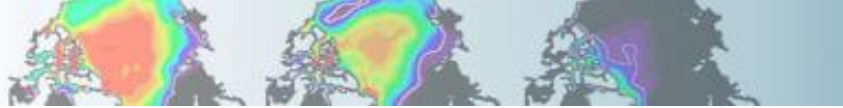
Community Earth System Model



Effects of the new aerosol parameterizations on aerosols and climate

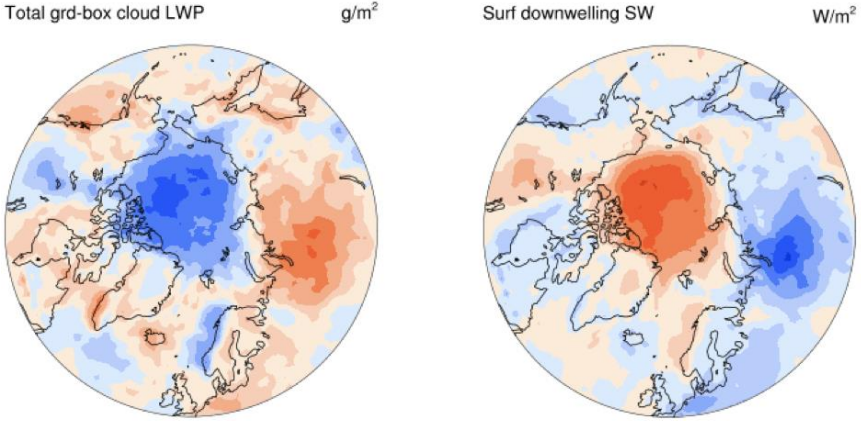
Simone Tilmes CCWG Liaison (tilmes@ucar.edu)

Mike Mills, Doug Kinnison, Louisa Emmons, Jean-Francois Lamarque, Andrew Gettelman, Alma Roux, Manish Shrivastava, Francis Vitt,
Pedro Campuzano Jost, Jose Jimenez
CAM-chem and WACCM team

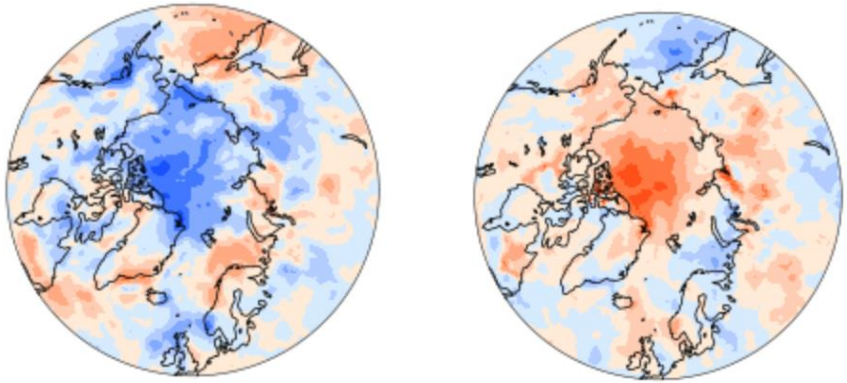
CESM Joint CCWG and WAWG and AMWG Session
Tuesday February 20th, 2019

Motivation: Differences in climate between CAM and WACCM

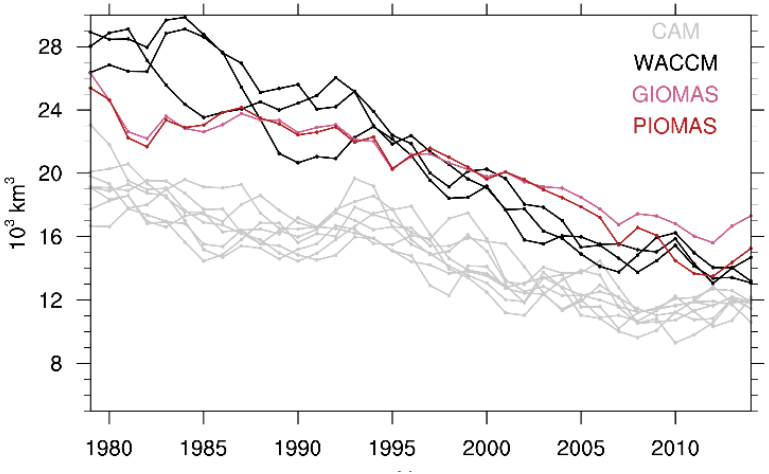
CAM – WACCM, JJA (fully coupled) present day



