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Aerosol Model Development Update

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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 is the role of anthropogenic pollutants on the formation of secondary-organic aerosols?
- 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

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

Aerosol Branch

- Coordinate MAM development efforts
- New aerosol process representations can be used/shared by different aerosol models
- Facilitate coupling of atmosphere and surface models
- Simplify merging onto trunk

Current 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 (going offline)
- MAM4: primary hydrophobic carbon mode added to MAM3
- Less absorbing dust physprops file
- Improved aerosol scavenging (Wang et al., 2013, GMD)

Prescribed MAM

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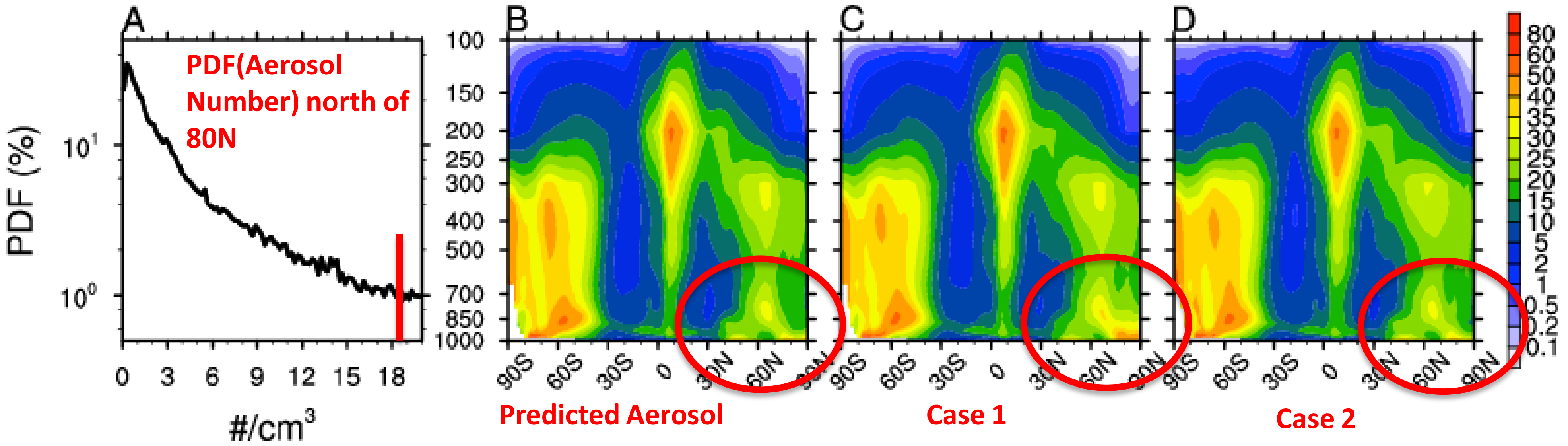

- Simple approach (prescribing monthly mean aerosol fields) leads to **excessive Arctic low cloud** during northern summer season and large difference in TOA energy balance. This is due to high frequency of very low aerosol number and mass concentrations simulated by CAM5.
- Random sampling approach based on log-normal frequency distribution reduces this bias. Computational efficiency increases by 50%.
- Current status: Testing and refining the method for different resolutions and different dycore.

MAM4

- With MAM3, CAM5 under-estimates carbonaceous aerosols at high-latitudes by 2-3 orders of magnitude, which can lead to under-estimation of snow melting in the Arctic.

- MAM4 (4-mode) includes the primary carbon mode (same as MAM7). The total number of tracers increases from 25 to 28.

- Computational cost is about 6% higher: 314 vs. 297 (PE hrs/sim yr).

- Improves carbonaceous aerosol simulations; very little effect on other aerosols

Convective transport and scavenging parameterization

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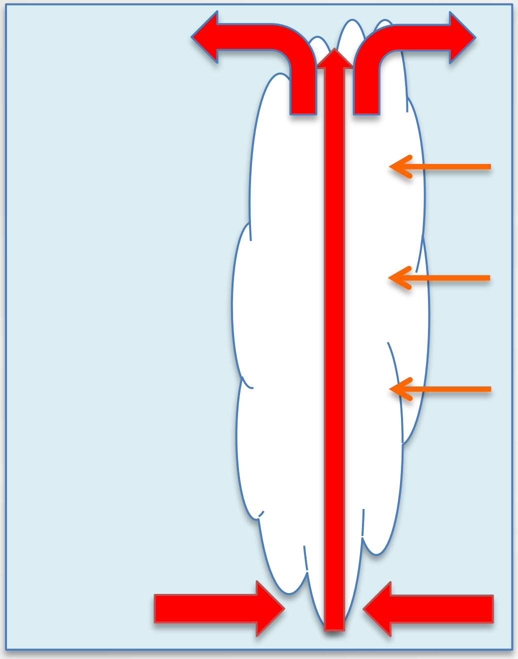
- Based on Wang et al. (2013), we include (1) inconsistency fix, and (2) unified treatment of convective transport and wet removal parameterization.



