

Aerosols Absorption & Radiative Forcing

AeroCom Workshop
Virginia Beach

2006/10/19

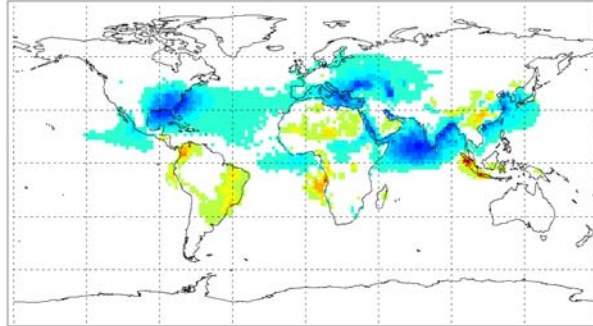
Philip Stier
Environmental Science and Engineering
California Institute of Technology



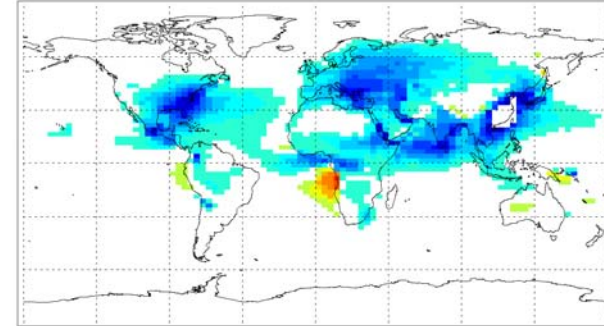
Motivation – Understanding Direct Aerosol Radiative Forcing

