CESM1.0/WACCM4 with CARMA3.0 Microphysics

Michael Mills
Charles Bardeen
CAM/CARMA (C. Bardeen)

**CAM**
- Sectional Microphysics
- Fortran 90
- Embeddable
- Shared with NASA Goddard

**CAM/CARMA**
- Clouds & Aerosols
- Integrated with RRTMG
- Shared with U. of Colorado
- CAM Optional Component

**Projects**
- Sea Salt (Fan)
- Dust (Su)
- Sulfates (Mills, English, Neely)
- Black Carbon (Mills, Smith)
- PSC (Zhu)
- Early Earth Haze (Wolf)
- Meteor Smoke (Bardeen)
- PMC (Bardeen)
- Cirrus (Bardeen)
- Meteor Impact (Bardeen, Mills, Garcia)
CARMA3.0: New Features

**CAM/CARMA**
- Radiatively active particles via RRTMG
- Diagnostic & prognostic particles
- Dry deposition integration
- Updated CAM wet deposition code
- OPEN/MP and hybrid modes
- Same result independent of decomposition and restarts
- Cloud (before coupling) & aerosol (after coupling) CARMA models
- Detrainment of cloud condensate to CARMA

**CARMA**
- Initialize CARMA every timestep or once against a reference temperature profile
- Multiple CARMA models in the same source tree
- 1-Dimensional
- Thread safe
- Mass and energy conserving within strict CAM requirements
- Substep retry mechanism for more efficient nucleation & growth
- Brownian diffusion
100 x 15-kt weapons detonated in India & Pakistan

Urban firestorms loft 5 Tg black carbon (BC) smoke into upper troposphere after initial rainout

CESM1/WACCM4-CARMA at 1.9° lat x 2.5° lon resolution

BC initialized at uniform mmr, 150-300 hPa in 50 columns on May 15, 2012

One BC bin, added to CAM namelist rad_climate section as prognostic aerosol with defined BC optical properties

Deposition passed to surface models

Control run: CMIP5 RCP4.5
Ozone Loss Mechanisms

1. smoke rises to the top of the stratosphere producing stronger and longer-lasting heating
2. two temperature-sensitive ozone loss reactions accelerate (Chapman and NO\textsubscript{x})
3. the rise of the smoke plume perturbs N\textsubscript{2}O, which leads to enhanced NO\textsubscript{x} production
4. radiative effects reduce the stratospheric circulation, so smoke and NO\textsubscript{x} stays in the stratosphere longer
Globally Averaged Anomalies

Surface Temperature

GISS ModelE (Robock)
WACCM4 (This Study)

Precipitation

SW Flux at the Surface
Clear Sky
All Sky
This heating induces vertical motions and the aerosols in the model layers that correspond to the upper troposphere (300–150 mb).

In the case investigated here, results in more solar heating than in previous nuclear winter scenarios, which considered aerosols (Turco et al., 1983) or used older-generation climate models with limited vertical resolution and low model tops limited to wars that occur in spring and summer, as previously found (Robock, 1984; Covey et al., 1984; Schneider et al., 2006) also accounts for black carbon particles, which have an effective radius of 0.1 µm at visible wavelengths (Tsigaridas et al., 2006; Turco et al., 1979; Thompson, 1988).
UV Indices, June, including BC attenuation
cloud-free conditions (J. Lee-Taylor)

Normal Ozone
- London: 6
- Washington: 10

Post-war Ozone
- London: 13
- Washington: 16

Post-war Ozone with BC attenuation
- London: 11
- Washington: 14

- Post-war Ozone with BC attenuation
- London: 10
- Washington: 13
Land model: BC deposition (5 Tg - control)
Land ice model: total ice content change (mm)

GC_ICE1 [mm], 01Mar2014 00:00
CARMA3.0: Known Issues

- Full initialization (rather than to reference temperature) can be very slow, particularly for coagulation.
- PPM advection code has noisy sedimentation when using hybrid coordinates.
- PPM advection code does not return fluxes out the top and bottom of the column, so a kludge was added to get flux out the bottom as a column difference.
- Standard fall velocity routine has odd kinks in areas where it transitions between different Reynolds regimes.
- Standard shape fall velocity routine is not handling all shapes and aspect ratios correctly.
- Growth code was not mass or energy conserving, so rlheat and gc are recalculated based upon condensed mass change.
- Wet radius is not used in coagulation, only in sedimentation.
- Particle swelling doesn’t work with fixed initialization.
- WACCM gives very high temperatures, outside the range of Murphy & Koop [2005] (123 K < T < 332 K). Should you ignore this, limit to some value, print warning message, …?
CAM/CARMA: Known Issues

- Wet deposition is being tested, and some configuration parameters for wet deposition are not currently configurable at the CARMAGROUP level.
- Core mass is sometimes larger than total mass. This can happen from parent model advection, but perhaps there are also other causes.
- WACCM/CARMA has been built (Mac, Bluefire, & Pleiades) and is in the process of being tested.
- WACCM is not yet validated with RRTMG. WACCM/CARMA has been built with CAMRT, but CARMA radiative code won’t support radiatively active particles with CAMRT.
- CAM can be slow to compile with ifort (shr_scam.F90 ~45 min, cldwat2m_micro.F90 ~10 min).