- Activate/remove only within updraft (temporary array holds conv cloud-borne aerosols)
- Secondary activation is considered
- Detrained aerosols in the upper troposphere
- All aerosol species are affected
- We have done (1) MAM4, (2) ConvTranScav, (3) MAM4+ConvTranScav simulations for both 1 deg and 2 deg resolution

MAM4 only

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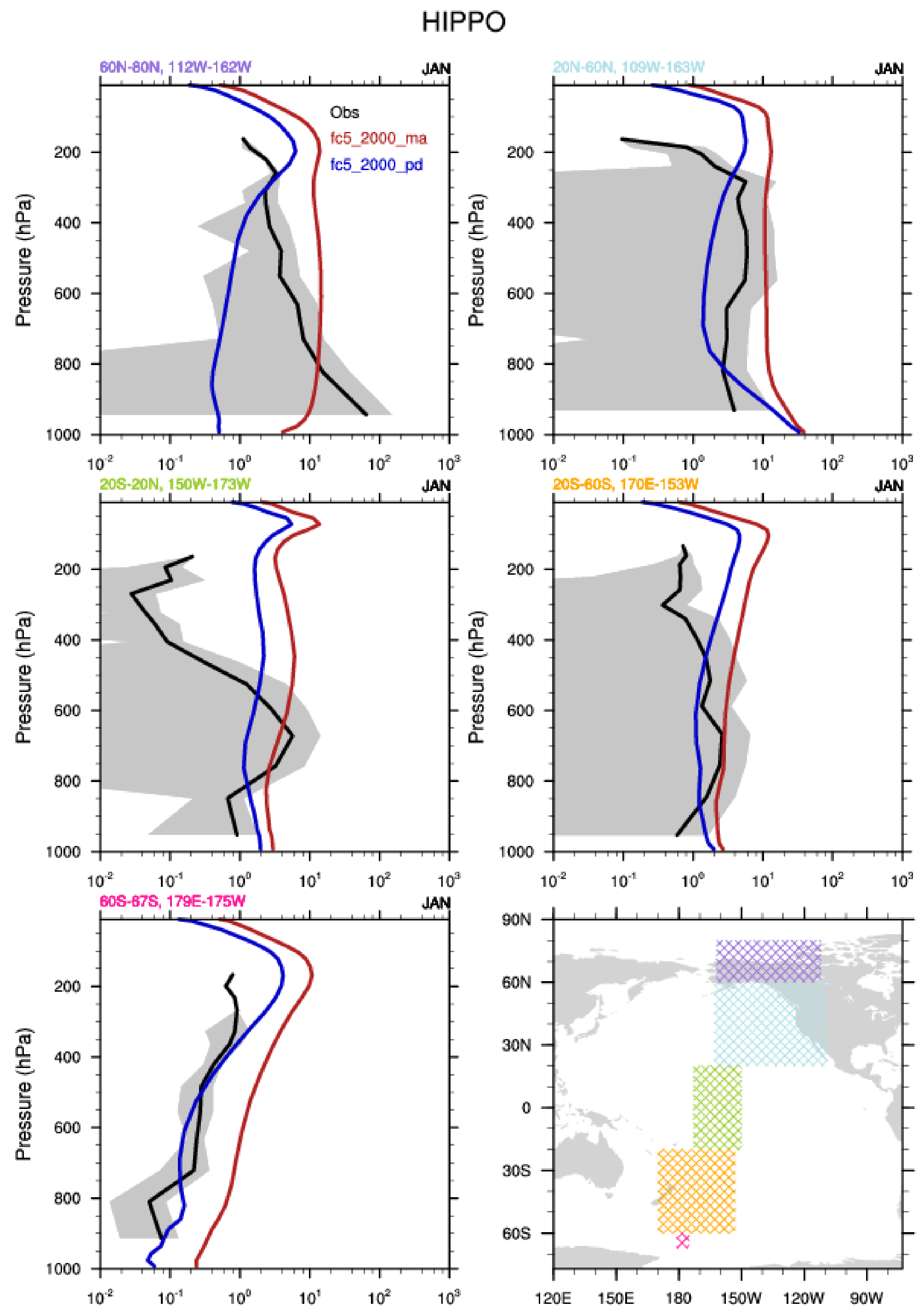
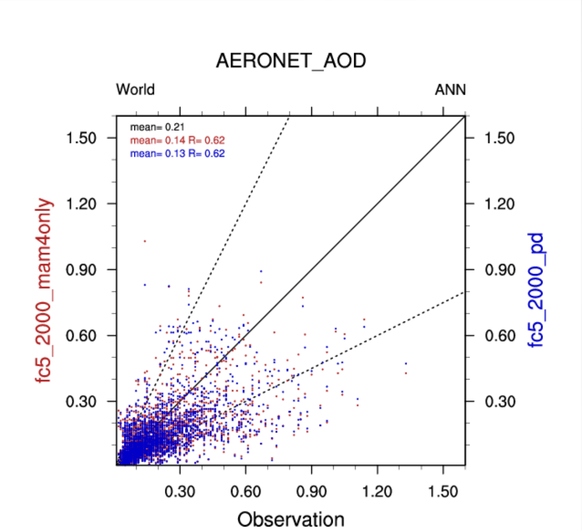
BC

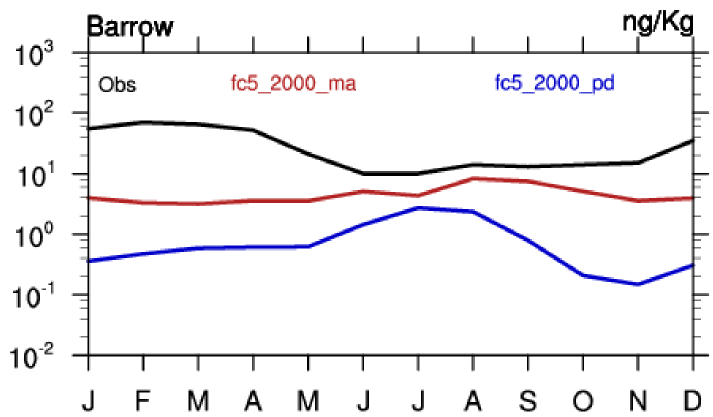
	fc5_2000_ma	fc5_2000_pd	difference	rel diff(%)
Sources (Tg/yr)	7.767	7.767	-0.000	-0.000
emission	7.767	7.767	-0.000	-0.000
Sinks (Tg/yr)	7.748	7.747	0.001	0.007
dry_dep	1.628	1.290	0.338	20.754
wet_dep	6.120	6.457	-0.337	-5.513
Lifetime (days)	5.651	3.921	1.730	30.614
Burden (Tg)	0.120	0.083	0.037	30.618
accumulation	0.081	0.083	-0.002	-2.529
primary_carbon	0.039	-999.000	-999.000	-999.000