CAM – WACCM, JJA (prescribed SSTs) present day

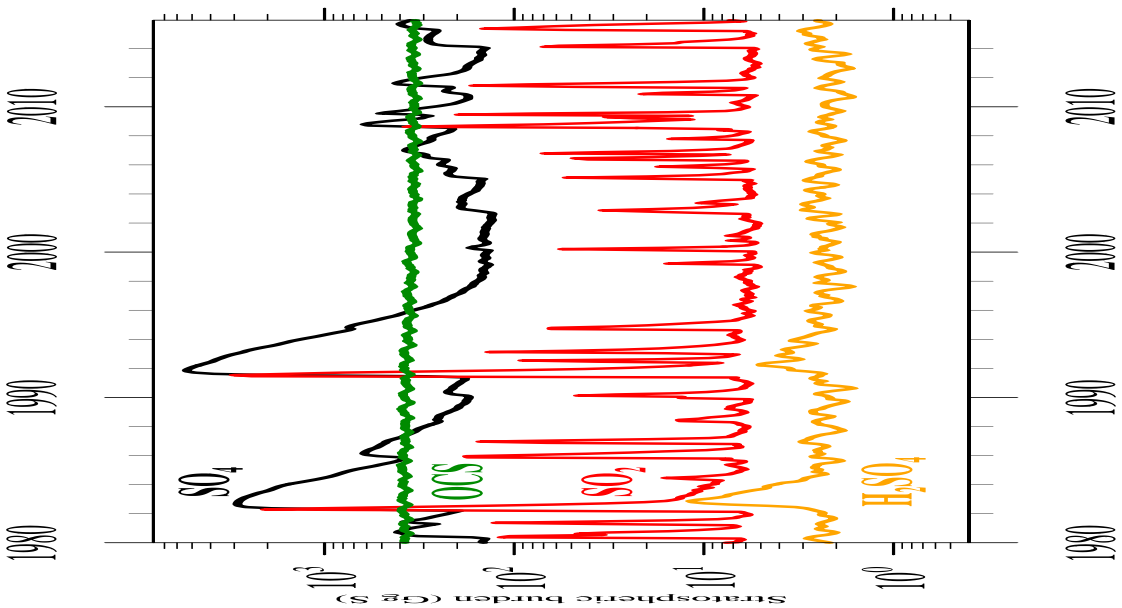


Arctic annual mean sea ice volume



By Alice K. DuVivier

Prognostic Volcanoes



Thanks to MikeMills

Results agree very well with observations

New SO_2 database

- Includes amount and altitude of SO_2 injections from eruptive volcanoes

OCS chemistry

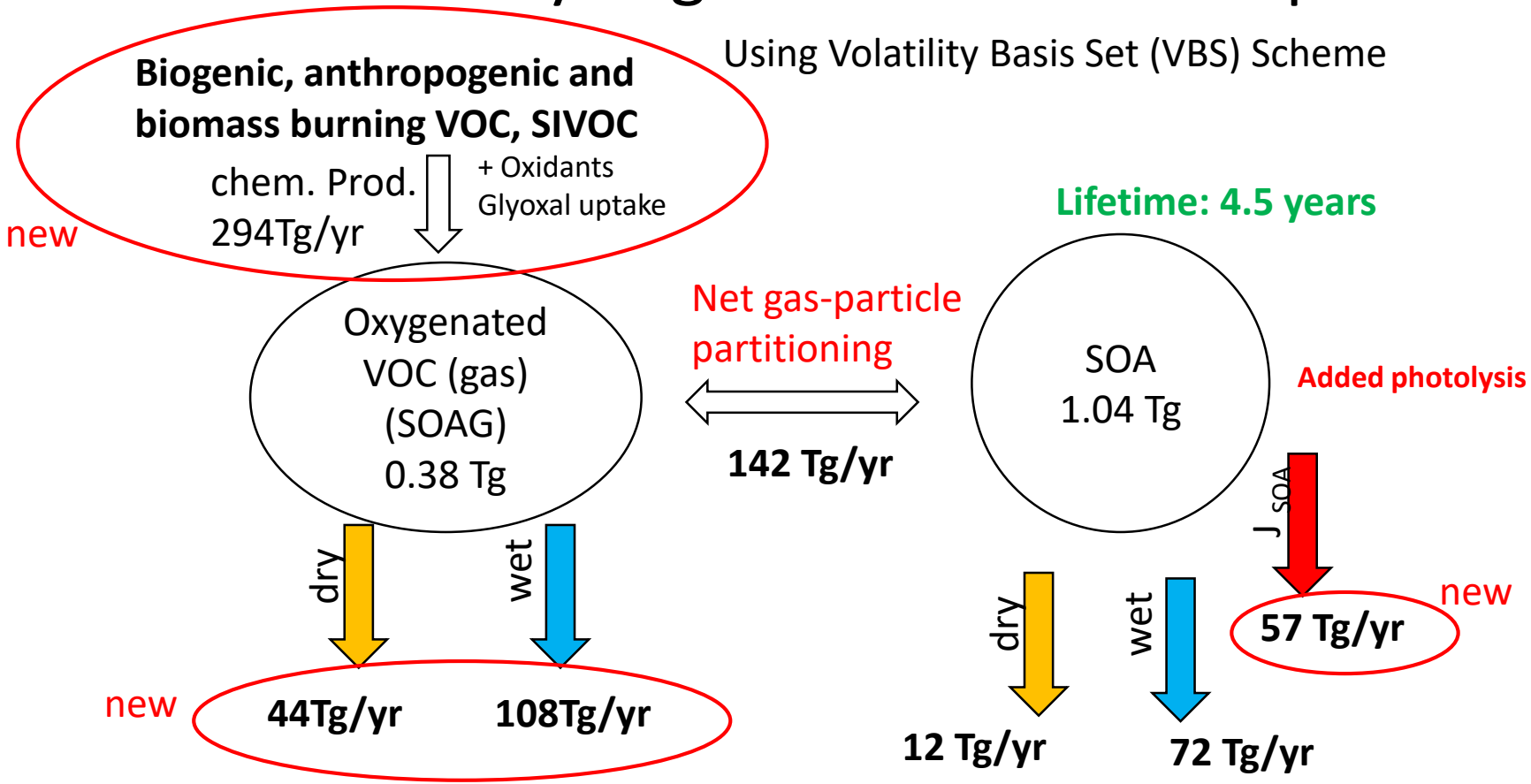
- Contributes to stratospheric sulfate

Interactive with chemistry, radiation and dynamics

- Includes interactive H_2SO_4 and SO_4 formation
- Requires comprehensive stratospheric chemistry

New Secondary Organic Aerosol Description

Using Volatility Basis Set (VBS) Scheme



Values very close to observational estimates!