**Annual-Mean
Top-Of-Atmosphere Total-Sky
Anthropogenic
Direct Aerosol
Radiative Forcing**

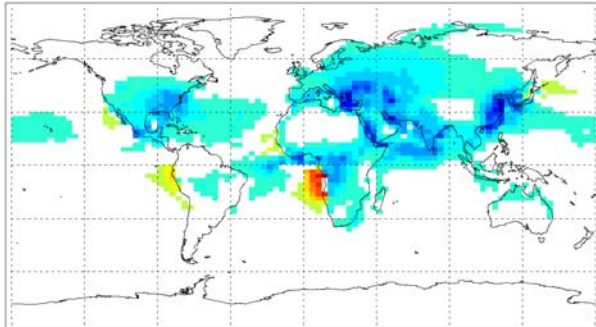
ECHAM5-HAM -0.12 Wm^{-2}



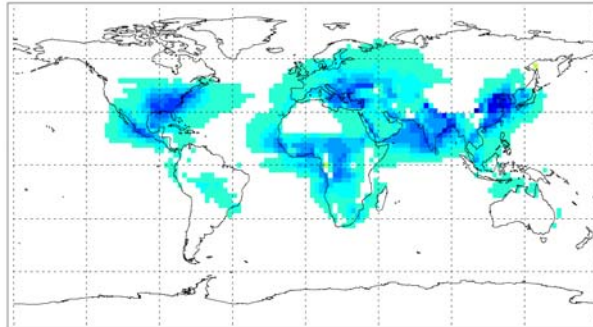
LOA -0.35 Wm^{-2}



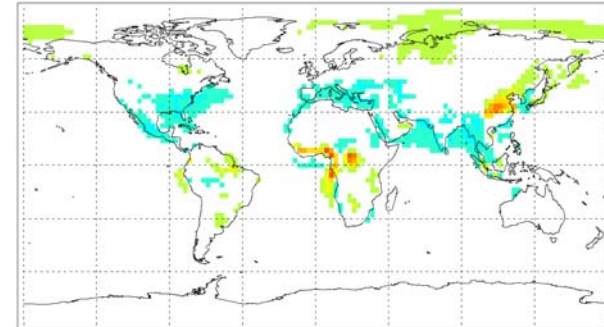
LSCE -0.28 Wm^{-2}



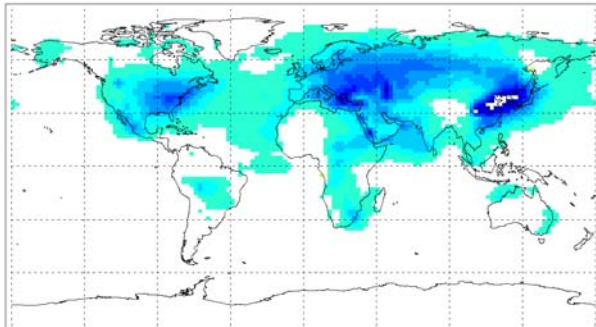
UIO-CTM -0.34 Wm^{-2}



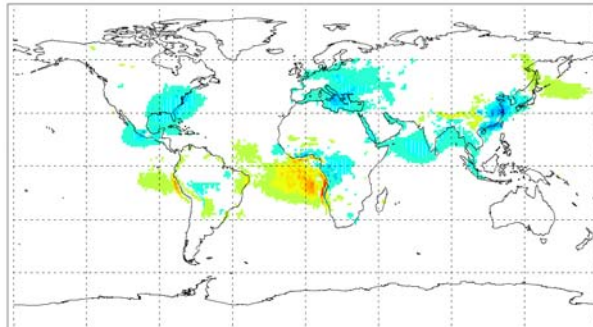
