State of WACCM(6)

Gettelman, Mills, Polvani

& The WACCM 'Team'

Thanks to:

Kinnison, Smith, Garcia, Richter, Bardeen, Tilmes, Vitt, Liu

Outline

- Logistics
- State of WACCM
- WACCM6 overview
- WACCM6 configurations
- Beyond WACCM6 (discussion)
  - WACCM6 Configurations
  - WACCM6 for CMIP6, MIPS
  - Future plans

Logistics

- Tuesday: All WACCM, All Day
  - Breaks outside: Breakfast @ 10a
  - Lunch: cafeteria here
  - Break early, Bus at 5:20
  - WACCM Information Exchange. 3:30 ‘Center Green South’
- Wednesday
  - 9 AM: Joint session with AMWG/ChemWG (Here)
  - 1:30 PM: Plenary (all working groups. Here)
  - 5 PM: Information Exchange
- Thursday
  - AM: Chem WG
  - Extra Terrestrial (ET) CAM meeting: 3:30p, CU (Room N100, 3665 Discovery Drive). Contact Curt Covey (covey1@llnl.gov)

State of WACCM

- CESM2 (WACCM6)
  - Have a finalized configuration
  - Testing it to make sure it performs as expected
  - Science freeze will occur once this is confirmed
  - Starting forcing runs soon
- WACCM6 will create forcing for CESM2
  1. Run FW1850 20 years with SSTs from B1850 coupled run
  2. Run B1850 100 years with forcing
  3. Re-run FW1850 for 20 years
  4. B1850 for another 200-300 years
  5. BW1850 for 250 years (WACCM6-CMIP6 Control)

WACCM6

WACCM Working Group

WACCM6 major advancements

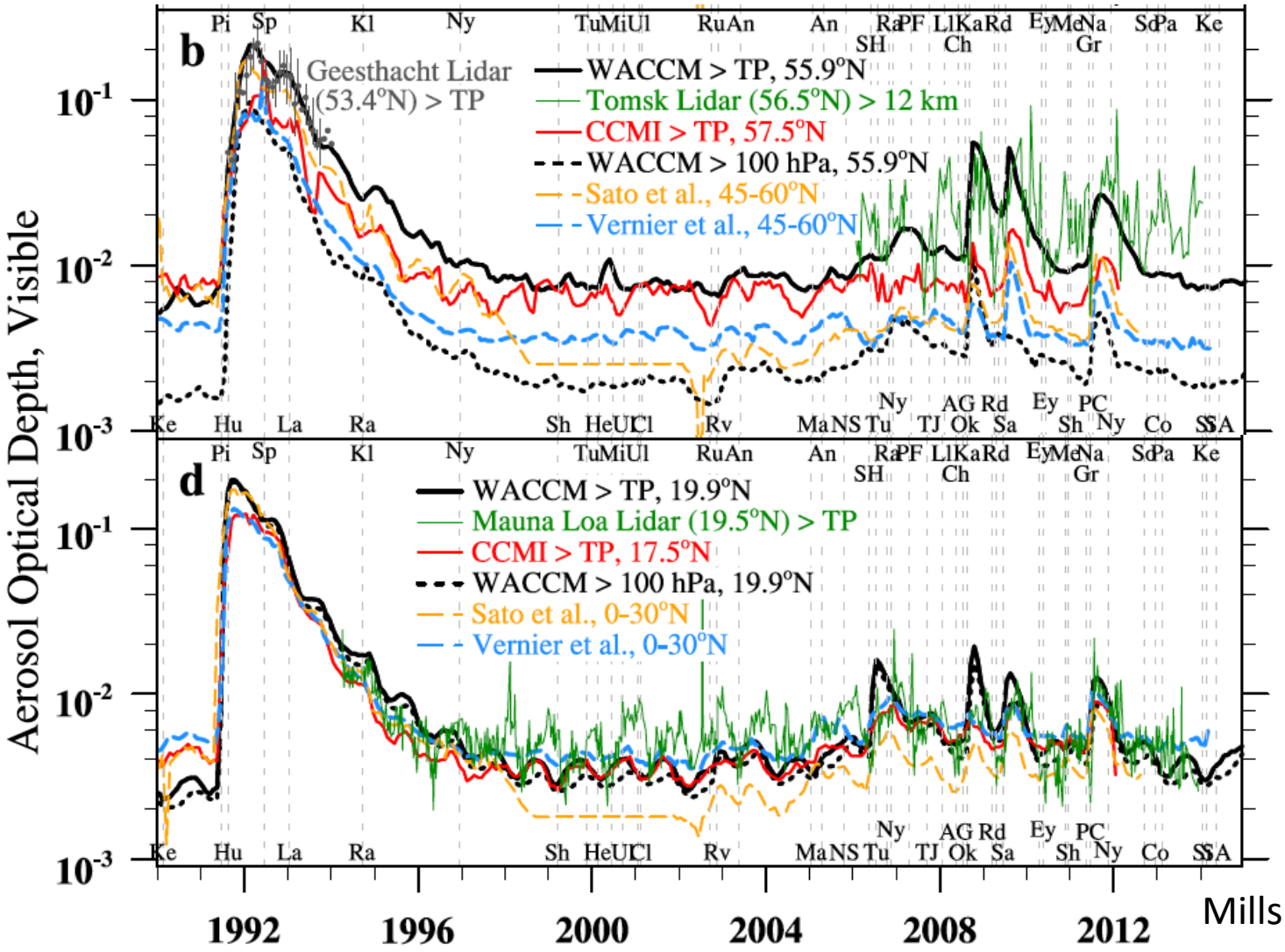
- Updated (and unified) chemistry
  - Better ozone hole evolution
  - Combined tropospheric and stratospheric chemistry
- Prognostic Stratospheric Aerosols
  - Better prediction of response to volcanic eruptions
- WACCM6 matches CAM6 physical parameterizations
  - Aerosol and Cloud adjustments made to CAM6 for WACCM6
- WACCM-X with interactive thermosphere
  - Simulations of the upper atmosphere
- Improved stratospheric variability
  - Internally generated QBO
  - SSW climatology improved

Column Physics and Chemistry

	Process	CESM1 (WACCM4) CCMI	CESM2 (WACCM6)
Column Physics	Horizontal Resolution	1.9˚x2.5˚	0.95˚x1.25˚
	Vertical Layers	26/66/88	32/70/88
	Boundary Layer	HB	CLUBB
	Shallow Convection	Hack	CLUBB
	Deep Convection	ZM	ZM
	Macrophysics	R&K	CLUBB
	Microphysics	R&K	MG 2.0
	Radiation	CAMRT	RRTMG
	Aerosols	Bulk	MAM4
	QBO	Nudged to Observations	Interactive
Chemistry	Chemical Mechanism	180 species	228 Species
	Chemical rates	JPL-11	JPL-15
	Sulfate SAD	Prescribed (CCMI)	Interactive (MAM)
	ICE SAD	Bulk Scheme	MG 2.0
	Solar Variability / ETF	Lean	Lean (updated)
	GHG abundances	Meinshausen, 2011	Meinshausen, 2016
	Halogens	WMO, 2010	Meinhassen, 2016