WACCM / CAM Simulations (obs. SSTs)

Simulations	years	SOA model	SO4	Chemistry
WACCM VBS (FW1850)	1850 (10)	standard VBS	PI avg. prognistic	TSMLT
WACCM VBS-ext (FWvbsx1850)	1850 (10)	extended VBS	PI avg. prognistic	TSMLT + OA sources
WACCM NoVBS				
WACCM SC (FWsc1850)				
CAM (F1850)				
WACCM VBS (FWHIST)				
WACCM VBS-ext (FWvbsx				
WACCM VBS-ext (no anthro)	1960-2014	extended VBS	prognistic	TSMLT + OA sources (no anthro)
WACCM NoVBS	1960-2014	simplified SOA	prognistic	TSMLT
WACCM SC (FWscHIST)	1960-2014	simplified SOA	precribed strat.	simple chemistry
CAM (FHIST)	1960-2014	simplified SOA	precribed strat	simple chemistry
WACCM VBS-ext (FWSDvbsxHIST)	2016-2017 (SD)	extended VBS	prognistic	TSMLT + OA sources
WACCM NoVBS	2016-2017 (SD)	simplified SOA	prognistic	TSMLT + OA sources

WACCM (new SOA, prognostic volcanoes) WACCMext

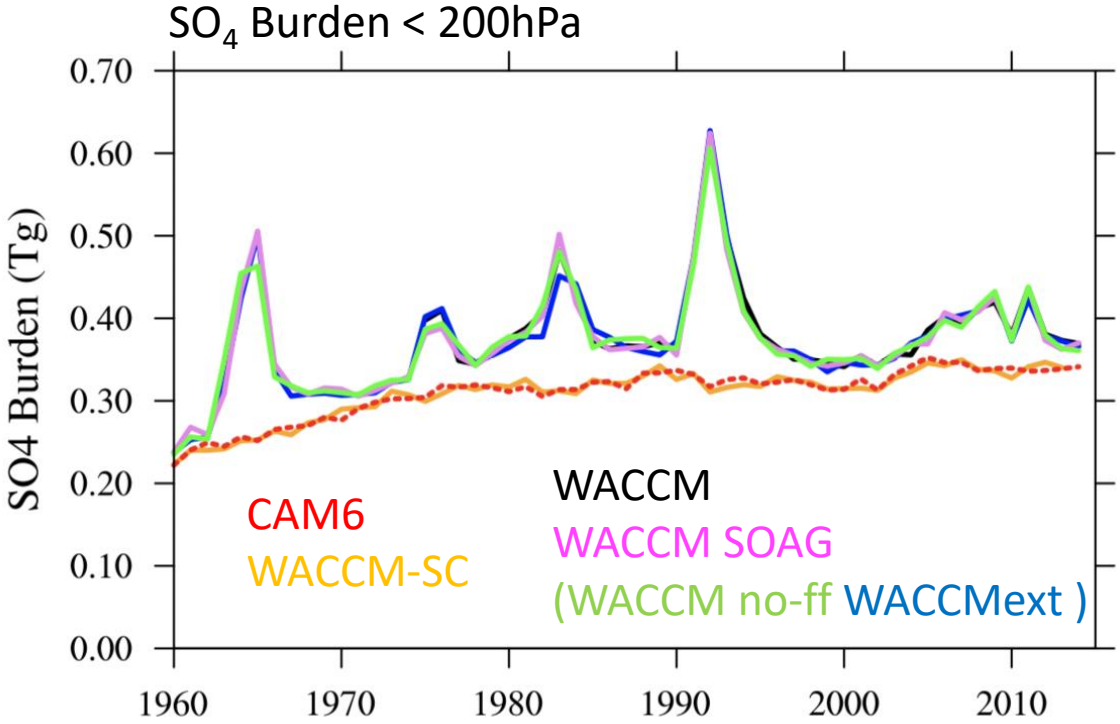
WACCM SOAG (simple SOA, prognostic volcanoes)

WACCM-SC (simple chemistry)

