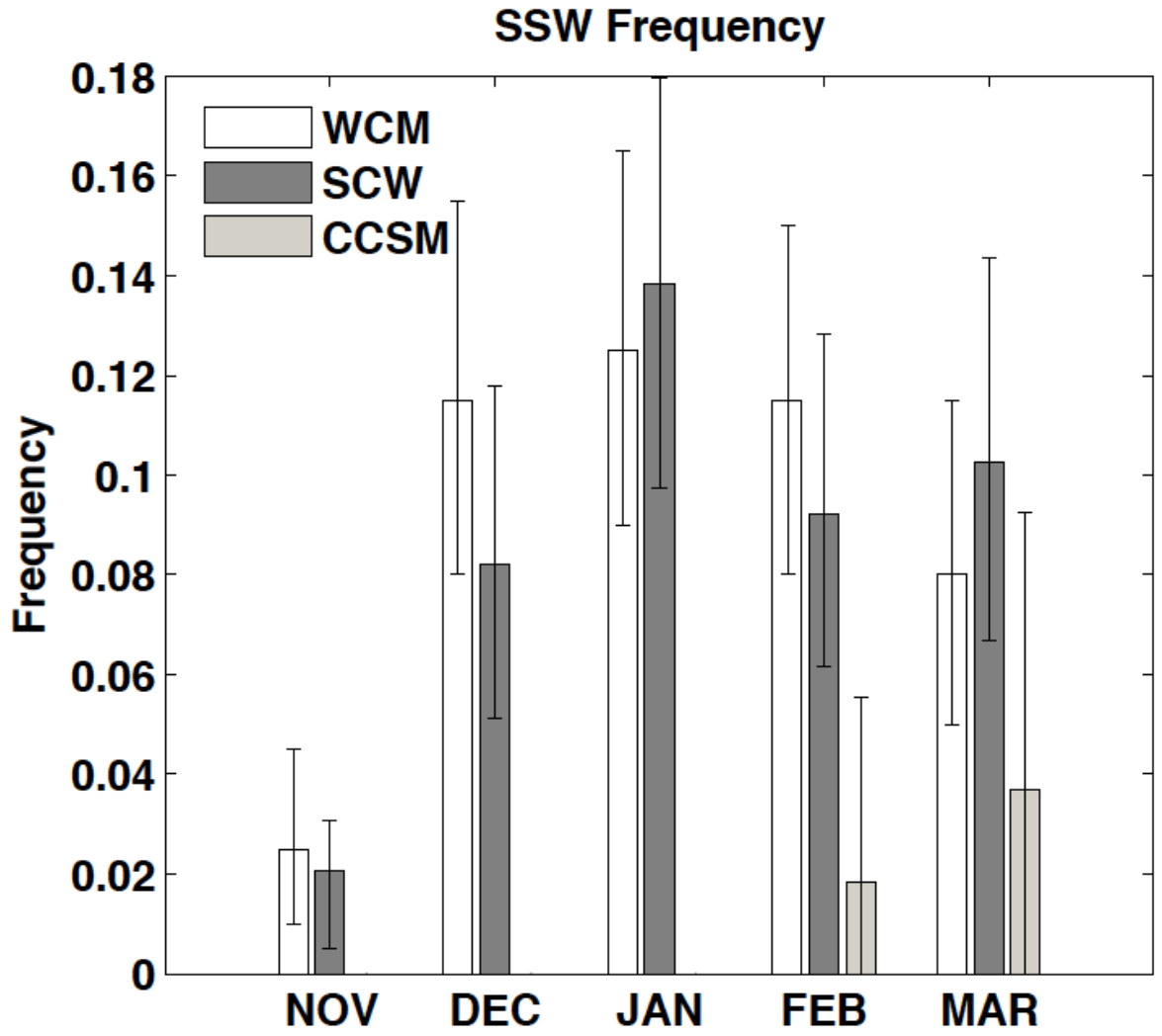
RMSE of U at 60N, 10hPa



RMSE of U at 60S, 10hPa



Sudden stratospheric warming (SSW) frequency



