

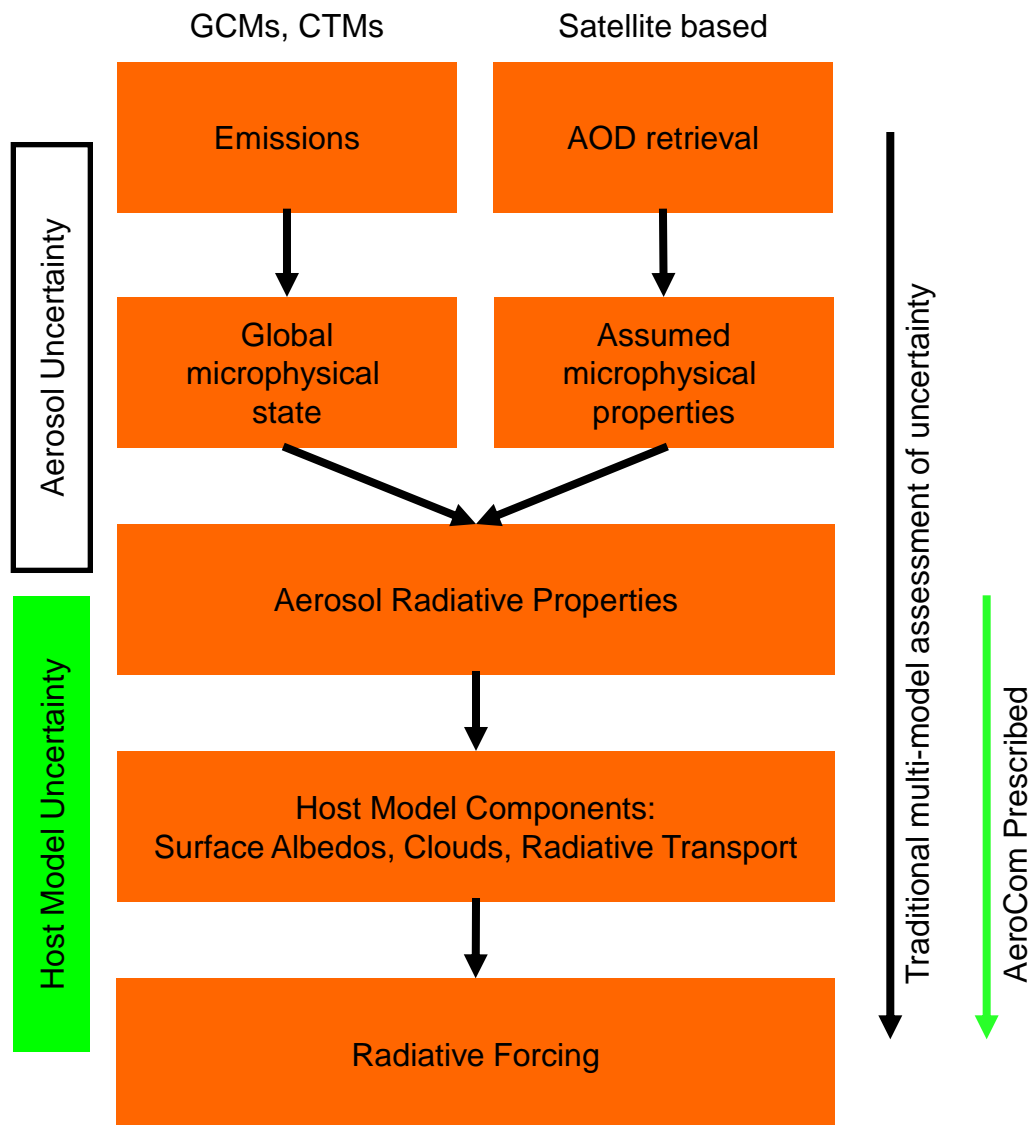
Host Model Uncertainties in Aerosol Radiative Forcing Estimates:
Results from the AeroCom Prescribed Intercomparison Study

AeroCom Meeting
University of Washington / PNNL
2012

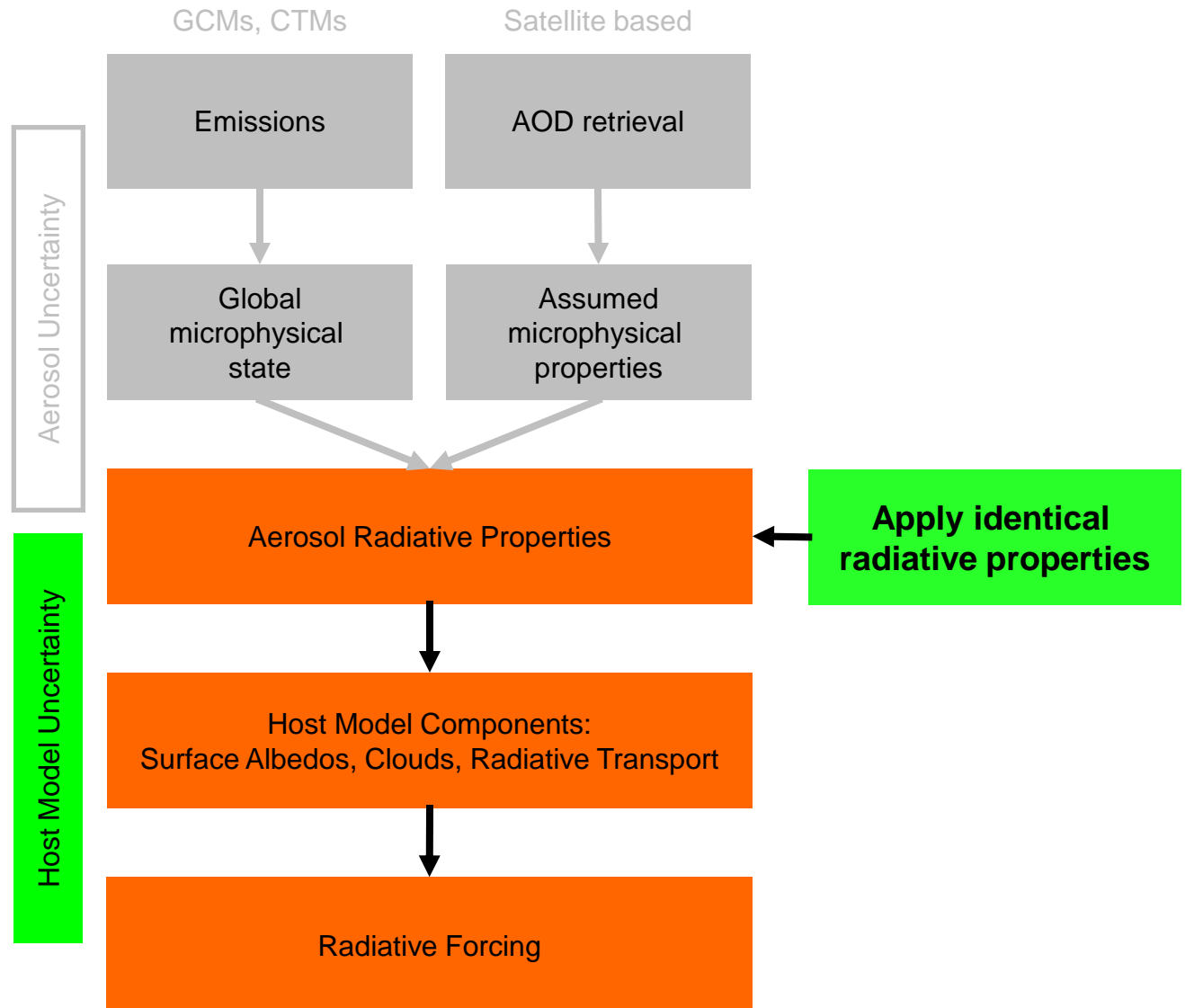
Philip Stier, Nick A. J. Schutgens, Huisheng Bian, Olivier Boucher,
Mian Chin, Steven Ghan, Nicolas Huneeus, Stefan Kinne, Guangxing
Lin, Gunnar Myhre, Joyce E. Penner, Cynthia Randles, Bjørn Samset,
Michael Schulz, Hongbin Yu, and Cheng Zhou



Assessment of aerosol direct radiative forcing



AeroCom Prescribed



Setup of AeroCom Prescribed

Prescribe aerosol radiative properties identically in all “models”

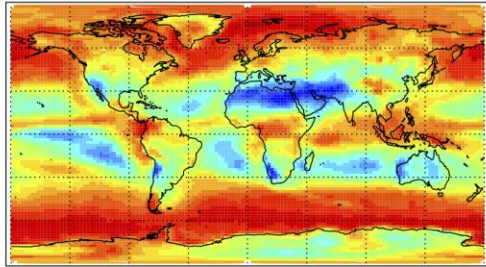
Name	Parameters	Comment
FIX0	AOD=0.0 SSA= n/a ANG=n/a ASY= n/a	<i>specified at 550 nm</i>
FIX2	AOD=0.2 SSA= 1.0 ANG=1.0 ASY=0.7	<i>Linear by height over lowest 2km Purely scattering case Used for spectral dependence of AOD at other solar wavelengths λ Solar-spectrally invariant forward scattering</i>
FIX3	AOD=0.2 SSA=0.8 ANG = 1.0 ASY=0.7	<i>Linear by height over lowest 2km Absorbing case Used for spectral dependence of AOD at other solar wavelengths λ Solar-spectrally invariant forward scattering</i>
FIX1	AOD _{PD} =0.132 SSA _{PD} = 0.963 AOD _{PI} =0.092 SSA _{PI} = 0.978	<i>Present-day (PD) at 545 nm AOD weighted mean Pre-industrial (PI) AOD weighted mean Monthly 3D distribution early release of Kinne et al. (2012)</i>



