The Whole Atmosphere Community Climate Model Version 6 (WACCM6!)

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Common Name	WACCM4	WACCM-CCMI	WACCM6
Horizontal Resolution	1.9°x2.5°	1.9°x2.5°	0.95°x1.25°
Vertical Levels	66	66	70
Deep Convection	ZM	ZM	ZM*
Boundary Layer	HB	HB	CLUBB
Shallow Convection	Hack	Hack	CLUBB
Macrophysics	RK	RK	CLUBB
Microphysics	RK	RK	MG2
Radiation	CAMRT	CAMRT	RRTMG
Aerosols	Bulk	Bulk	MAM4
QBO	Nudged	Nudged	Interactive
Chemical Mechanism	MA(59)	TSMLT (180)	TSMLT1 (228)
Chemical Rates	JPL-06	JPL-11	JPL-15
Sulfate SAD	CCMVal2	CCMI	Interactive
Ice SAD	Bulk	Bulk	MG2
Solar Variability	CMIP5-Solar	CCMVal2-Solar	CMIP6-Solar
GHG Abundances	CMIP5 RCPs	CMIP5 RCPs	CMIP6 SSPs
Halogens	CMIP5 RCPs	WMO 2010	CMIP6 SSPs

WACCM6: Headlines

- Same physical parameterizations/tuning as CAM6 + additional GW parameterizations
- Prognostic Stratospheric Aerosols
- Optional D-region ('MAD') Chemistry
- WACCM-X2.1 included (still WACCM4 physics)
- Features: O_3 Hole, Interactive QBO, Good variability from tape recorder to SSWs

WACCM-X 2.1

Extend CESM to the Thermosphere (500km)

- Reduced thermosphere GW eddy diffusion (Hanli Liu Talk Thursday)
  - More atomic Oxygen = better neutral composition & ion density
- Weimer ‘05 high-latitude potential option
- Steady-state electron temperature solver option
- Full D-region ion chemistry option
- Assimilative Mapping of Ionospheric Electrodynamics (AMIE) Capability
- DART Data assimilation capability (Nick Pedatella talk Thursday (AM)
- Next step is to move to CAM 6 physics & 1° horizontal resolution

WACCM6 Configurations/Simulations

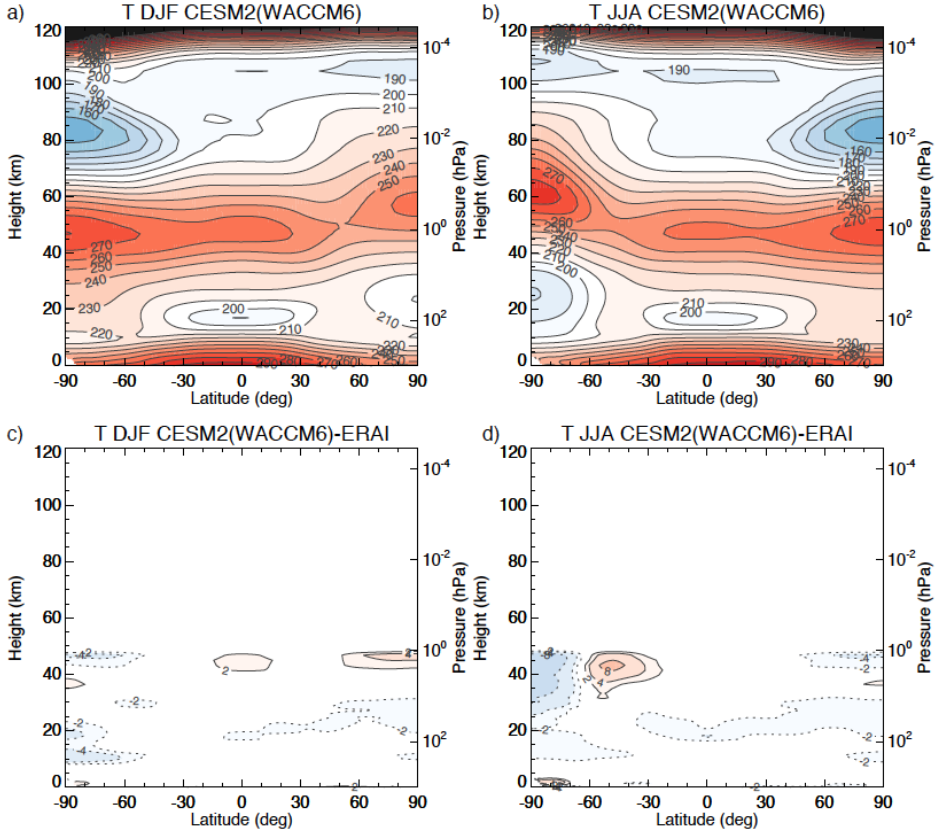
- Historical Fixed SST (AMIP): 3 ensembles FWHIST
- Coupled
  - 1850 Control (500 yrs): B1850
  - 1850-2014, 3 ensembles: BWHIST
- Specified Dynamics: 1980-2014 nearly complete (FWSD)
- Specified Chemistry: Exists, have not run it yet (FWSC)
- Above all 1˚ resolution. 70L: 2˚ resolution being developed.
- L110 version will also be developed
- WACCM-X2.0

Component Set	FWHIST	FWSD	BW1850	BWHIST	FWD	FWX
CAM Component Set	FHIST	FWSD	B1850	BHIST	N/A	N/A
WACCM Ensembles	3	1	1	3	1	1
# Years or Dates	1950-2014	2005-2017	500	1850-2014		
Coupled Ocean/Ice	No	No	Yes	Yes	No	No
Specified Dynamics	No	Yes	No	No	No	No
Chemistry	TSMLT1	TSMLT1	TSMLT1	TSMLT1	TSMAD	TSMLT
Cost (CPU hrs/sim yr)						

