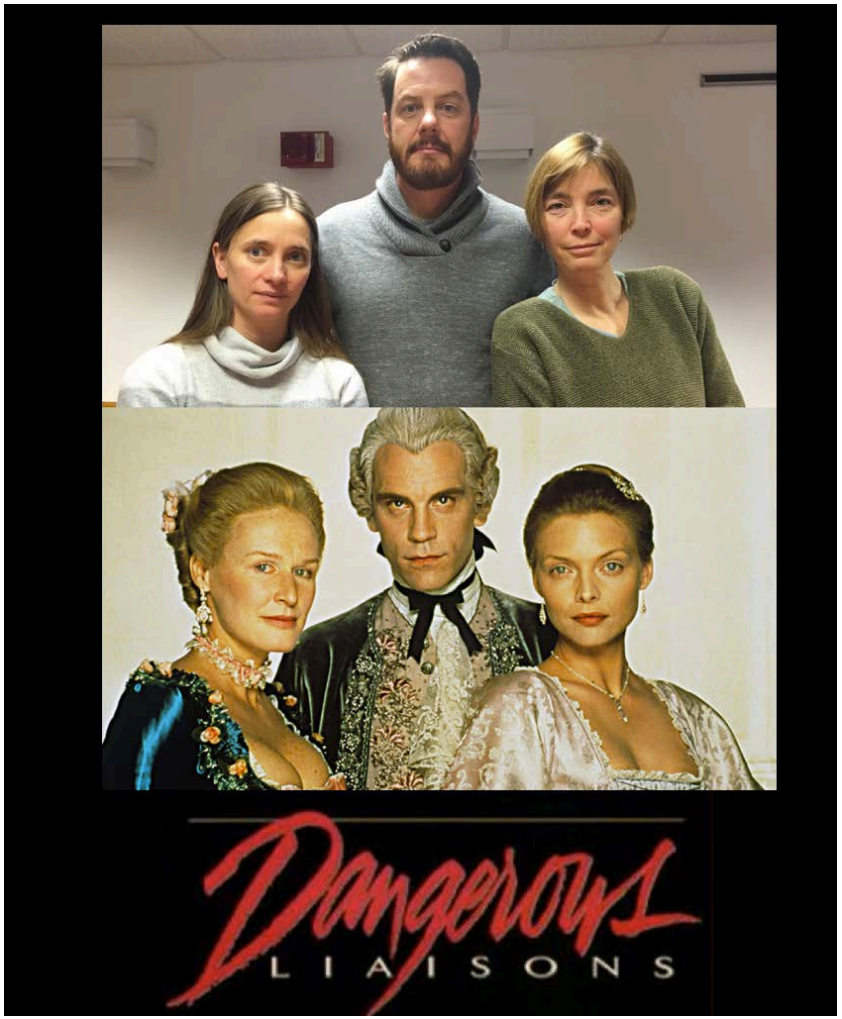
Summary of the WACCM/CAM/chemistry modeling suite

Liaisons: Simone Tilmes, Mike Mills, Cecile Hannay,
Doug Kinnison, Andrew Gettelman, Louisa Emmons
CAMchem, WACCM, and AMWG team!



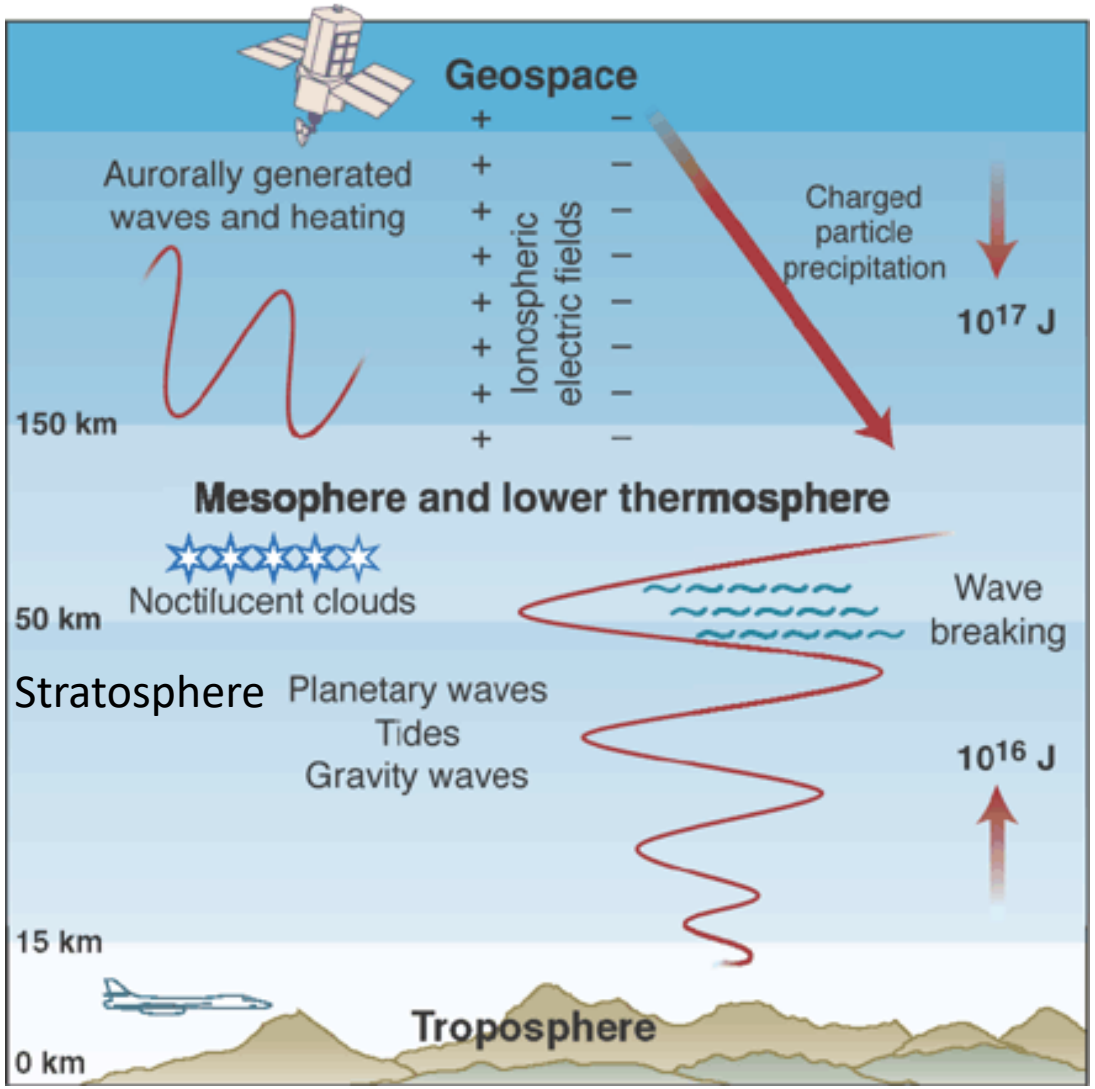
Summary of the WACCM/CAM/chemistry modeling suite

