CESM1.0/WACCM4 with CARMA3.0 Microphysics

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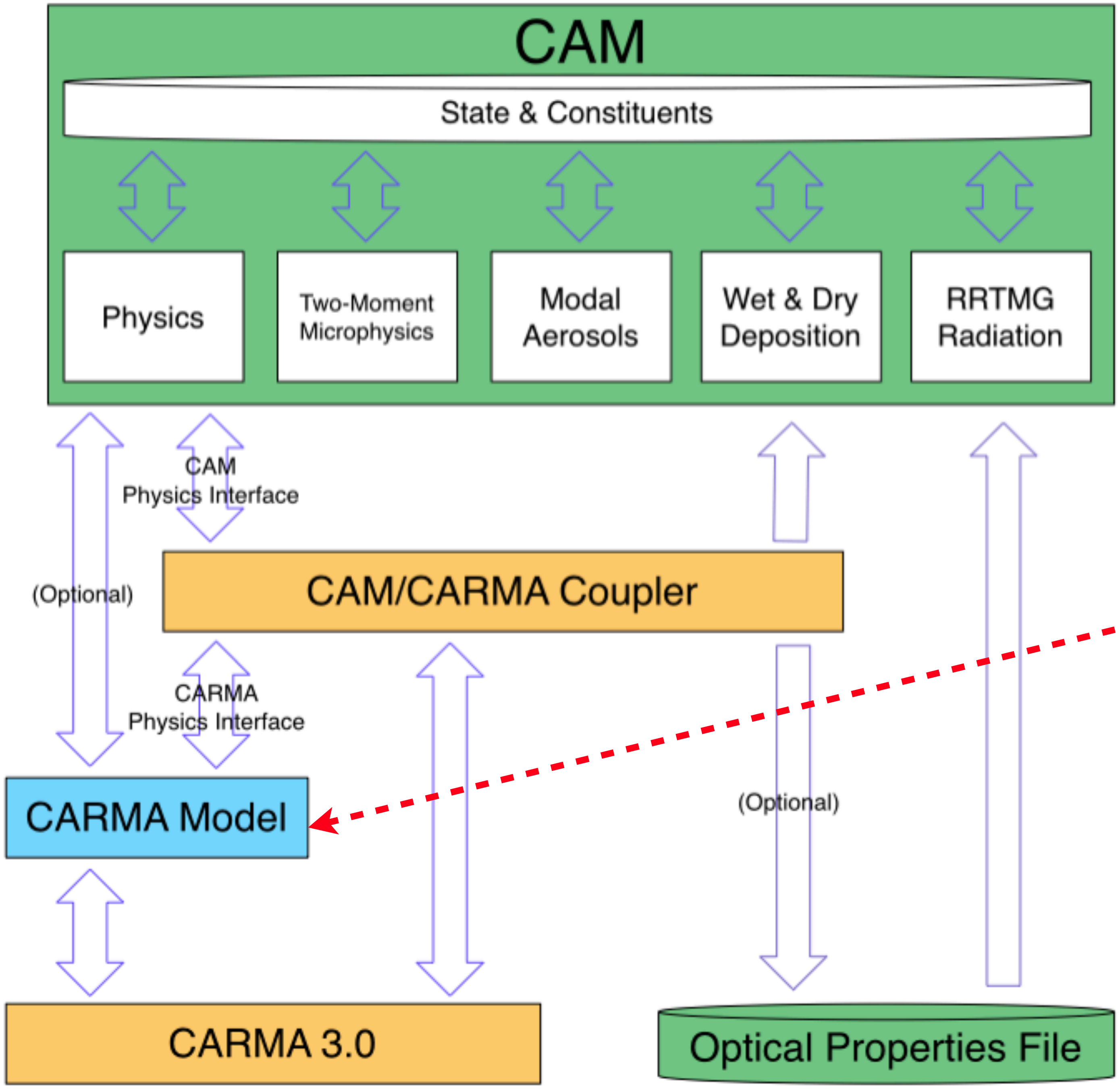
Charles Bardeen

CAM/CARMA (C. Bardeen)



CARMA

- 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)