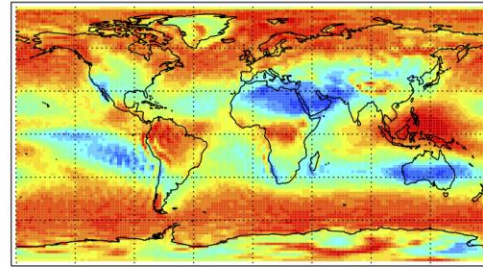
Host Model Effects

Cloud Fraction

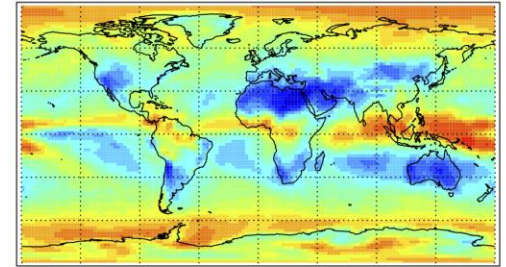
CAM5.1-PNNL Cloud Fraction: 0.63



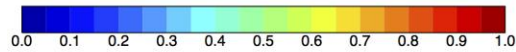
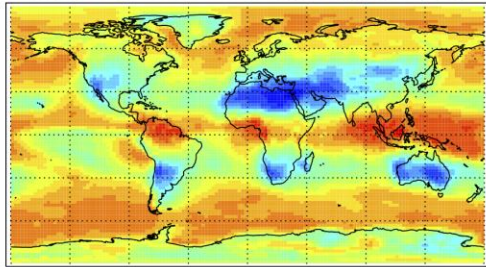
ECHAM5-HAM2 Cloud Fraction: 0.63



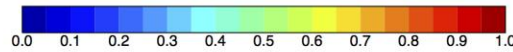
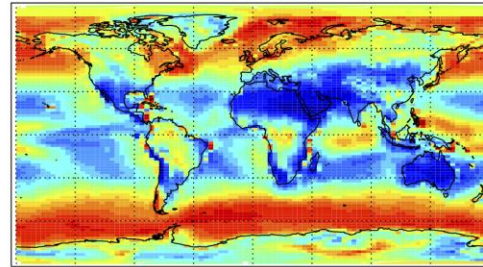
GOCART-GEOS4 Cloud Fraction: 0.49



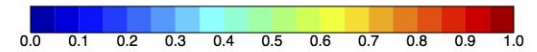
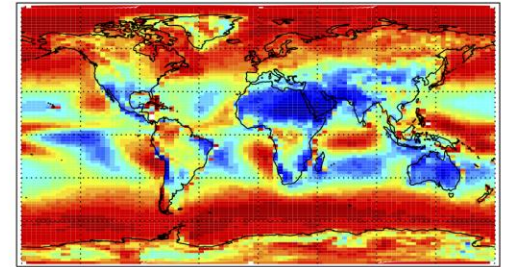
GOCART-MERRA Cloud Fraction: 0.60



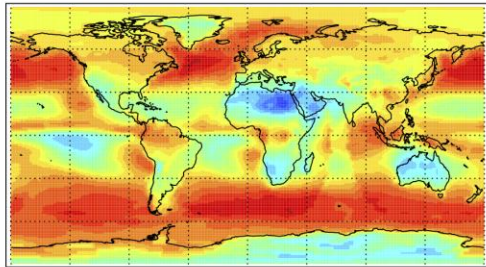
LMDZ Cloud Fraction: 0.48



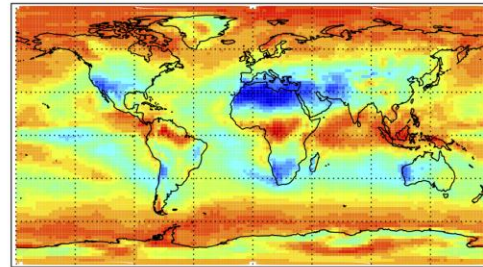
LMDZ-39L Cloud Fraction: 0.61



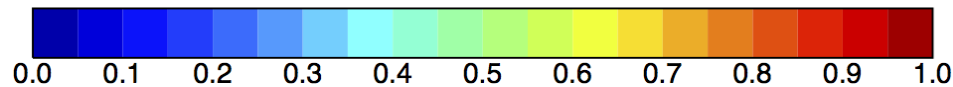
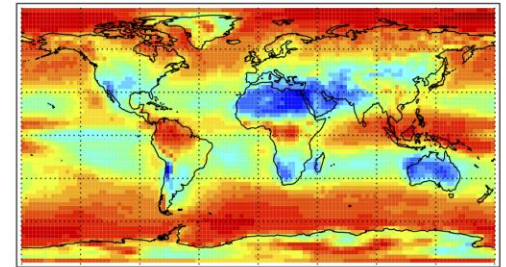
MPI-2stream Cloud Fraction: 0.67



IMPACT Cloud Fraction: 0.60



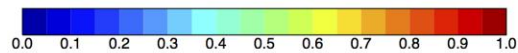
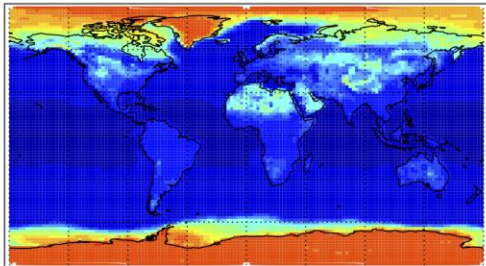
OsloCTM2 Cloud Fraction: 0.63



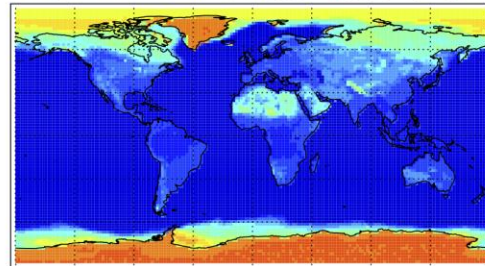
Host Model Effects

Surface Albedo

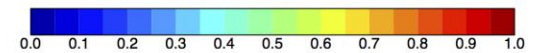
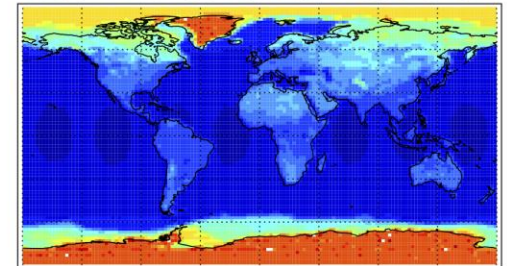
CAM5.1-PNNL Surface Albedo: 0.155



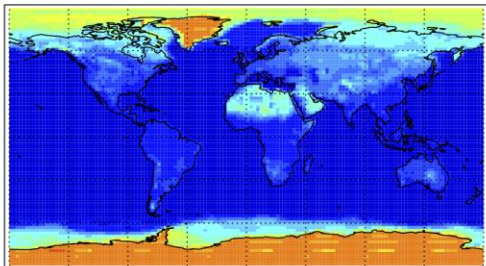
ECHAM5-HAM2 Surface Albedo: 0.161



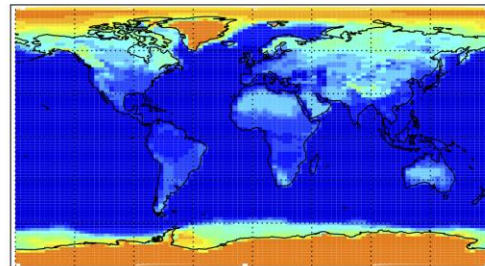
GOCART-GEOS4 Surface Albedo: 0.164



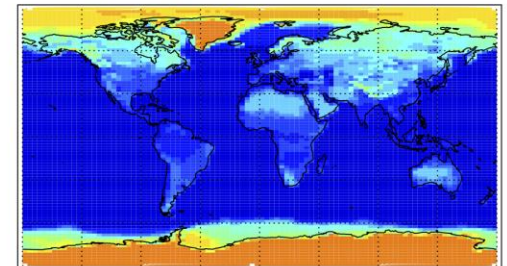
GOCART-MERRA Surface Albedo: 0.150



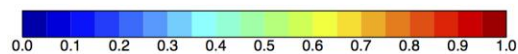
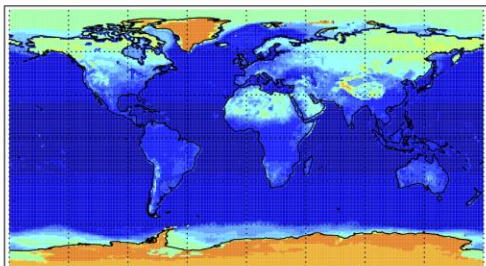
LMDZ Surface Albedo: 0.160



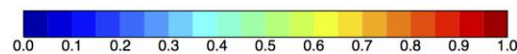
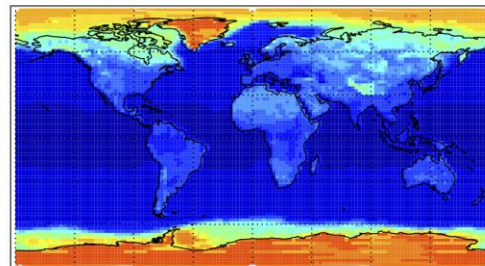
LMDZ-39L Surface Albedo: 0.159



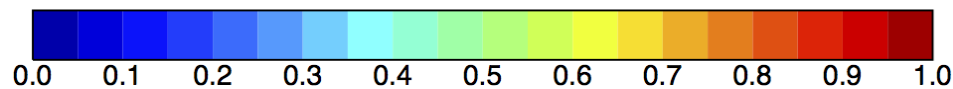
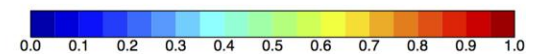
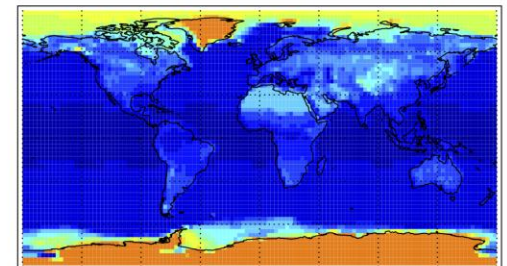
MPI-2stream Surface Albedo: 0.203



IMPACT Surface Albedo: 0.154



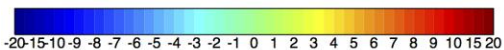
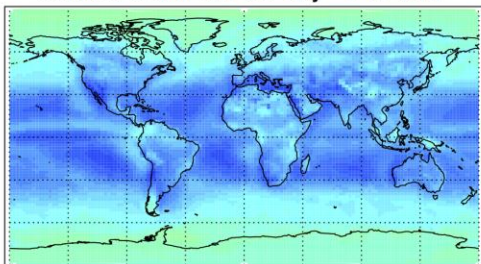
OsloCTM2 Surface Albedo: 0.137