Different regions in the atmosphere require different physics and chemistry

WACCM X

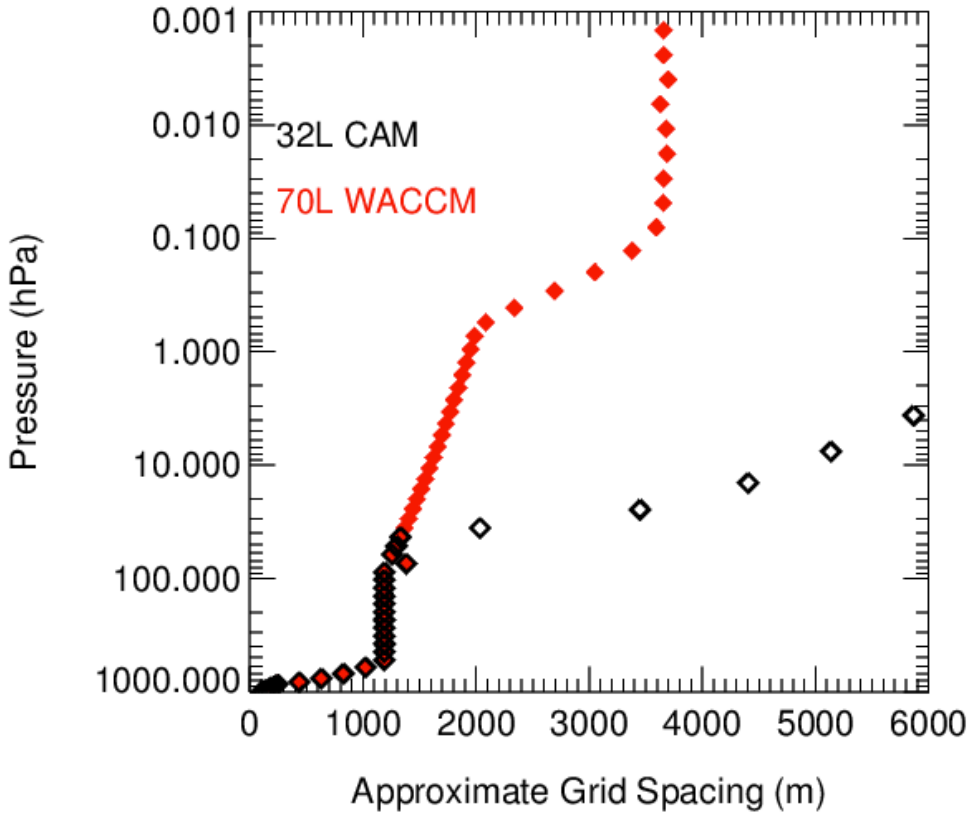
WACCM top →

CAM top →



CESM2 WACCM/CAM physics

Unified vertical grid below about 50hPa



WACCM 70L / CAM 32L

- Same lower atmosphere physics, GW, radiations etc.
- WACCM adds convective and frontal GW
- WACCM adds heating terms for the upper atmosphere and ions physics

CESM2 Chemistry and Aerosol Descriptions

Unified chemistry in WACCM 70L /CAM-chem 32L (low top)

TSMLT (troposphere/stratosphere/mesosphere/lower thermosphere)

- 228 chemical and aerosol species
- 589 reactions

those include

- 26 photo-ionization reactions (not used for low top)
- WACCM will also produce a middle atmosphere version
- Prognostic volcanoes / sulfur chemistry in the stratosphere
- Interactive secondary organic aerosol production

Simplified chemistry in CAM and WACCM SC (specified chemistry)