CAM

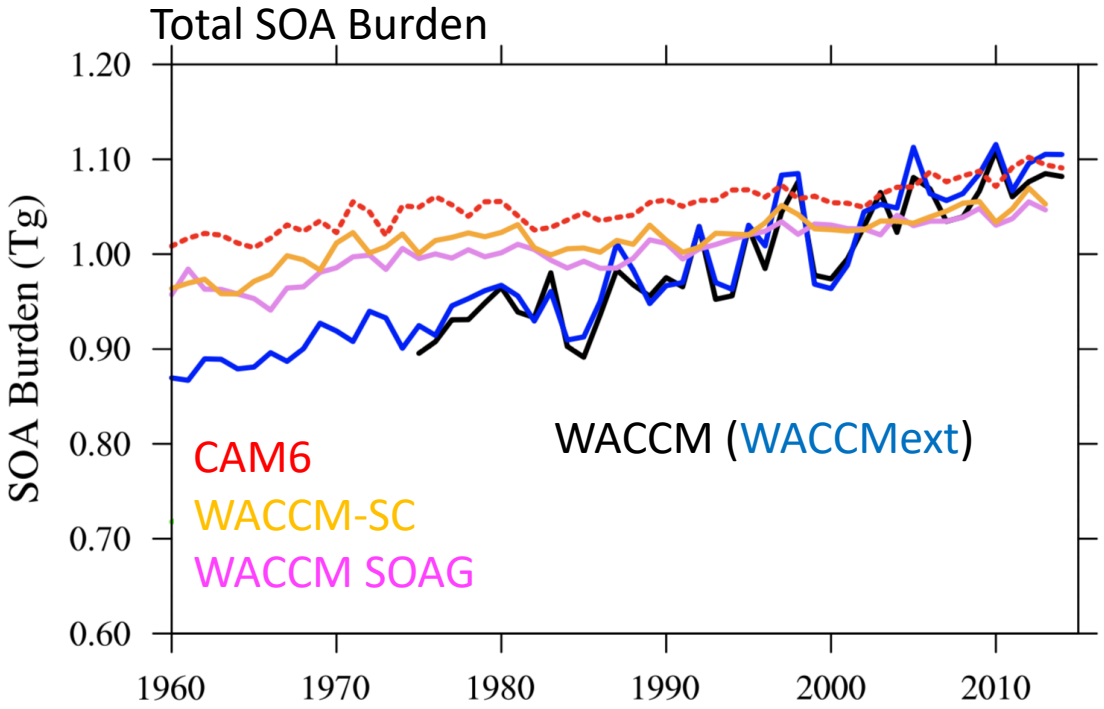
Tilmes et al., in preparation

CESM2 Tropospheric Aerosol Evolution



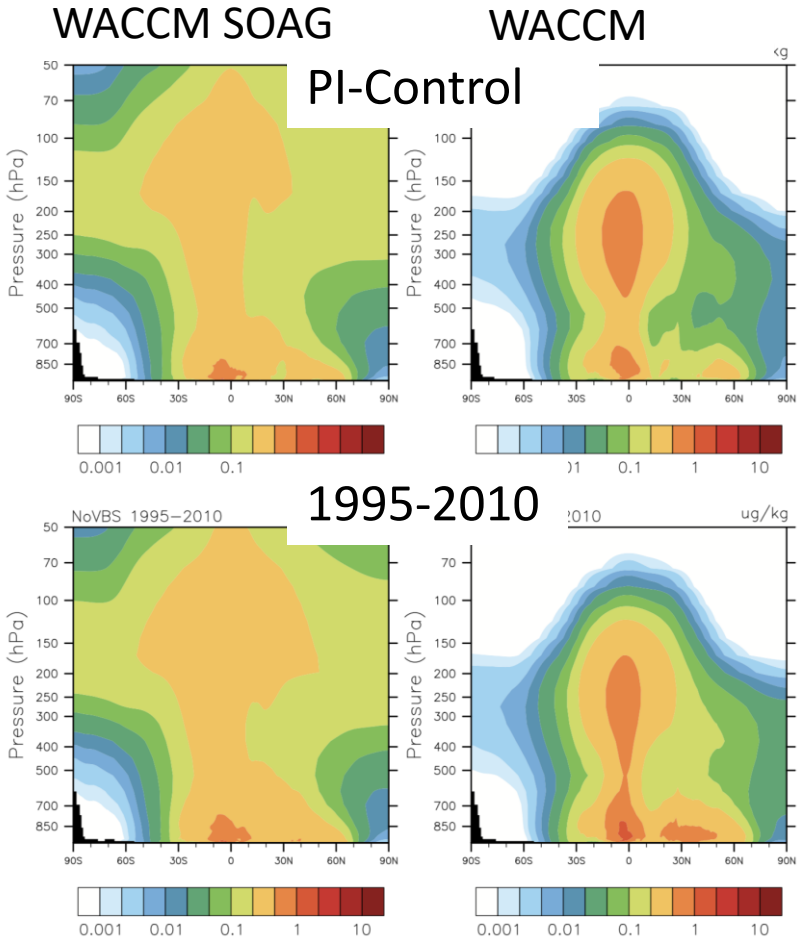
- More tropospheric sulfate in WACCM; missing OCS sources in WACCM-SC
- No transport of sulfates from the stratosphere in CAM and WACCM-SC

CESM2 Tropospheric Aerosol Evolution



- More SOA in low vs high top model
- Little change if adding chemistry and prognostic sulfates
- Different trend and more variability with new SOA scheme