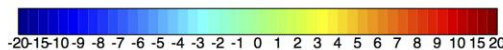
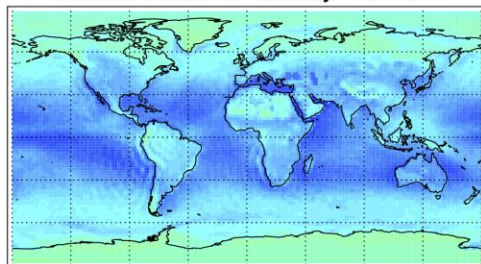
Radiative Forcing: Scattering Case

All-sky top-of-atmosphere radiative forcing for FIX2-FIX0

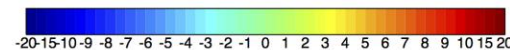
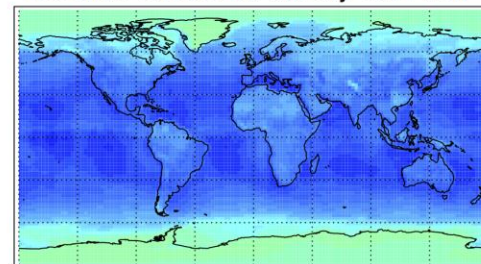
CAM5.1-PNNL RF All-Sky -4.46 Wm^{-2}



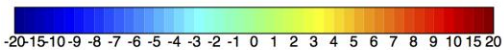
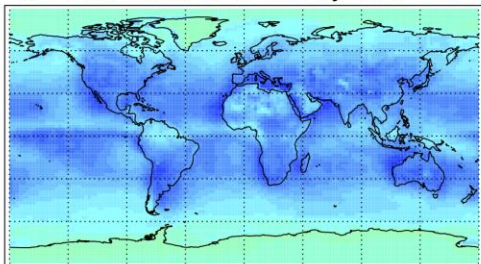
ECHAM5-HAM2 RF All-Sky -4.31 Wm^{-2}



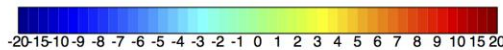
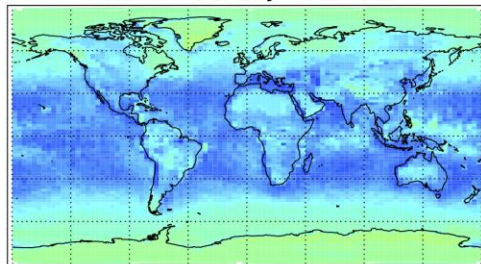
GOCART-GEOS4 RF All-Sky -5.97 Wm^{-2}



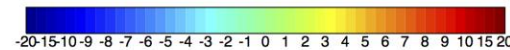
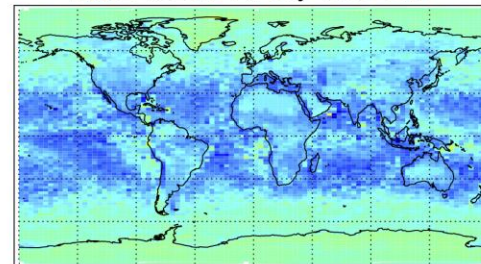
GOCART-MERRA RF All-Sky -4.58 Wm^{-2}



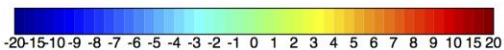
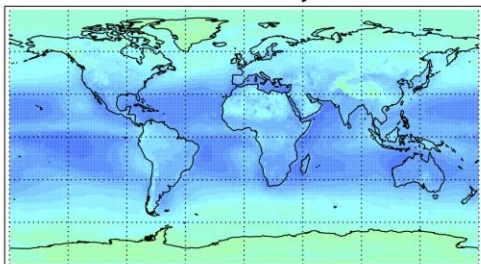
LMDZ RF All-Sky -4.12 Wm^{-2}



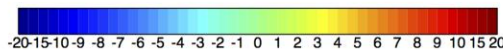
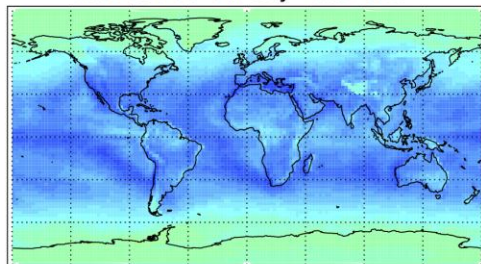
LMDZ-39L RF All-Sky -3.86 Wm^{-2}



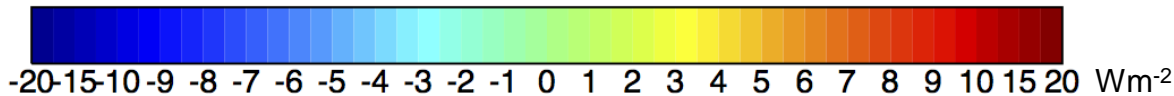
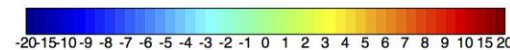
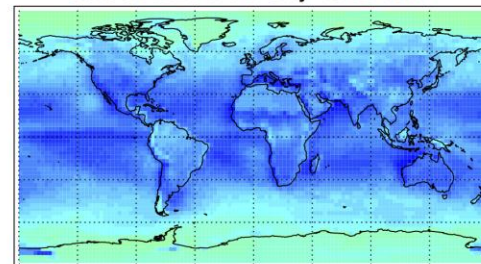
MPI-2stream RF All-Sky -3.63 Wm^{-2}



IMPACT RF All-Sky -4.54 Wm^{-2}



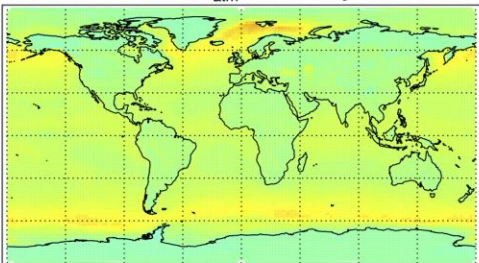
OsloCTM2 RF All-Sky -5.12 Wm^{-2}



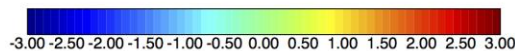
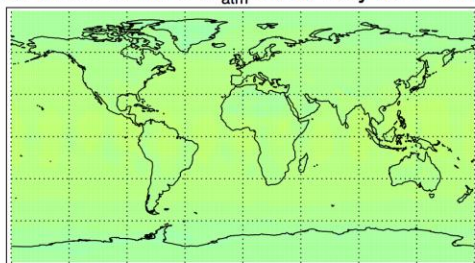
Radiative Forcing: Scattering Case

Clear-sky atmospheric radiative forcing for FIX2-FIX0

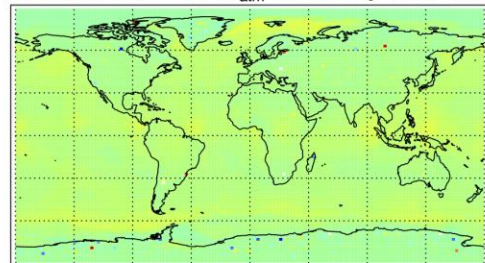
CAM5.1-PNNL RF_{atm} Clear-Sky 0.32 Wm⁻²



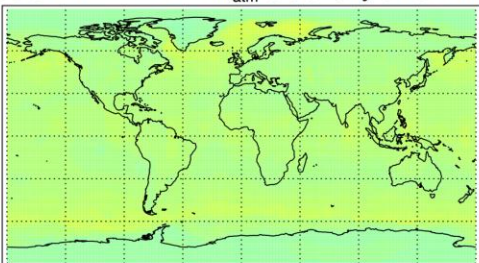
ECHAM5-HAM2 RF_{atm} Clear-Sky 0.11 Wm⁻²



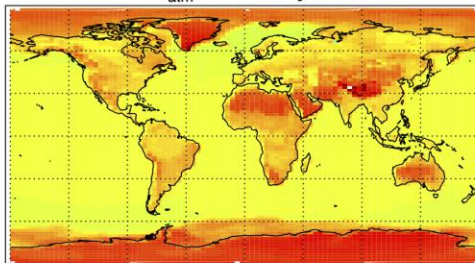
GOCART-GEOS4 RF_{atm} Clear-Sky 0.16 Wm⁻²



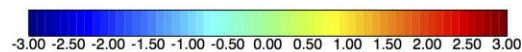
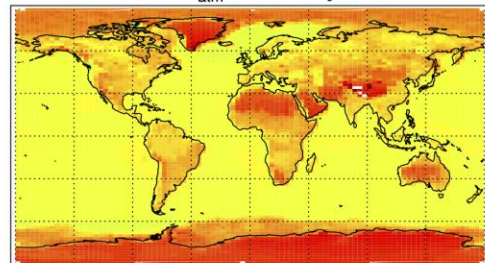
GOCART-MERRA RF_{atm} Clear-Sky 0.13 Wm⁻²



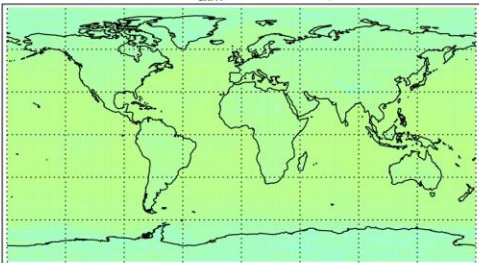
LMDZ RF_{atm} Clear-Sky 0.95 Wm⁻²



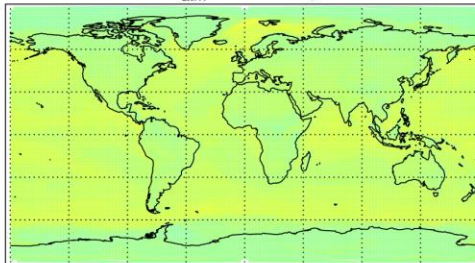
LMDZ-39L RF_{atm} Clear-Sky 0.98 Wm⁻²



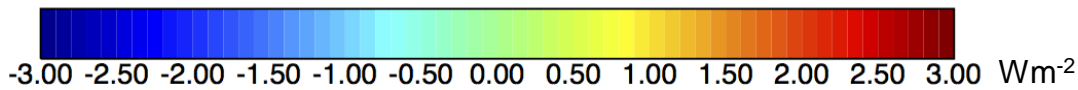
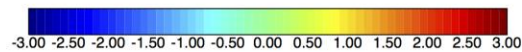
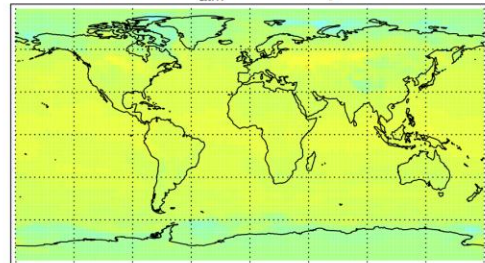
MPI-2stream RF_{atm} Clear-Sky -0.00 Wm⁻²