Results

- Climo/Ann Cycle
- Variability
- Trends
- Low v. High Top & Chemistry

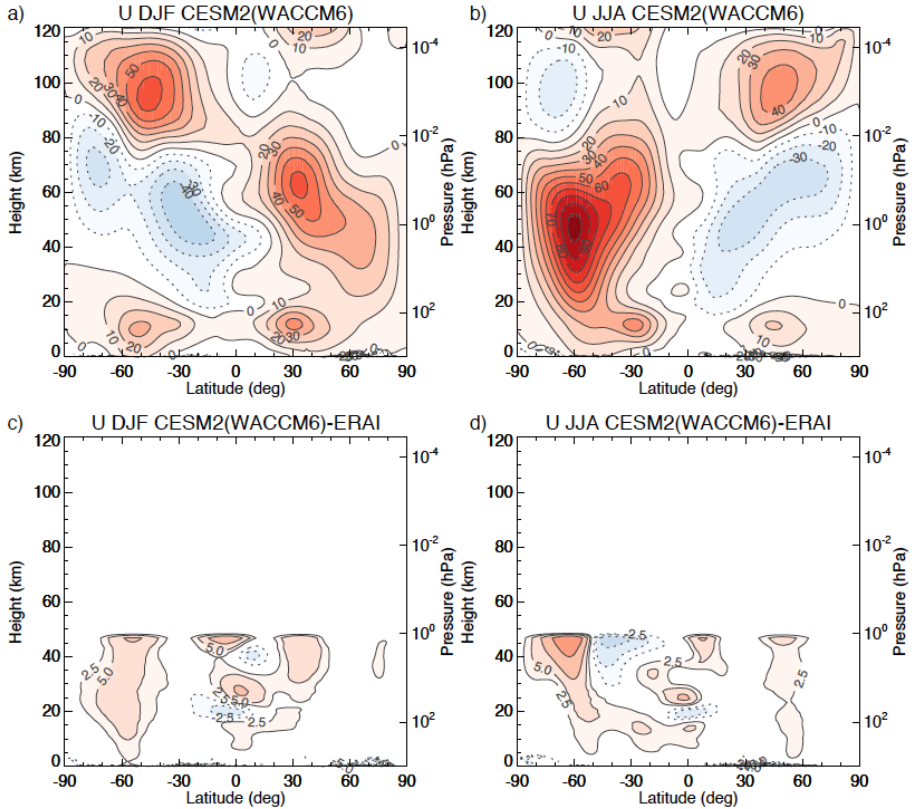
Climo: WACCM6 v. T



1985 - 2013 Averages

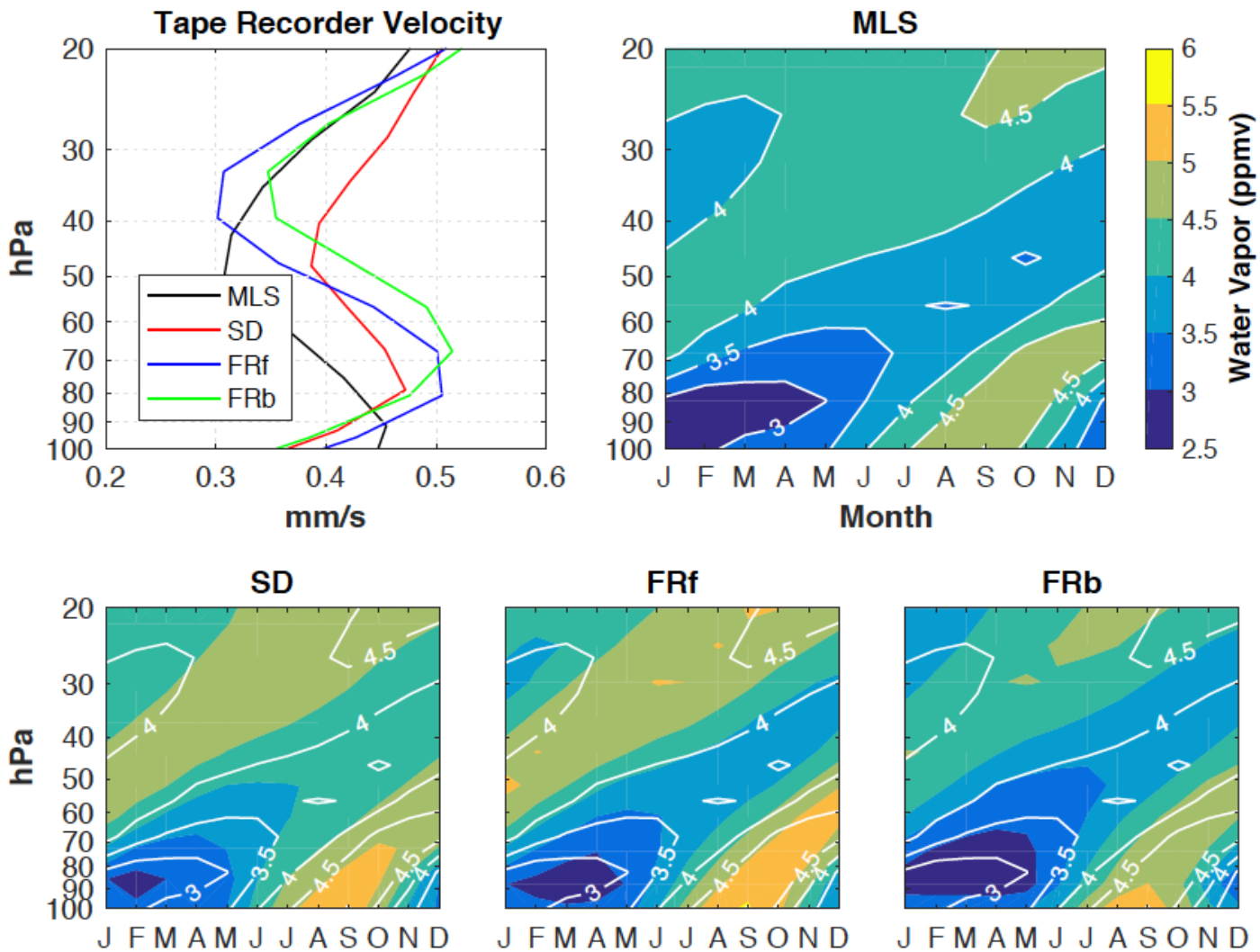
Credit: Richter

Climo: WACCM6 v. U