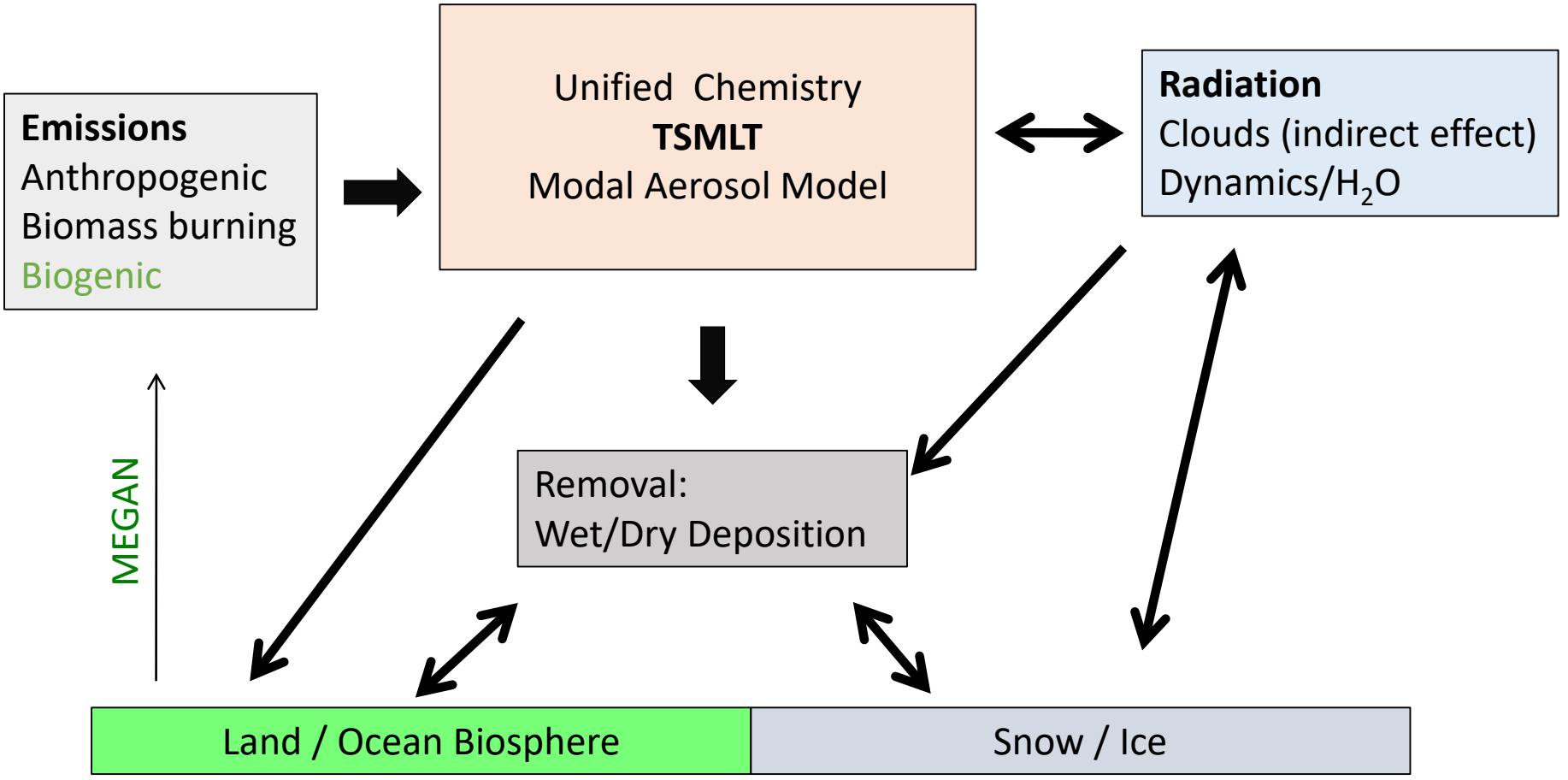
Simplified chemistry mainly for aerosol production

- Simple chemistry, 7 reactions (H_2O_2, H_2SO_4, SO_2, DMS)
- Prescribed oxidants (O_3, OH, NO_3, HO_2) from WACCM
- Prescribed ozone for radiation (from WACCM)
- Nitrogen deposition rates from WACCM -> described in CLM
- Prescribed SOAG yields, will be tuned with