UIO-GCM -0.01 Wm^{-2}



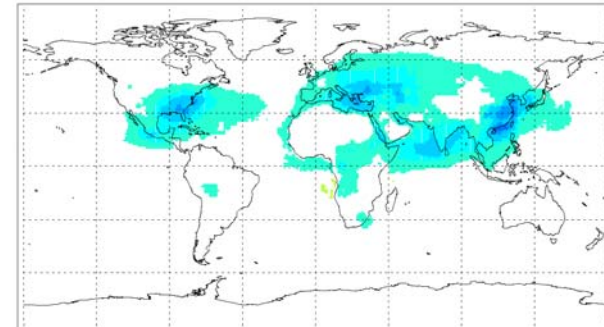
UMI -0.41 Wm^{-2}



SPRINTARS 0.04 Wm^{-2}



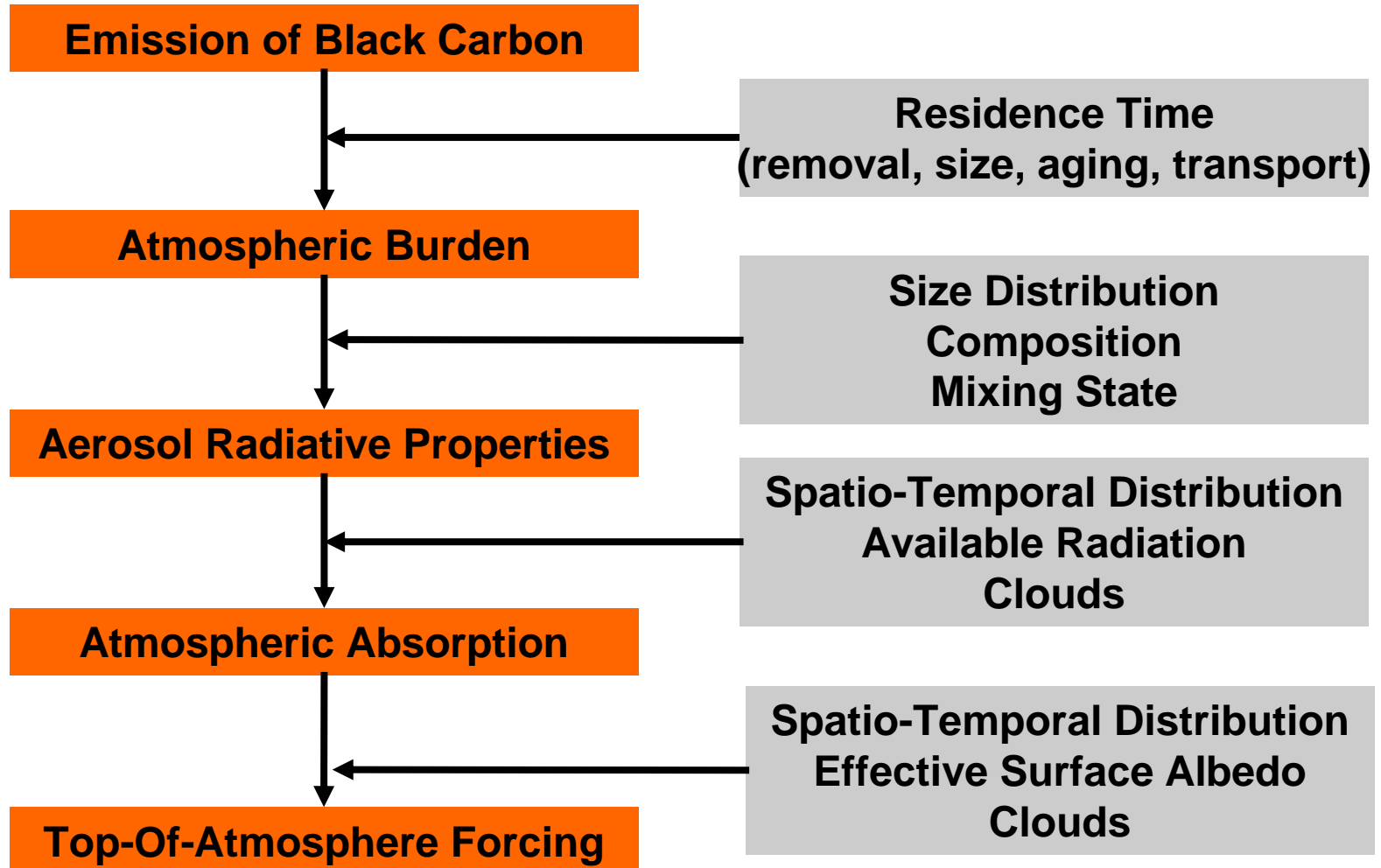
AeroCom -0.18 Wm^{-2}



Objective

Positive contribution of absorption to Direct Aerosol Radiative Forcing

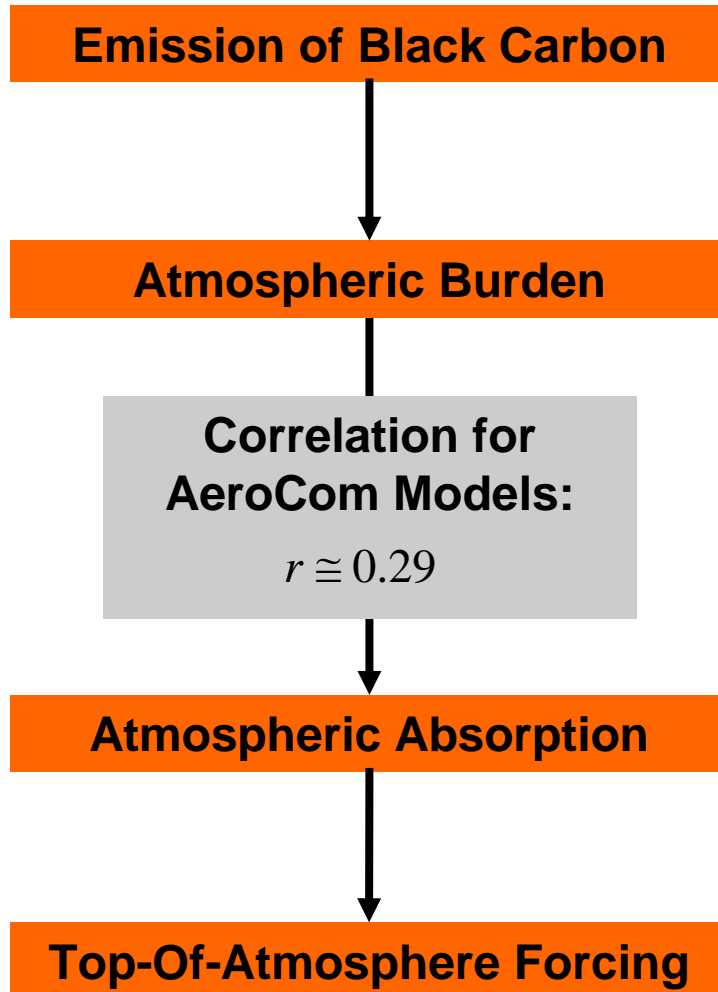
Increase understanding of link(s) between emissions and forcing