1985 - 2013 Averages

Credit: Richter



Credit: Glanville

Variability/Trends

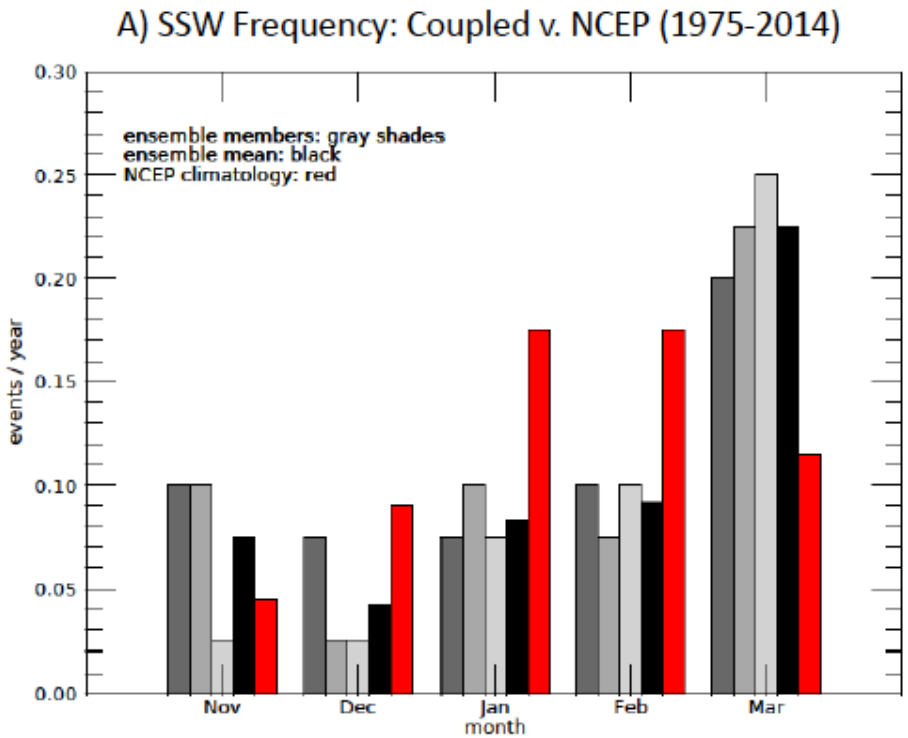
Variability:

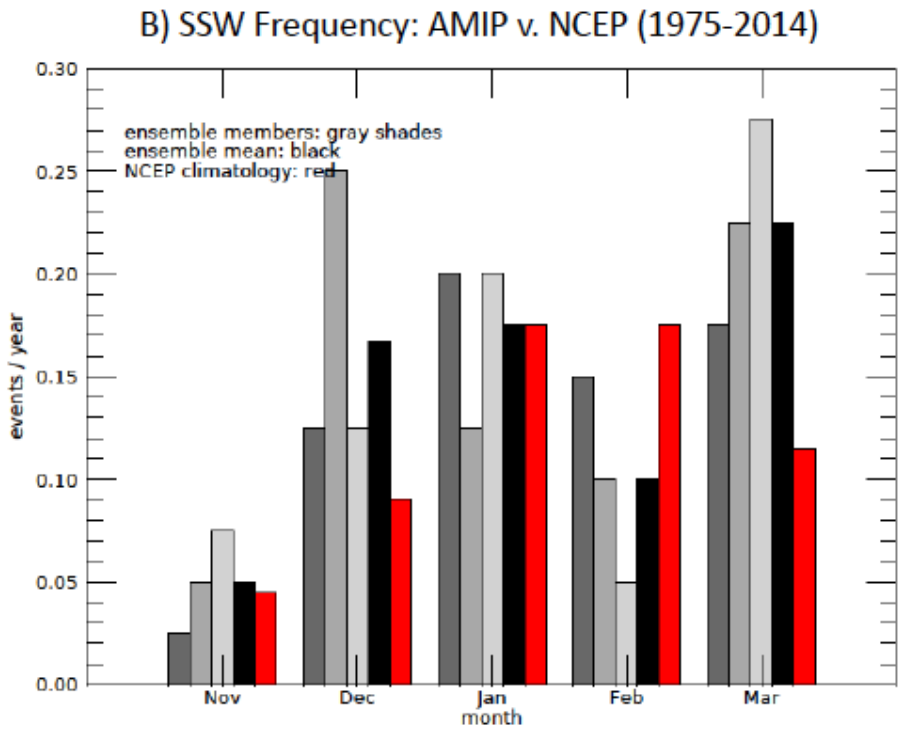
- SSWs from PI control
- QBO: WACCM-FR
- Volcanoes