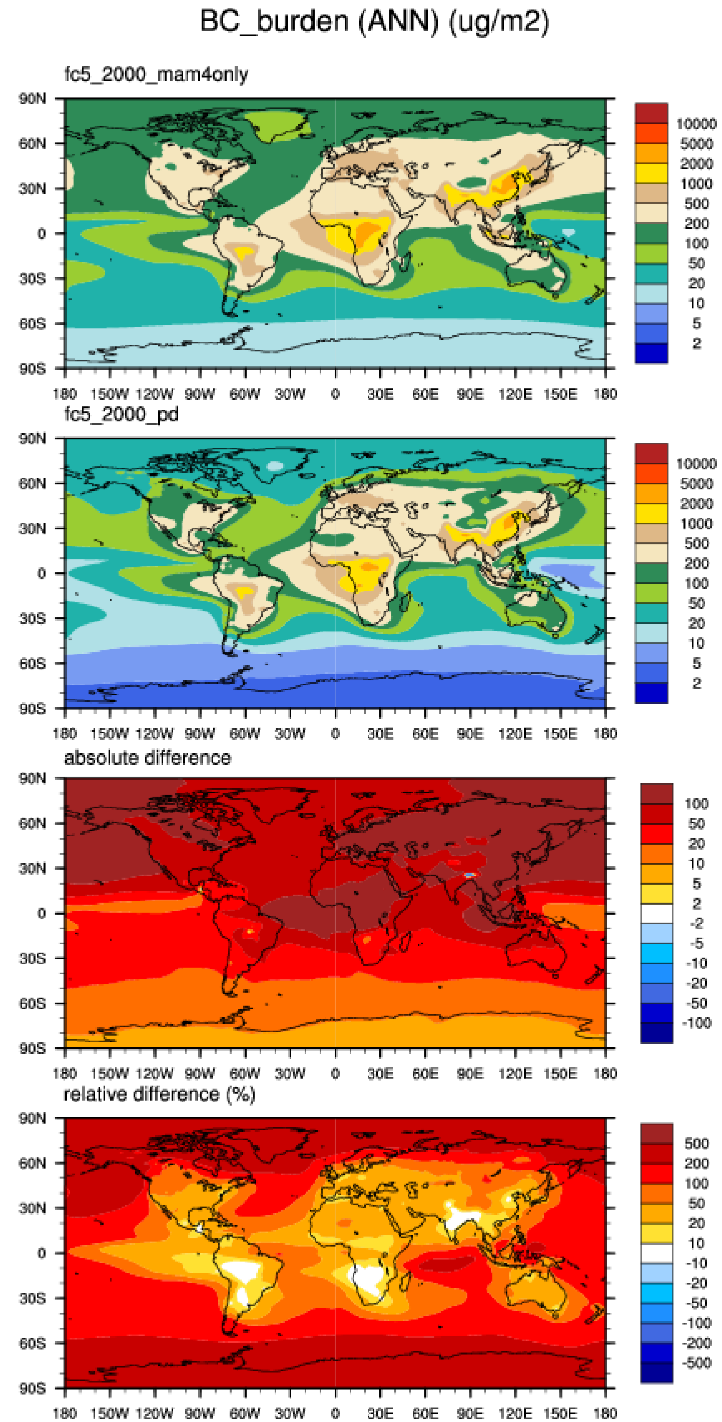
BC vertical profile



MAM4 aerosol results





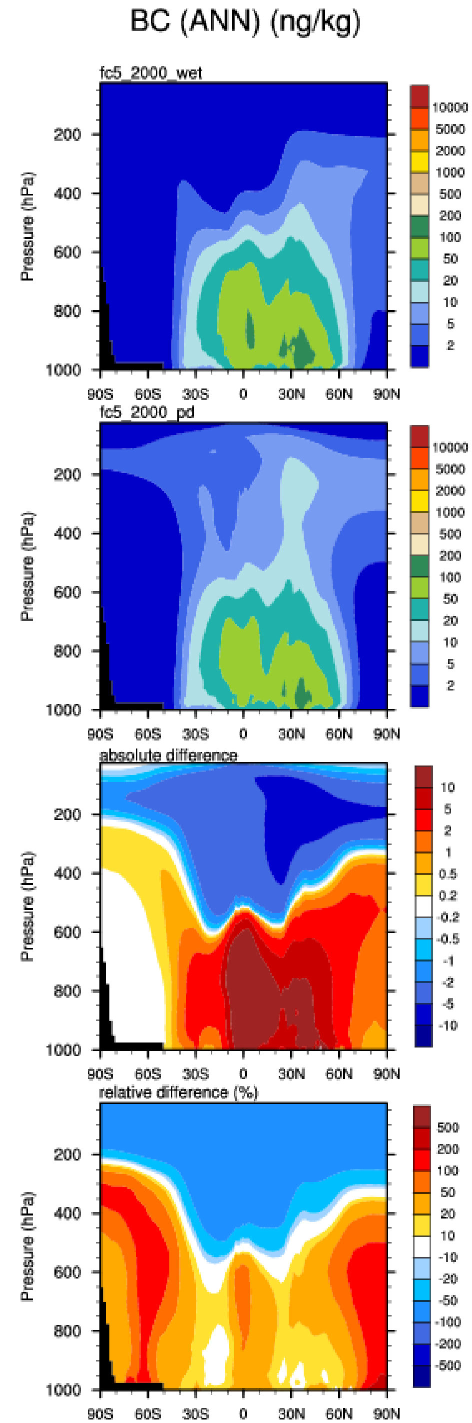


ConvTranScav

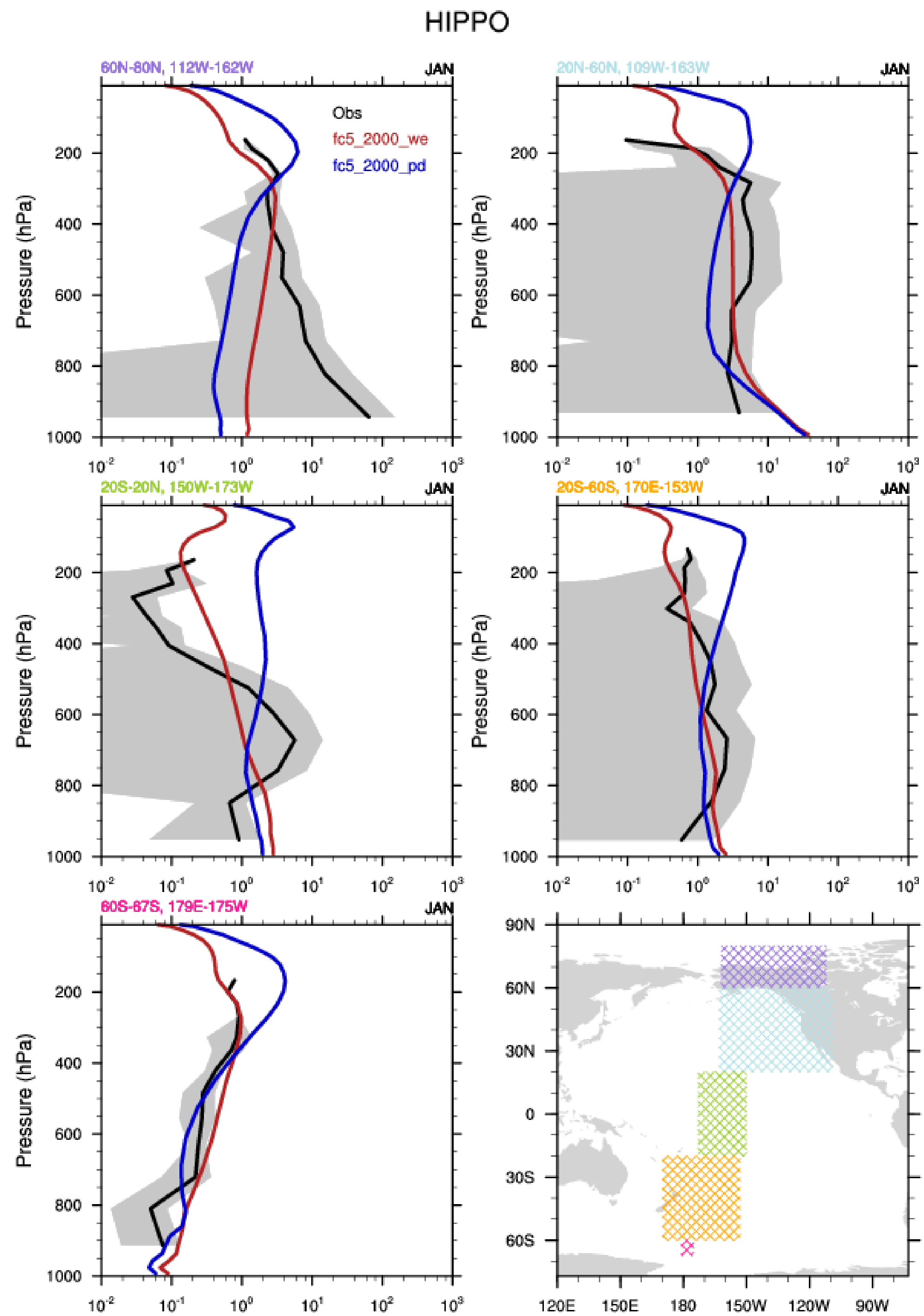
BC

	fc5_2000_we	fc5_2000_pd	difference	rel diff(%)
Sources (Tg/yr)	7.767	7.767	0.000	0.000
emission	7.767	7.767	0.000	0.000
Sinks (Tg/yr)	7.727	7.747	-0.021	-0.267
dry_dep	1.312	1.290	0.022	1.689
wet_dep	6.414	6.457	-0.043	-0.667
Lifetime (days)	4.282	3.921	0.361	8.424
Burden (Tg)	0.091	0.083	0.007	8.180
accumulation	0.091	0.083	0.007	8.180
primary_carbon	-999.000	-999.000	-999.000	-999.000