IMPACT RF_{atm} Clear-Sky 0.28 Wm⁻²

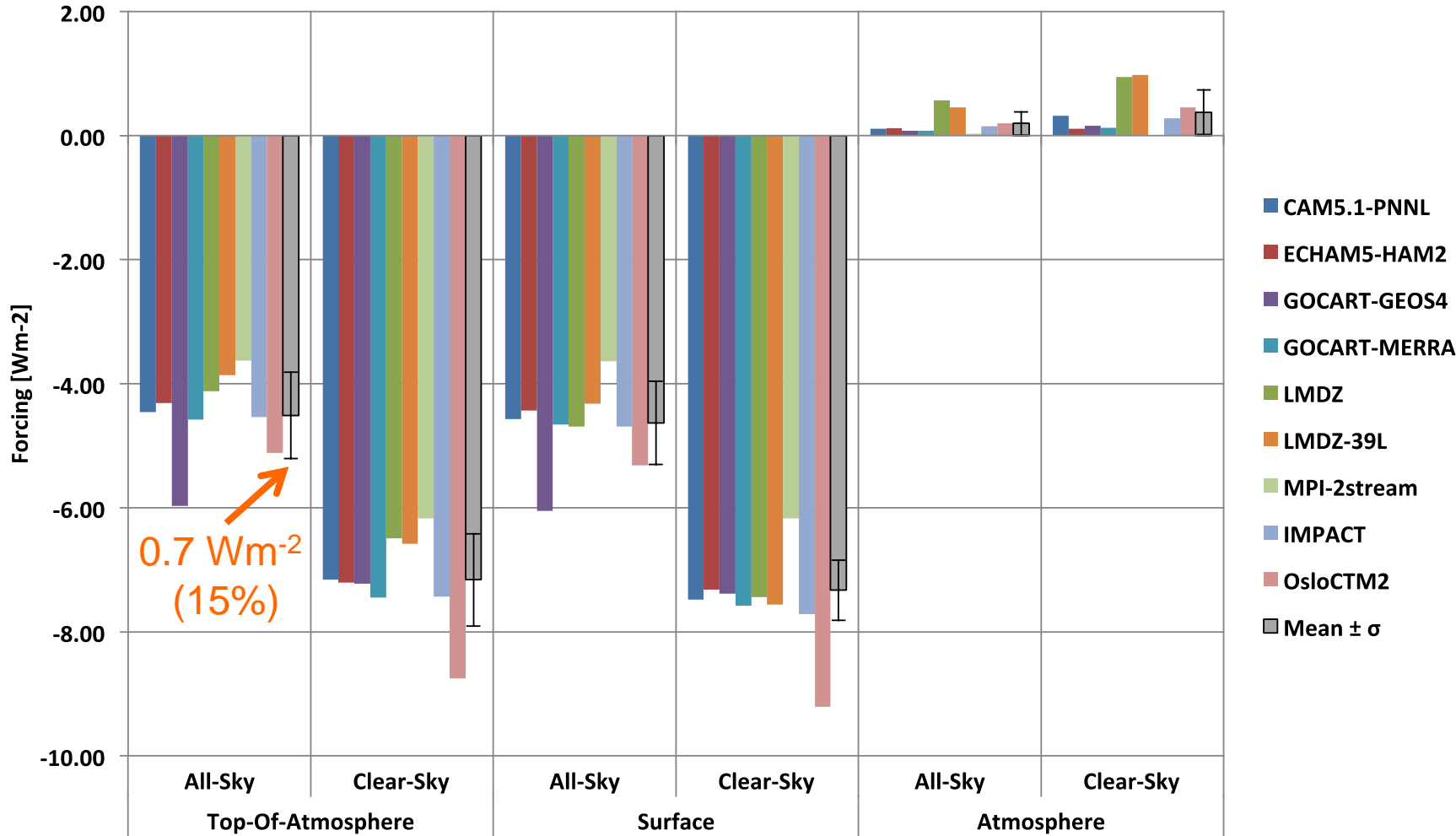


OsloCTM2 RF_{atm} Clear-Sky 0.46 Wm⁻²



Summary: Scattering Case (FIX2-FIX0)

AeroCom Prescribed Radiative Forcings: Scattering Case (FIX2-FIX0)



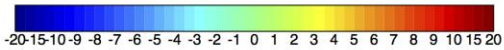
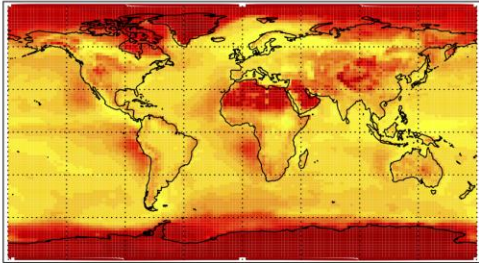
0.7 Wm⁻²
(15%)

- CAM5.1-PNNL
- ECHAM5-HAM2
- GOCART-GEOS4
- GOCART-MERRA
- LMDZ
- LMDZ-39L
- MPI-2stream
- IMPACT
- OsloCTM2
- Mean ± σ

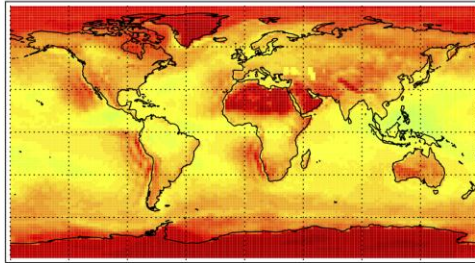
Radiative Forcing: Absorbing Case

All-sky top-of-atmosphere radiative forcing for FIX3-FIX2

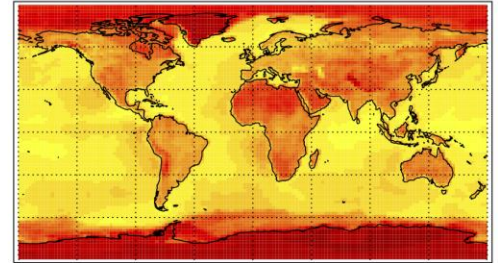
CAM5.1-PNNL RF All-Sky 5.52 Wm^{-2}



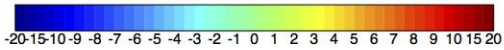
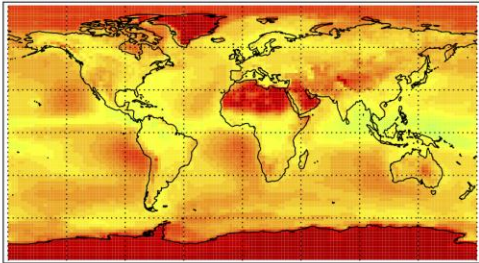
ECHAM5-HAM2 RF All-Sky 4.97 Wm^{-2}



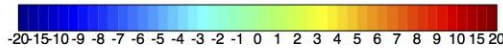
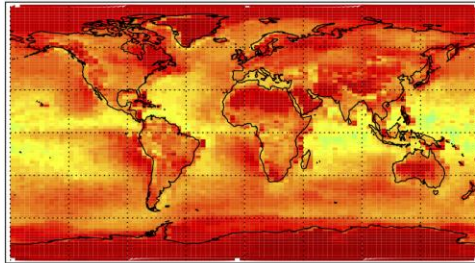
GOCART-GEOS4 RF All-Sky 5.17 Wm^{-2}



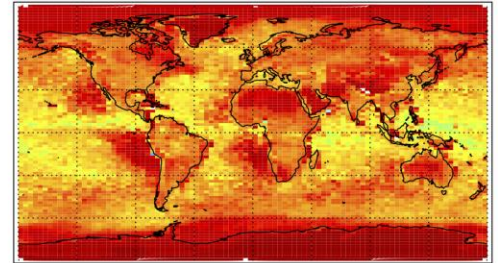
GOCART-MERRA RF All-Sky 4.89 Wm^{-2}



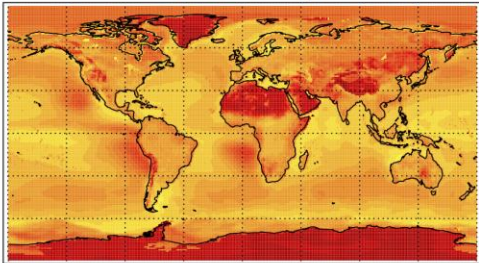
LMDZ RF All-Sky 6.62 Wm^{-2}



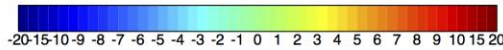
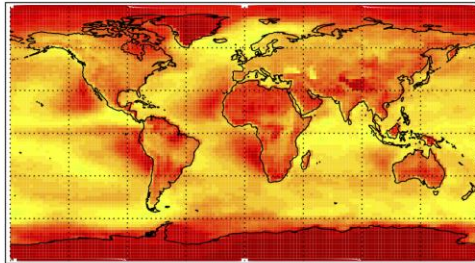
LMDZ-39L RF All-Sky 6.60 Wm^{-2}



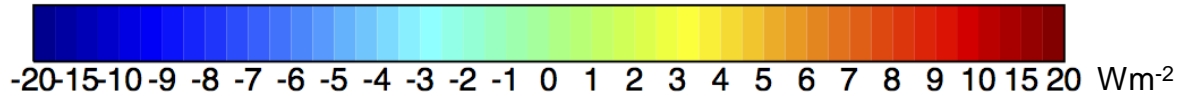
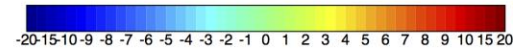
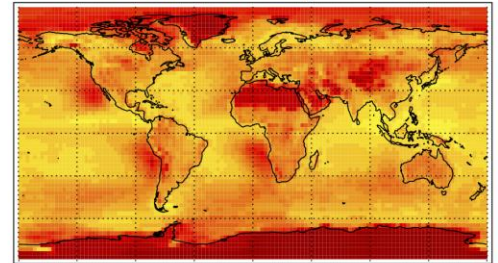
MPI-2stream RF All-Sky 6.41 Wm^{-2}