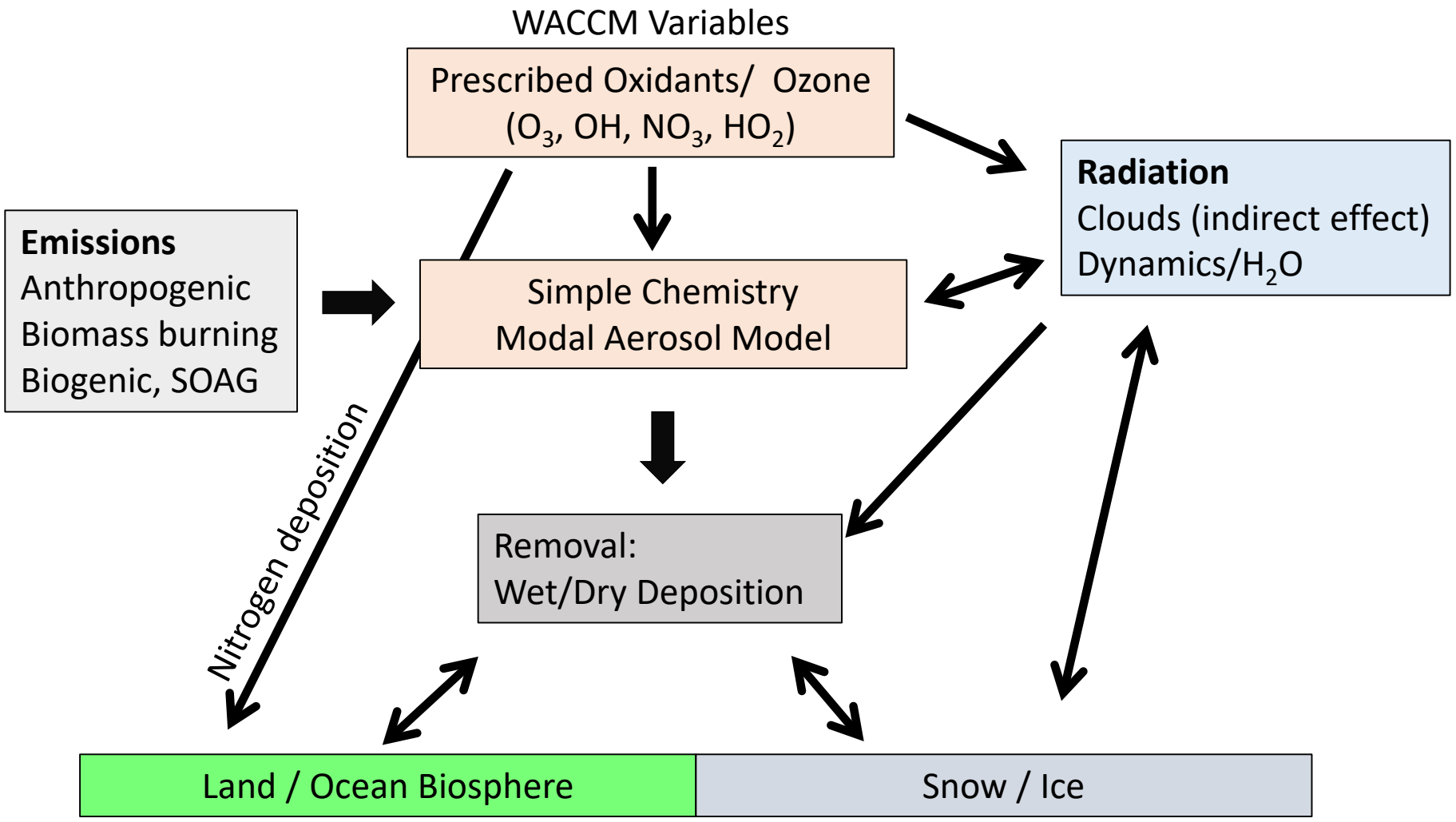
New CMIP6 emissions

- Updated injection heights
- Different setup of surface and elevated emissions

WACCM Chemistry, Interactions with other Components



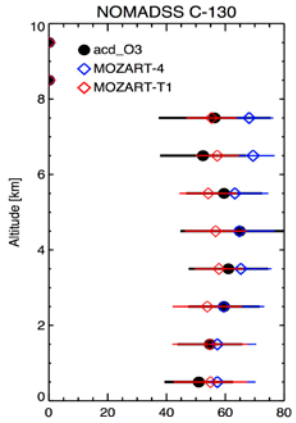
CAM Chemistry, Interactions with other Components



CESM2 Tropospheric Chemistry (TS1)

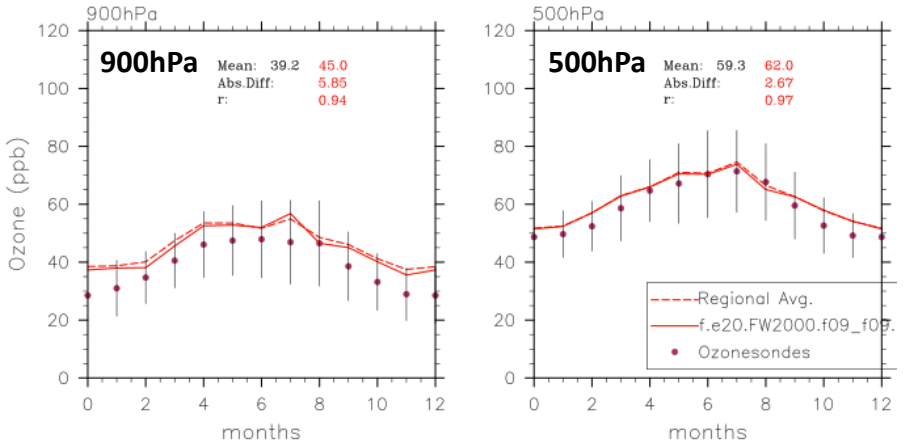
The tropospheric chemistry mechanism has been updated to accommodate **state of the art tropospheric chemistry**

- Provide more detailed representation of **SOA precursors** (terpenes, aromatics, glyoxal)
- Update isoprene oxidation based on recent research to include **OH recycling**
- Include specific species that are observed, allowing **for more precise model evaluation** (benzene, toluene, xylenes, individual terpenes, organic nitrates, glyoxal, etc.)