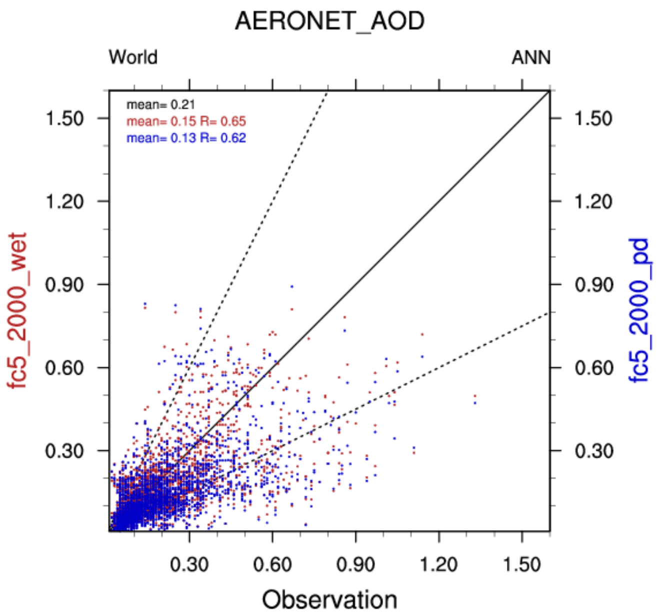
ConvTranScav

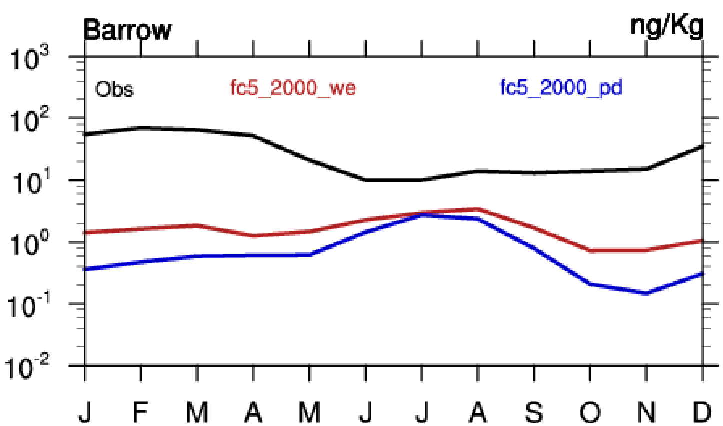


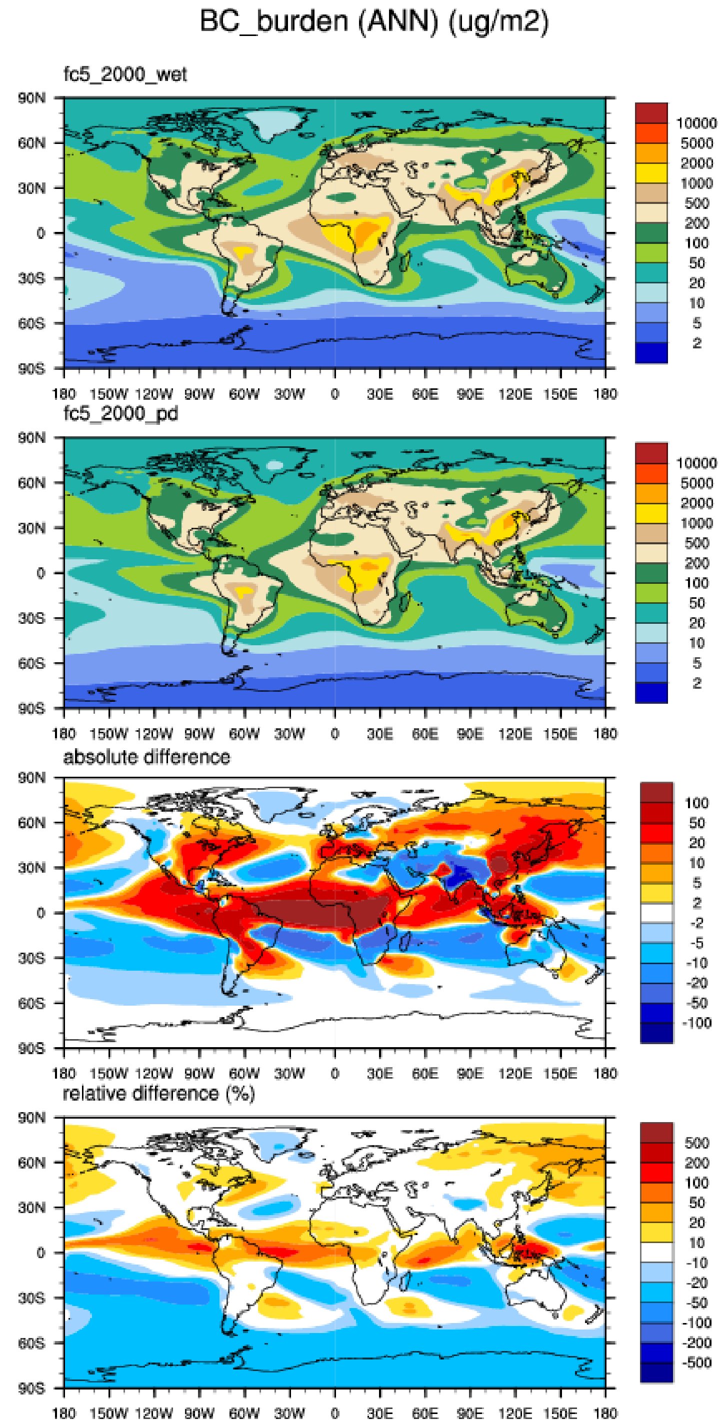
ConvTranScav



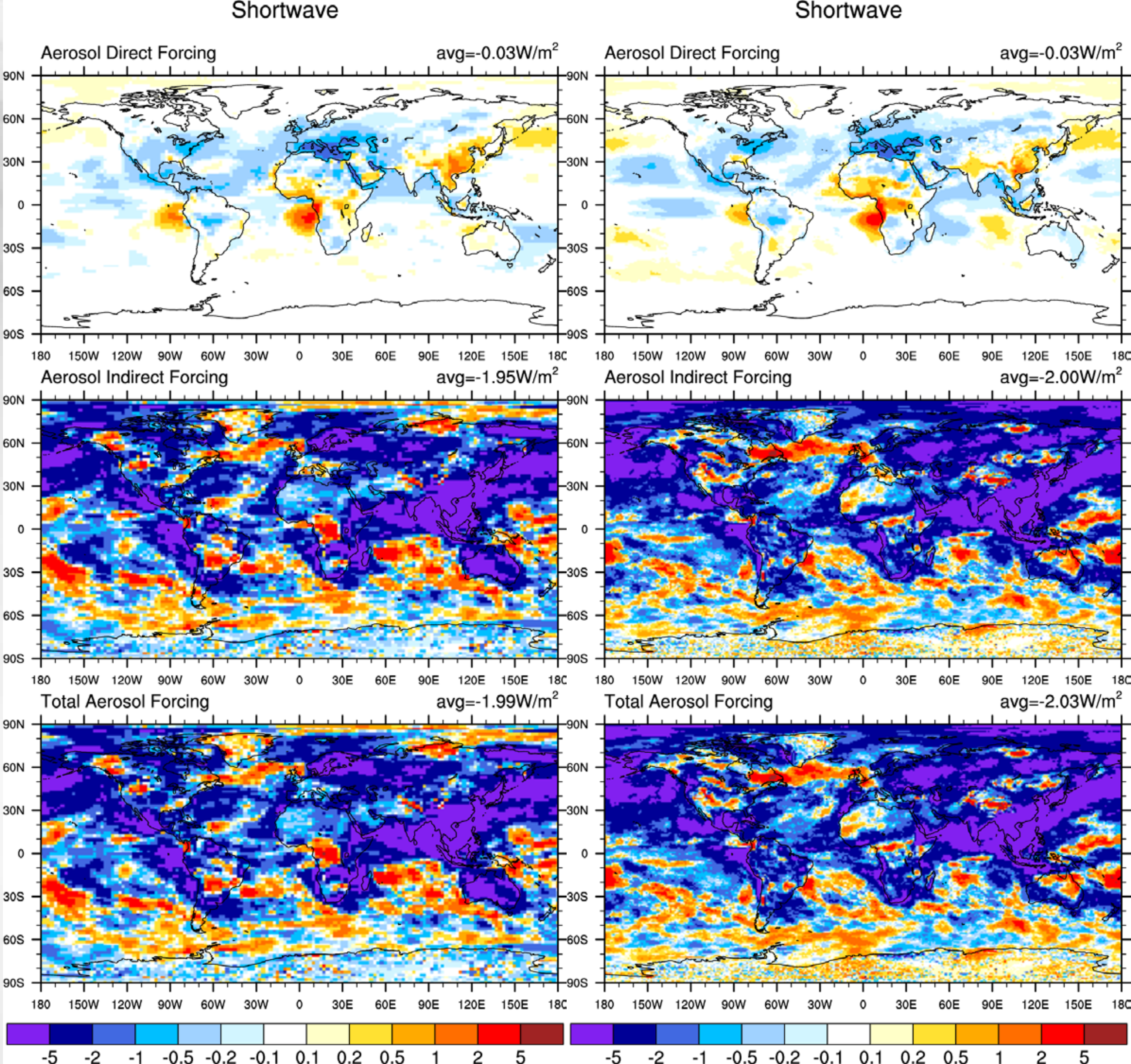
ConvTranScav