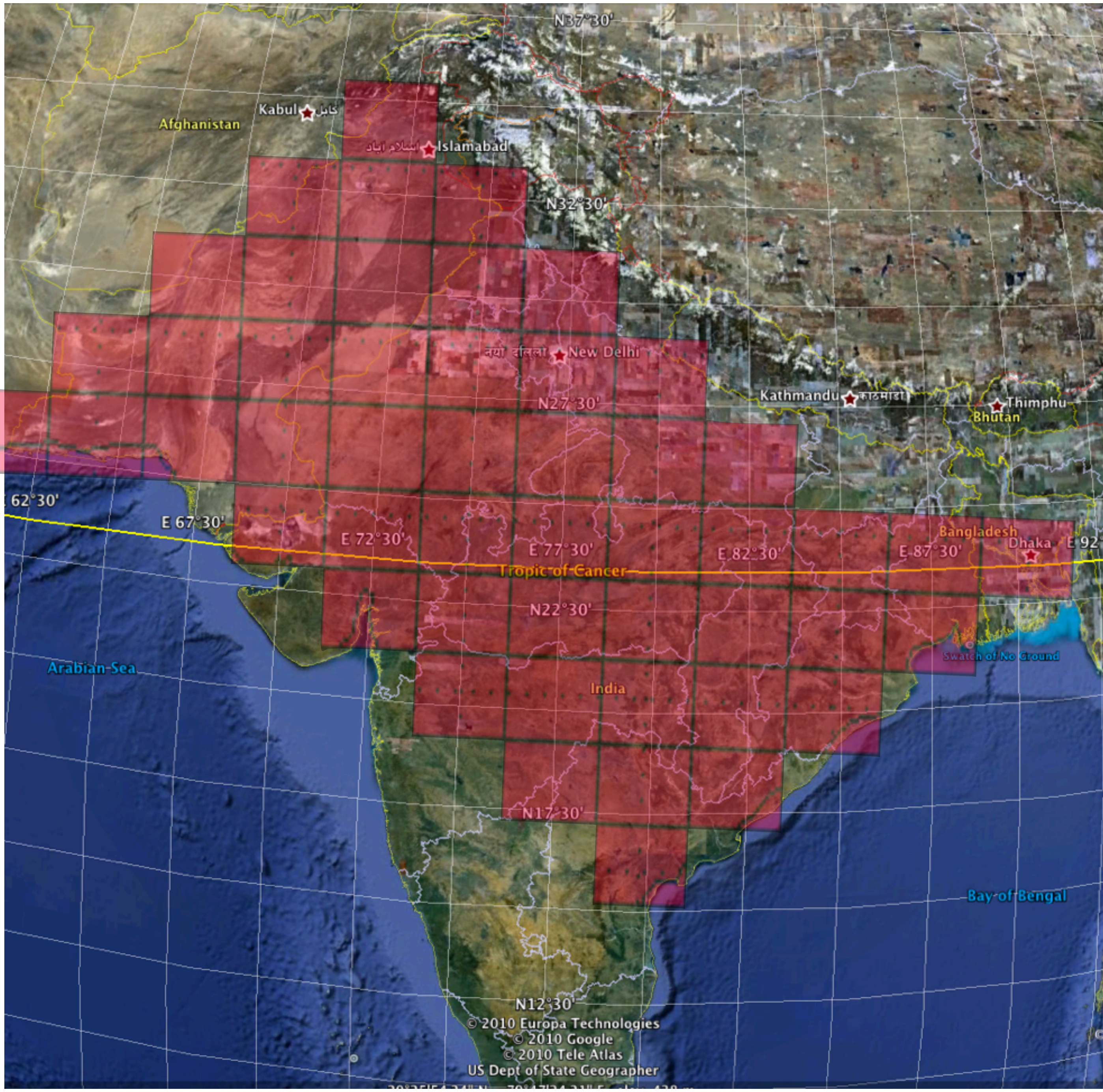
CARMA3.0: New Features

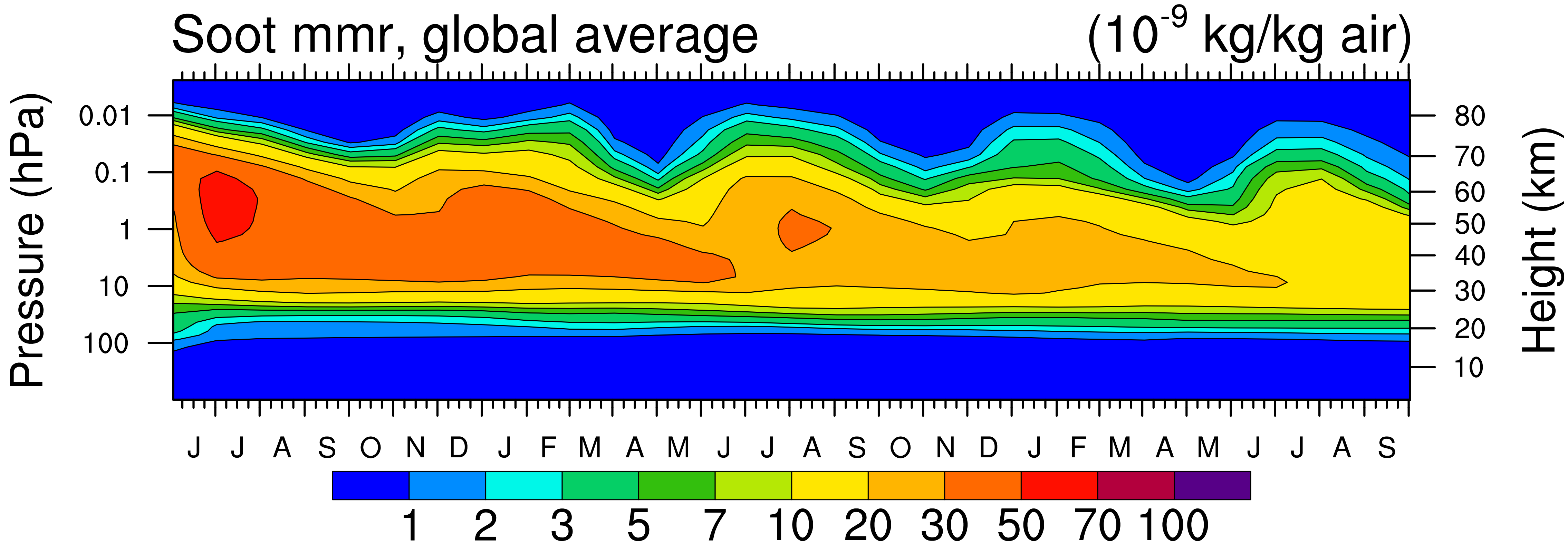
New! Improved!