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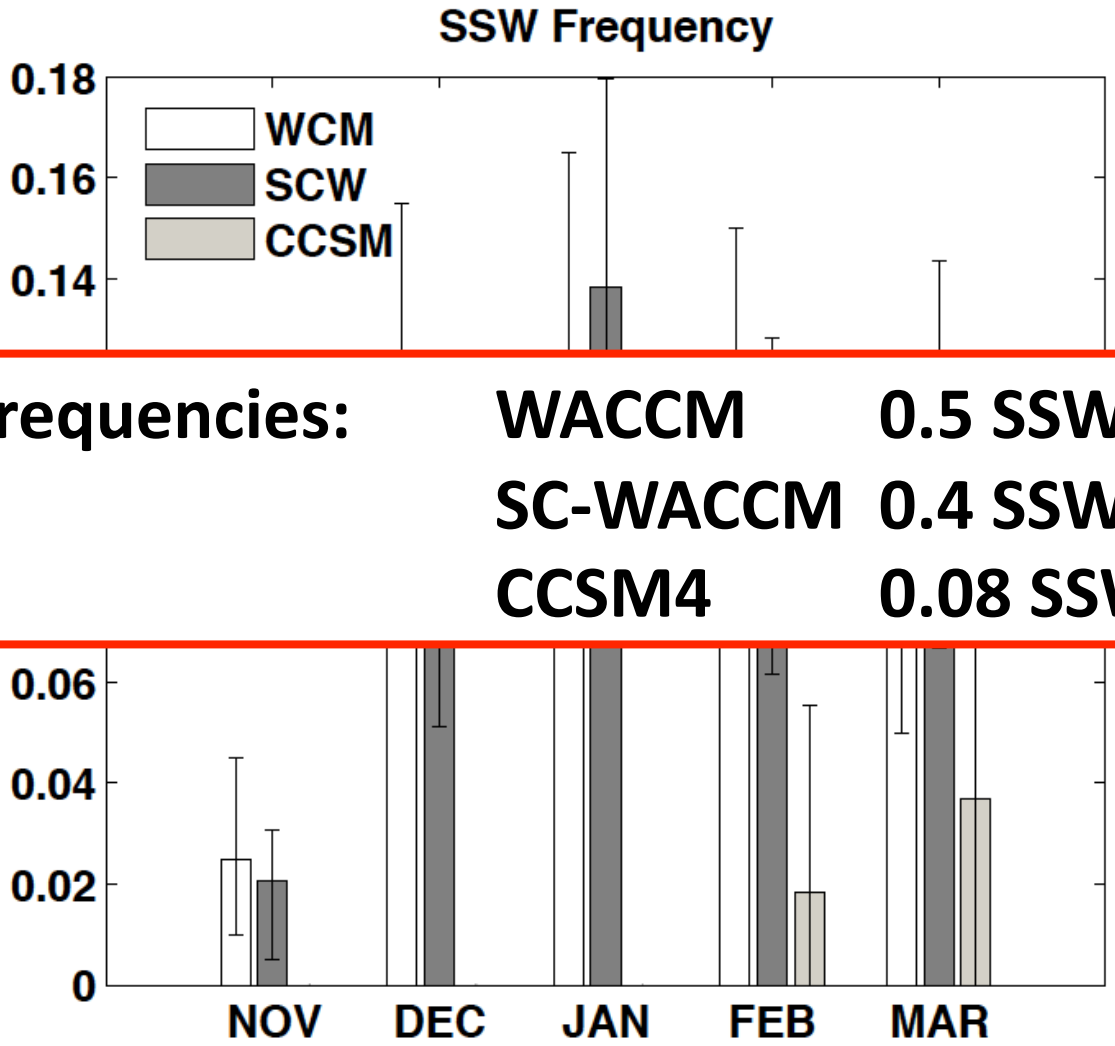
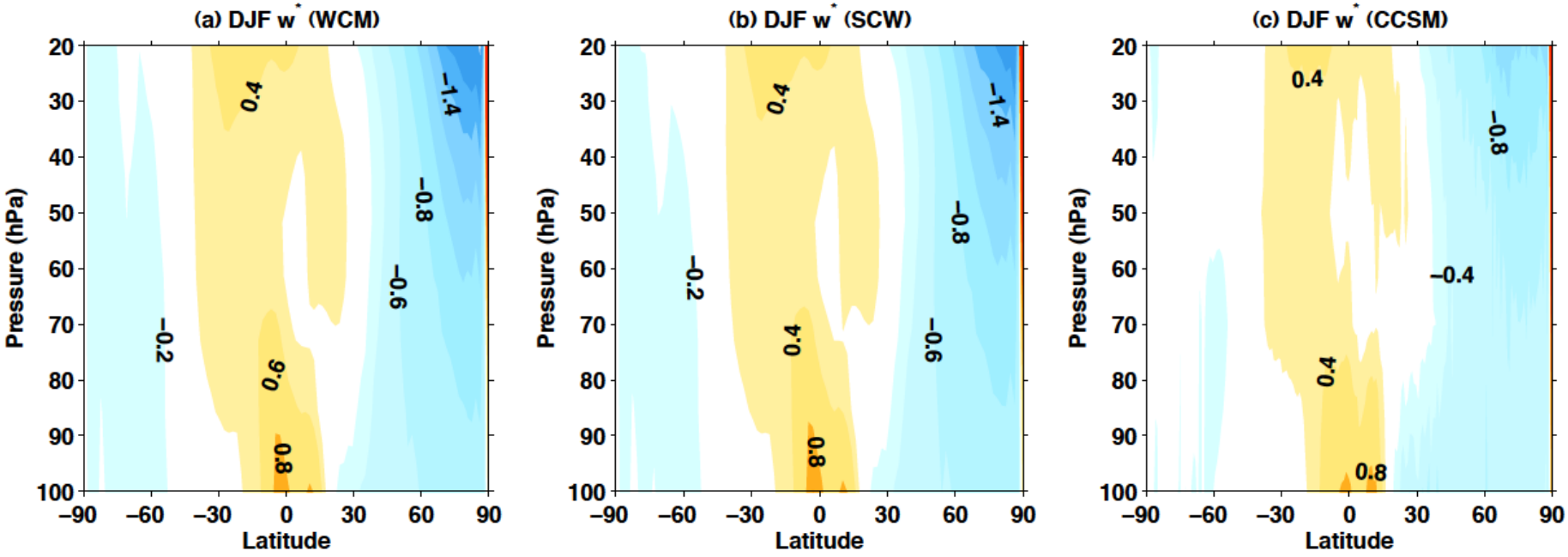