WACCM Secondary Organic Aerosols

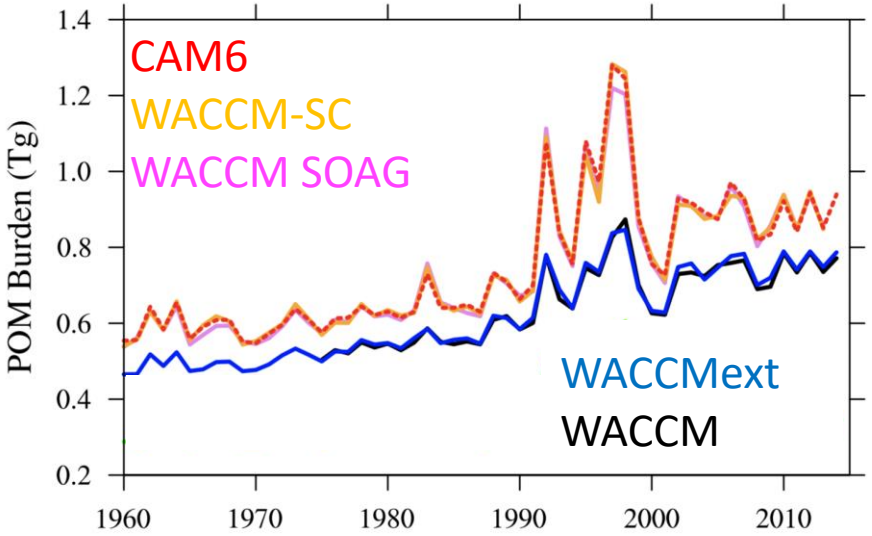


New VBS scheme

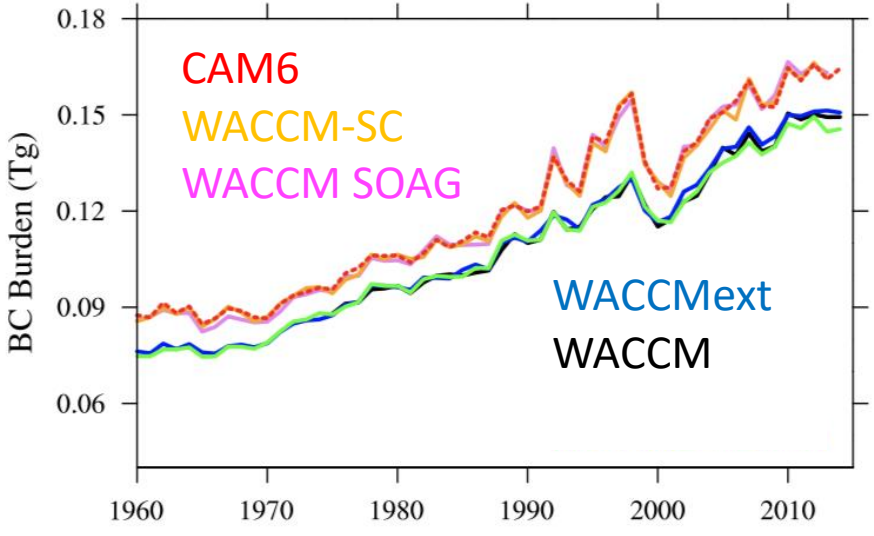
- Formation of SOA slower due to chemical processing -> reduced SOA near surface, more SOA in upper Tropics
- Removal processes included for SOAG (deposition) and SOA (photolysis) -> reduced values in high latitudes

CESM2 Tropospheric Aerosol Evolution

POM Burden



BC Burden



- Drop in POM and BC with new SOA scheme for both PI and present day

Tropospheric Aerosol Budgets: POM

POM	WACCM SOAG	WACCM VBS	difference	rel diff(%)
Burden (Tg)	0.938	0.753	0.185	19.708
accumulation	0.627	0.635	-0.008	-1.348
primary carbon	0.311	0.118	0.193	62.106
Burden (Tg) (<500hPa)	0.623	0.536	0.088	14.048

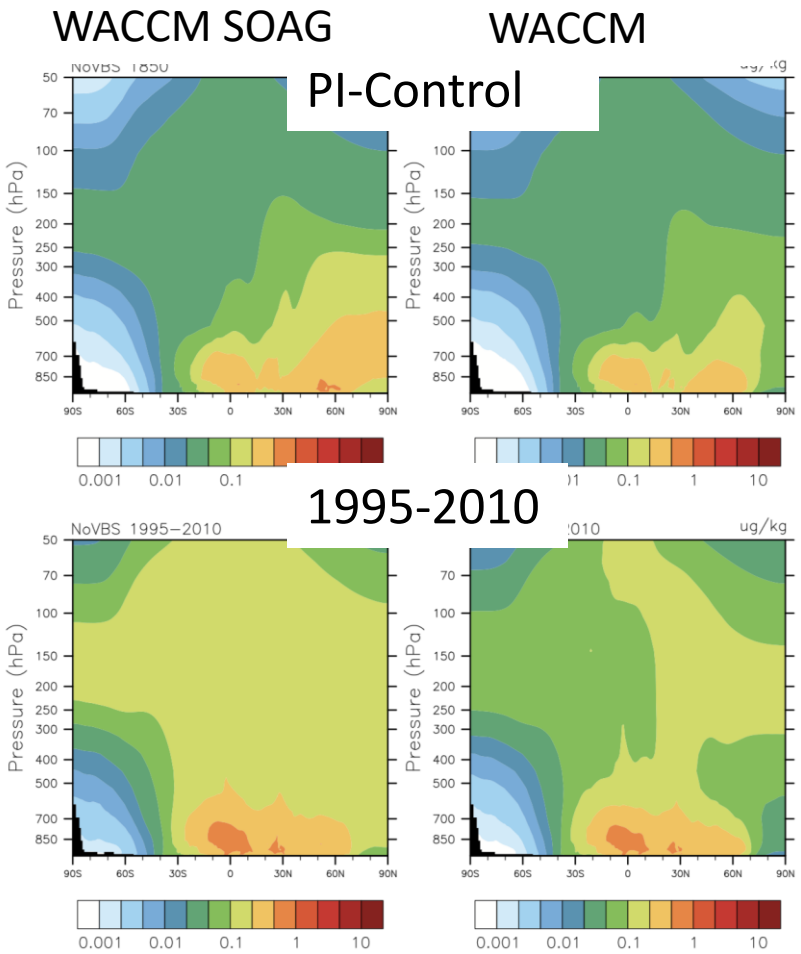
Changes due to the new SOA scheme:

-> increased burden in the accumulation mode in POM

-> reduction in the primary carbon mode

-> higher removal of POM and BC

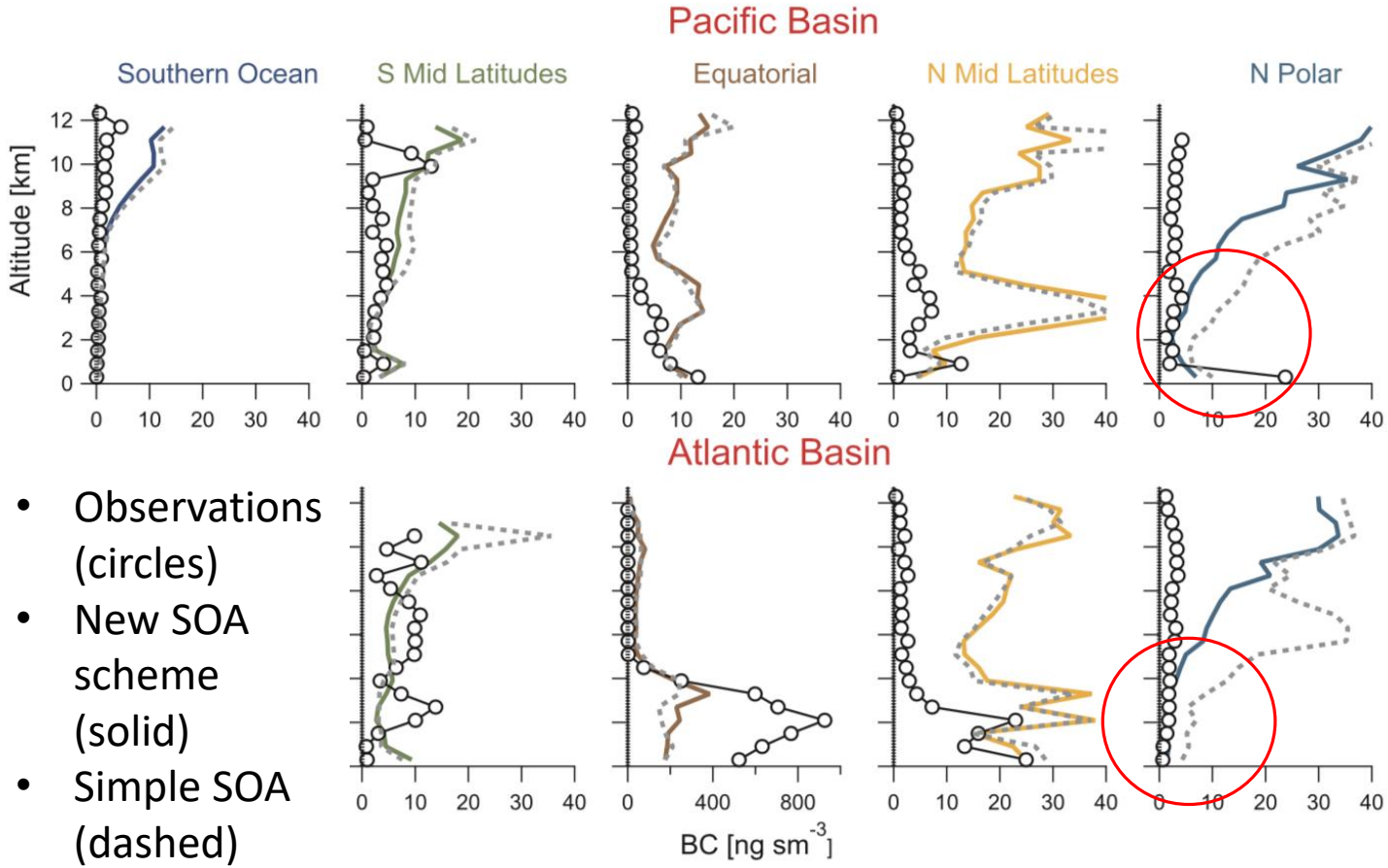
WACCM Primary Organic Aerosols (POM)



New VBS scheme

- Reduction of POM and BC with the addition of the new SOA scheme, in particular in the NH high latitudes

WACCM Black Carbon compared to aircraft obs.



- Observations (circles)
- New SOA scheme (solid)
- Simple SOA (dashed)

New SOA scheme

- Improved POM and BC in NH high latitudes < 6km
- Potential impact on clouds over the Arctic

Differences in radiation between different WACCM versions

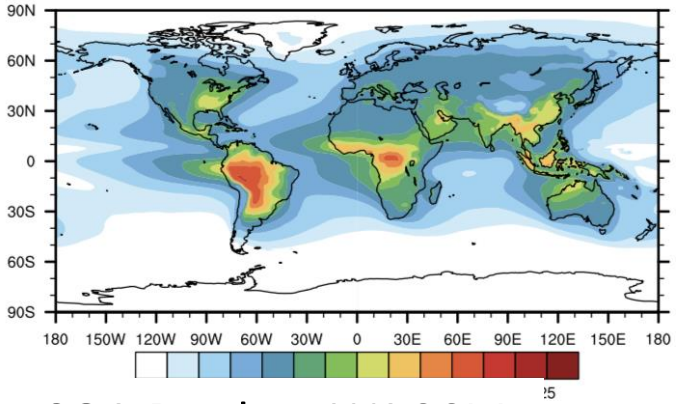
	RESTOM W/m^2	FSNS W/m^2	AOD	POM Tg	BC Tg	SOA Tg	SO_4 Tg
WACCM (VBS)	3.34 +/- 0.54	166.14 +/- 0.18	0.14	0.74	0.132	1.05	0.29
SOAG -VBS	-0.22	-0.58	-0.005	0.19	0.015	-0.02	0.00
SC - VBS	-0.05	0.06	-0.002	0.19	0.015	-0.01	-0.02

- Increase in BC and POM in WACCM SOAG vs. VBS -> cooling
- Less tropospheric sulfate in WACCM-SC -> counteracting effect from SOA changes

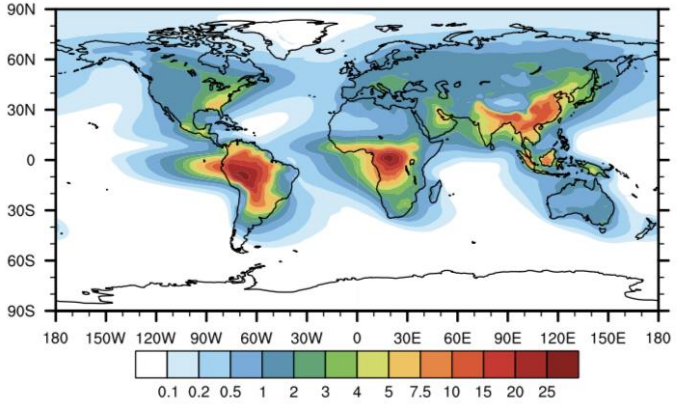
-> Changes in Climate in including Chemistry can be expected