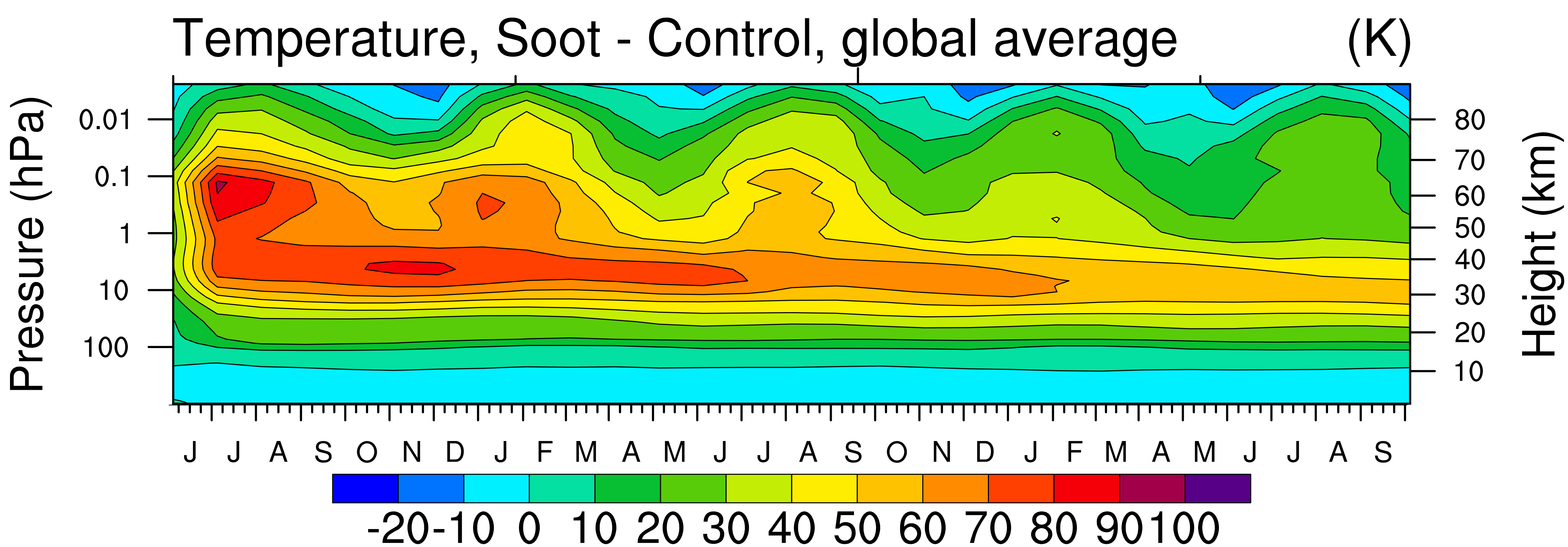
- CAM/CARMA
  - Radiatively active particles via RRTMG
  - Diagnostic & prognostic particles
  - Dry deposition integration
  - Updated CAM wet deposition code
  - OPEN/MP and hybrid modes
  - Same result independent of decomposition and restarts
  - Cloud (before coupling) & aerosol (after coupling) CARMA models
  - Detrainment of cloud condensate to CARMA
  - Initialize CARMA every timestep or once against a reference temperature profile
  - Multiple CARMA models in the same source tree
- CARMA
  - 1-Dimensional
  - Thread safe
  - Mass and energy conserving within strict CAM requirements
  - Substep retry mechanism for more efficient nucleation & growth
  - Brownian diffusion

Regional Nuclear War Simulation

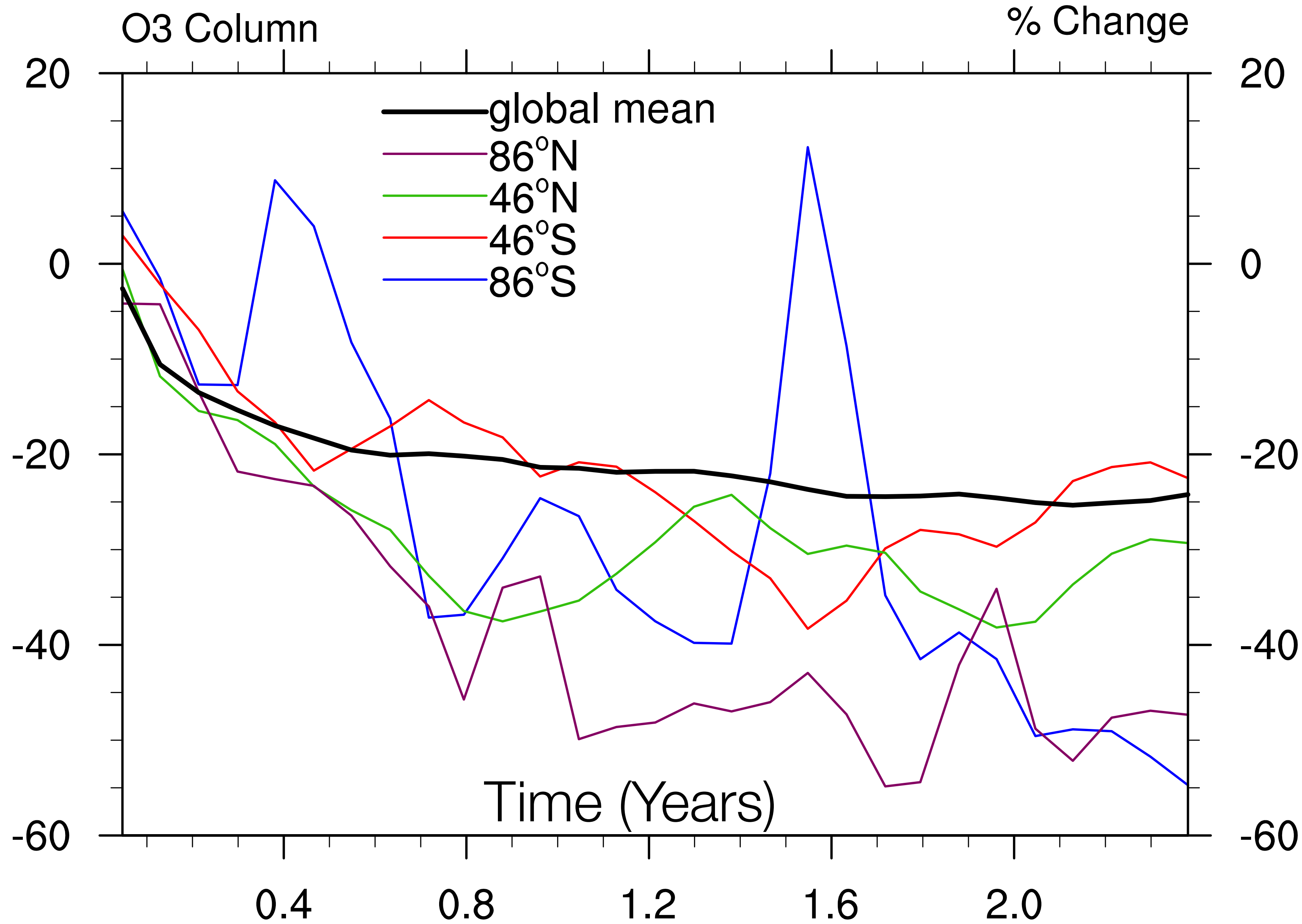
- 100 x 15-kt weapons detonated in India & Pakistan
- Urban firestorms loft 5 Tg black carbon (BC) smoke into upper troposphere after initial rainout
- CESM1/WACCM4-CARMA at 1.9° lat x 2.5° lon resolution
- BC initialized at uniform mmr, 150-300 hPa in 50 columns on May 15, 2012
- One BC bin, added to CAM namelist rad_climate section as prognostic aerosol with defined BC optical properties
- Deposition passed to surface models
- Control run: CMIP5 RCP4.5




