Evaluation of Simulated Aerosols and Clouds in CAM5 with Different Representation of Aerosol Microphysics

Catherine Chuang
Arthur Mirin
Philip Cameron-Smith
Daniel Bergmann

Lawrence Livermore National Laboratory

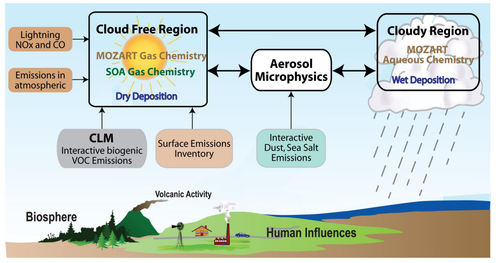
A Size-Resolved Aerosol Model with Comprehensive SOA Formation is Implemented in CAM5

Goals

(1) Explore the sensitivity of simulated aerosol life cycle and aerosol/cloud interactions to the treatment of aerosol microphysics

(2) Improve the default aerosol representation in CAM5/CESM

CAM_Sect uses a comprehensive treatment for the links of aerosols to their precursor gases and with the interactive biogenic sources.



Chemistry

- MOZART photochemistry and sulfate chemistry (200 reactions)
- SOA chemistry (10 reactions)
  - Empirical representation of SOA precursor

Toluene	+ OH	→ c_1	TOLAER1	+ c_2	TOLAER2	+	OH
Xylene	+ OH	→ c_1	XYLAER1	+ c_2	XYLAER2	+	OH
Humulene	+ OH	→	HUMAER			+	OH
Limonene	+ OH	→ c_1	LIMAER1	+ c_2	LIMAER2	+	OH
α-Pinene	+ OH	→ c_1	APINAER1	+ c_2	APINAER2	+	OH
α-Pinene	+ O3	→ c_3	APINAER3	+ c_4	APINAER4	+	O3
β-Pinene	+ OH	→ c_1	BPINAER1	+ c_2	BPINAER2	+	OH
β-Pinene	+ O3	→ c_1	BPINAER3	+ c_2	BPINAER4	+	O3
β-Pinene	+ NO3	→	BPINAER5			+	NO3
Isoprene	+ OH	→ c_1	ISOPAER1	+ c_2	ISOPAER2	+	OH

xxxAERy is surrogate SOA precursor compound. Coefficients ci are based on smog chamber data.

- 111 gas species

Aerosol microphysics

- MADRID 1
  - ISORROPIA and growth law equations for inorganic species
  - Empirical gas/particle partition coefficients for condensable organic species
- 224 aerosol tracers in 8 size bins
  - 26 aerosol components (18 for SOAs), aerosol water, aerosol number
    Na, SO4, NH4, NO3, Cl, Dust, EC, POM, 4 biogenic SOAs, 4 anthropogenic SOAs

Biogenic VOC emissions

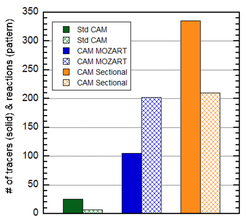
- MEGAN
- Interactive emissions of 15 VOC species from CLM
  isoprene, α-pinene, β-pinene, limonene, humulene, CO, C_2H_5OH, CH_3OH, CH_3COCH_3, CH_3CHO, CH_2O, C_2H_4, C_2H_6, C_3H_6, C_3H_8

Aerosol/cloud interactions

- Based on Abdul-Razzak-Ghan (2002)
- Effective particle solubility varies with aerosol components in each size bin

CAM_Sect contains more number of tracers (solid) and chemical reactions (pattern) than other aerosol modules in CAM

- The number of constituents carried in CAM_Sect is 335, as compared to 25 for Std CAM (MAM3)
- To run one month simulation at 2° resolution takes about 12 minutes at LLNL Sierra using 960 cores

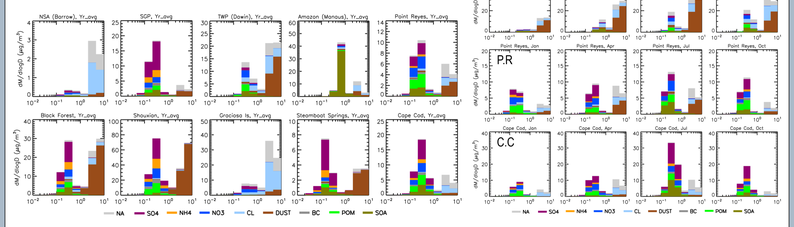


MOZART : Model for OZone And Related chemical Tracers [Emmons et al., 2009]
MADRID : Model of Aerosol Dynamics, Reaction, Ionization, and Dissolution [Zhang et al., 2004]
MEGAN : Model of Emissions of Gases and Aerosols from Nature [Guenther et al., 2006]

CAM_Sect Presents Detailed Aerosol Microphysical Features Important for Radiation and Cloud Properties

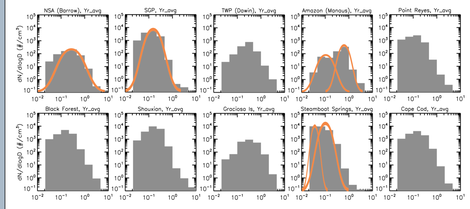
Significant temporal and spatial variations of aerosol properties underlie the uncertainty of aerosol climate effects.