Trends

- O_3 hole
- 20^{th} Century Temp

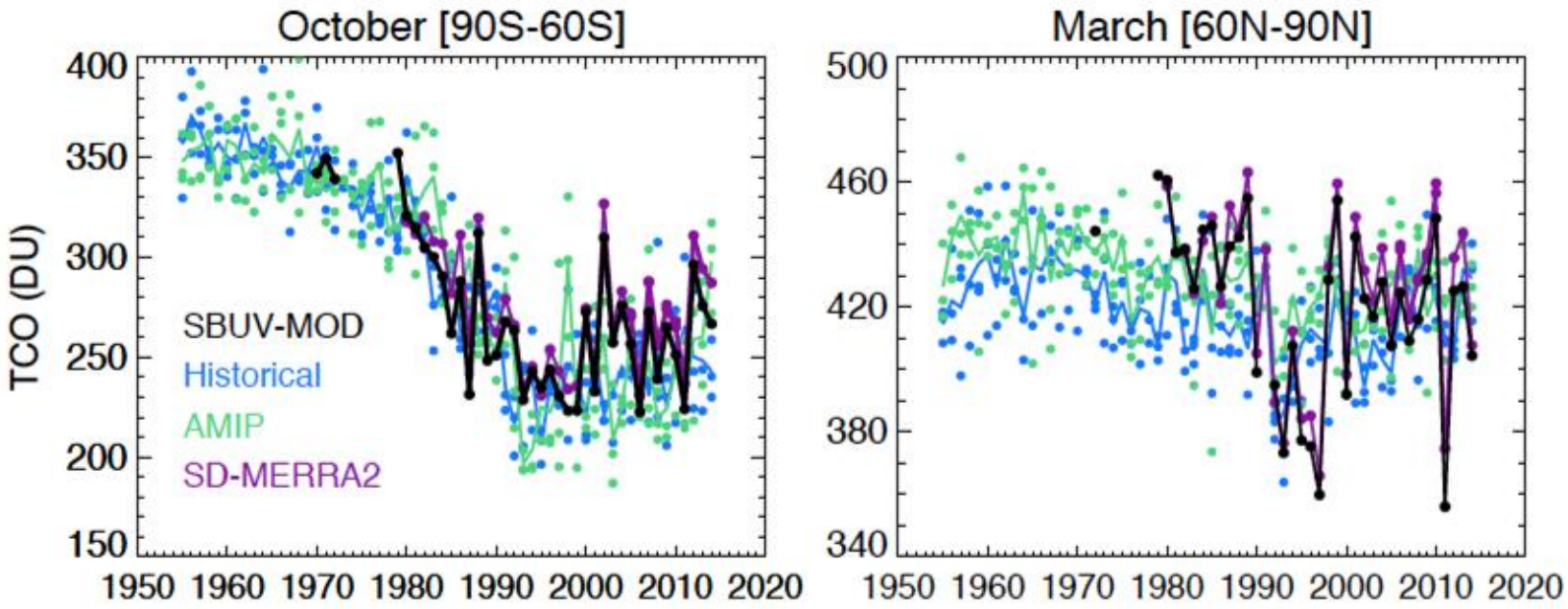
SSW Frequency





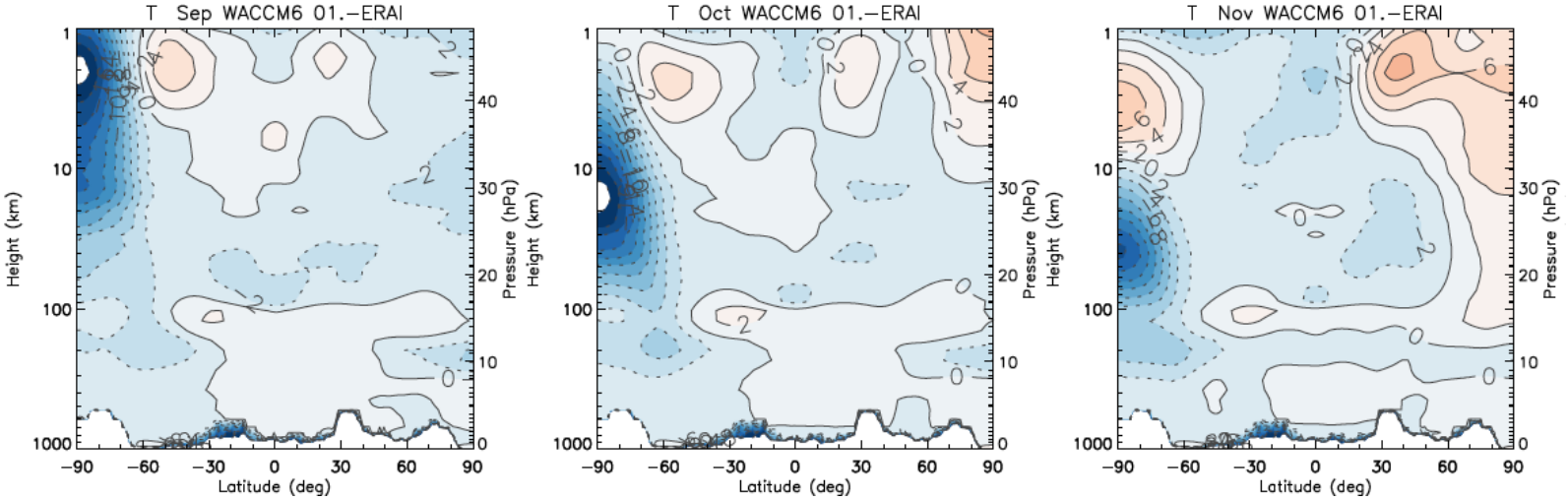
Credit: Garcia

Polar O_3 Evolution



Credit: Kinnison

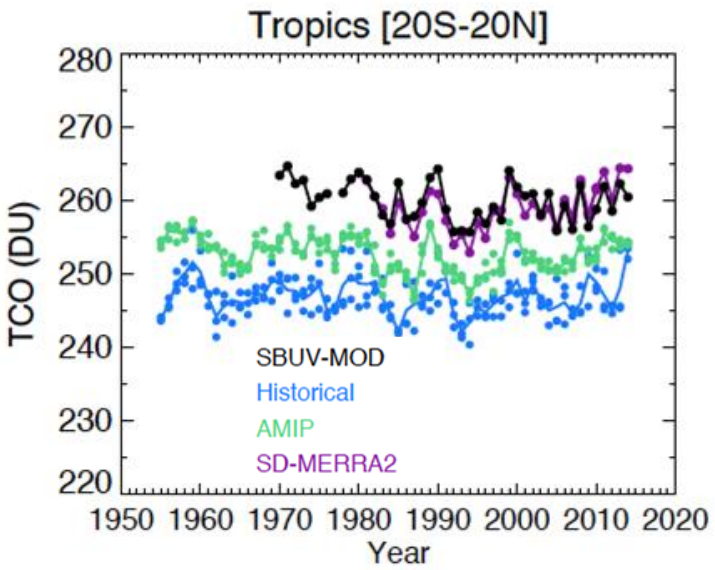
T biases and Polar O_3

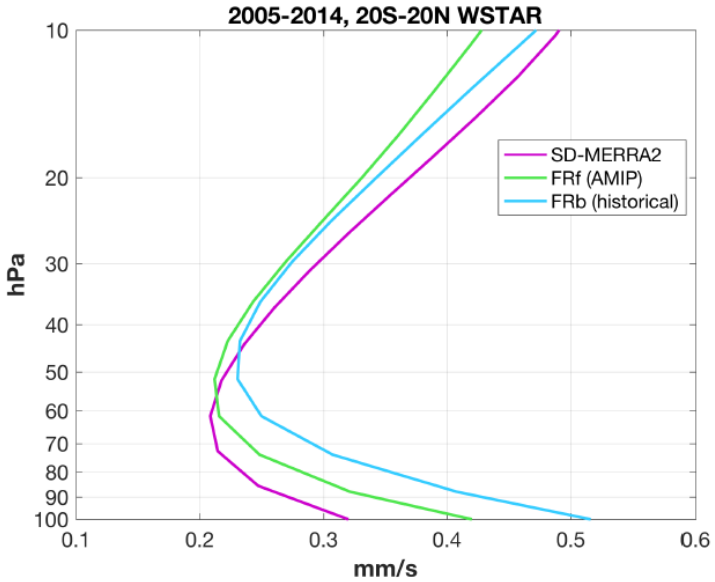


1985 - 2013 Averages

The main region of O3 depletion in the model will happen between 100-30hPa. In the LS there does