Soot mmr, global average
(10^{-9} kg/kg air)
Pressure (hPa)
0.01
0.1
1
10
100
Height (km)
80
70
60
50
40
30
20
10
J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1 2 3 5 7 10 20 30 50 70 100

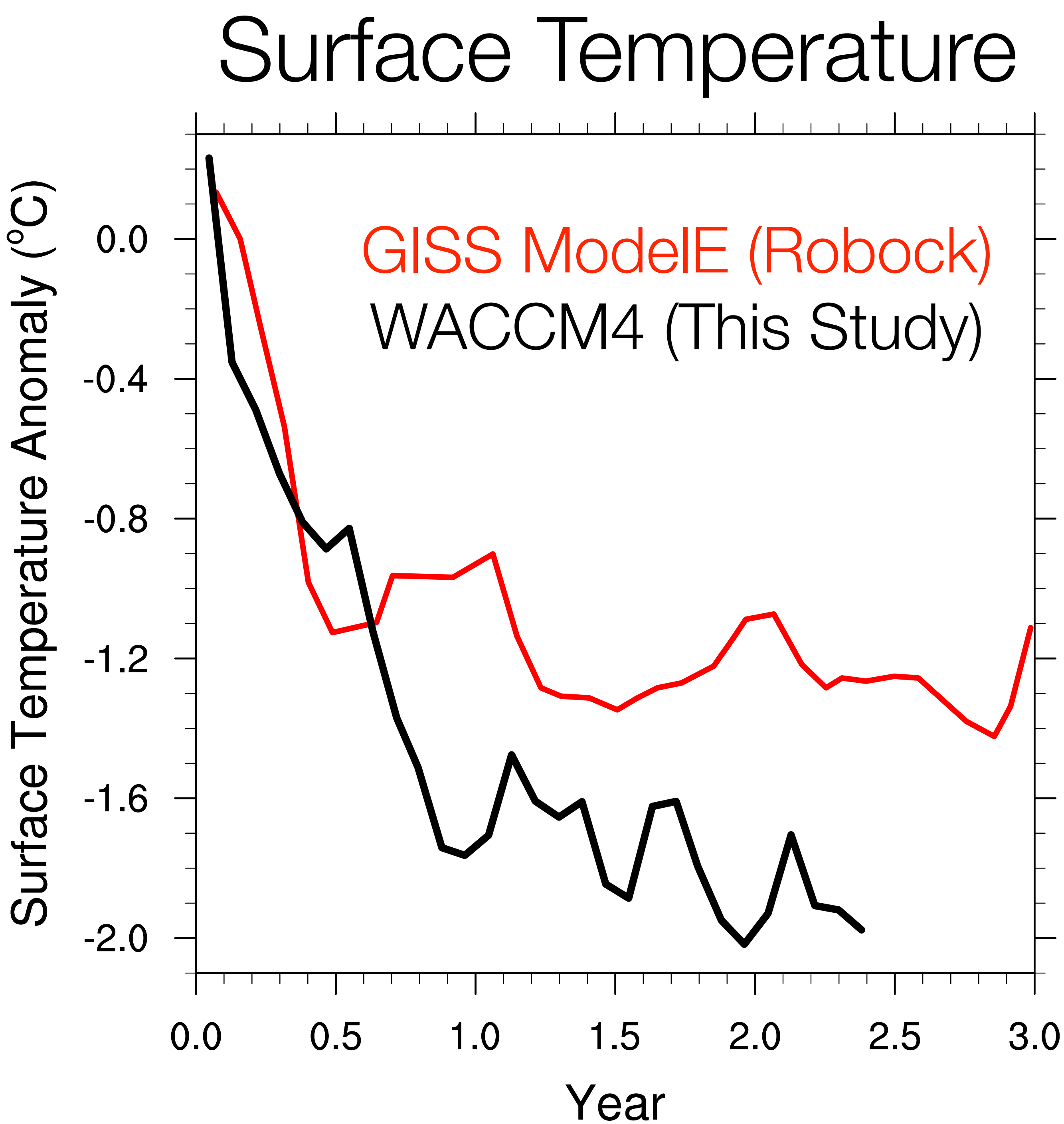

Temperature, Soot - Control, global average
(K)
Pressure (hPa)
0.01
0.1
1
10
100
Height (km)
80
70
60
50
40
30
20
10
J J A S O N D J F M A M J J A S O N D J F M A M J J A S
-20 -10 0 10 20 30 40 50 60 70 80 90 100