Prognostic Stratospheric Volcanoes

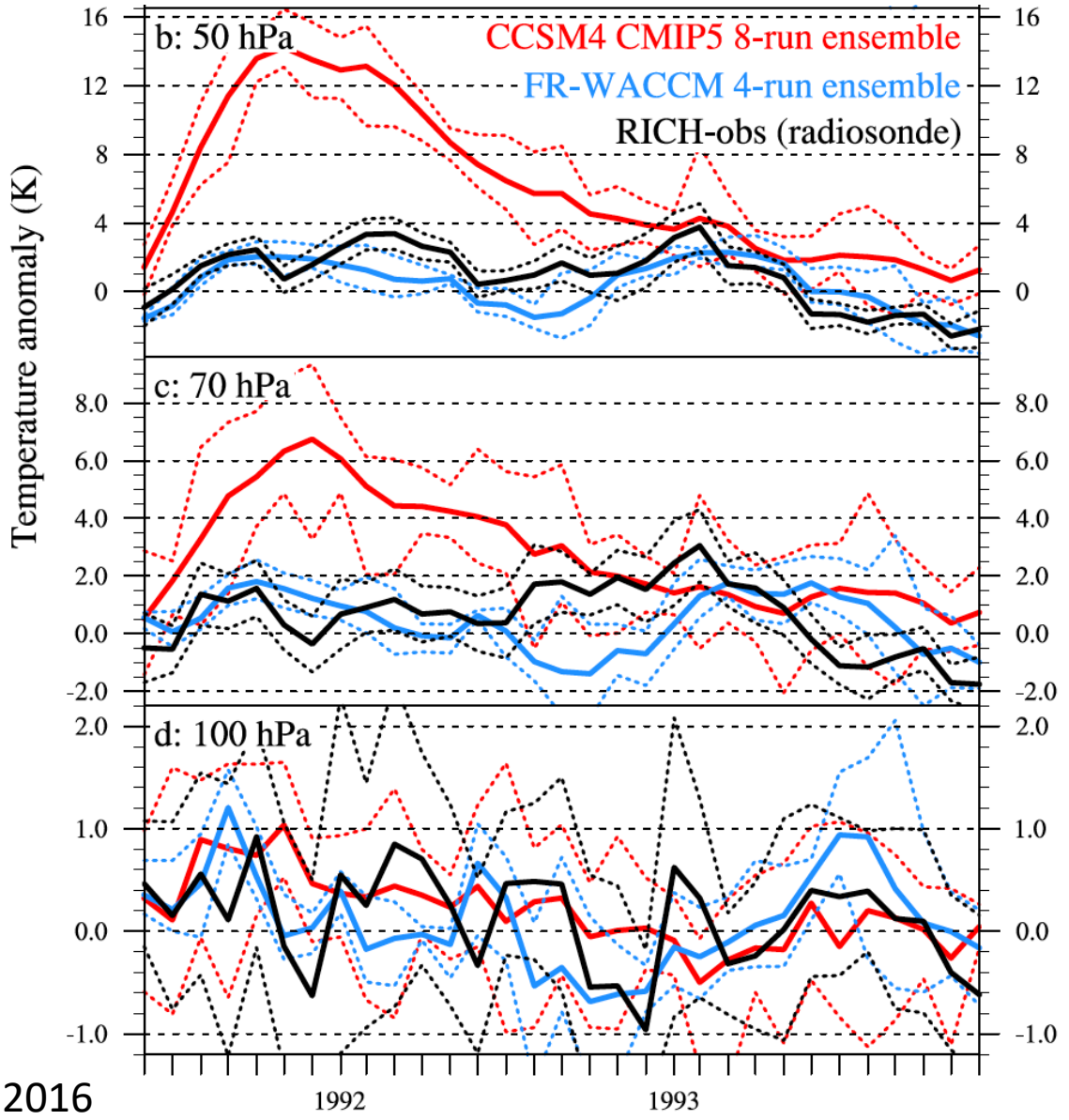
Prognostic Stratospheric Sulfur in WACCM: AOD compares well to observations



Mills et al 2016

Prognostic Stratospheric Volcanoes

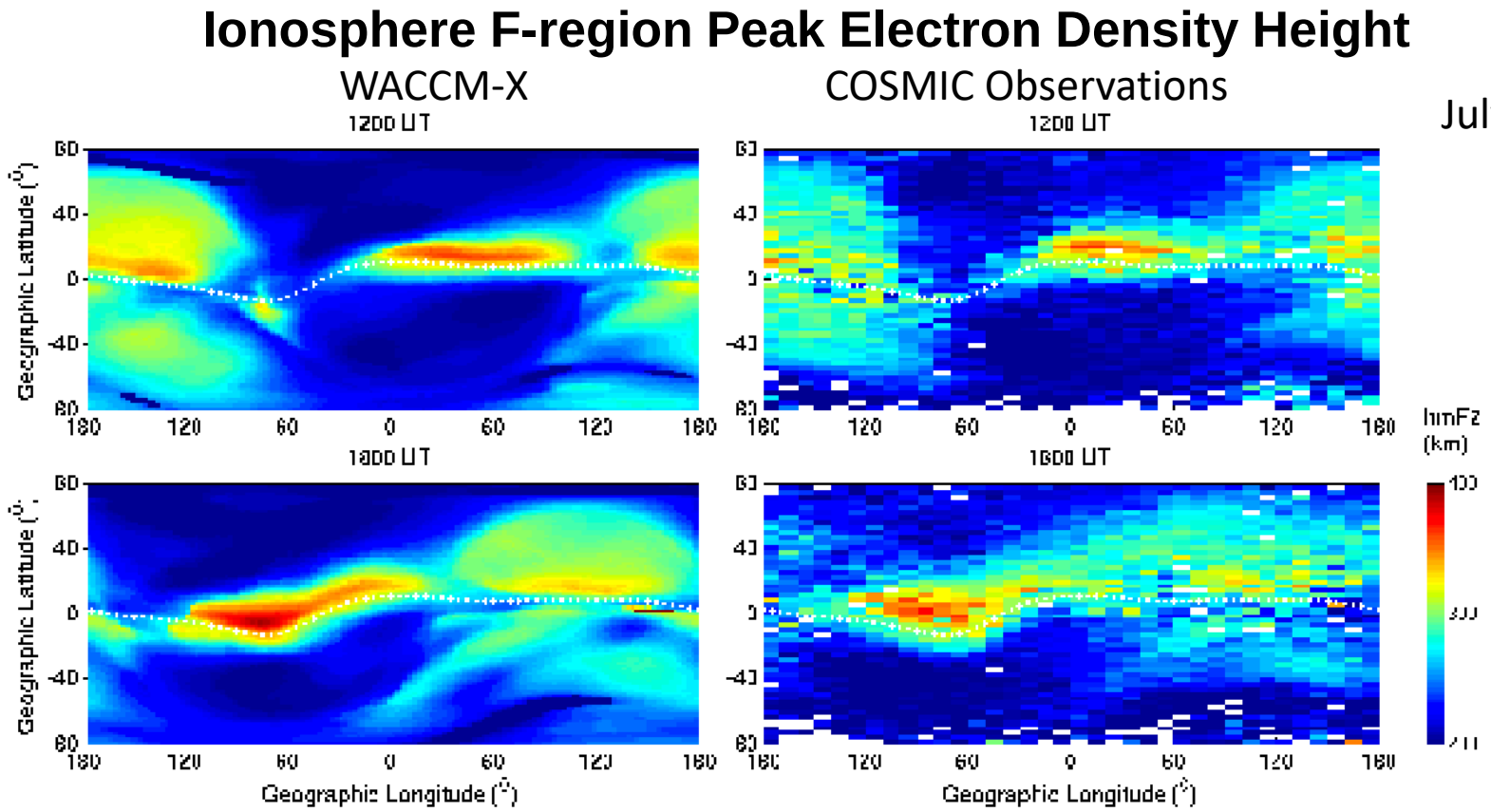
Temperature anomalies due to volcanoes are improved with Prognostic Treatment over CCSM4/CESM1