seem to be a -2K bias in September poleward of ~80˚S. But may be 'lucky' in that bias does not affect major area of O_3 depletion in space/time

Tropical O_3 Evolution





Faster upwelling 100-50hPa leads to less tropical O_3

Credit: Kinnison, Glanville

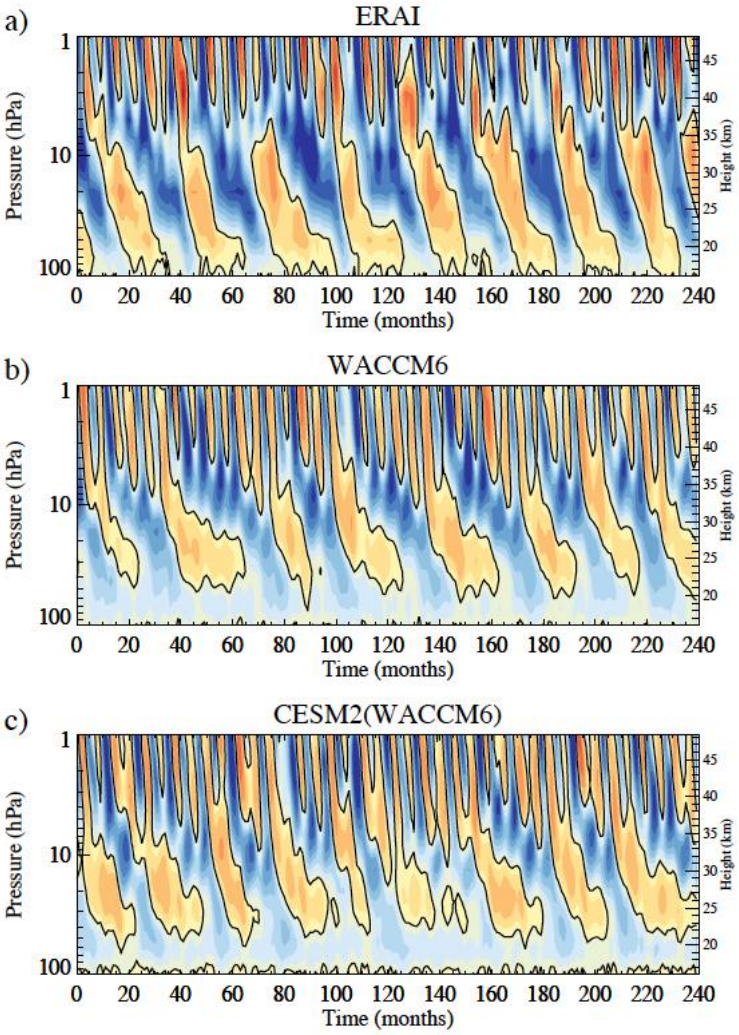
QBO

Averaged over 1979 - 2014, the QBO periods are:
ERAI: 28.3 months
AMIP: 28.9 months (3 ens avg)
Coupled: 27.0 months (3 ens avg)