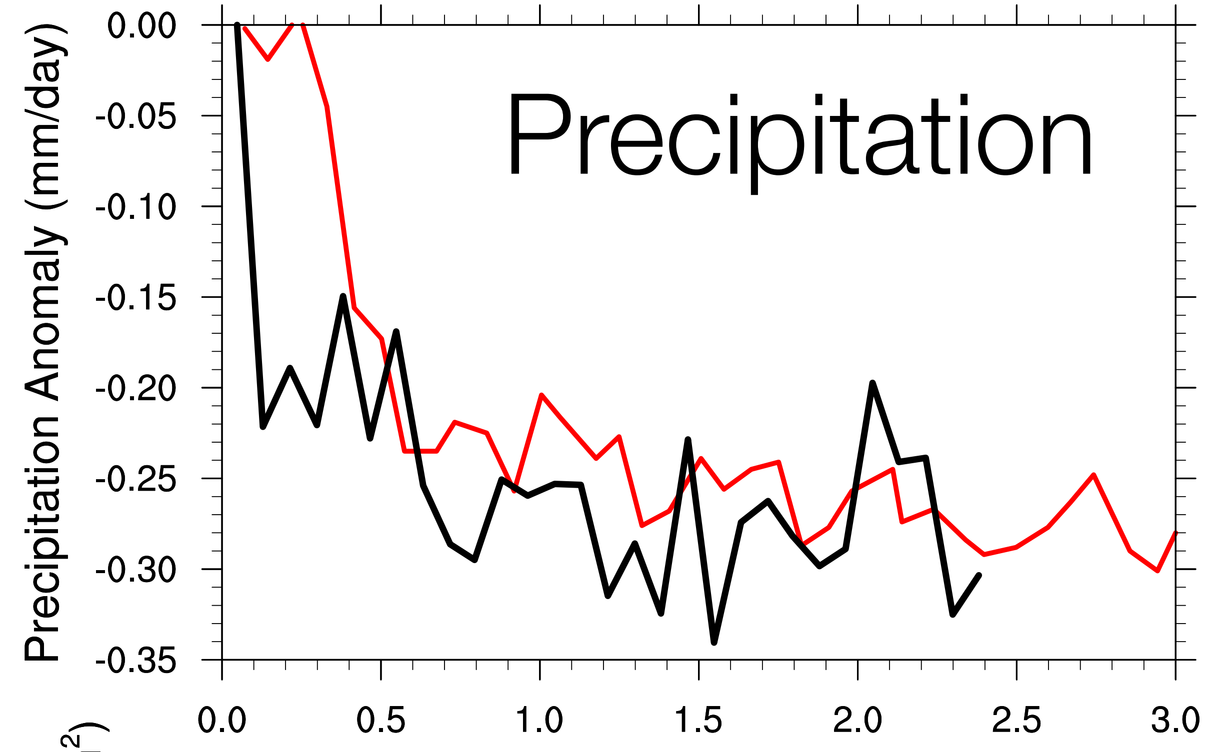
Ozone Loss Mechanisms

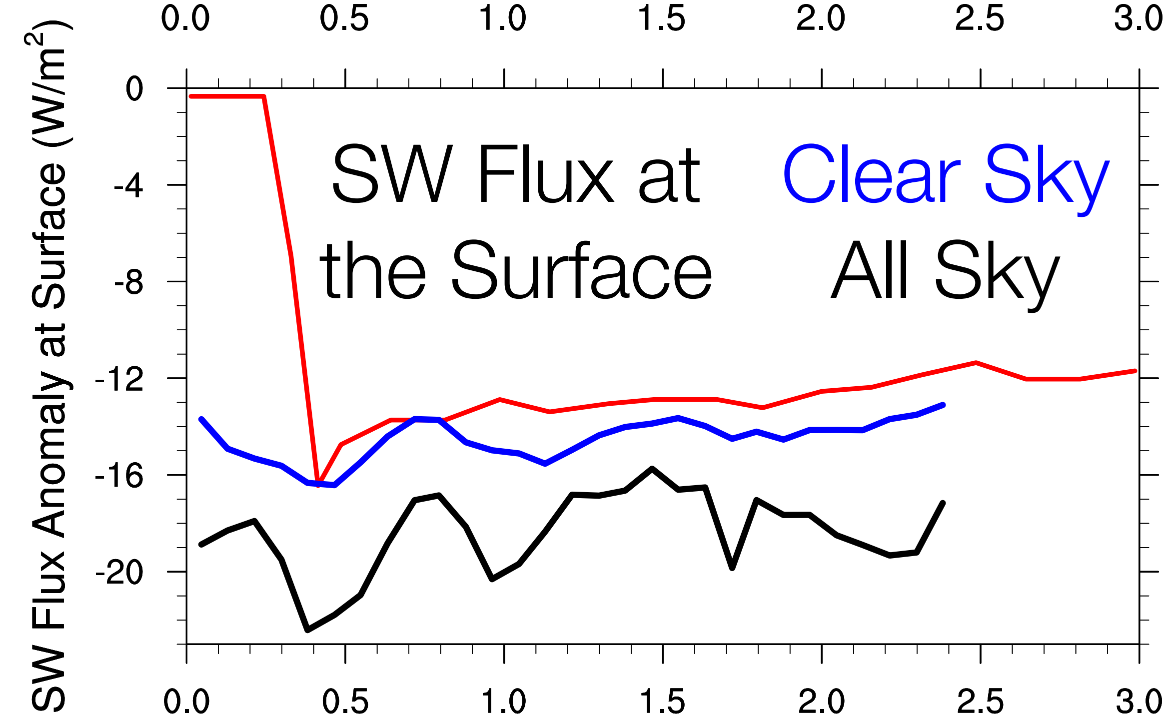


1. smoke rises to the top of the stratosphere producing stronger and longer-lasting heating
2. two temperature-sensitive ozone loss reactions accelerate (Chapman and NO_x)
3. the rise of the smoke plume perturbs N_2O, which leads to enhanced NO_x production
4. radiative effects reduce the stratospheric circulation, so smoke and NOx stays in the stratosphere longer