Mills et al 2016

WACCM-X in CESM2

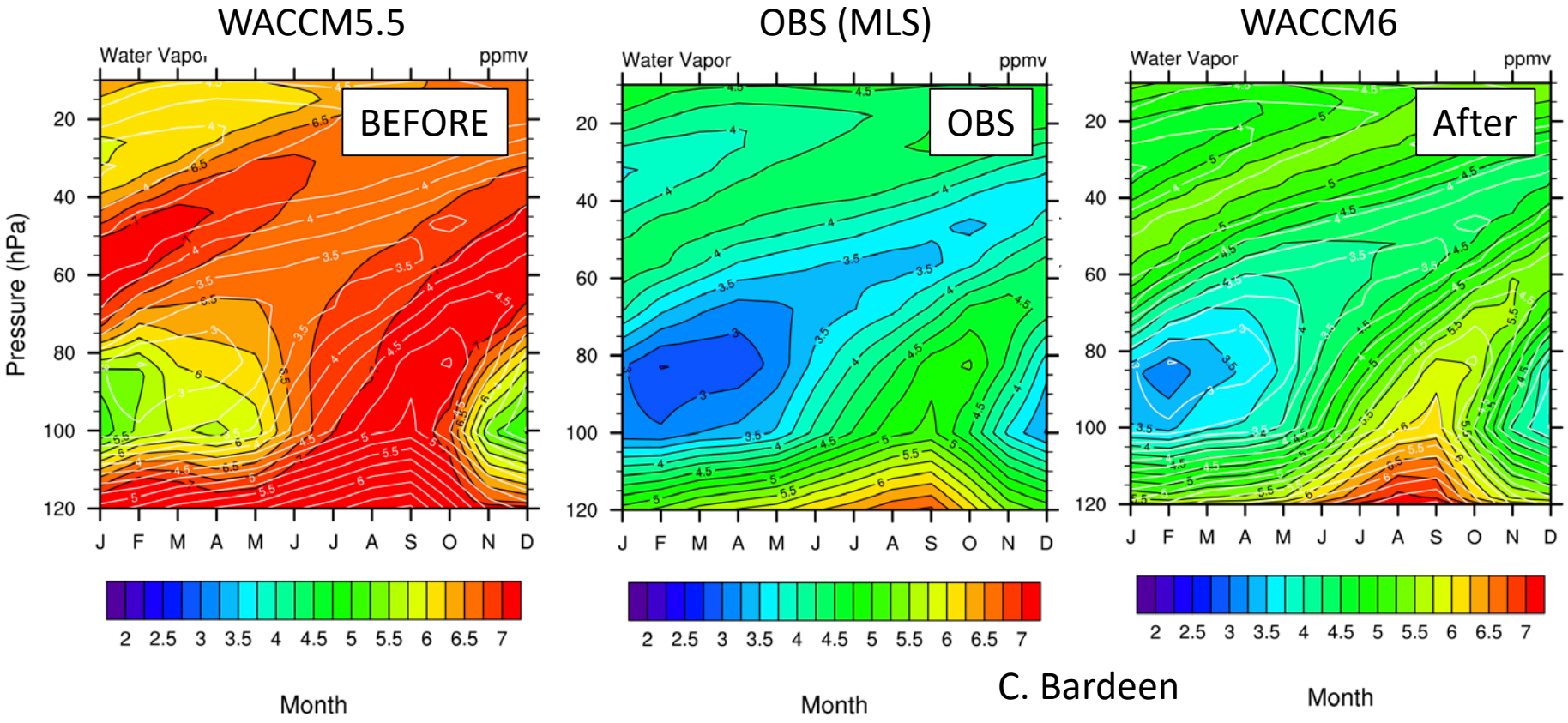
Now with an ionosphere (750km)



- WACCM-X in CESM2 interactive ionosphere
  - ionospheric electrodynamics, ion transport and ion temp
- Image ionosphere peak electron density height matches COSMIC obs
  - Measure of ionosphere electrodynamics

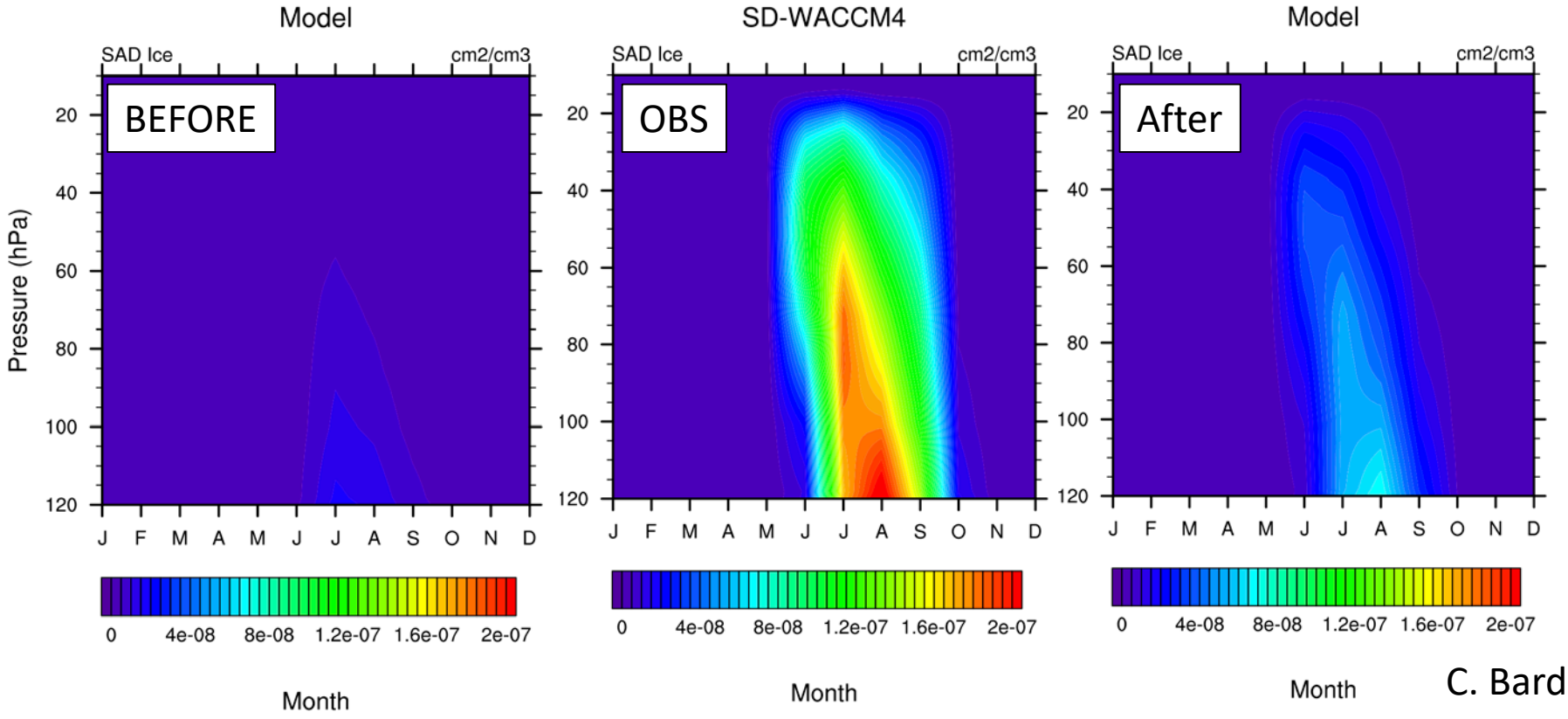
Ice Microphysics #1: Wet Stratosphere

- CAM4/WACCM4 consistent stratospheric H2O (free running or specified dyn)
- CAM5.5/WACCM5.5 too wet when using specified dyn
- Why? MG too little deydration (using gridbox average RH for growth)
- WACCM6/CAM6: Add subgrid-scale factor for RH based upon cloud fraction



Ice Microphysics #2: Polar Water & Ice

- Ice and H2O in the polar strat affect heterogeneous chemistry and O3
- WACCM5.5: too much dehydration and too little ice surface area v. WACCM4
- Changes to Ice Nucleation,Ice min size & Fall Speed
- The adjustments are also beneficial in the upper troposphere.