Regional Changes with new SOA scheme

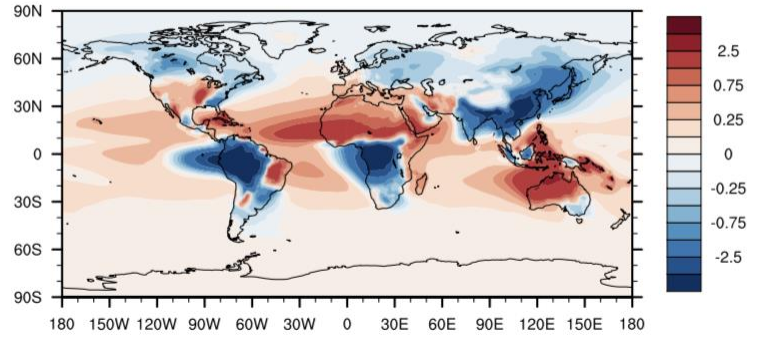
SOA Burden: WACCM SOAG



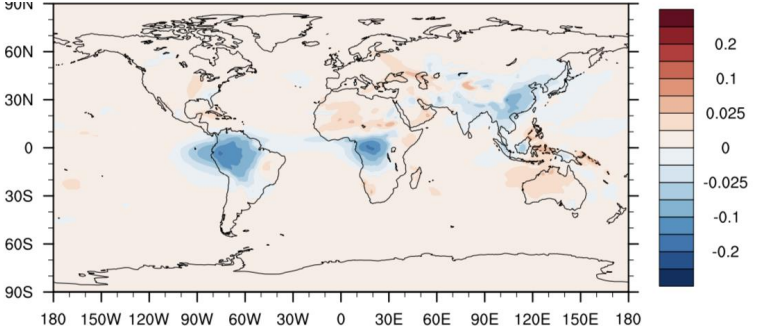
SOA Burden: WACCM



SOA Burden: WACCM (SOAG) minus WACCM



AOD: WACCM (SOAG) minus WACCM

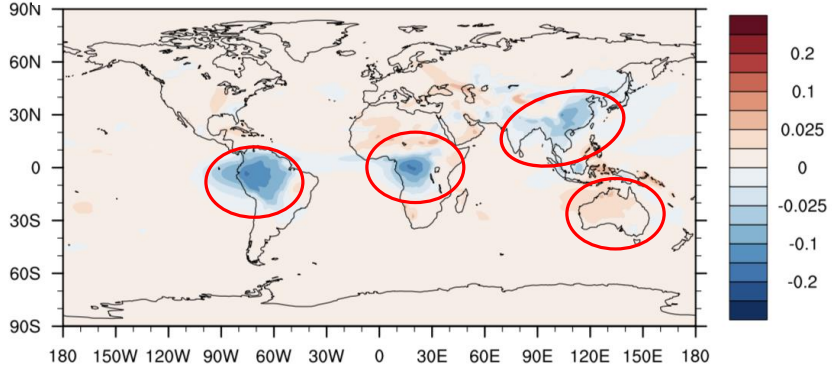


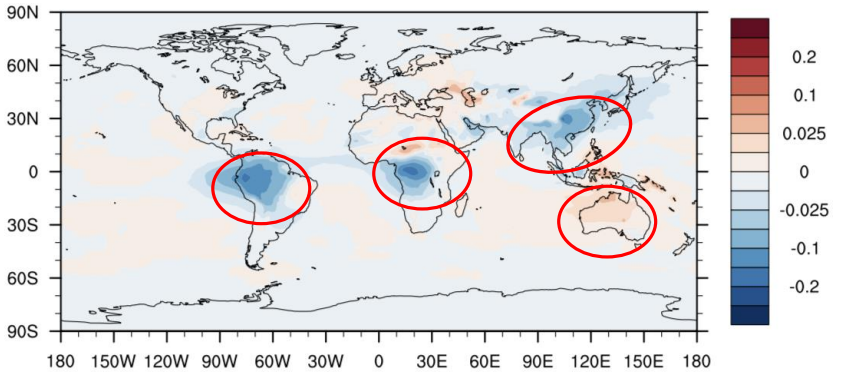
Changes in AOD and TS

Simple minus new SOA scheme

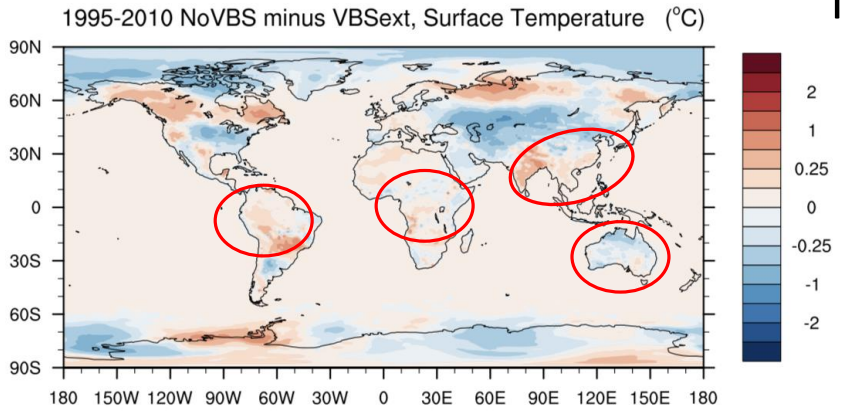
AOD

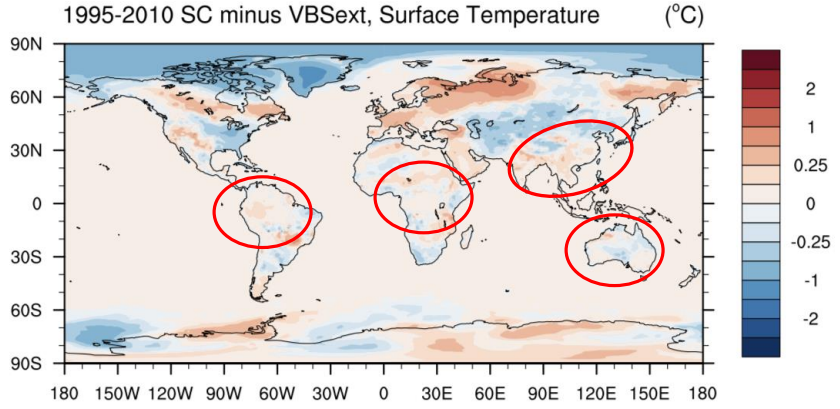
WACCM(SC) minus WACCM





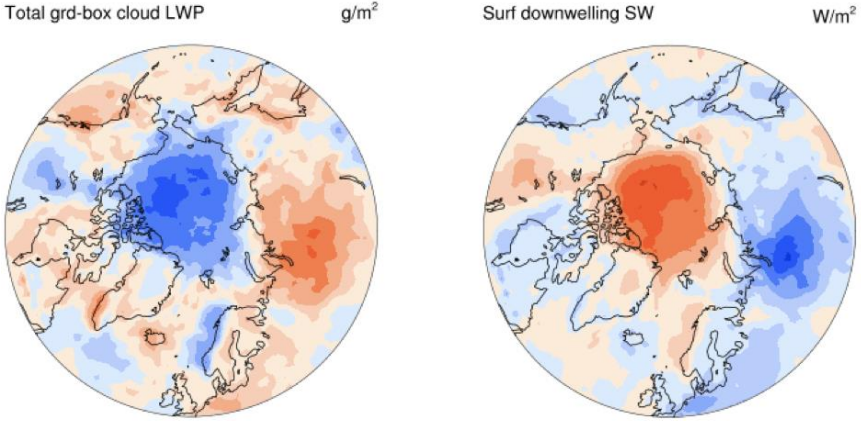
TS



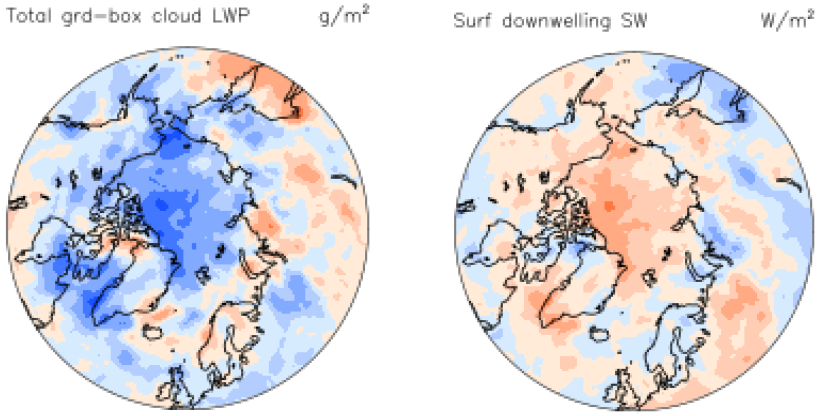


Motivation: CAM and WACCM are different, example Arctic sea-ice extend

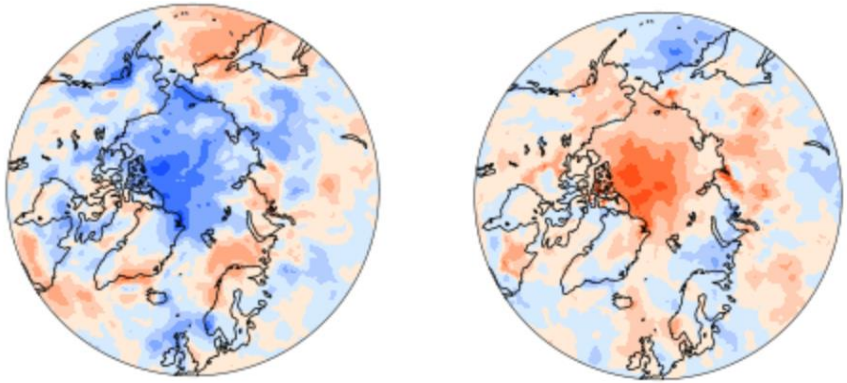
CAM – WACCM, JJA (fully coupled) present day



WACCM(SOAG) – WACCM, JJA (prescribed SSTs)



CAM – WACCM, JJA (prescribed SSTs) present day



Addition of the new Secondary Organic Aerosol scheme to WACCM as resulted in similar changes.

Conclusions

- WACCM includes new aerosol schemes that only run with comprehensive chemistry
- Comprehensive secondary organic aerosol scheme impacts other aerosols (POM and BC), resulting in changes in AOD and climate
- Interactive sulfate aerosols counteract changes from other aerosols globally
- Differences between WACCM and CAM are a result of the new aerosol parameterizations, and a result of differences between high and low top

Extras

CESM2 Tropospheric Aerosol Evolution

BC	WACCM SOAG	WACCM VBS	difference	rel diff(%)
Burden (Tg)	0.051	0.042	0.009	17.681
accumulation	0.029	0.032	-0.003	-11.406
primary carbon	0.023	0.010	0.012	54.699
Burden (Tg) (<500hPa)	0.040	0.033	0.007	16.857
SO4	**WACCM SOAG**	**WACCM VBS**	**difference**	**rel diff(%)**
Burden (TgS)	0.512	0.515	-0.003	-0.667
accumulation	0.330	0.353	-0.022	-6.749
aitken	0.019	0.017	0.002	8.714
coarse	0.163	0.145	0.017	10.588
Burden (TgS) (<500hPa)	0.089	0.088	0.001	0.997

Regional Changes in SWCF and TS