OBS
28.3 mo

FWHIST
(AMIP)
28.9 mo

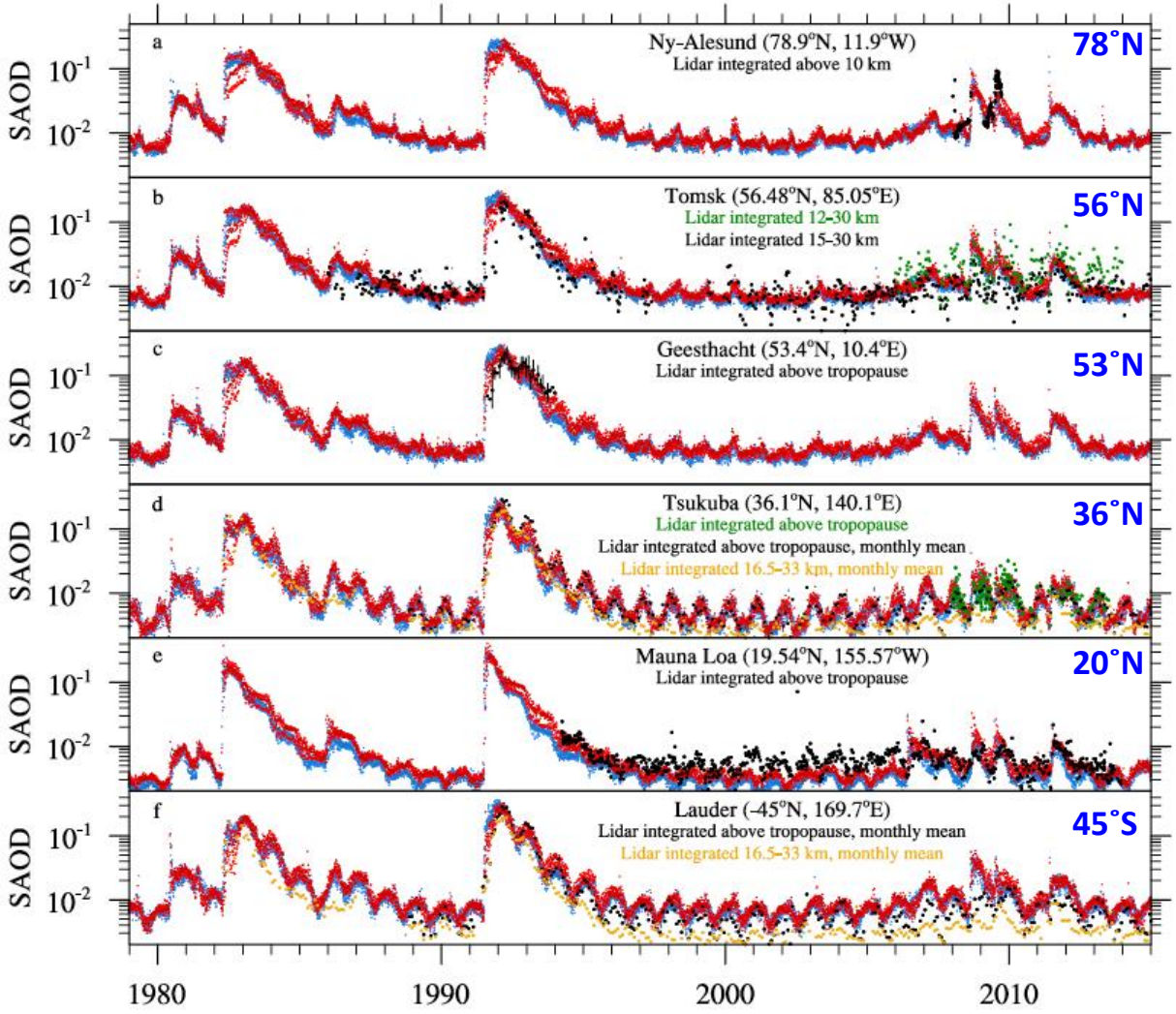
BWHIST
(Coupled)
27.0 mo



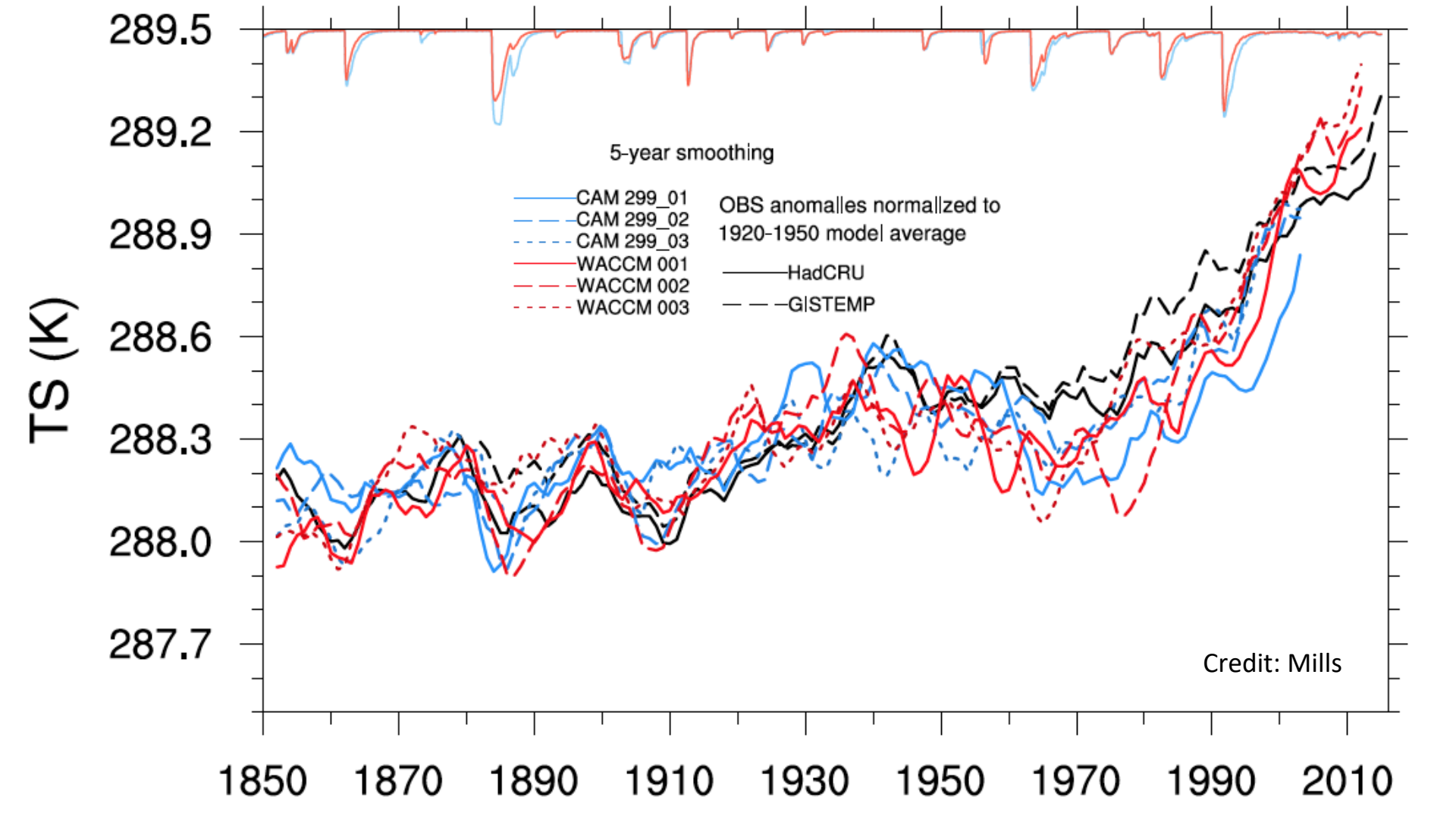
Credit: Richter

Volcanic Aerosols

Now including the Southern Hemisphere!



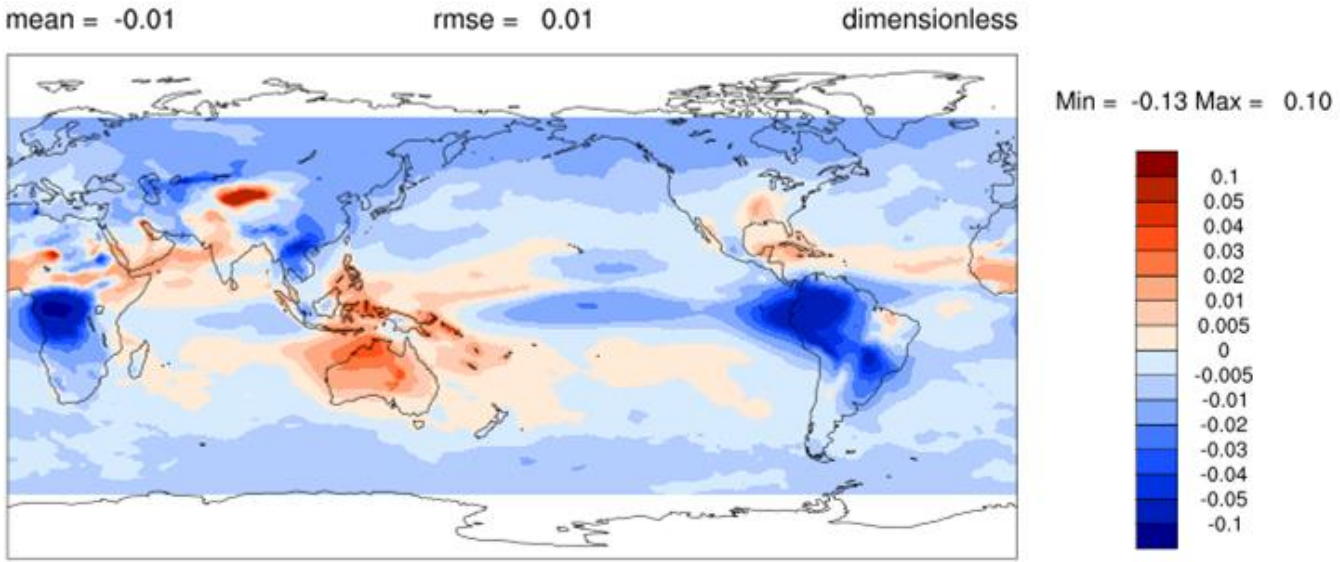
Credit: Mills


289.5
289.2
288.9
288.6
288.3
288.0
287.7
TS (K)
5-year smoothing
CAM 299_01
CAM 299_02
CAM 299_03
WACCM 001
WACCM 002
WACCM 003
OBS anomalies normalized to
1920-1950 model average
HadCRU
GISTEMP
Credit: Mills
1850
1870
1890
1910
1930
1950
1970
1990
2010

CAM6 v. WACCM6

CAM6 & WACCM6 have same tuning & very similar climate.