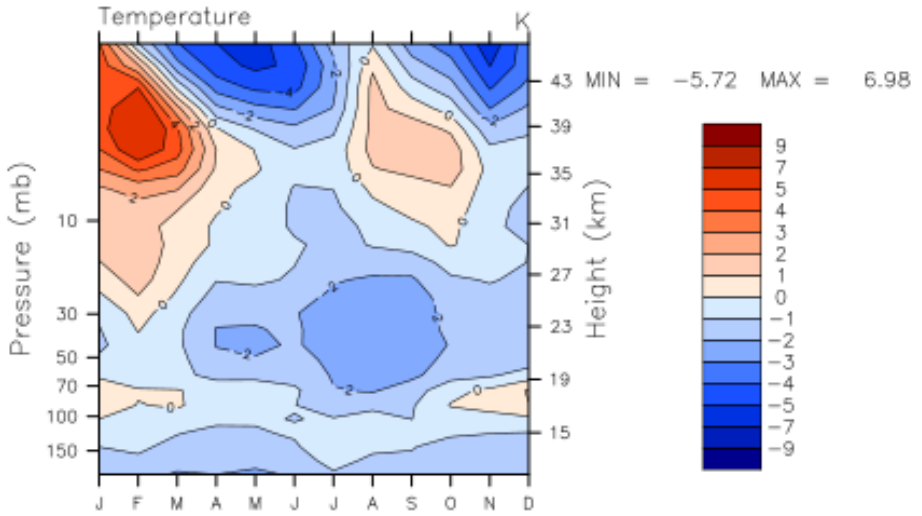
C. Bardeen

WACCM6 Climatologies

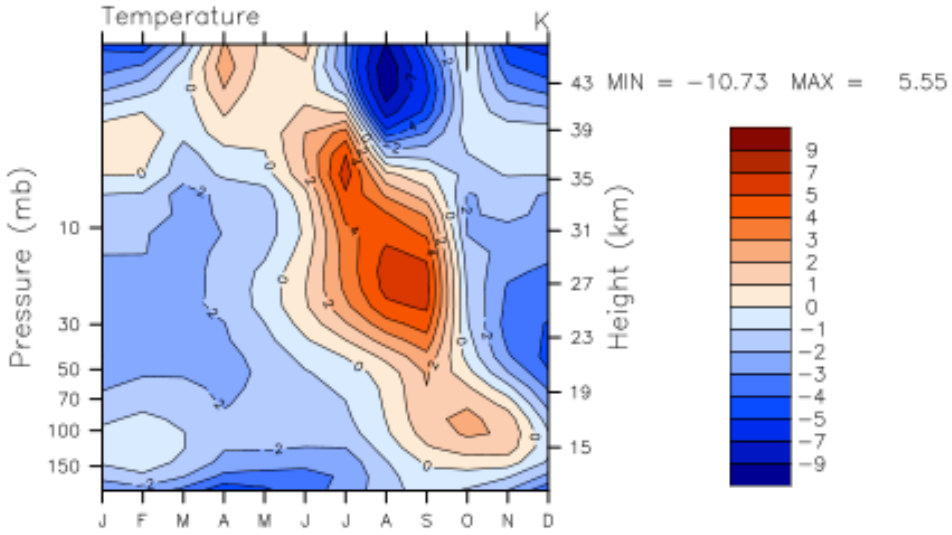
- Have WACCM6-SC simulation for 25 years
- Limited SD configuration (2011)
- Limited FR (8 years or so)

Temperature

FR-WACCM6



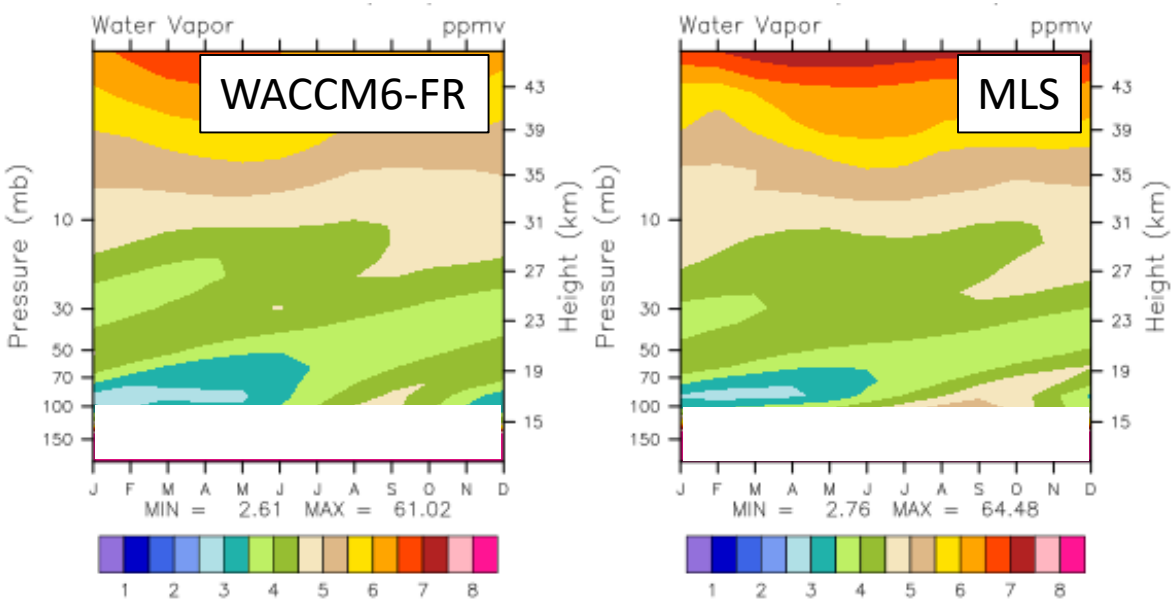
Tropics: 10˚N-10˚S
Cold point bias < 2K



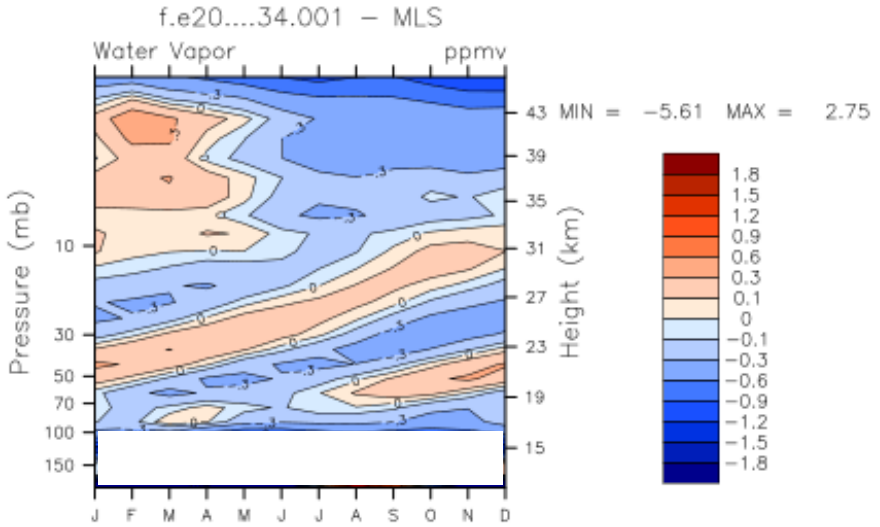
SH (60˚S-90˚S)
Bigger biases in LS
(may affect O3)