Winter Frequencies:

WACCM	**0.5 SSWs yr^{-1}**
SC-WACCM	**0.4 SSWs yr^{-1}**
CCSM4	**0.08 SSWs yr^{-1}**

The residual circulation is also well represented in SC-WACCM



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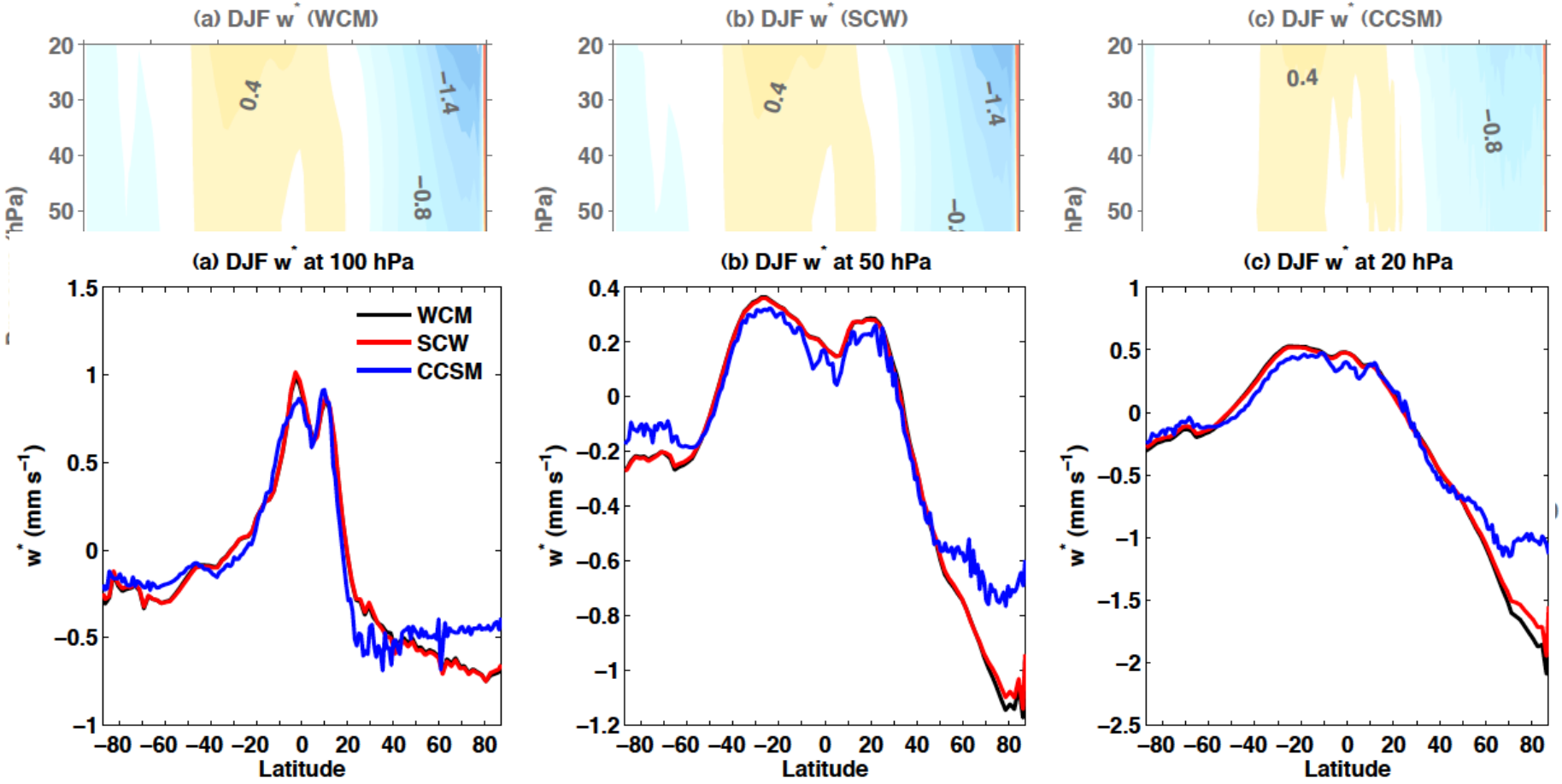
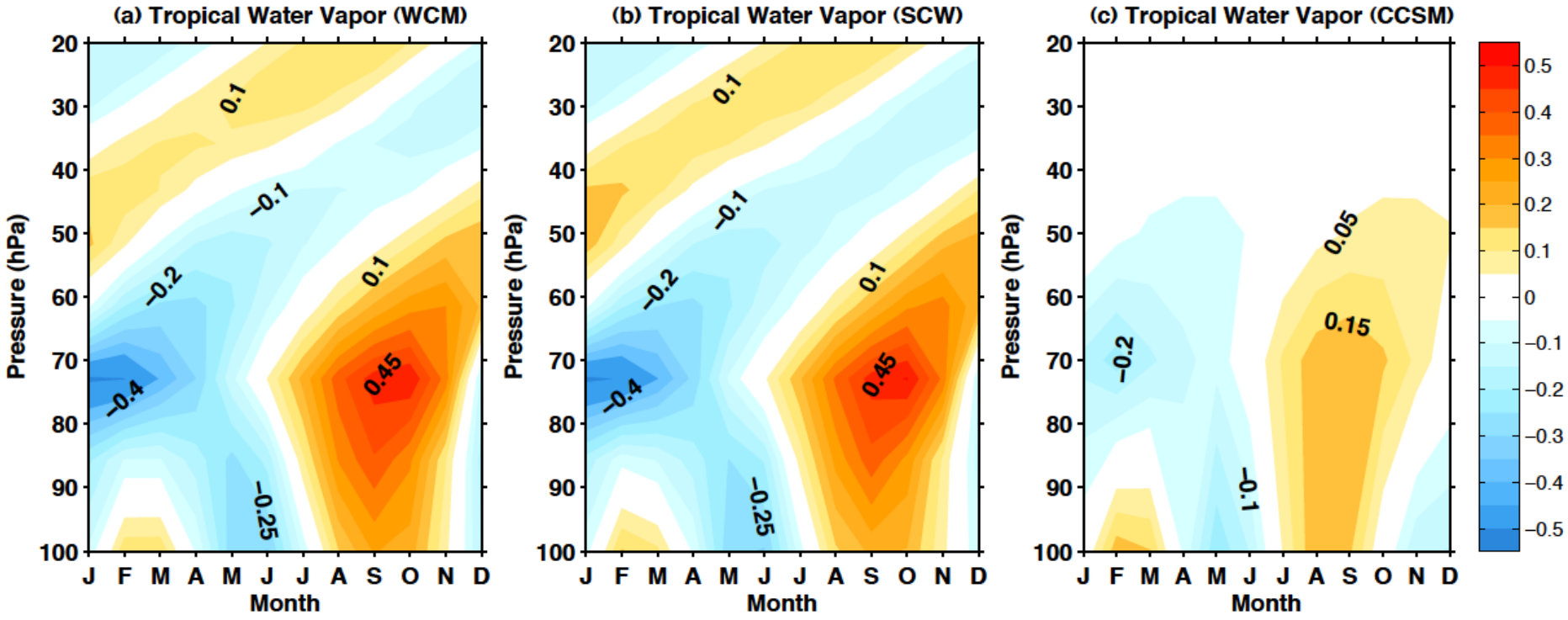