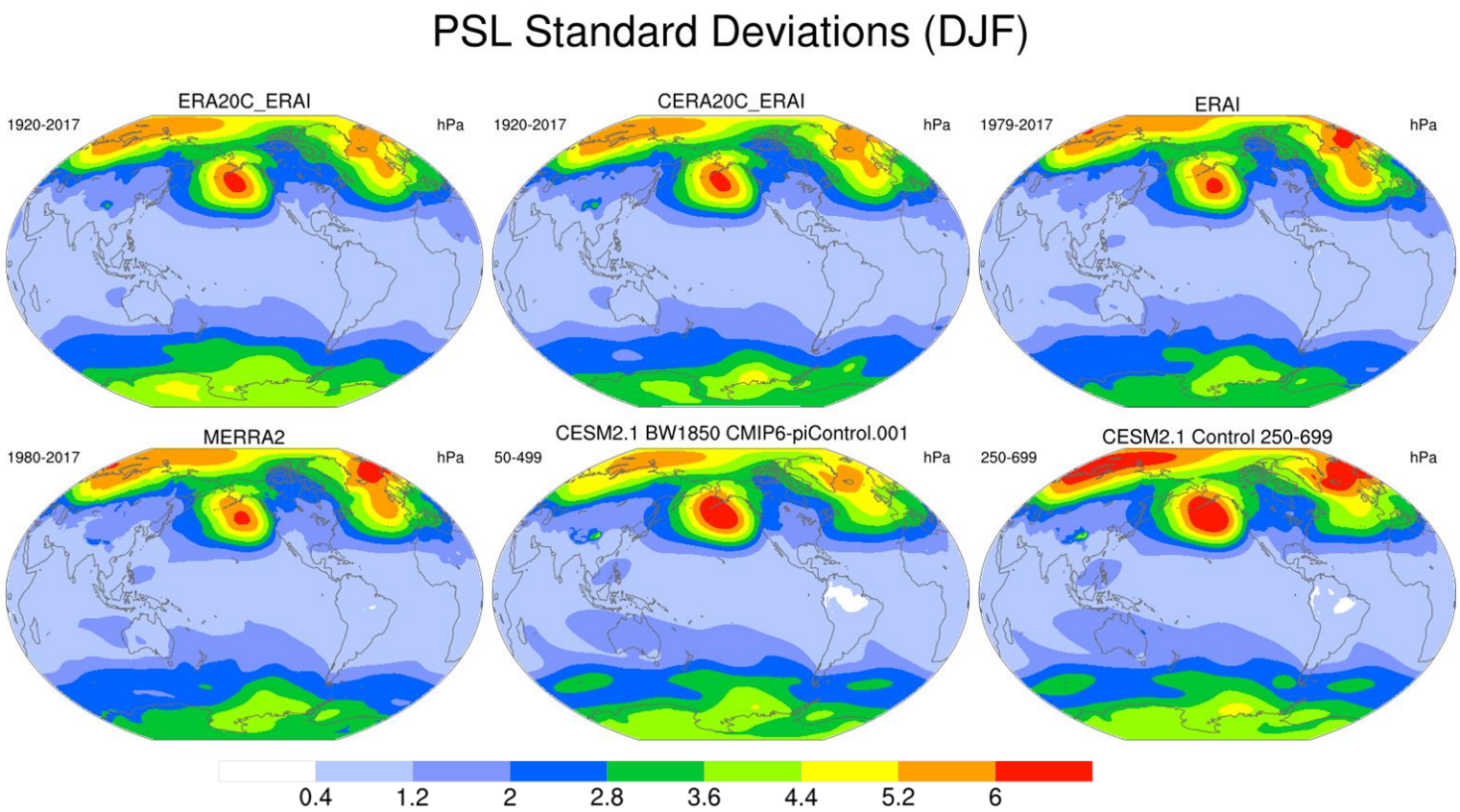
WACCM6 coupled slightly different TOA balance point (1Wm-2) due to clearsky & clouds compensating



1. WACCM 'TOA' Clearsky differs from CAM by 2Wm-2 (upper atmosphere processes)
2. WACCM has lower AOD (tropospheric chemical processing & different aerosol scheme): impacts Cloud Radiative effects (~1Wm-2 less for +LW and -SW)
3. Better high latitude surface pressure variability (and perhaps mean too) in WACCM

WACCM v. CAM Variability

WACCM Has better High Latitude winter variability down to the surface than CAM



WACCM6!

- QBO & SSWs good
- Reduced Wind and Temp biases
- Improvements in O3 hole better T and Chem
- Prognostic Volcanoes (Geoengineering)
- Interactive Secondary Organic Aerosols (land coupling)
- Same code as low top model
- Full chemistry (Unified strat/trop)
- Trop Chemistry creates some cloud differences
- Stratosphere may improve variability (stay tuned)