Tropical LS Water Vapor

Tape Recorder



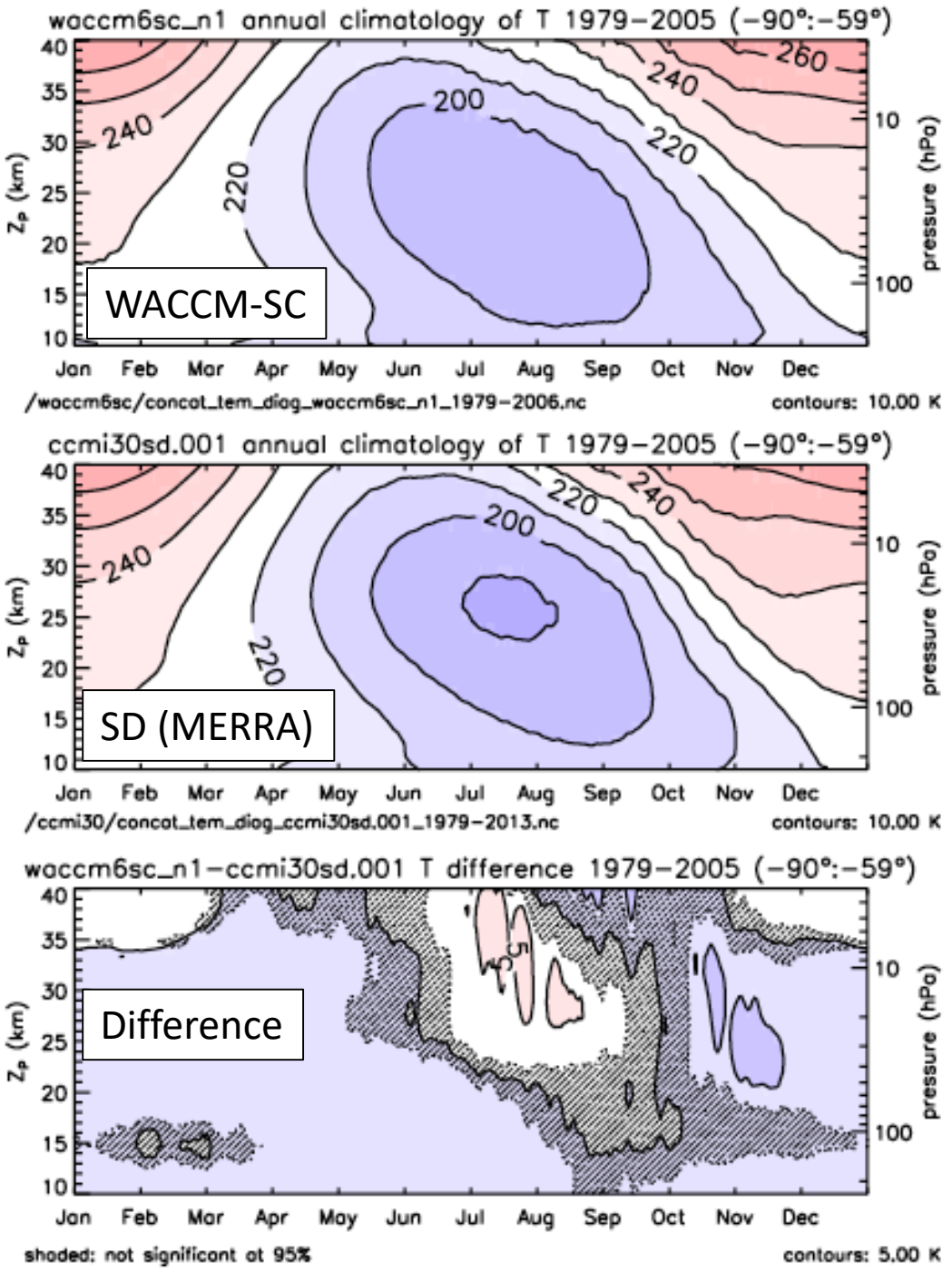
Tape recorder has only small biases



WACCM6-SC

SH 60˚S-90˚S Temperatures

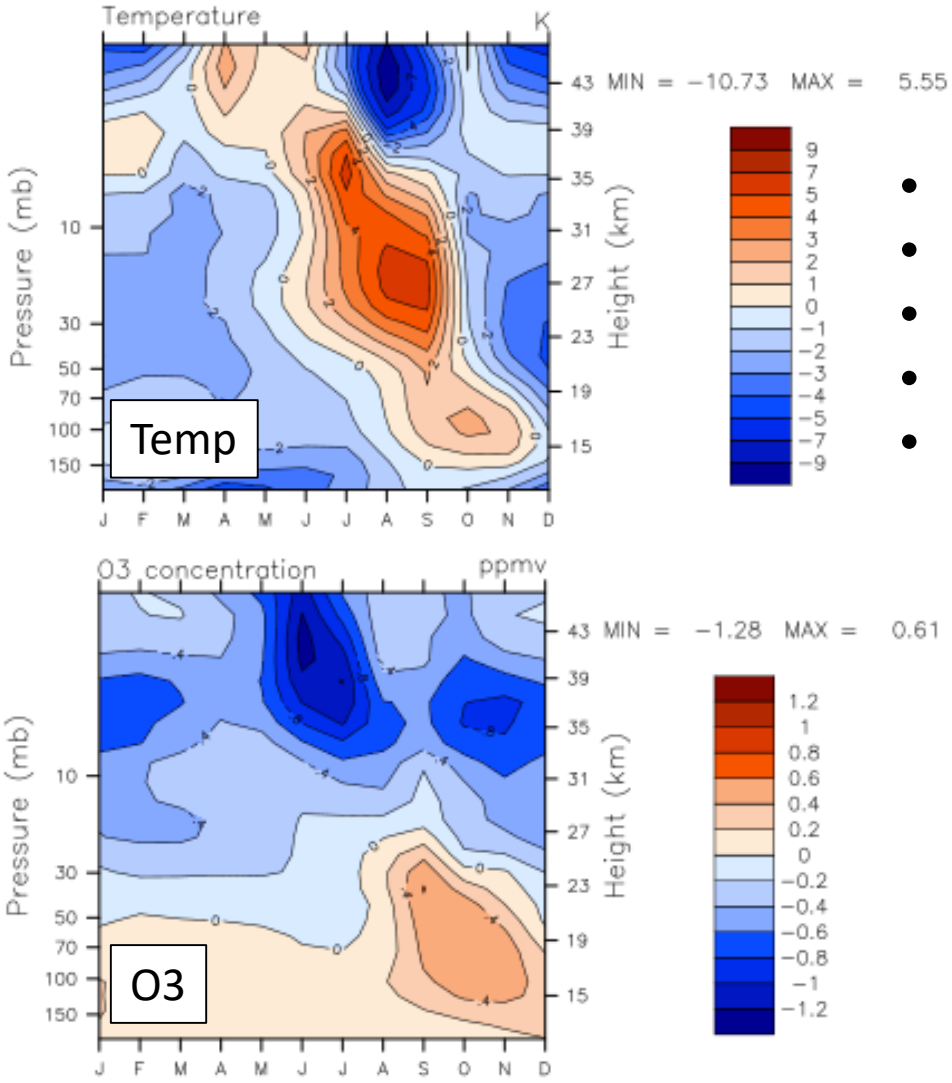
Temperatures look ‘OK’ in SH
Note: LS difference snot significant