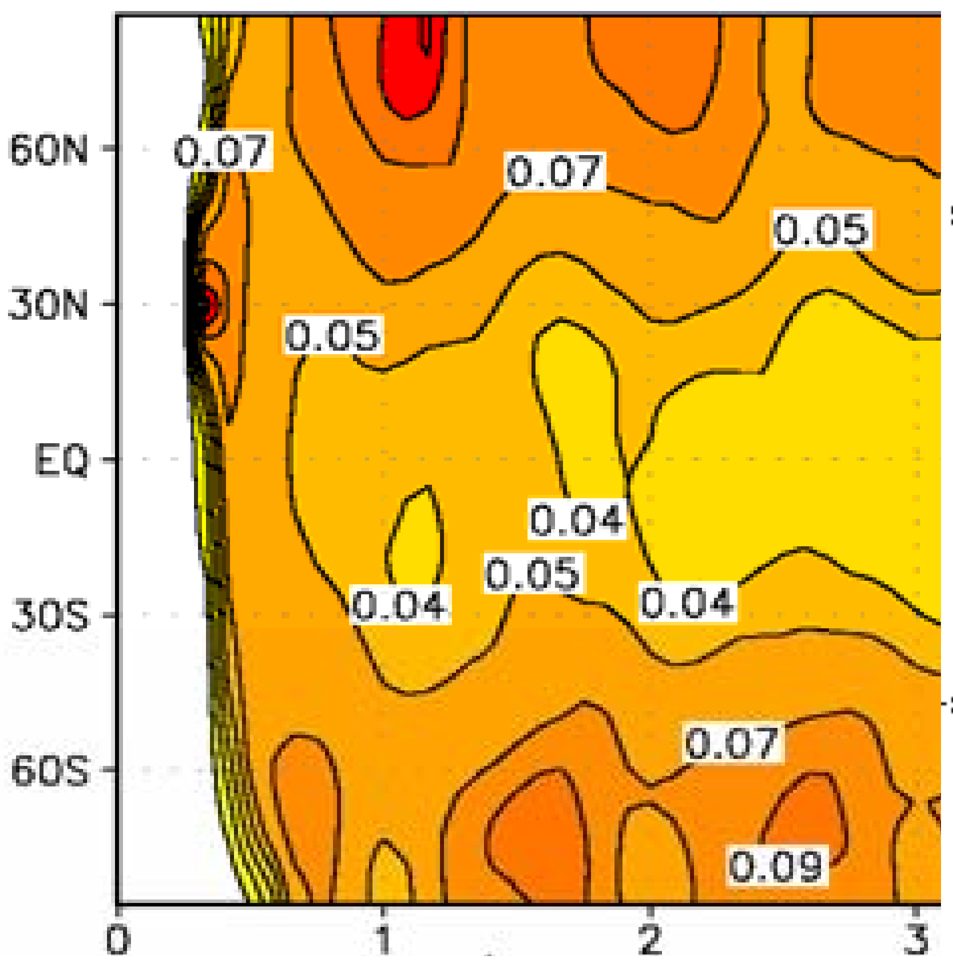
Globally Averaged Anomalies



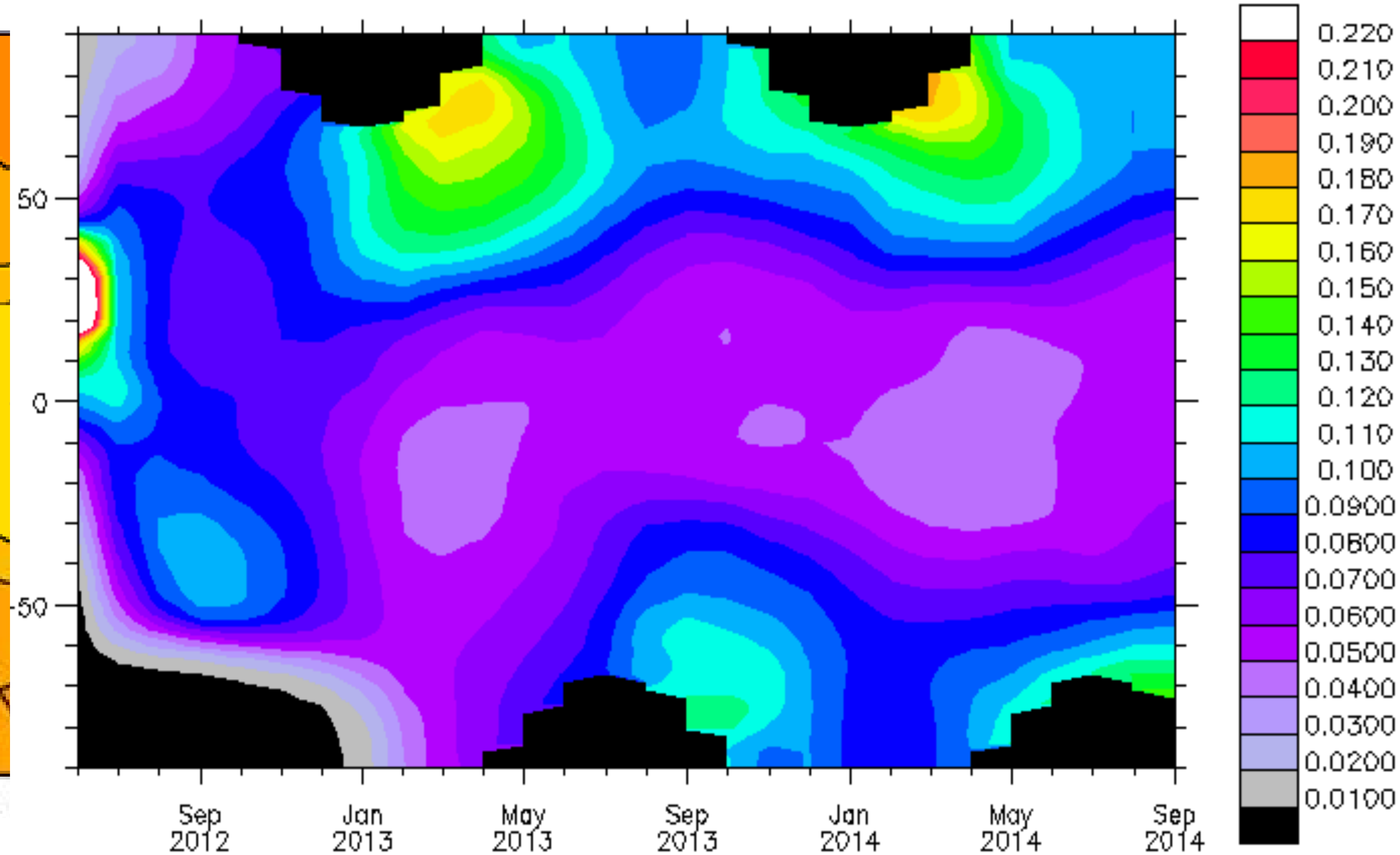