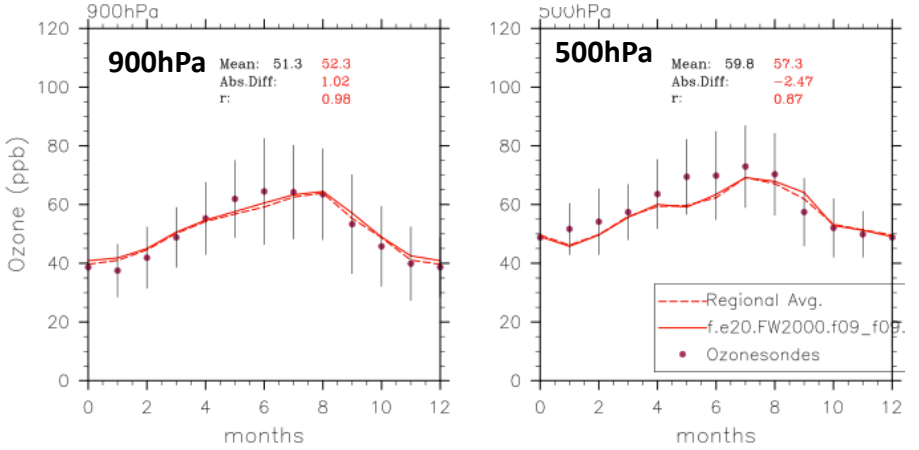


New Chemistry

Western Europe



Eastern US

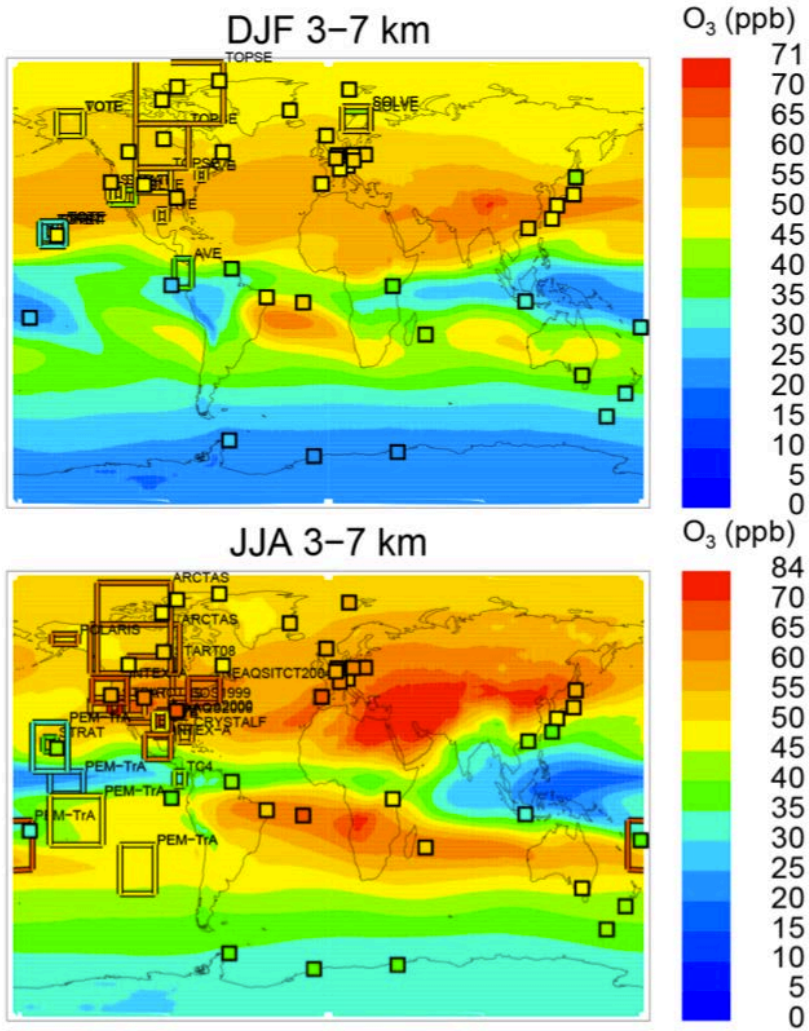


CESM2 Tropospheric Chemistry (TS1)

3-D monthly mean oxidants are prescribed in CAM (no daily cycle)

- SO4 formation not realistic in particular in the stratosphere and highly polluted regions
- Prognostic volcanoes are not implemented in CAM

Time varying 3-D ozone and OH distribution



CCMI model results in comparison to observations

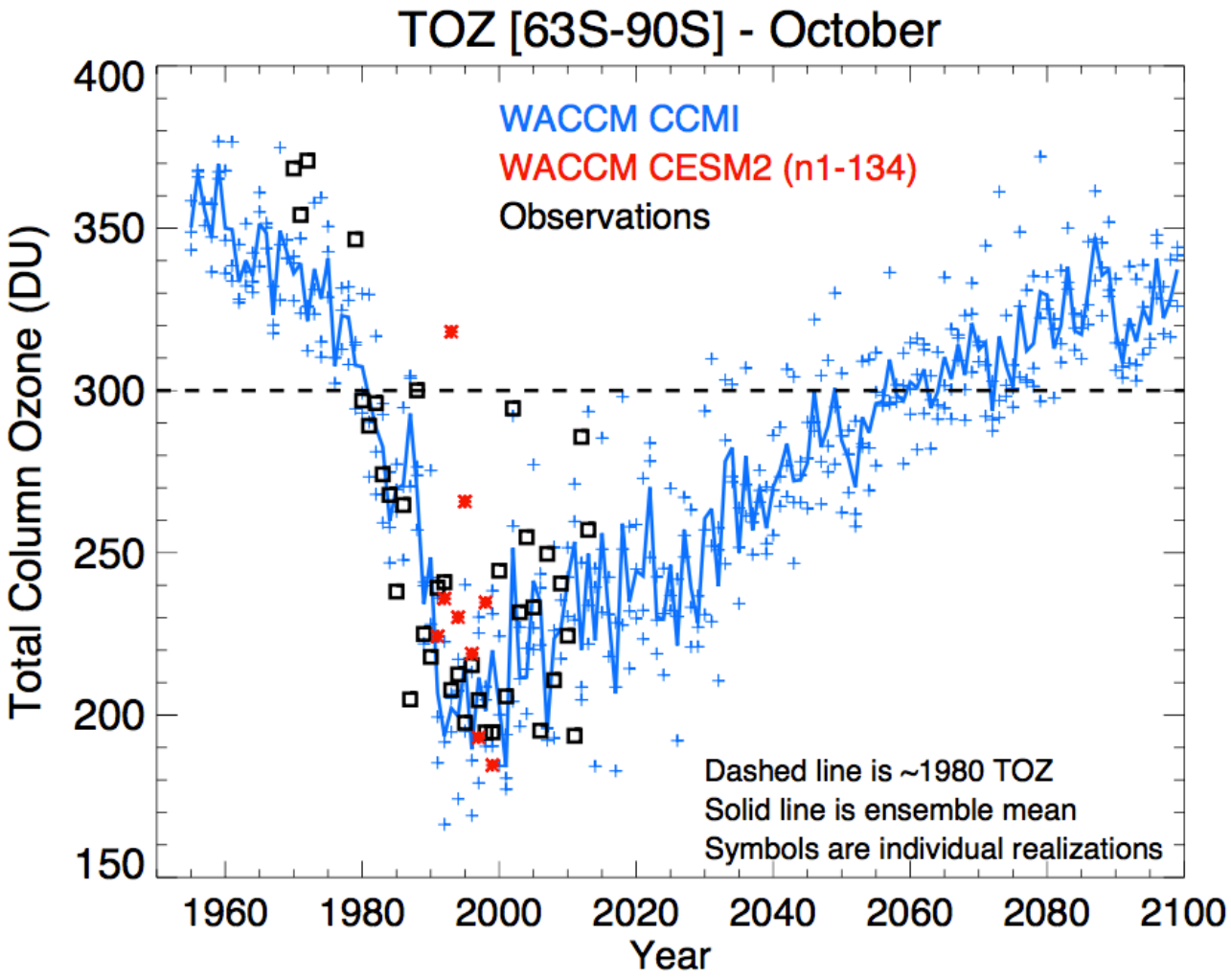
CESM2 Stratospheric Chemistry

WACCM4 CCMI

- Very good reproduction of the ozone hole evolution

CESM2

- very similar results compared to CCMI
- Representation strongly depends on the dynamical representation in the model
- In general even improved compared to CCMI