IMPACT RF All-Sky 5.75 Wm^{-2}



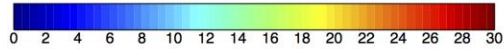
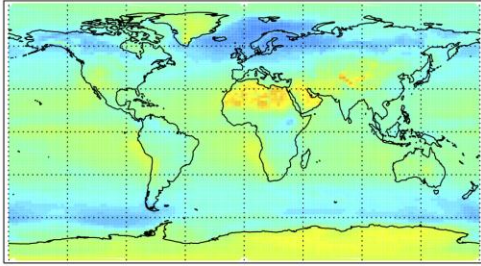
OsloCTM2 RF All-Sky 6.00 Wm^{-2}



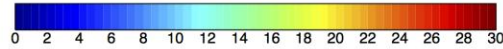
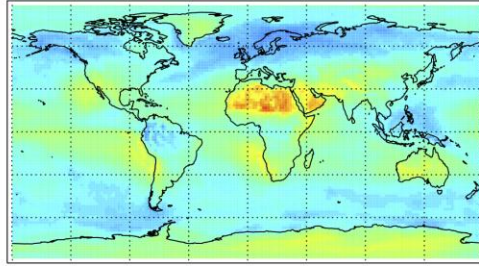
Radiative Forcing: Absorbing Case

All-sky atmospheric radiative forcing for FIX3-FIX2

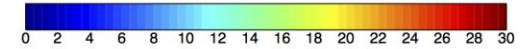
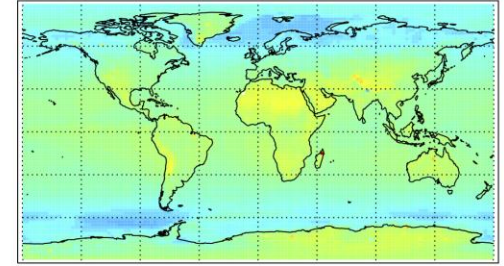
CAM5.1-PNNL RF_{atm} All-Sky 13.75 Wm⁻²



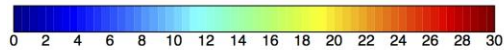
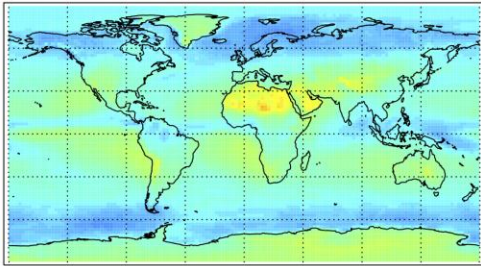
ECHAM5-HAM2 RF_{atm} All-Sky 13.04 Wm⁻²



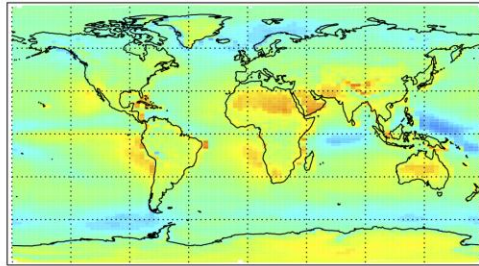
GOCART-GEOS4 RF_{atm} All-Sky 14.20 Wm⁻²



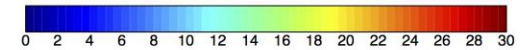
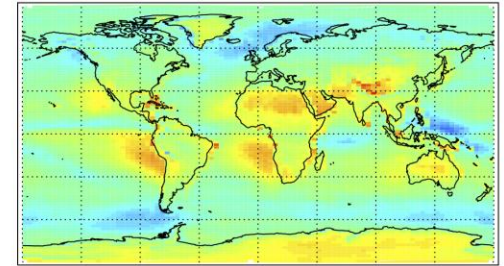
GOCART-MERRA RF_{atm} All-Sky 12.74 Wm⁻²



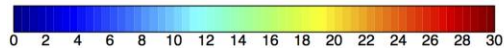
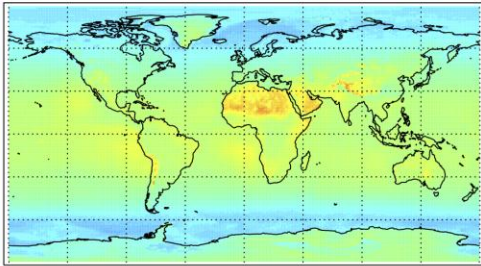
LMDZ RF_{atm} All-Sky 15.38 Wm⁻²



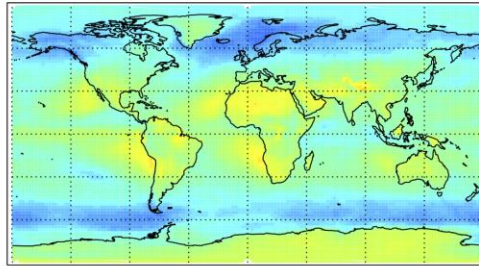
LMDZ-39L RF_{atm} All-Sky 15.31 Wm⁻²



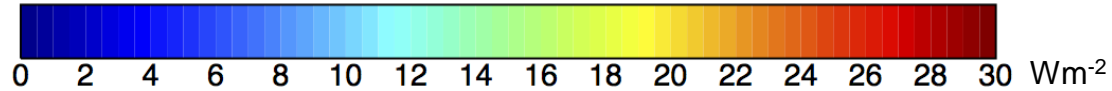
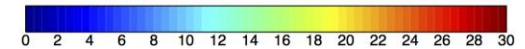
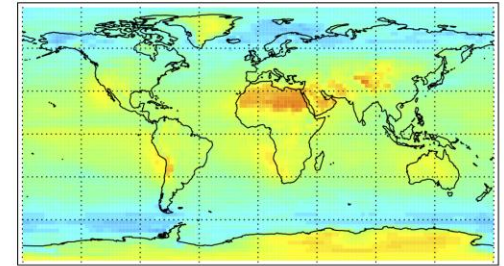
MPI-2stream RF_{atm} All-Sky 14.47 Wm⁻²



IMPACT RF_{atm} All-Sky 13.70 Wm⁻²

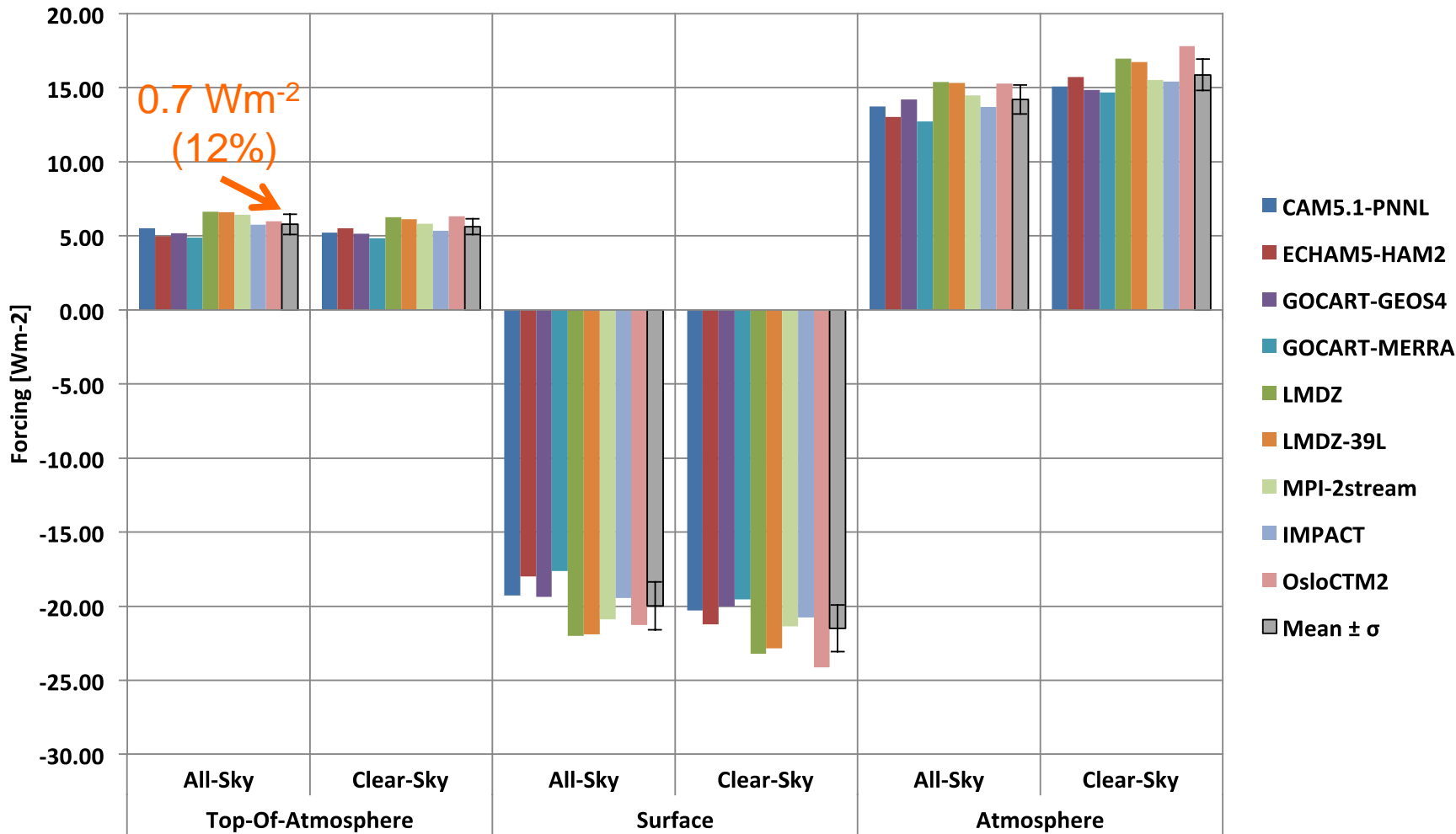


OsloCTM2 RF_{atm} All-Sky 15.27 Wm⁻²



Summary: Absorbing Case (FIX3-FIX2)