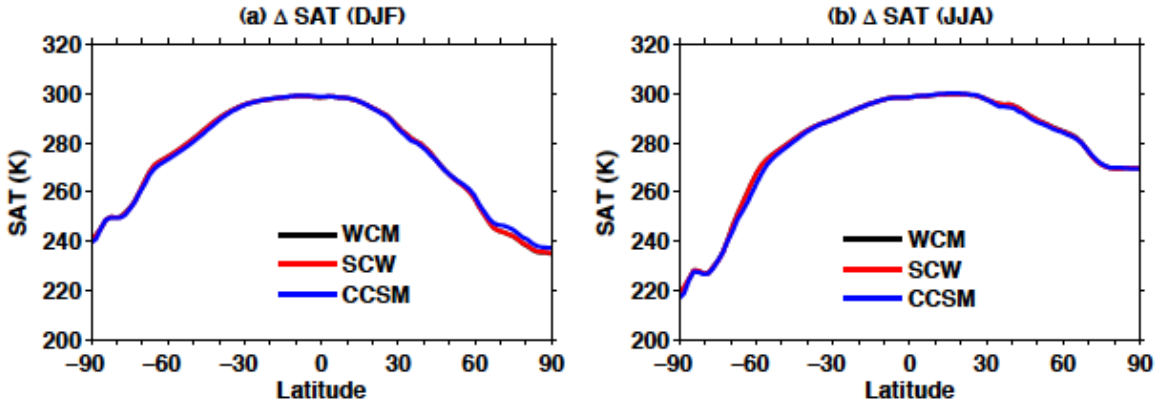
The tropical water vapor tape recorder



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

Surface climate

DJF



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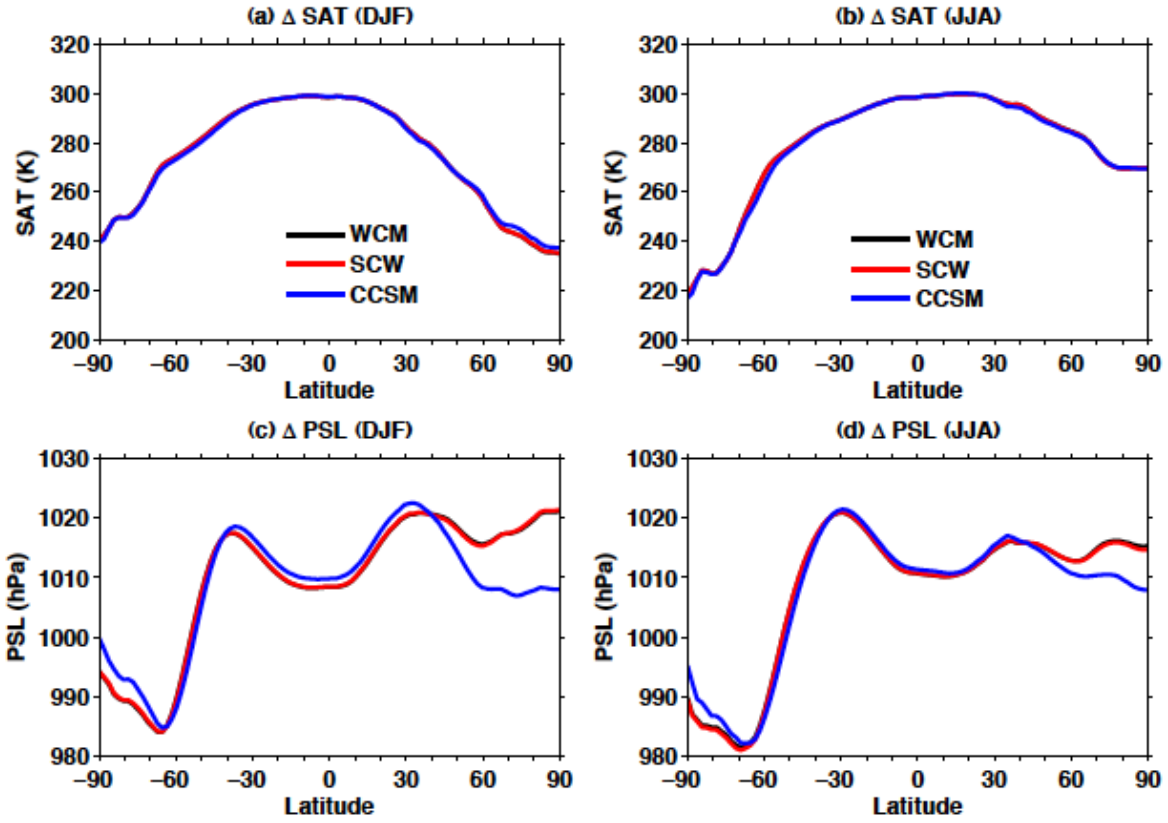