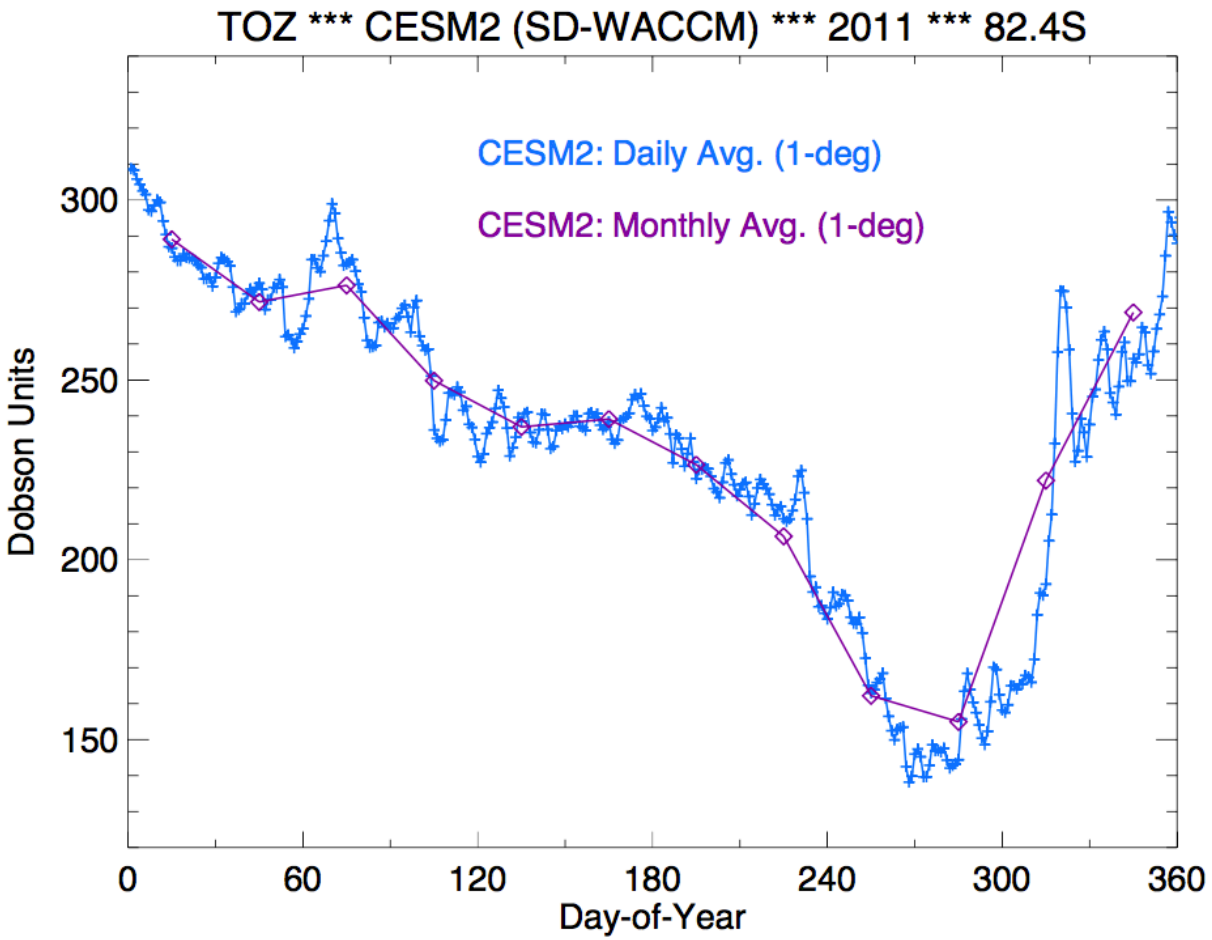


CESM2 [f.e20.FWAMIP.f09_f09.134.Pinatubo.001]

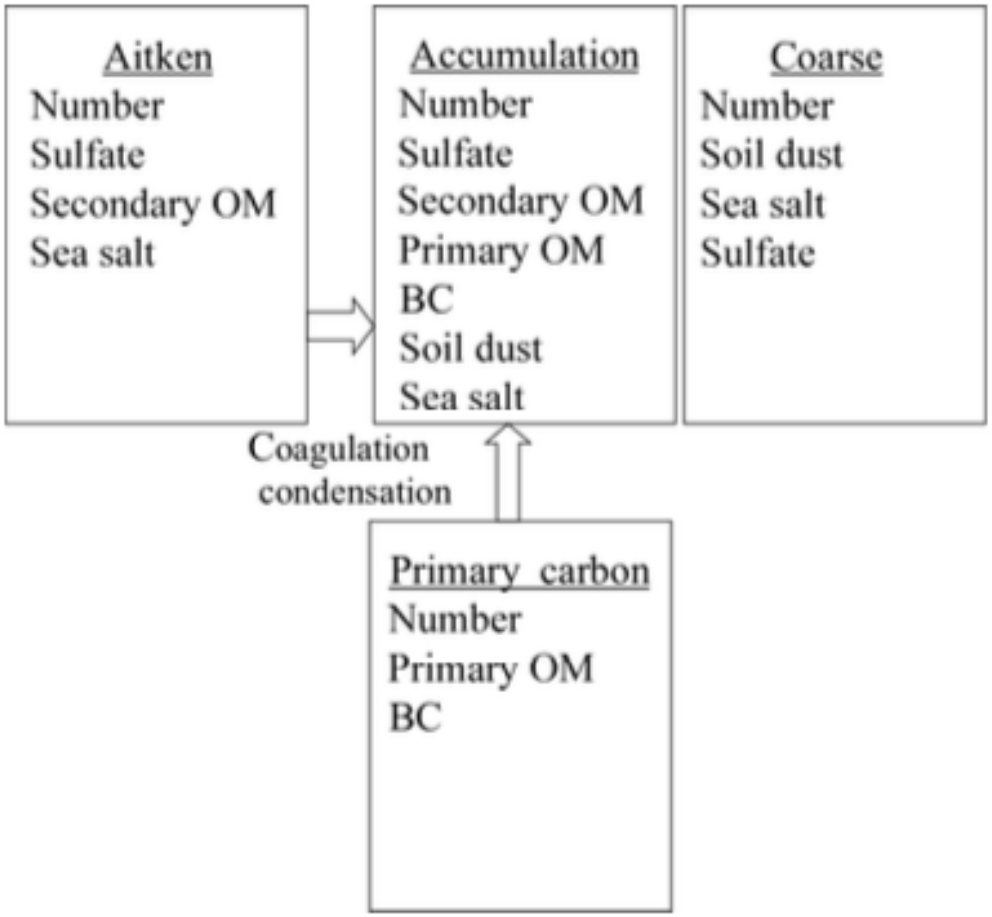
CESM2 Stratospheric Chemistry

Input for CAM

- 5-day zonal mean ozone fields (for radiation)
- important to capture the evolution of the ozone hole