Annual means (below) and seasonal variations (right) of simulated size-resolved aerosol mass concentrations by CAM_Sect at the ARM sites



ARM sites

Annual averages of aerosol number size distributions simulated by CAM_Sect

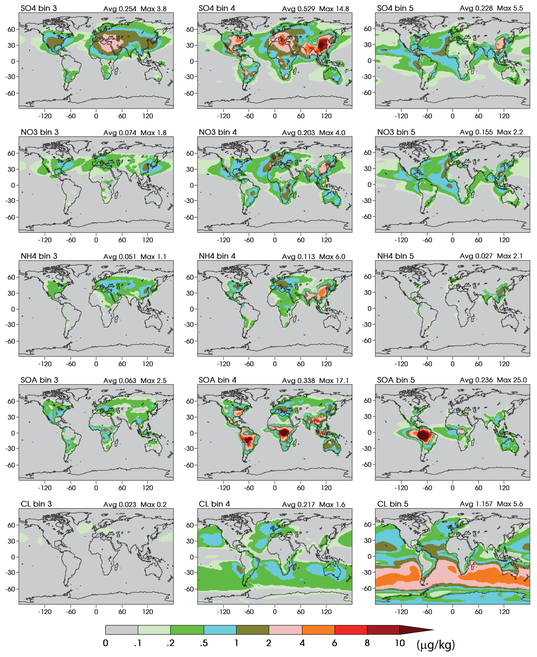


The orange curve represents the fitted log-normal function.

- The widths of aerosol number size distributions vary substantially
- Bimodal distributions are noticed in some locations

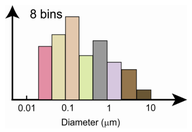
The large fractions of SO_4, NO_3, and NH_4 are from anthropogenic sources in the N. hemisphere. SOAs from biogenic emissions make up a significant portion of global aerosol mass concentrations.

Annual sulfate, nitrate, ammonium, SOAs, and chloride at surface for size bins 3 – 5



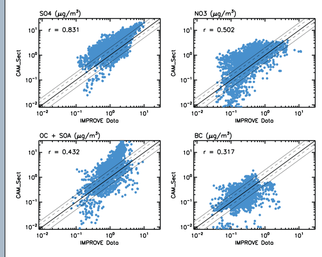
8 size bins (diameter)

Bin 1:	0.022	-	0.046 μm
bin 2:	0.046	-	0.10
Bin 3:	**0.10**	**-**	**0.22**
bin 4:	**0.22**	**-**	**0.46**
bin 5:	**0.46**	**-**	**1.0**
bin 6:	1.0	-	2.2
bin 7:	2.2	-	4.6
bin 8:	4.6	-	10

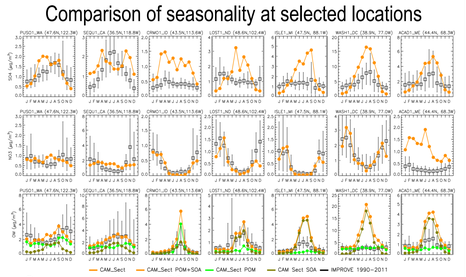


Validation of CAM_Sect Simulations with Data and Comparison to CAM_MAM Results

Comparison of 5 year averages of monthly means from CAM_Sect with the monthly averages of IMPROVE data in U.S. national parks between 1990-2011



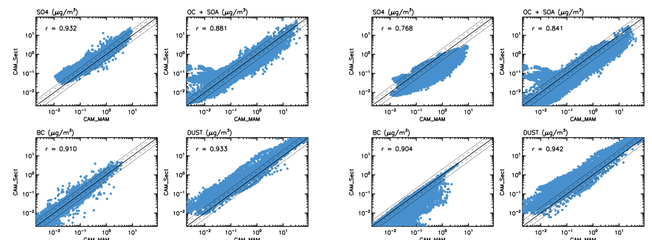
Comparison of seasonality at selected locations



Square represents the 20-year average of the observed mean, vertical line represents the inter-annual range.

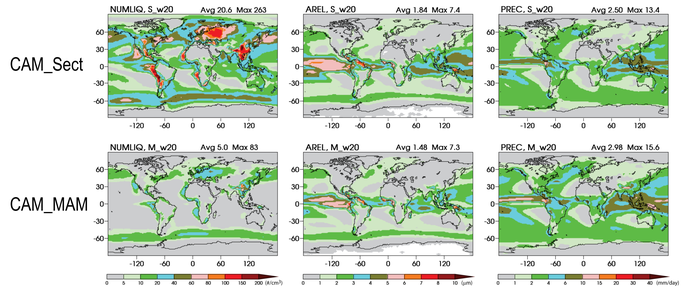
Comprehensive SOA treatment in CAM_Sect helps to reduce the bias in spatial and temporal distributions of organic particles over the west of U.S.

Comparison of simulated aerosols from CAM_Sect and CAM_MAM shows substantial dependency on the emissions Inventory used in each model.



Correlation of annual aerosol concentrations at surface between CAM_Sect and CAM_MAM. (Left) Global Fire Emissions Inventory for CAM_Sect and AR5 emissions for CAM_MAM. (Right) Same as Left but replacing SO_2, POM, and BC with ARM5 emissions in CAM_Sect.

Cloud properties are sensitive to different representations of aerosol microphysics.



Simulations of cloud drop number concentration (NUMLQ), effective radii (AREL), and precipitation rate (PREC) at ~950 mb from CAM_Sect and CAM_MAM

Conclusion and Future Work

Preliminary comparisons of CAM_Sect simulations with IMPROVE data show reasonable agreement.

Future work

- Compare the simulated aerosols from CAM5_Sect and CAM5_MAM in hindcast mode to observations from DOE-sponsored field campaigns
- Develop parameterizations of optical properties for size-resolved internally mixed aerosols
- Examine the variations of aerosol optical depth and their relationship with cloud properties
- Explore the time evolution of simulated aerosol size distributions and verify with the ARM data

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