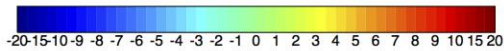
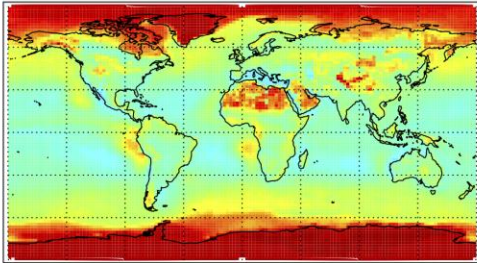
AeroCom Prescribed Radiative Forcings: Absorbing Case (FIX3-FIX2)



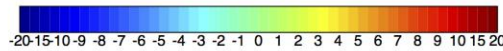
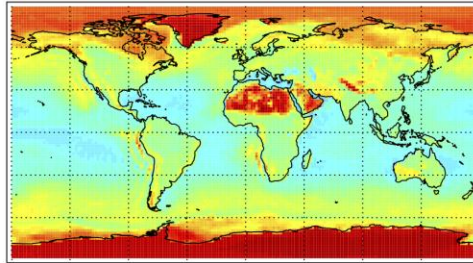
Radiative Forcing: Scattering & Absorbing Case

All-sky top-of-atmosphere radiative forcing for FIX3-FIX0

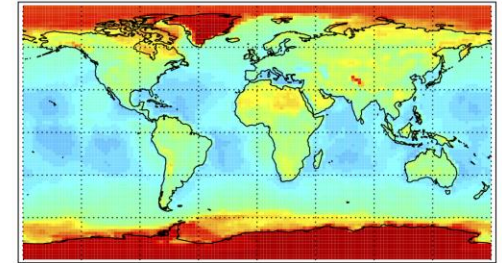
CAM5.1-PNNL RF All-Sky 1.06 Wm^{-2}



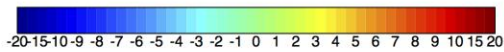
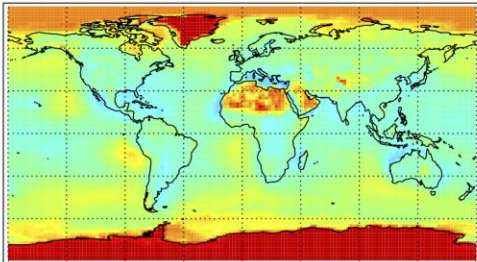
ECHAM5-HAM2 RF All-Sky 0.66 Wm^{-2}



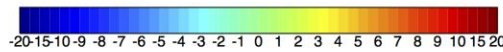
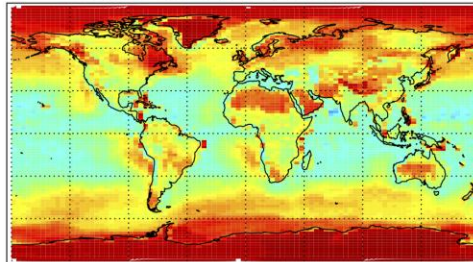
GOCART-GEOS4 RF All-Sky -0.80 Wm^{-2}



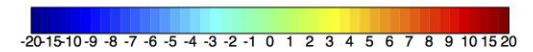
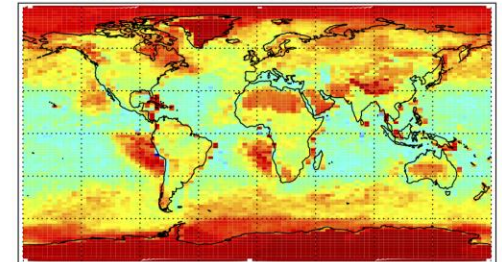
GOCART-MERRA RF All-Sky 0.32 Wm^{-2}



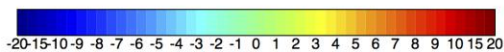
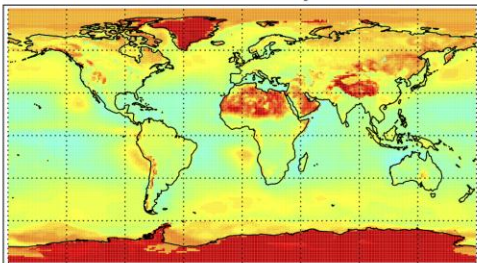
LMDZ RF All-Sky 2.50 Wm^{-2}



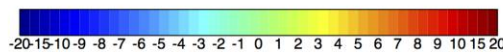
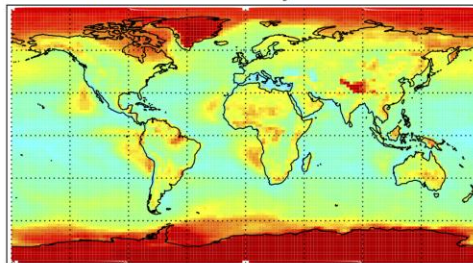
LMDZ-39L RF All-Sky 2.74 Wm^{-2}



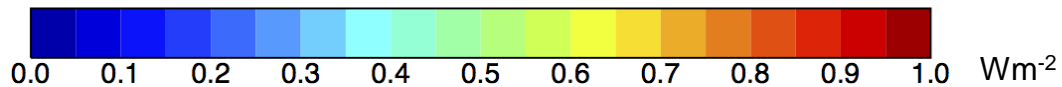
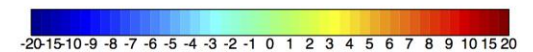
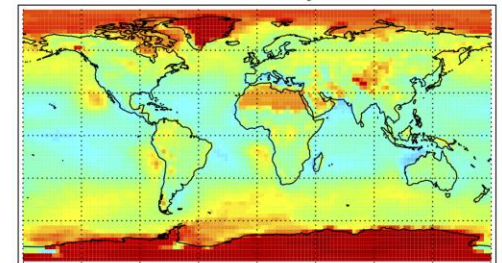
MPI-2stream RF All-Sky 2.78 Wm^{-2}



IMPACT RF All-Sky 1.22 Wm^{-2}



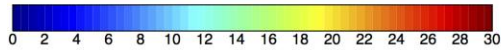
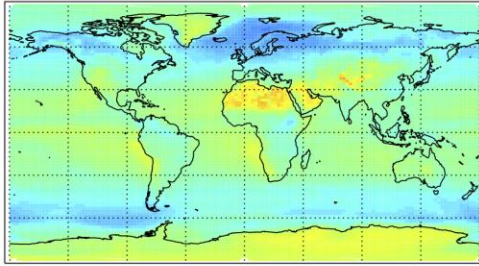
OsloCTM2 RF All-Sky 0.88 Wm^{-2}



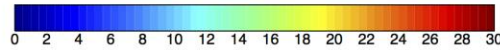
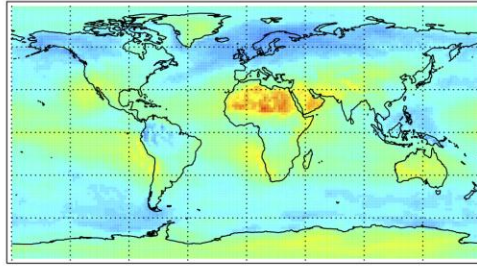
Radiative Forcing: Scattering & Absorbing Case

All-sky atmospheric radiative forcing for FIX3-FIX0

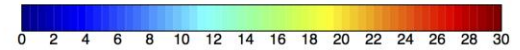
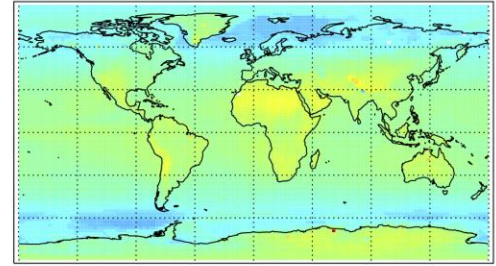
CAM5.1-PNNL RF_{atm} All-Sky 13.86 Wm⁻²



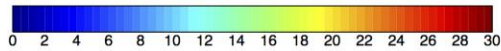
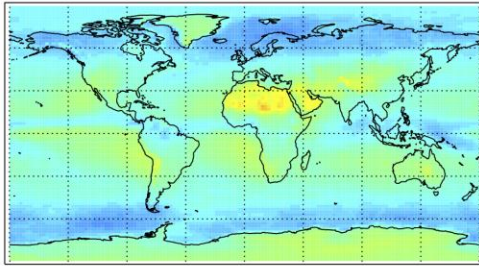
ECHAM5-HAM2 RF_{atm} All-Sky 13.16 Wm⁻²



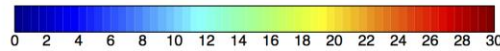
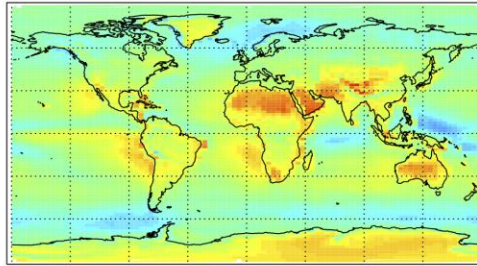
GOCART-GEOS4 RF_{atm} All-Sky 14.28 Wm⁻²



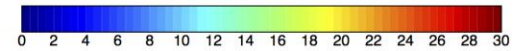
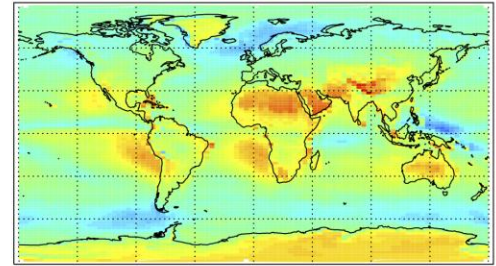
GOCART-MERRA RF_{atm} All-Sky 12.81 Wm⁻²



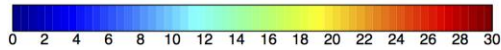
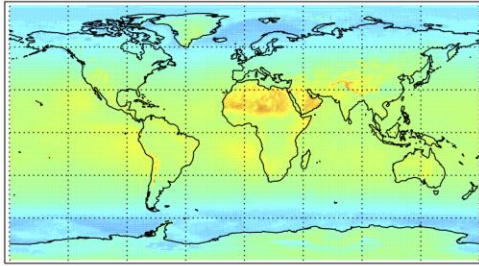
LMDZ RF_{atm} All-Sky 15.95 Wm⁻²