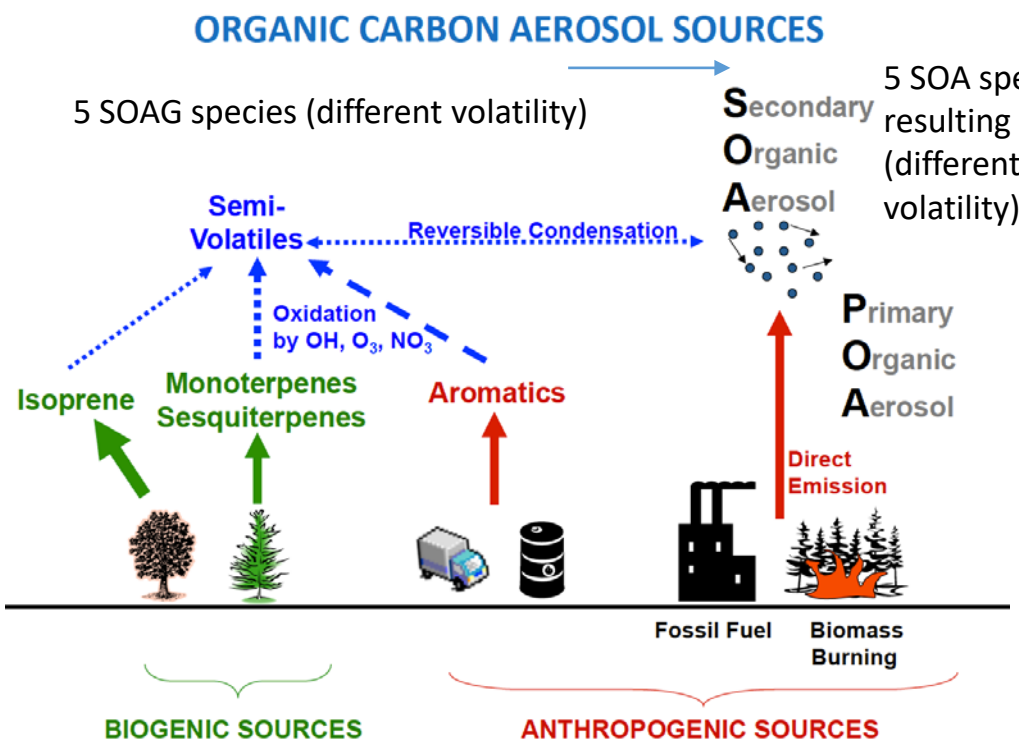
Tropospheric Aerosols (MAM4), in CESM2 (CAM and WACCM)



Sulfate: emissions, gas-phase, aqueous phase, and nucleation (dependent on oxidants)
Black Carbon/POM: emissions / aging
Dust, sea-salt: internally derived emissions
Secondary Organic aerosols (different in WACCM): emissions, estimated yield that produce SOAG, prescribed from CMIP6 emissions, multiplied by a factor to match expected burden

Liu et al., 2016

CESM2 Secondary Organic Aerosols



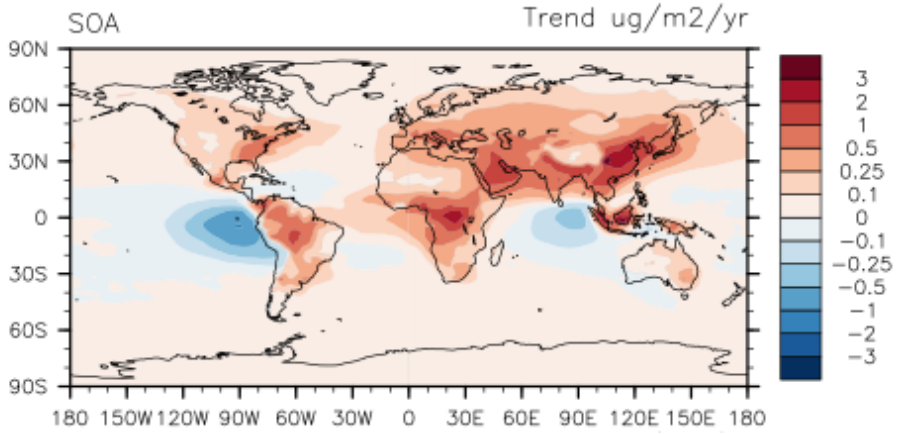
From C. Heald, MIT Cambridge

Simplified SOA scheme updated to include volatility basic set (VBS)

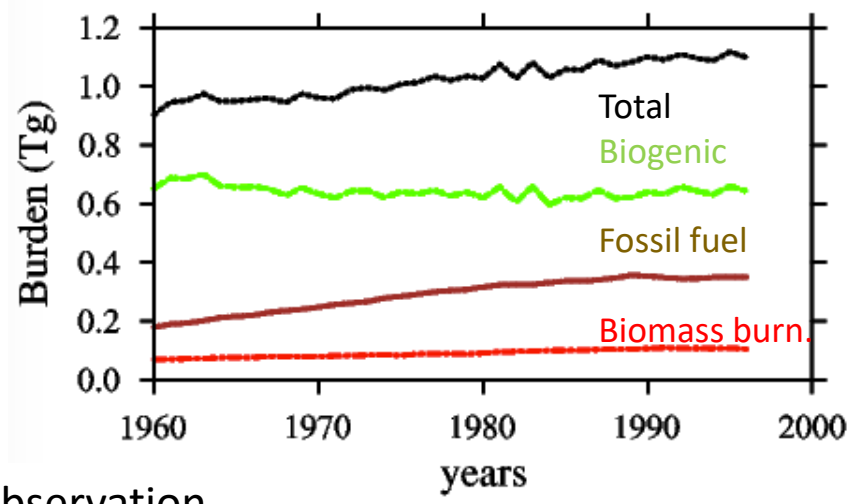
- Interactive calculation of SOAG
- Merge 3 different categories (biomass burning, fossil fuel and biogenic) SOAG into one category. Average Henry's law coefficient for different categories.
- 12 new species, significant reduction in computer time, 5-7% increase from base description.