Column-integrated optical depths



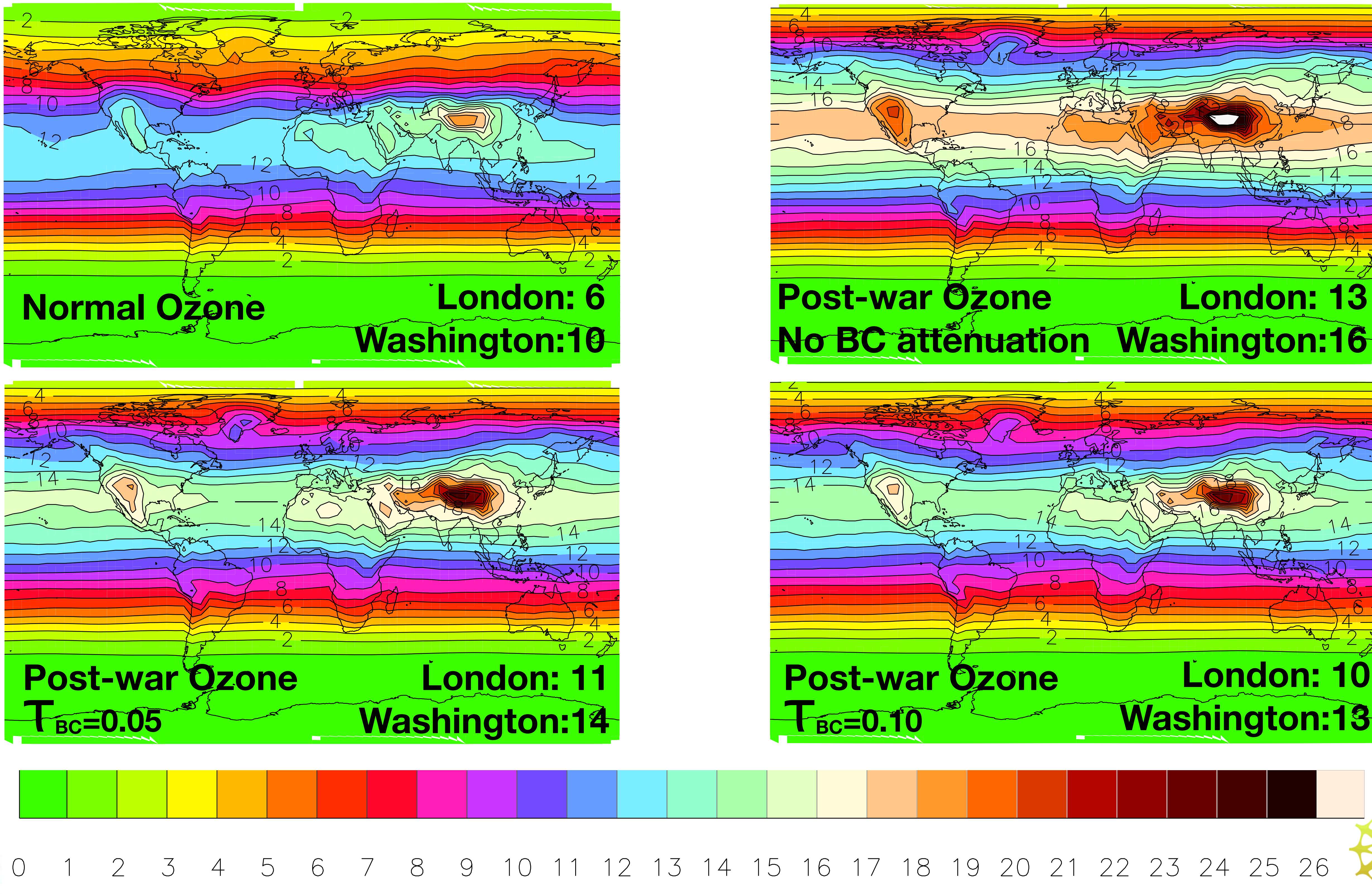
GISS ModelE (Robock *et al.*, ACP, 2007)



