An Aerosol Branch

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Aerosol Science Questions

• What are the direct and indirect effects of anthropogenic aerosol on the past, present and future planetary energy balance?
• What are the effects of anthropogenic aerosol on the global and regional water balance?
• What are the impacts of anthropogenic aerosol on past and future climate?
• What is the role of aerosol deposition in surface biology?
• How much does climate-wildfire feedback contribute to climate variability?
• What is the role of climate-dust feedback?
• How strong is the climate-DMS feedback?
• What are potential impacts of engineered aerosol?
Aerosol Options in CAM

• Bulk Aerosol Model (BAM)
• Modal Aerosol Model (MAM)
• Community Aerosol-Radiation-Microphysics for Atmospheres (CARMA)
• LLNL Sectional Model
A Modal Aerosol Model Branch

• Coordinate MAM development efforts
• Facilitate coupling of atmosphere and surface models
• Simplify merge onto trunk
Current MAM Branch

https://svn-ccsm-models.cgd.ucar.edu/cam1/branches/aerosol/

- Updated to cesm1.2
- Prescribed aerosol option (in cesm1.2)
- Diagnostic radiation for any MAM specie (in cesm1.2)
- AeroCom diagnostics (in cesm1.2 as history_aero_optics)
- Modal optics coefficients calculations
- MAM4: primary hydrophobic carbon mode added to MAM3
- Less absorbing dust physprops file
- Improved aerosol scavenging (H. Wang GMD)
Prescribed Aerosol in CAM5: Random sampling based on log-normal distribution approach produces very similar climate to predicted aerosol.

- Case 1: Conditionally sampled approach results in **excessive Arctic low cloud** during northern summer season and large difference in TOA energy balance. This is due to high frequency of very low aerosol number and mass concentrations simulated by CAM5.

- Case 2: Random sampling approach based on log-normal frequency distribution solves the problem and produces climate very similar to fully coupled (TOA energy difference is less than 0.03 W m$^{-2}$). Computational efficiency increases by 50%. It is on the CAM5 trunk.

Yoon, Rasch & Ghan
Improved Aerosol Scavenging

H. Wang et al., GMDD, 2013
BC vertical distribution

• Convective scavenging and transport mods increase polar concentrations in lower troposphere
• Externally-mixed mode puts much more BC in the Arctic middle troposphere
4-Mode version of MAM

- **Aitken**
  - number
  - sulfate
  - secondary OM
  - sea salt

- **Accumulation**
  - number
  - sulfate
  - secondary OM
  - primary OM
  - BC
  - soil dust
  - sea salt

- **Coarse**
  - number
  - soil dust
  - sea salt
  - sulfate

- **Primary Carbon**
  - number
  - primary OM
  - BC

Coagulation and condensation

All modes log-normal with prescribed width.

Total transported aerosol tracers: **18**

Cloud-borne aerosol and aerosol water predicted but not transported.

**Computer time is ~10% higher than MAM3**
Aerosol mass burden %diff. \((\text{MAM4-MAM3})/\text{MAM3}\)
BC compared with SP2 (highlat.)
Seasonal BC at surface (highlat.)

(a) Barrow (157°W, 71°N)

(b) Alert (62°W, 83°N)

(c) Zeppelin (12°E, 79°N)

(d) Halley (26°W, 76°S)

OBS  MAM3  MAM4  MAM7
Future MAM Branch

- Prescribed aerosol option (in cesm1.3)
- Diagnostic radiation for any MAM specie (in cesm1.3)
- AeroCom diagnostics (in cesm1.3 as history_aero_optics)
- MAM4: primary hydrophobic carbon mode added to MAM3
- Less absorbing dust physprops file
- Improved aerosol scavenging (H. Wang GMDD)
- Improved dust emission size distribution (Cornell, PNNL)
- Speciation of dust: optics (Cornell) & ice nucleation (PNNL)
- More general aerosol thermodynamics (PNNL)
- Ammonium & nitrate (NCAR)
- Speciation of POM: hygroscopicity (PNNL)
- Ion-induced nucleation & subgrid homogeneous nuc (SUNY-Albany, PNNL)
- Marine organic sources (NC State, Harvard, LANL, Scripps, PNNL)
Aerosolization of film by bubble bursting.

Bubbles rest on surface; film drains, preferentially reducing non-surfactants.

Collection of surfactants on bubble surfaces by impaction, interception and diffusion, followed by adhesion/adsorption. Upward transport and deposition in SML.

Blanchard (1982)

S. Burrows, S. Elliott et al., 2013, in prep.
Chemically-resolved submicron sea spray aerosol
Dry mass fraction, February

Lipids
Proteins
Polysaccharides

Organic mass fraction vs. chl-a

S. Burrows, S. Elliott et al., 2013, in prep.
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- Marine organic sources (NC State, Harvard, LANL, Scripps, PNNL)
- Secondary organic aerosol intercomparison (MIT, NCAR, PNNL, LLNL, UM)
- Coupled fire smoke emissions (Cornell & PNNL)
- Coupled DMS emissions (LANL, ORNL, LLNL, PNNL)
- Coupling MAM to SNICAR (Flanner & PNNL)
- MAM volcanic aerosol (NCAR, PNNL)
- Geoengineering stratosphere, CCN (NCAR, PNNL)
- Frost flower sources (Scripps, LANL)
Beyond MAM

• Generalize as many aerosol processes as possible to accommodate other aerosol representations
  – Primary emissions
  – Condensation of sulfuric acid
  – Water uptake
  – Aerosol optical properties
  – Aerosol activation
  – Nucleation scavenging
  – Impaction scavenging
  – Sedimentation
  – Dry deposition
  – Impacts on snow albedo
Dust at high resolution

- Strong resolution dependence of soil erodability
- Do not use
  - inputdata/atm/cam/dst/dst_0.9x1.25_c100121.nc
  - inputdata/atm/cam/dst/dst_0.47x0.63_c100121.nc
  - inputdata/atm/cam/dst/dst_0.23x0.31_c100121.nc