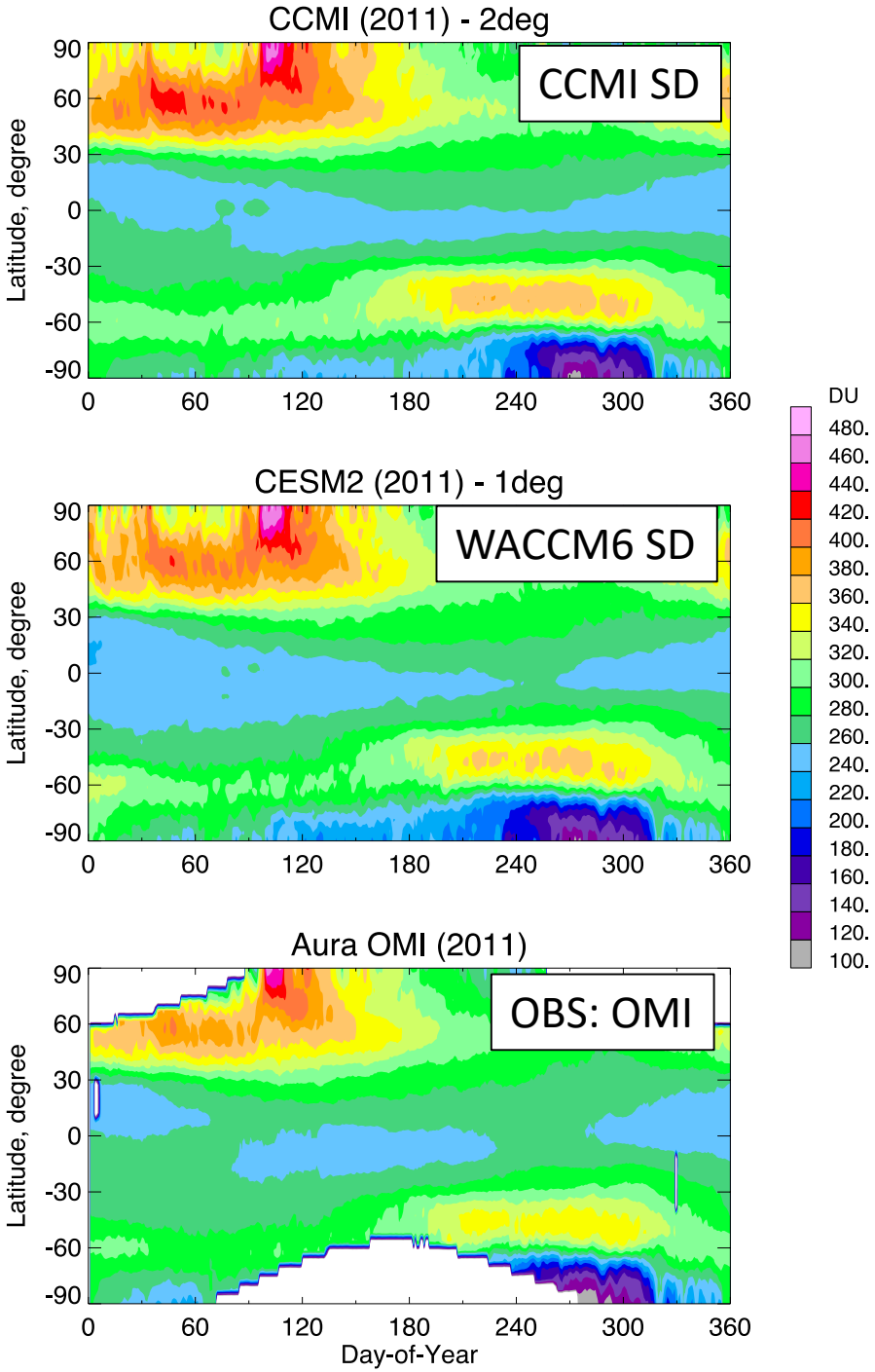
Thanks to: R. Garcia

WACCM6 O3 v. OBS

MERRA T, MLS O3 (60-90S)



- FR WACCM (a few years F2000)
- Seems to show LS temperature biases
- In the SH Polar LS
- Warmer T → Less O3 loss
- Note: T biases similar in WACCM-SC, LS not significantly different



Ozone Hole Evolution

WACCM SD 2011: Total O3

Comments:

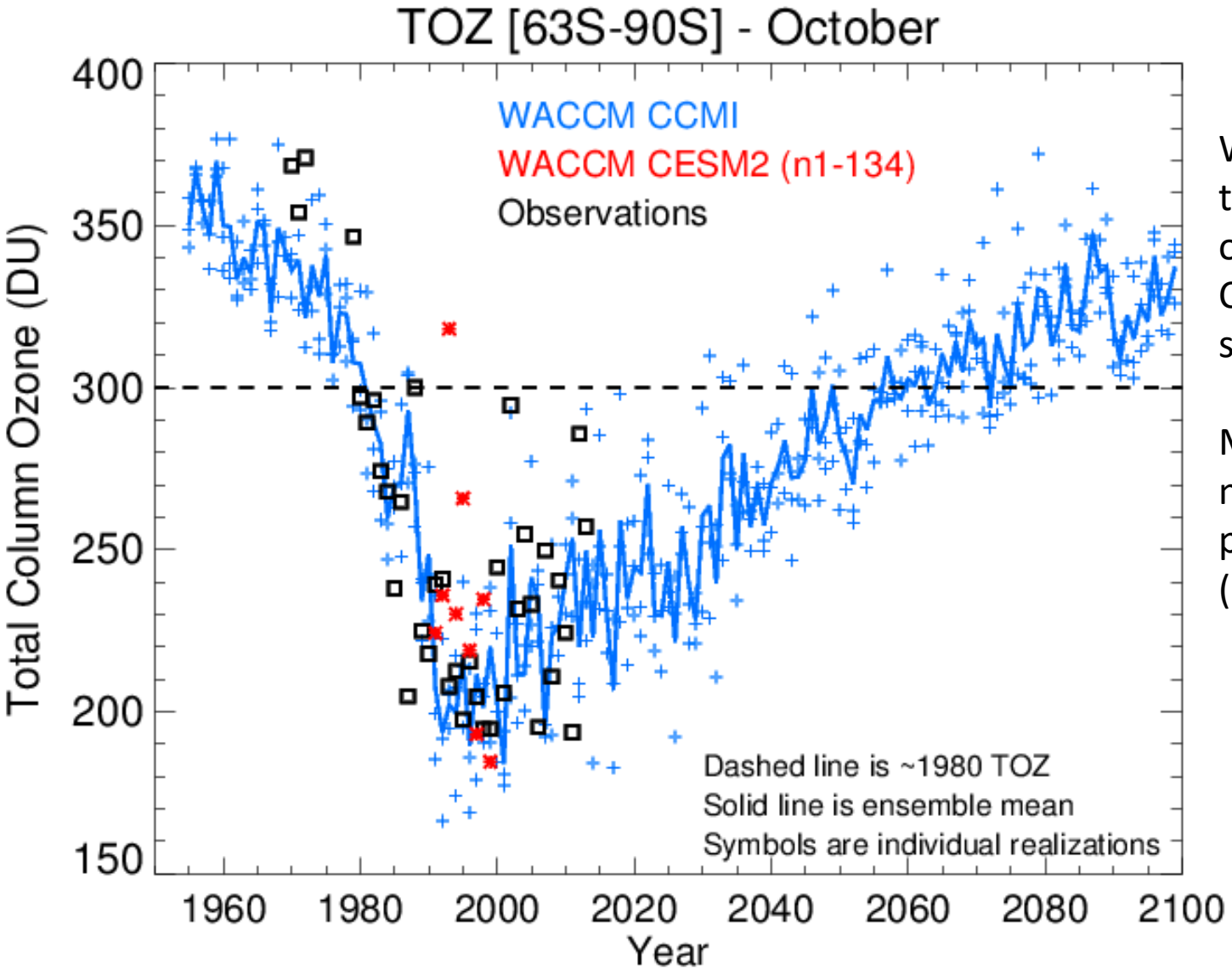
CCMi & WACCM6 compare well to TOZ observations for year 2011.