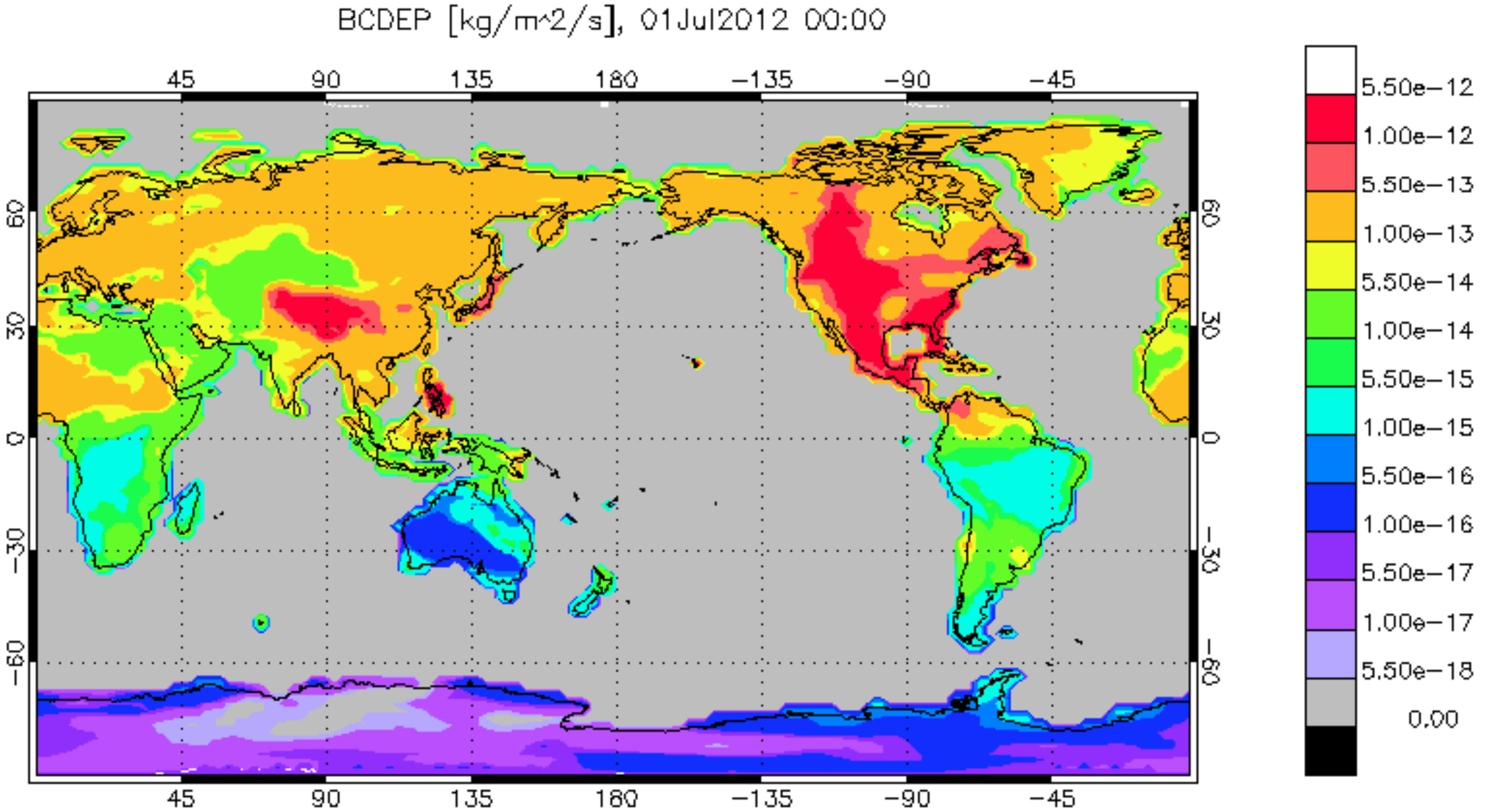
CESM/WACCM

UV Indices, June, including BC attenuation

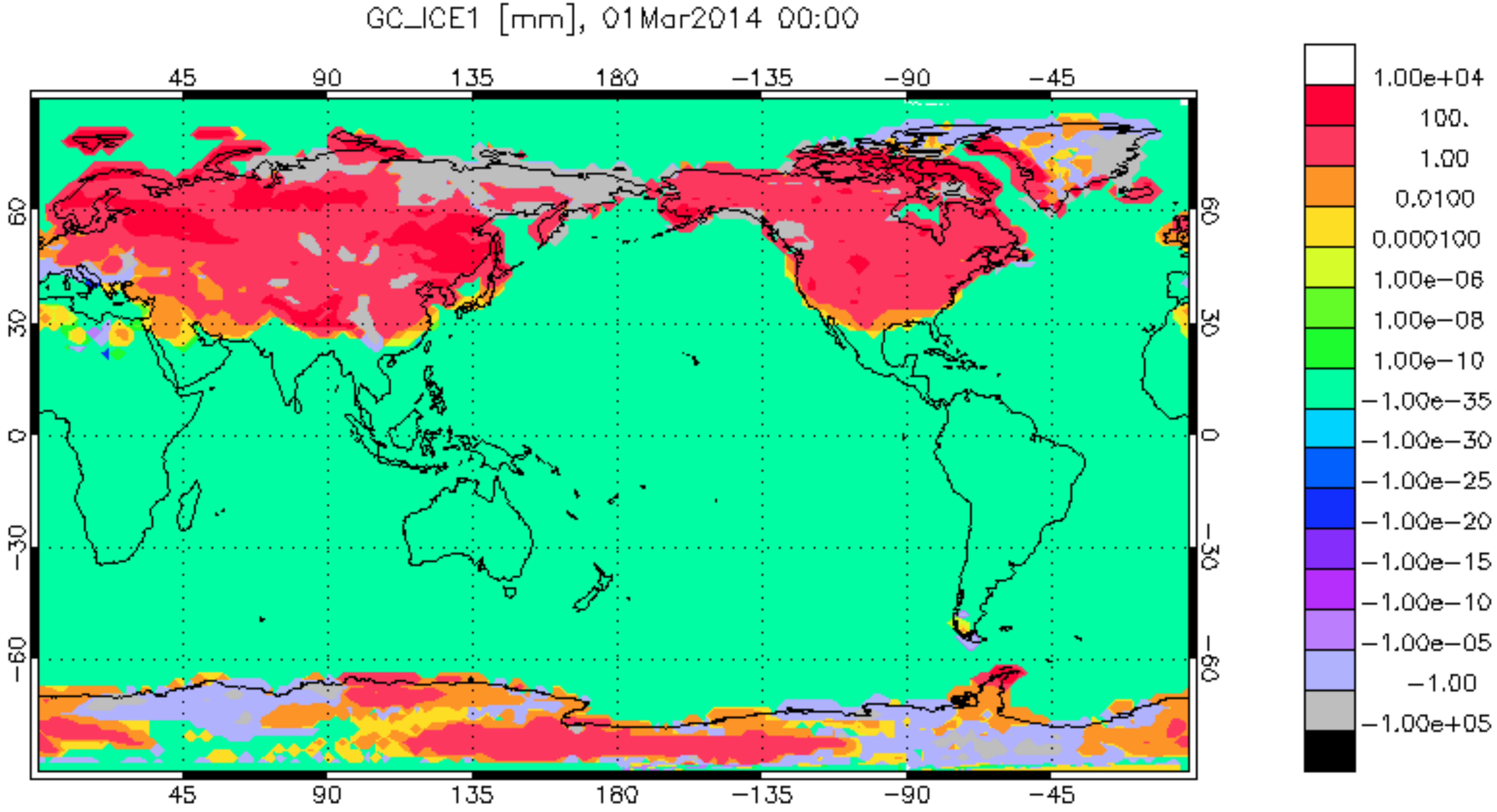
cloud-free conditions (J. Lee-Taylor)



Land model: BC deposition (5 Tg - control)



Land ice model: total ice content change (mm)



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).