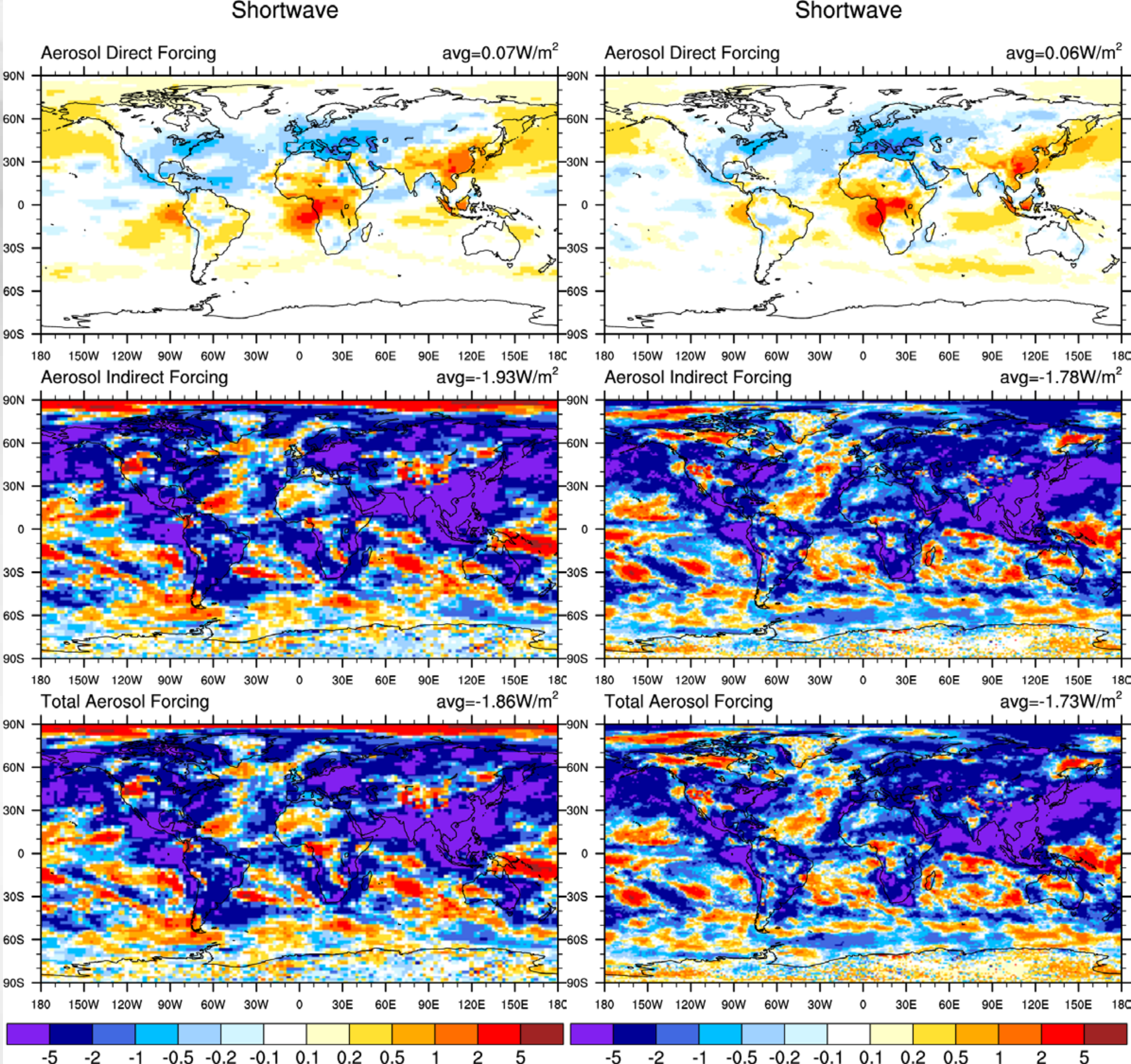




CAM5.3

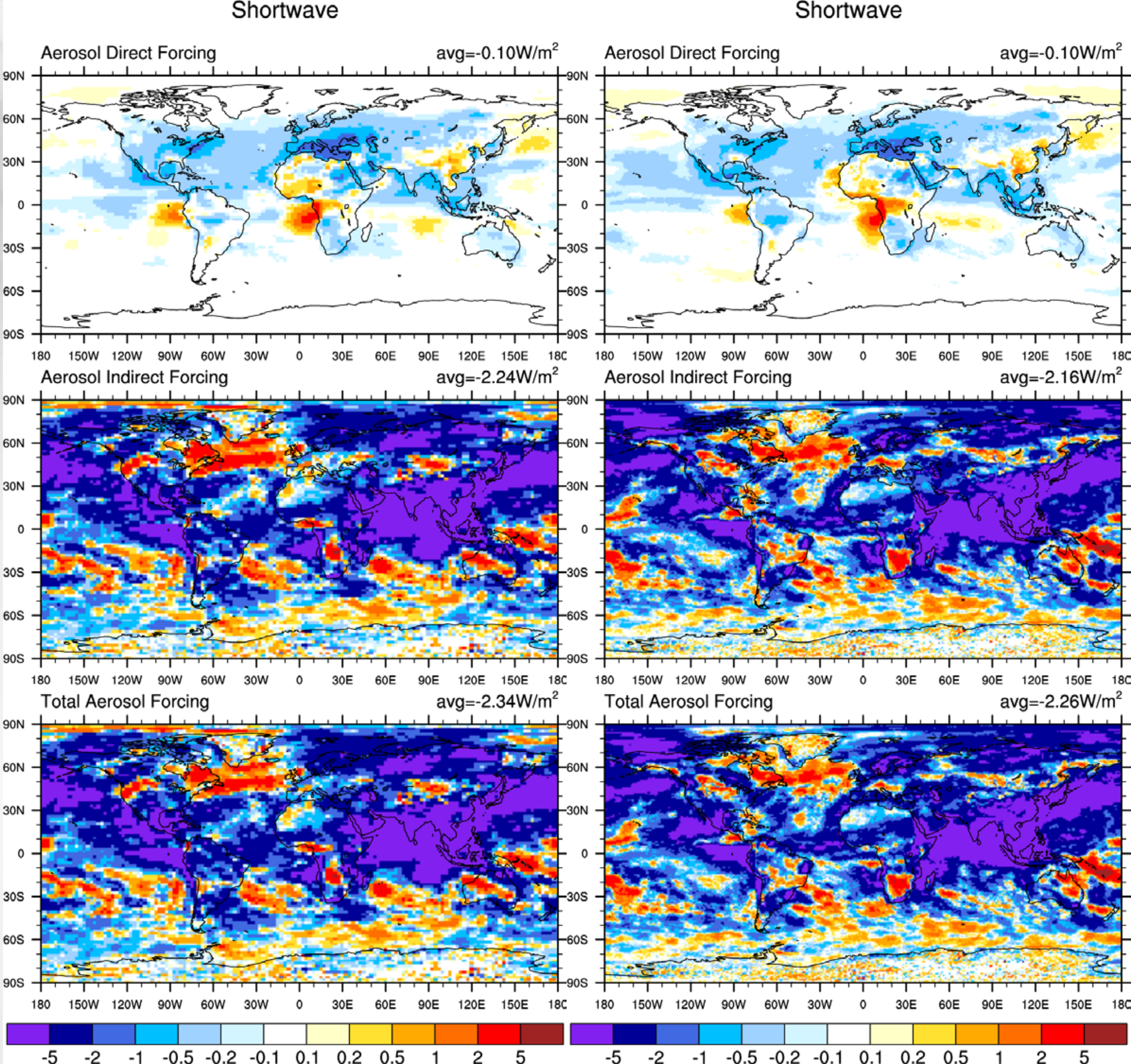

Shortwave
Shortwave
Aerosol Direct Forcing
avg=-0.03W/m2
Aerosol Direct Forcing
avg=-0.03W/m2
Aerosol Indirect Forcing
avg=-1.95W/m2
Aerosol Indirect Forcing
avg=-2.00W/m2
Total Aerosol Forcing
avg=-1.99W/m2
Total Aerosol Forcing
avg=-2.03W/m2
90N 60N 30N 0 30S 60S 90S
180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180
-5 -2 -1 -0.5 -0.2 -0.1 0.1 0.2 0.5 1 2 5