CESM2 Secondary Organic Aerosols

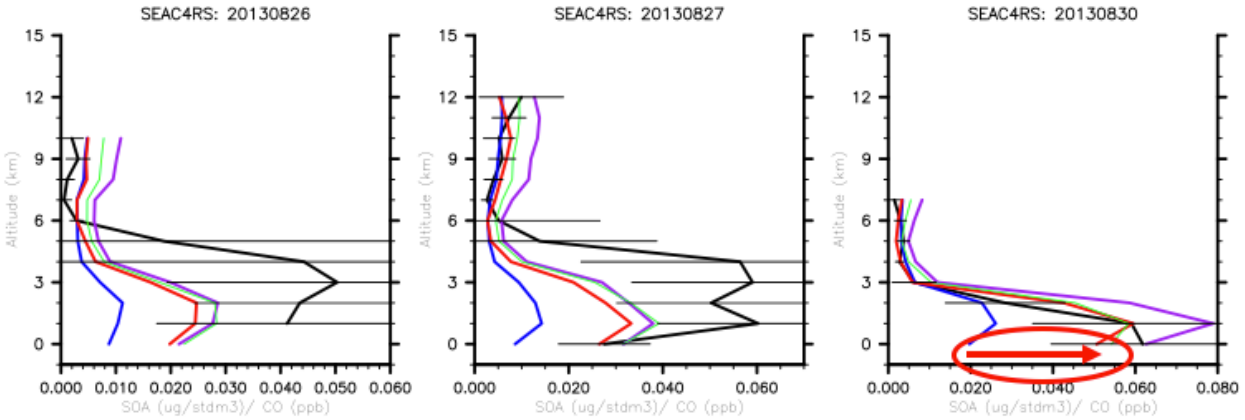
SOA Trend between 1960 and 2000



SOA Burden

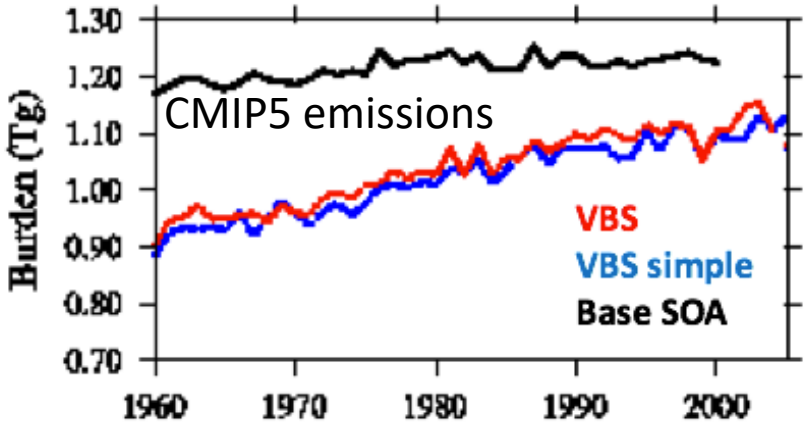


Comparison to Aircraft observation



SOA base
SOA VBS

CESM2 Secondary Organic Aerosols



SOA descripting in CAM

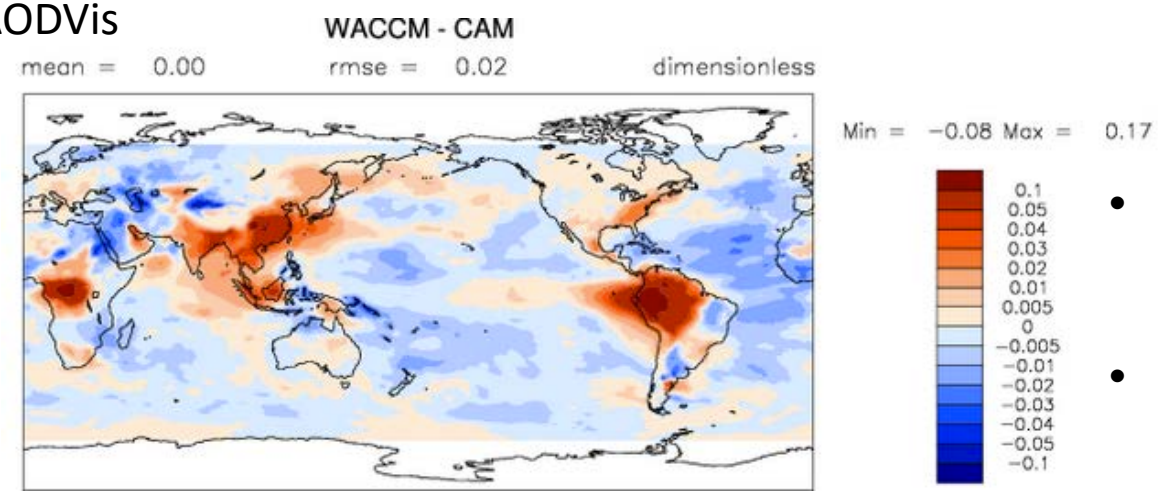
- Based on SOAG emissions (no photochemistry)
- No interactions with climate or land surface
- SOAG emissions in CAM scaled

- **F2000: CAM 1.0Tg, WACCM 1.1Tg**

Comparison WACCM /CAM F2000 case (6 years)

variable	WACCM	CAM
RESTOM	1.88	1.75
FLNT	236.8	235.2
FLNTC	262.1	259.7
SWCF	50.7	49.6
Sulfate	0.54 TgS	0.43 TgS
BC/OC	0.12/0.66 TgC	0.13/0.77 TgC
SOA	1.1 TgC	1.0TgC

AODVis



- Differences in chemistry and aerosol formation change AOD in source regions
- Slight differences in regional climate is expected

Conclusions

- Unified chemistry for WACCM/CAMchem (TSMLT) in released compsets
- Chemistry in both stratosphere and troposphere compares well with observations
- CAM required 3D monthly oxidants field and 5-day stratospheric ozone fields
- Some differences between WACCM and CAM are expected due to more complex and interactive processes running with full chemistry