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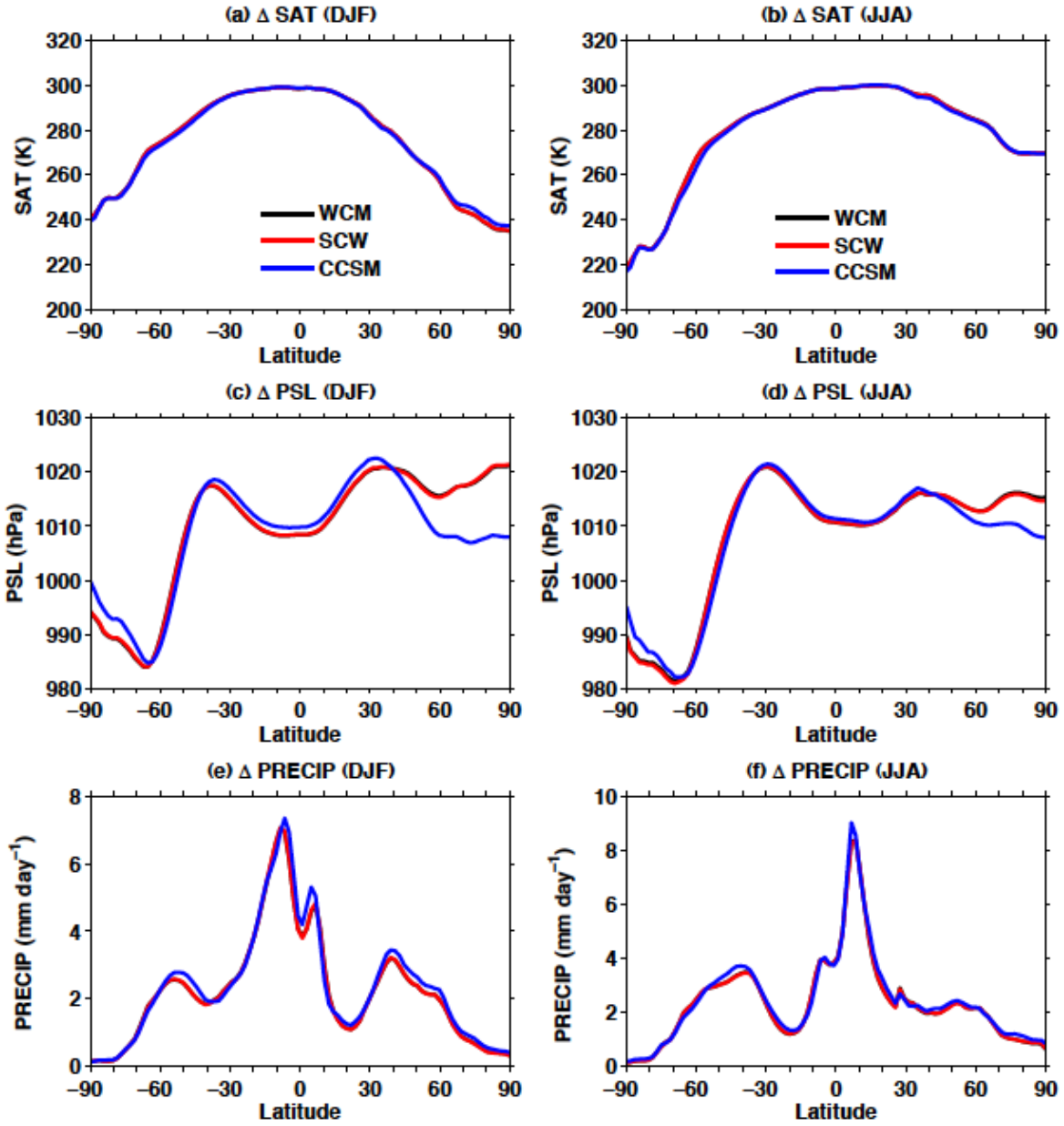
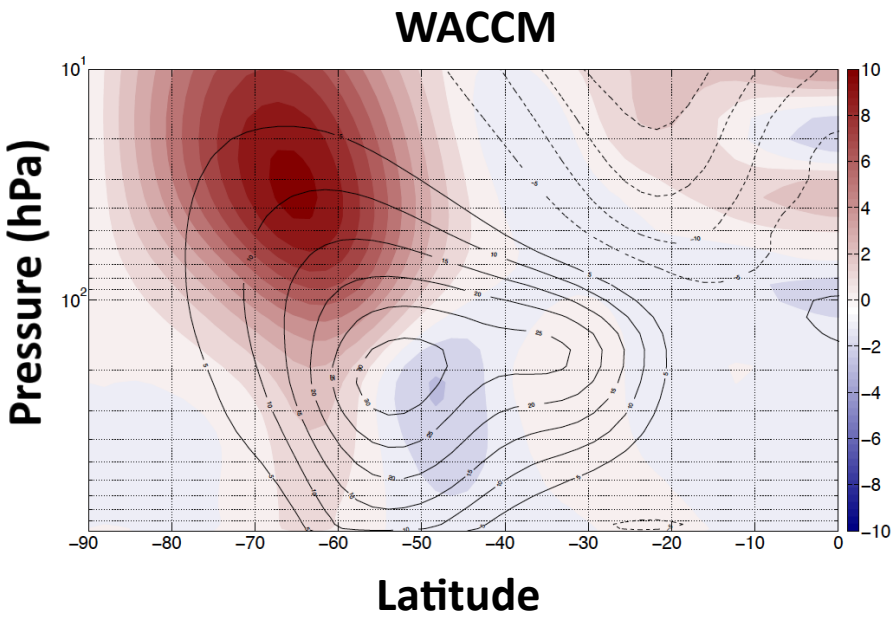