CAM5.3 + MAM4

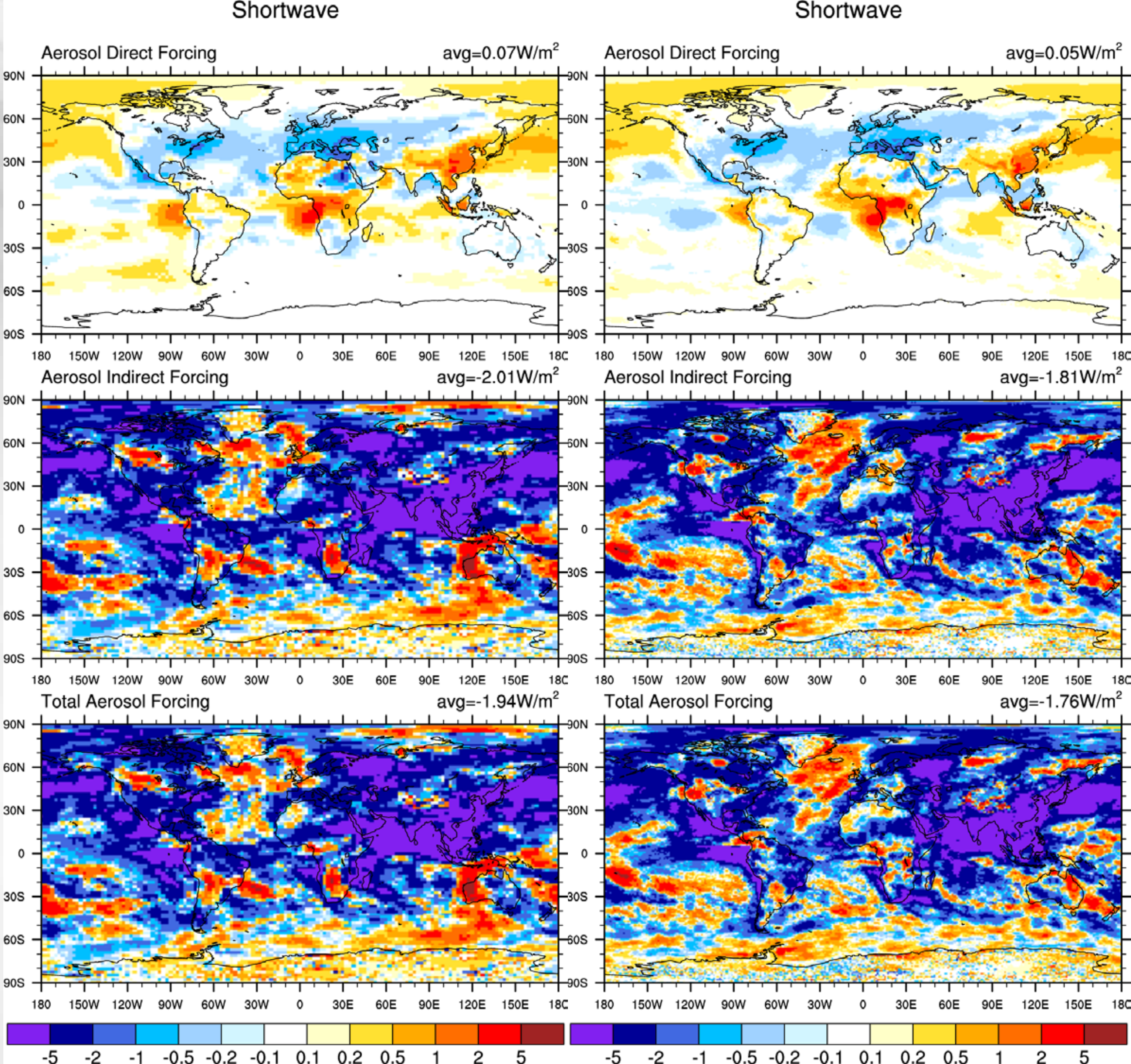


Shortwave
Shortwave
Aerosol Direct Forcing
avg=0.07W/m2
Aerosol Direct Forcing
avg=0.06W/m2
Aerosol Indirect Forcing
avg=-1.93W/m2
Aerosol Indirect Forcing
avg=-1.78W/m2
Total Aerosol Forcing
avg=-1.86W/m2
Total Aerosol Forcing
avg=-1.73W/m2
90N 60N 30N 0 30S 60S 90S
180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180
-5 -2 -1 -0.5 -0.2 -0.1 0.1 0.2 0.5 1 2 5

CAM5.3
+ ConvTranScav



CAM5.3
+ MAM4
+ ConvTranScav



Efforts to improve aerosol simulation

- 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 (PNNL, Wyoming)
- Less absorbing dust physprops file
- Unified treatment of convective transport and scavenging (PNNL)
- Resolution dependence of aerosol simulation (PNNL)
- Improved dust emission size distribution (Cornell, PNNL, Wyoming)
- Speciation of dust: optics (Cornell) & ice nucleation (Wyoming)
- 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)
- Secondary organic aerosol intercomparison (MIT, NCAR, PNNL, LLNL, UM)
- Coupled fire smoke emissions (NCAR & 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)