- Polar NH (60N) Spring maximum: CESM2 is more consistent with OMI.
- Polar SH (60S) Spring maximum: CESM2 is more consistent with OMI.
- Polar, SH Spring: There is more depletion near 1 Oct (day 270) in CCMI.
- Polar, SH, Winter: CESM2 has lower TOZ in May and throughout the winter.

D. Kinnison

FR WACCM6 Ozone Hole Evolution

Only have about 9 years



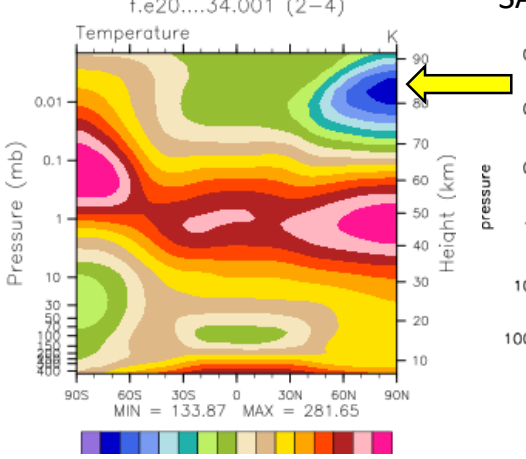
WACCM6 TOZ within the range of observations and 3 CCMI REFC2 simulations.

Multiple realizations needed to fully assess polar ozone depletion. (1950-2014)

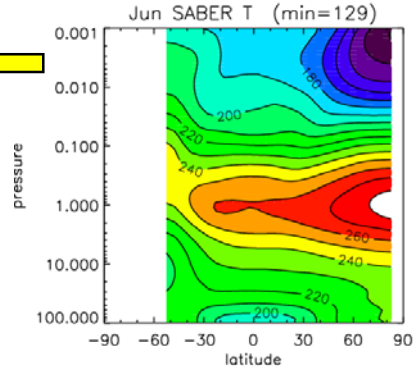
D. Kinnison

Cold Summer Mesopause

WACCM6, 3 years

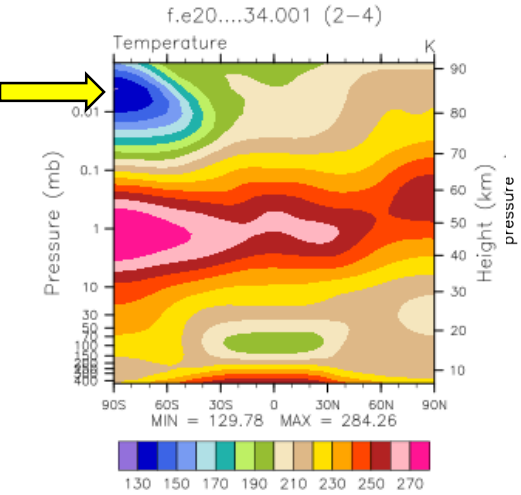


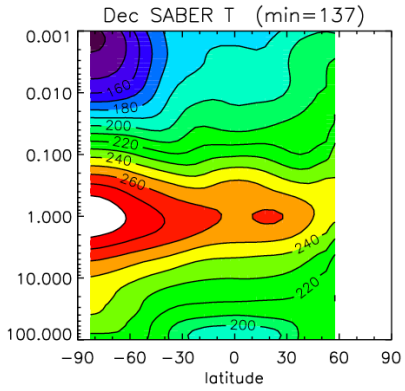
SABER observations 2002-2016



Summer mesopause

June
WACCM warmer
than SABER
(134K vs 129K)





Summer mesopause

December
WACCM cooler
than SABER
(130K vs 137K)

Other discrepancies:

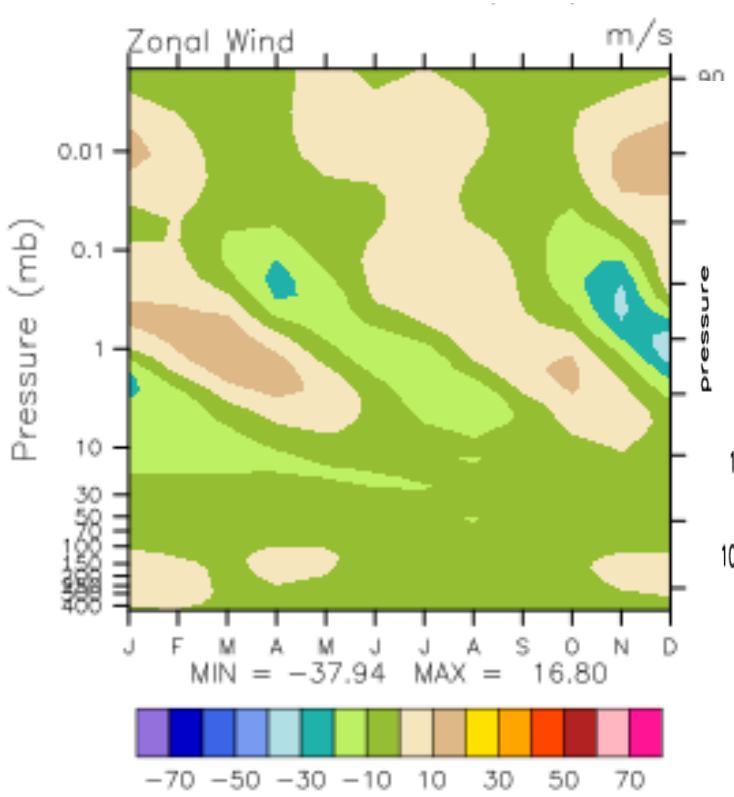
- WACCM global mesospheric T too warm
- WACCM summer stratopause too cool
- WACCM summer mesopause altitude too low (probably related to overall high mesospheric T