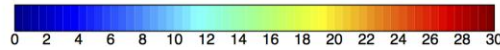
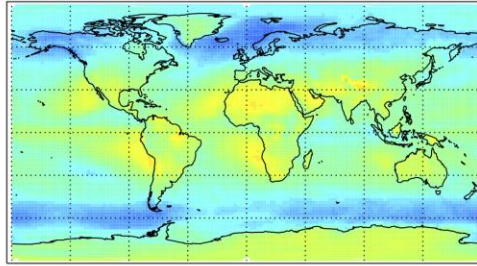
LMDZ-39L RF_{atm} All-Sky 15.78 Wm⁻²



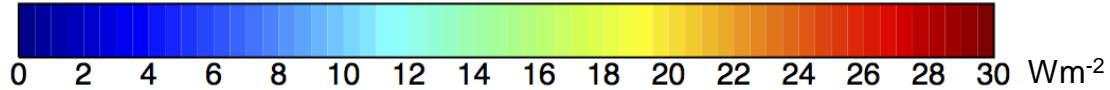
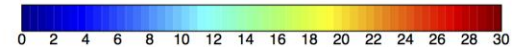
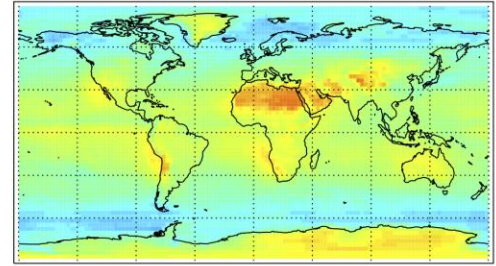
MPI-2stream RF_{atm} All-Sky 14.48 Wm⁻²



IMPACT RF_{atm} All-Sky 13.86 Wm⁻²

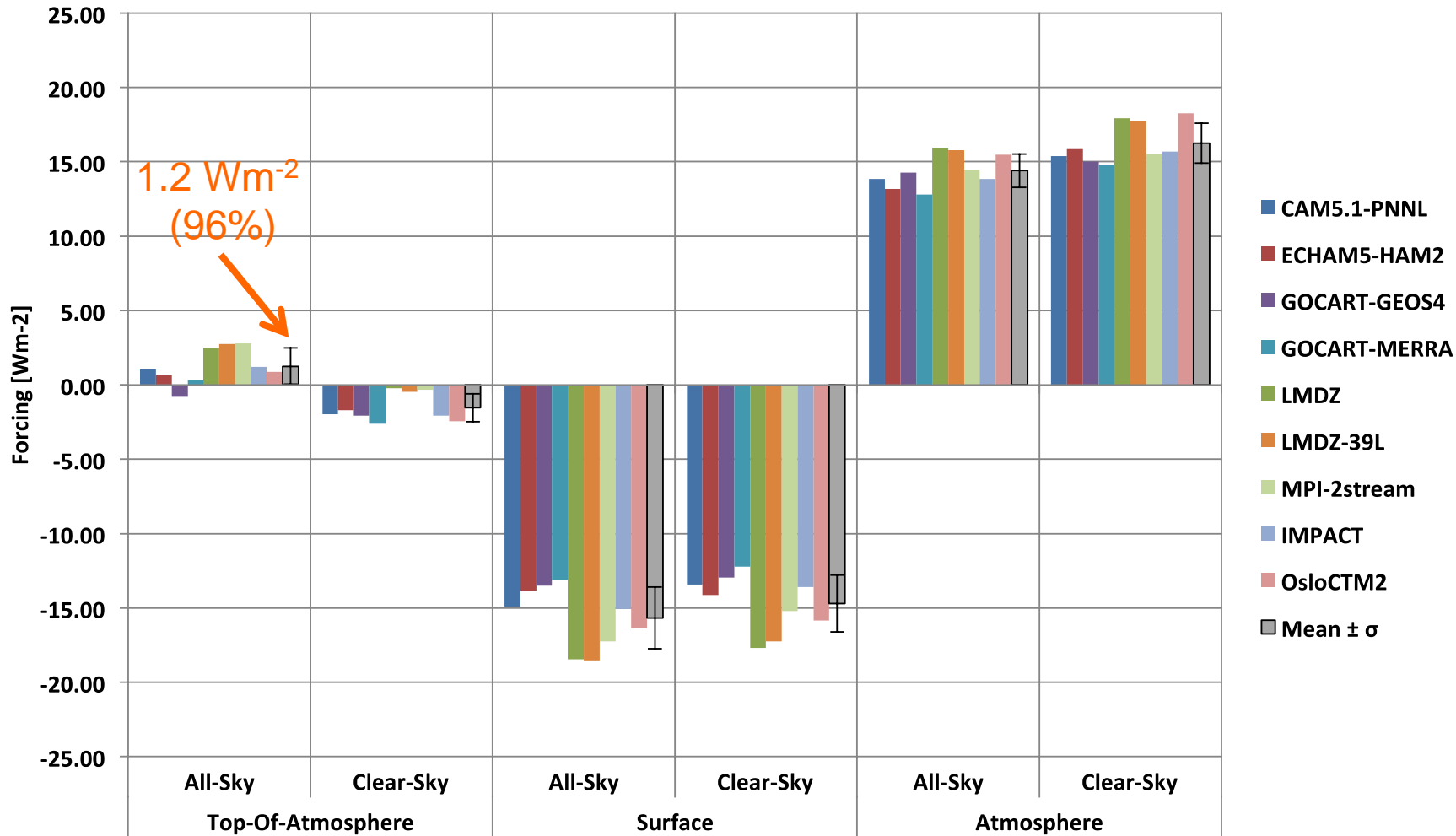


OsloCTM2 RF_{atm} All-Sky 15.48 Wm⁻²



Summary: Scatting & Absorbing Case (FIX3-FIX0)

AeroCom Prescribed Radiative Forcings: Scattering&Absorbing Case (FIX3-FIX0)



Attribution to Host Model Effects

How do we attribute inter-model forcing variability to host model effects?

Locally decompose forcing error:

$$\Delta RF_{TOA}^{all} = \underbrace{\frac{\overbrace{\partial RF_{TOA}^{all}}^{\text{Sensitivity}}}{\partial A_{sur}} \Delta A_{sur}}_{\text{Surface albedo}} + \underbrace{\frac{\overbrace{\partial RF_{TOA}^{all}}^{\text{Sensitivity}}}{\partial A_{cld}} \Delta A_{cld}}_{\text{Clouds}}$$

where

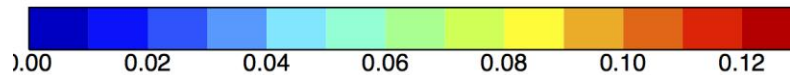
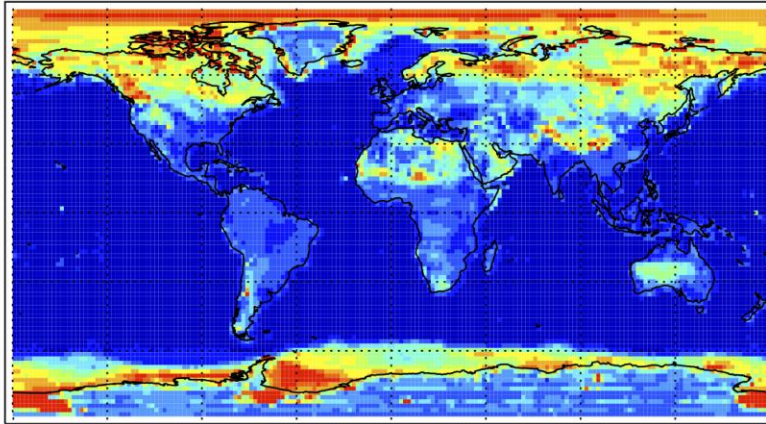
$$A_{cld} = \frac{F_{all}^{\uparrow} - F_{clr}^{\uparrow}}{F_{all}^{\downarrow}}$$

Attribution to Host Model Effects

Host model perturbations (inter-model standard deviation):

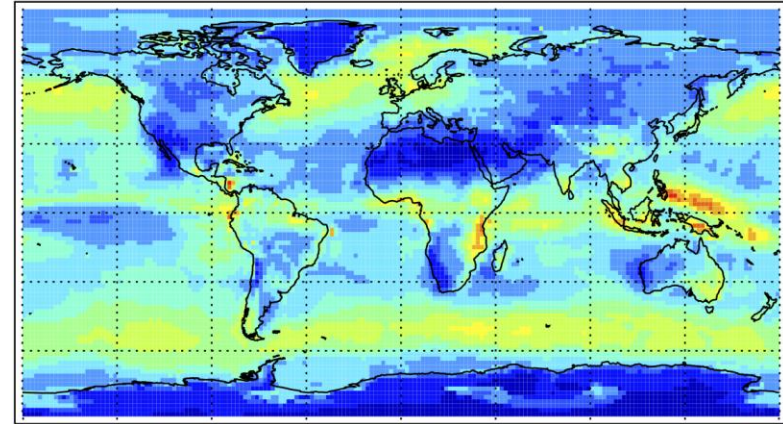
Surface Albedo ΔA_{sur}

Clear-Sky FIX2 StdDev surface albedo



Cloudy Albedo ΔA_{cld}

FIX2 StdDev cloud albedo



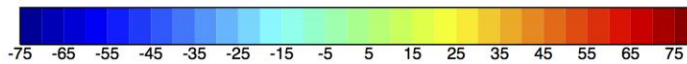
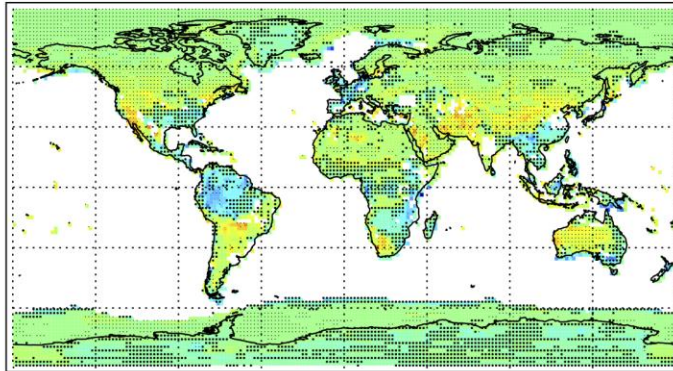
Attribution to Host Model Effects