JJA

Historical Simulations

SH summertime zonal wind trends during ozone depletion era



Figures courtesy of Ryan Neely

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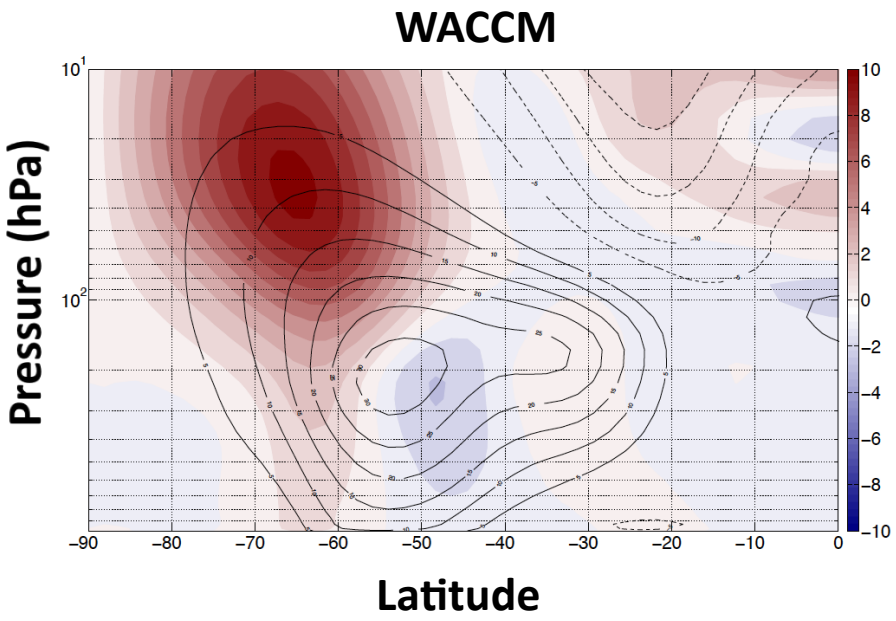