Thanks to: A. Smith

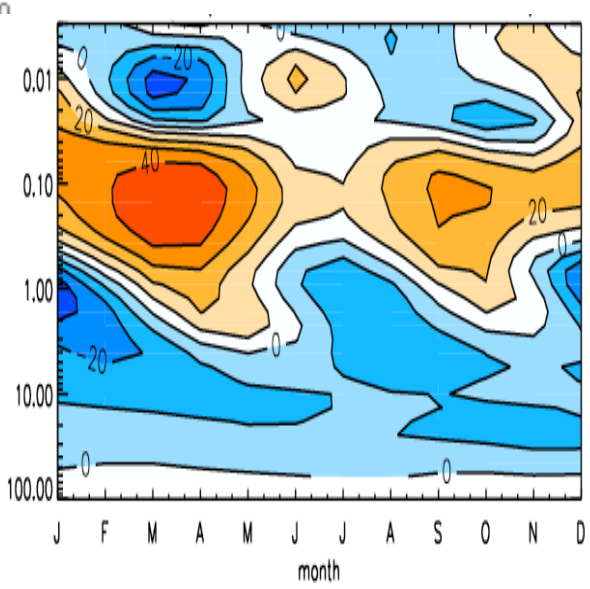
Thanks to: A. Smith

SAO in equatorial zonal wind

WACCM6 zonal wind 10°S to 10°N



SABER geostrophic zonal wind 2002-2016
8°S to 8°N

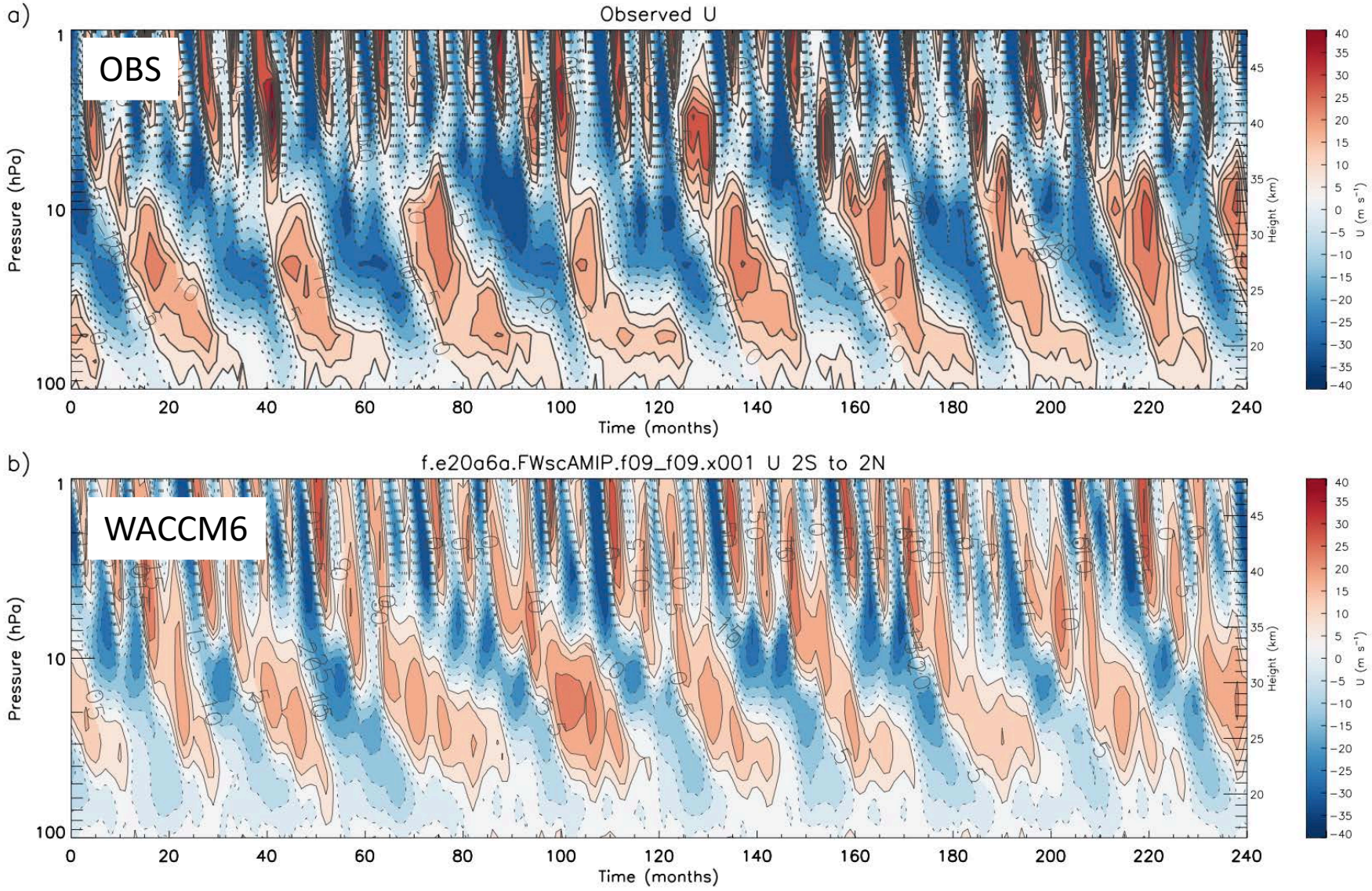


- WACCM has some semiannual variation but much weaker than the observation-based SAO and wrong vertical structure.
- This suggests a need for changes in the momentum forcing by resolved and/or parameterized waves.

WACCM6 QBO

Richter (Garcia Talk)

N1 simulation WACCM-SC run



Sudden Stratospheric Warmings

- Climatology better than WACCM4, seen some variability in frequency
- Latest estimate using a 20 day separation criteria is 18/28 years, or ~0.64/yr. Close to obs (~0.5-0.6/yr)
- Not sure of final results.
- Counts very sensitive to March it seems

WACCM6 Configurations

- ‘Full’ WACCM (WACCM6) 1˚
  - 70L, full chemistry, 140km lid
  - FW2000, FWHIST, BWHIST, BW1850
- WACCM6-SC 1˚
  - 70L, fixed ozone and oxidants, 140km lid
  - FWHISTSC
- WACCM-X 2.0 (2˚)
  - 126L, 750km lid, WACCM4 physics
  - Ionospheric Physics, Transport
  - FWX Comp Set
- Other options (not full scientific support):
  - High vertical resolution: L110 Initial condition
  - Reduced Chemistry: Middle atmosphere mechanism exists
  - Will also have 2˚ versions

Future WACCM Plans

Gettelman, Mills, Polvani

& The WACCM ‘Team’

Discussion Outline

- WACCM6 Configurations Review
- WACCM6 for CMIP6 (MIPs…)
- Beyond WACCM6/CESM2: emerging science

WACCM6 Configurations

What are we missing?

- ‘Full’ WACCM (WACCM6) 1˚
  - 70L, full chemistry, 140km lid
  - FW2000, FWHIST, BWHIST, BW1850
- WACCM6-SC 1˚
  - 70L, fixed ozone and oxidants, 140km lid
  - FWHISTSC
- WACCM-X 2.0 (2˚)
  - 126L, 750km lid, WACCM4 physics
  - Ionospheric Physics, Transport
  - FWX Comp Set
- Other options (not full scientific support):
  - High vertical resolution: L110 Initial condition
  - Reduced Chemistry: Middle atmosphere mechanism exists
  - Will also have 2˚ versions

WACCM For CMIP6

'DECK' Experiments

- WACCM6 will create forcing for CESM2
  1. Run FW1850 20 years with SSTs from B1850 coupled run
  2. Run B1850 100 years with forcing
  3. Re-run FW1850 for 20 years
  4. B1850 for another 200-300 years
  5. BW1850 for 250 years (WACCM6-CMIP6 Control)
- WACCM6 Deck
  - BW1850 (#5 above)
  - 1%/yr, 4xCO2, AMIP (1979-2014), 20th Century (x3)
- ScenarioMIP: SSP5-8.5, SSP3-7, SSP2-4.5, SSP1-2.6

WACCM6: MIP, MIP, MIP

- QBOi (Richter)
- Solar Variability (Marsh)
- Dyn Var (Marsh, Simpson)
- VolMIP (Mills)
- ISA-MIP (interactive stratospheric aerosols: Mills)
- AerChemMIP (Lamarque/Emmons)
- GeoMIP (Tilmes)

Beyond WACCM6/CESM2

- WACCM-X → WACCM6X (merge up to WACCM6)
- Global Electric Circuit
- High vertical resolution (SAO)
- Heterogeneous Chemistry Updates
- FAST-J or TUV
- Other emerging science issues?