Scattering Case: FIX2-FIX0

Sensitivity

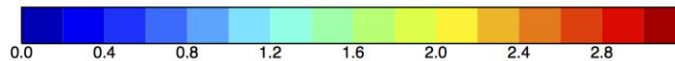
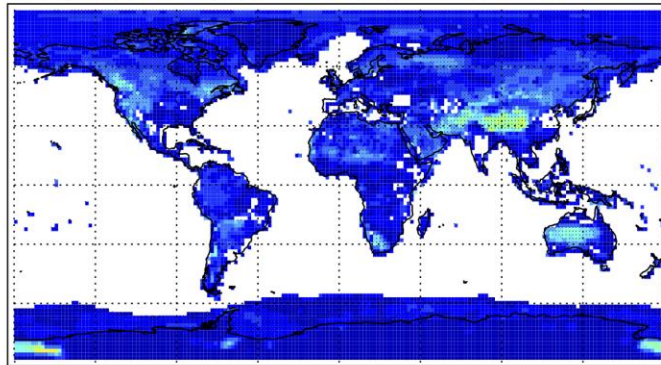
$$\frac{\partial RF_{TOA}^{all}}{\partial A_{sur}}$$

Slope [Wm⁻²] All-Sky RF vs surface albedo (FIX2-FIX0)



Forcing Error

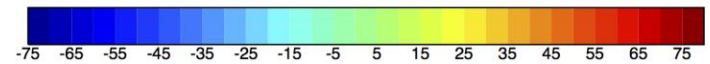
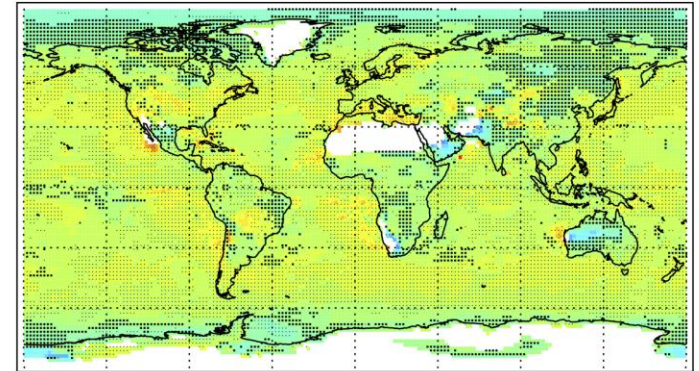
Error [Wm⁻²] All-Sky RF due to surface albedo (FIX2-FIX0)



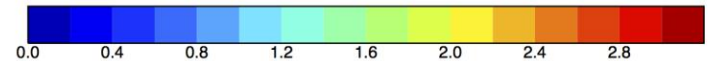
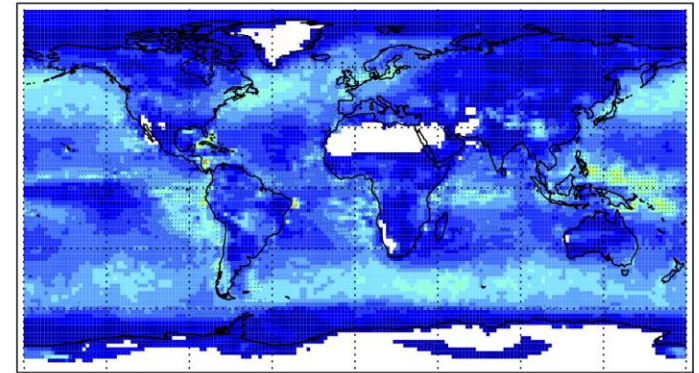
$$\frac{\partial RF_{TOA}^{all}}{\partial A_{sur}} \Delta A_{sur}$$

$$\frac{\partial RF_{TOA}^{all}}{\partial A_{cld}}$$

Slope [Wm⁻²] All-Sky RF vs cloudy albedo (FIX2-FIX0)



Error [Wm⁻²] All-Sky RF vs cloudy albedo (FIX2-FIX0)



$$\frac{\partial RF_{TOA}^{all}}{\partial A_{cld}} \Delta A_{cld}$$

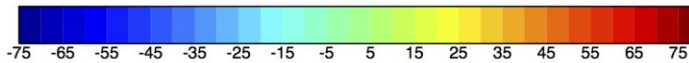
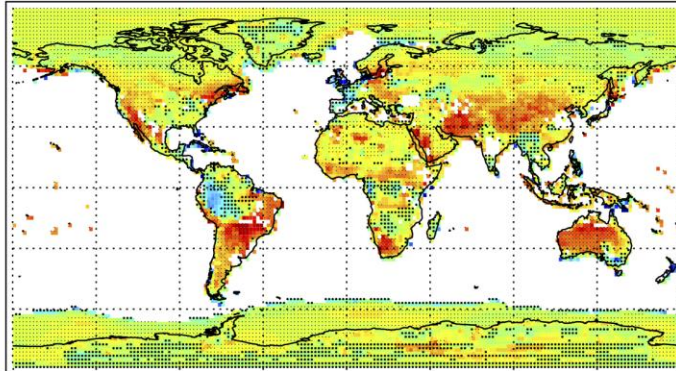
Attribution to Host Model Effects

Absorbing Case: FIX3-FIX0

Sensitivity

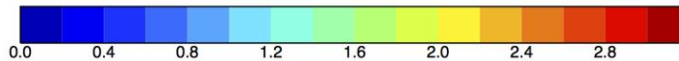
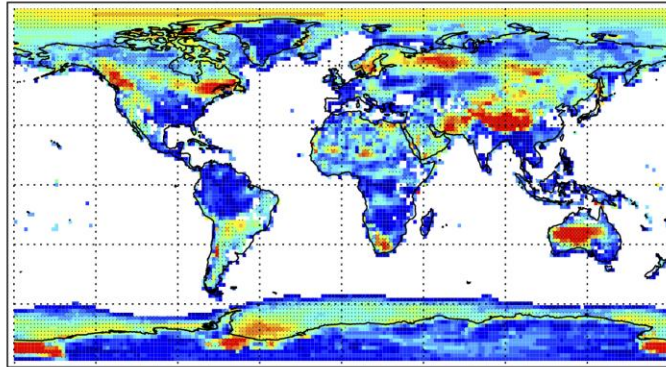
$$\frac{\partial RF_{TOA}^{all}}{\partial A_{sur}}$$

Slope [Wm^{-2}] All-Sky RF vs surface albedo (FIX3-FIX0)



Forcing Error

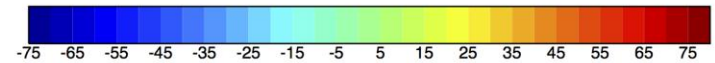
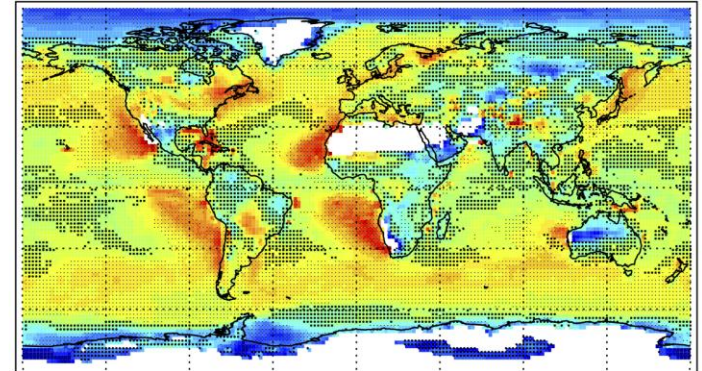
Error [Wm^{-2}] All-Sky RF due to surface albedo (FIX3-FIX0)



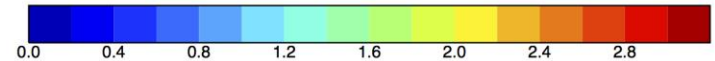
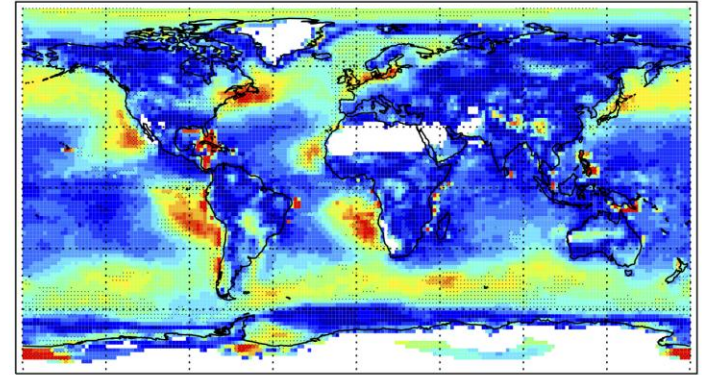
$$\frac{\partial RF_{TOA}^{all}}{\partial A_{sur}} \Delta A_{sur}$$

$$\frac{\partial RF_{TOA}^{all}}{\partial A_{cld}}$$

Slope [Wm^{-2}] All-Sky RF vs cloudy albedo (FIX3-FIX0)



Error [Wm^{-2}] All-Sky RF vs cloudy albedo (FIX3-FIX0)



$$\frac{\partial RF_{TOA}^{all}}{\partial A_{cld}} \Delta A_{cld}$$

Conclusions

- Current models show considerable diversity in model parameters relevant for the calculation of aerosol radiative forcing
- Significant differences in atmospheric forcings for the purely scattering case highlight the contribution of structural differences in the radiation schemes
- Even for identically prescribed aerosol radiative properties aerosol radiative forcings show significant diversity:
 - Scattering case: 0.70 Wm^2 (15%)
 - Partially absorbing case: 1.21 Wm^2 (96%)
- Multi-model “diversity” is not a true measure of aerosol uncertainty

So what do we do now?

- **We are still accepting submissions for the revised paper**
- Uncertain host model effects should be part of AeroCom evaluation suite
- Diversity of absorption in scattering case demands for careful evaluation of some radiative transfer scheme
- Aim to reduce host model effect diversity by next AeroCom / AR6 (at least for surface albedos)
- A number of obvious follow up studies