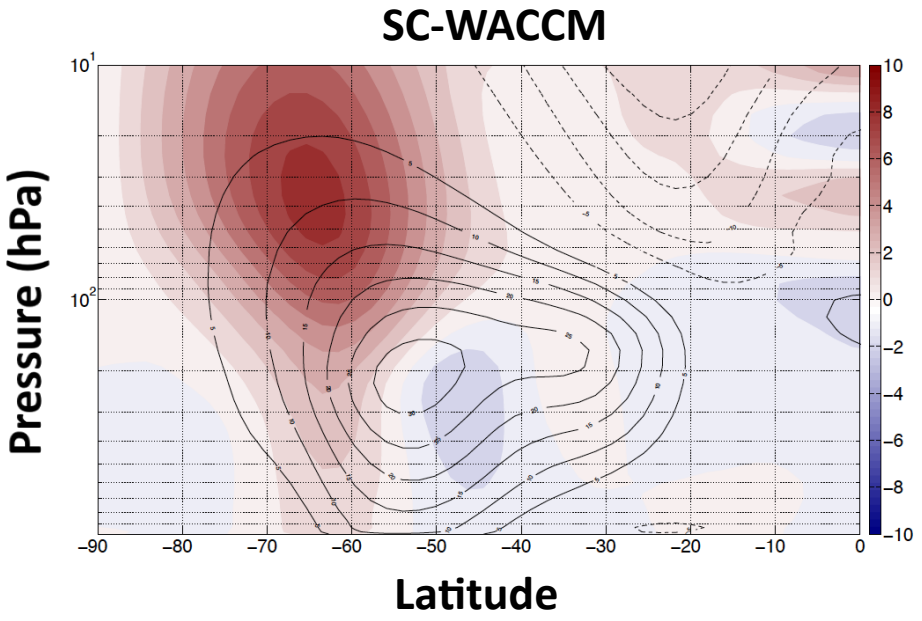

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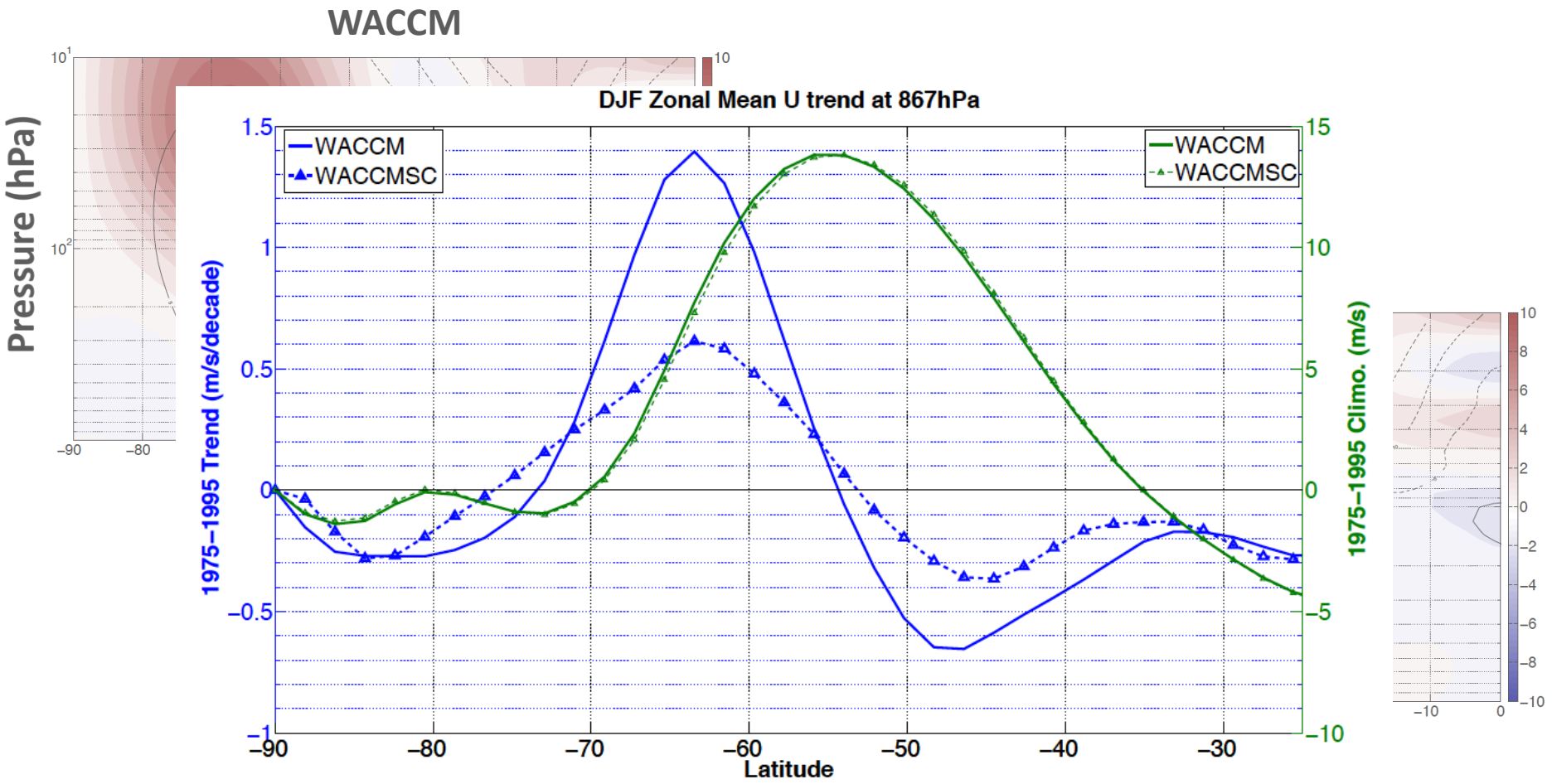

Figures courtesy of Ryan Neely

Summary

- SC-WACCM simulates a climate very similar to that of WACCM.
- SC-WACCM runs twice as fast as WACCM.
- For large perturbations in ozone, coupled chemistry becomes important; WACCM and SC-WACCM diverge.