Method

Break down problem in individual steps

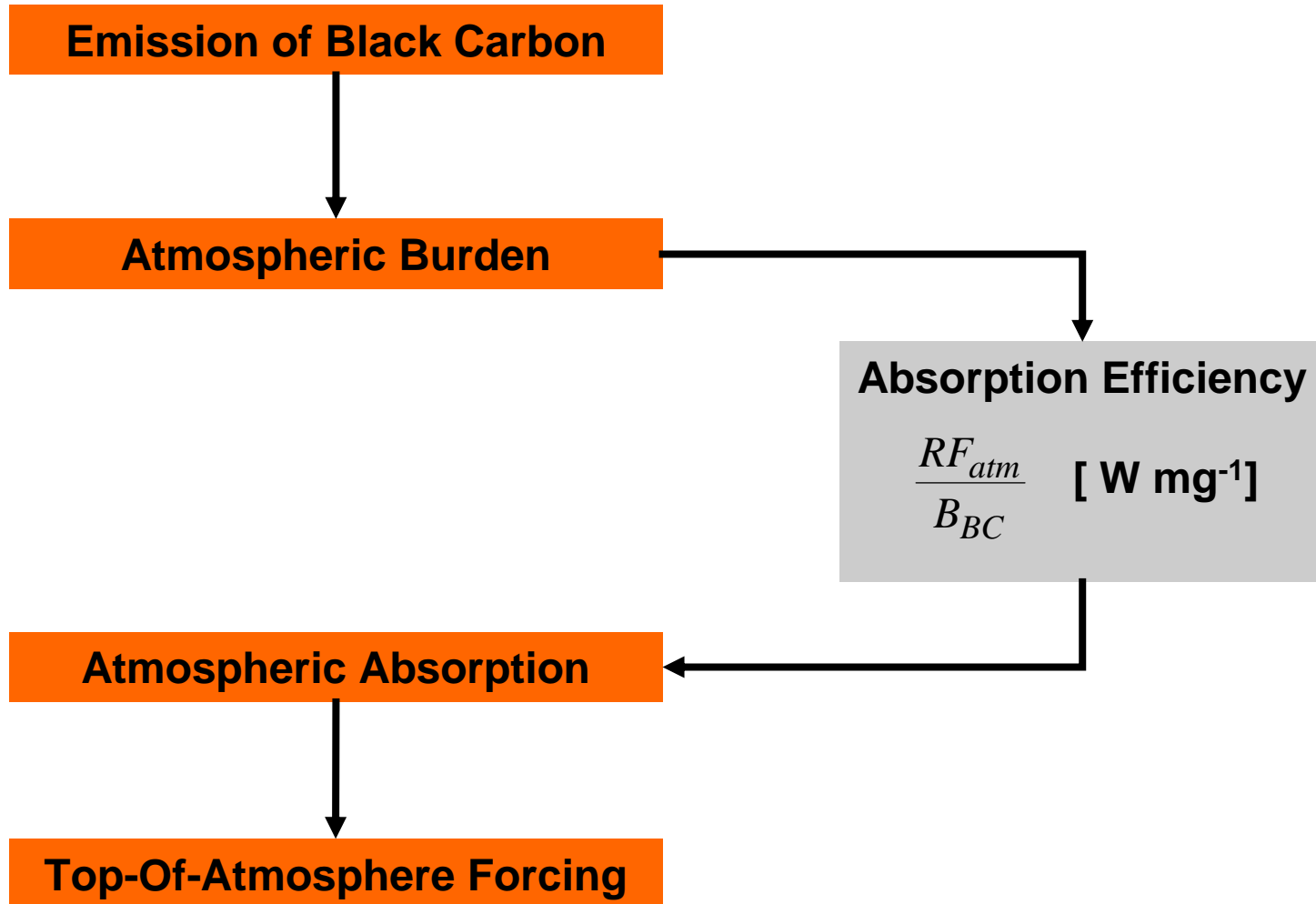
Traditionally:



Method

Break down problem in individual steps

Traditionally:

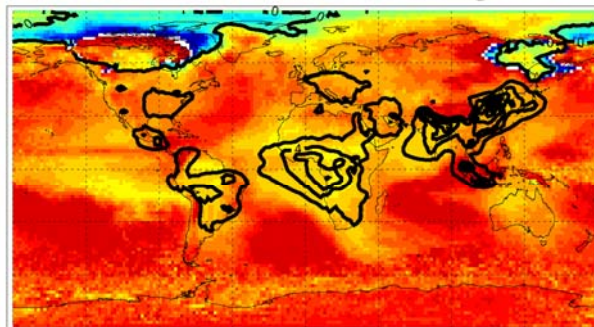


Aerosol Absorption Efficiency by Mass

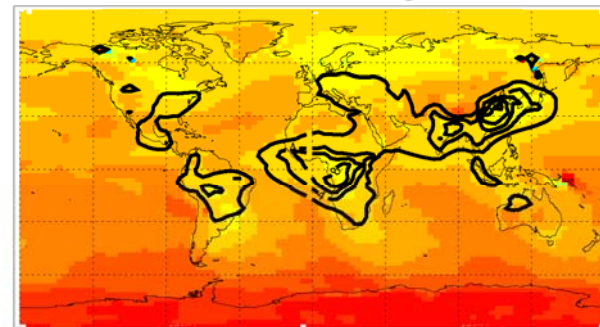
Annual-Mean
Anthropogenic

$$\text{Absorption Efficiency} = \frac{RF_{abs}}{B_{BC}}$$

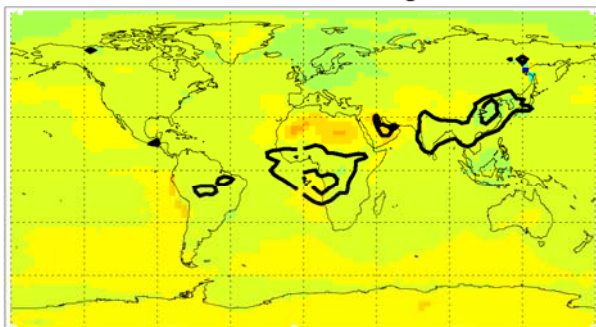
ECHAM5-HAM 5.5 Wmg⁻¹



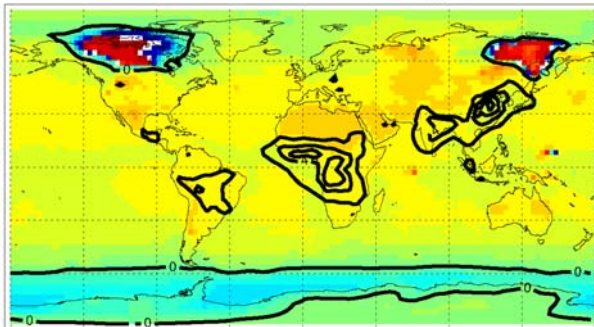
LOA 4.6 Wmg⁻¹



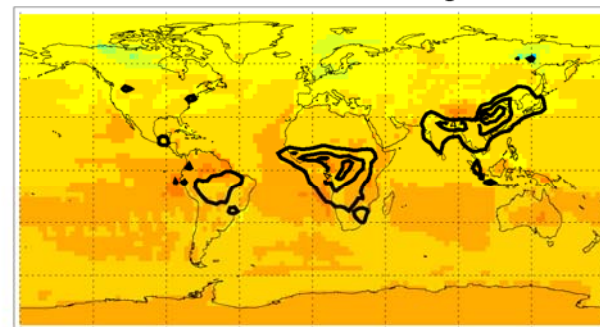
LSCE 2.6 Wmg⁻¹



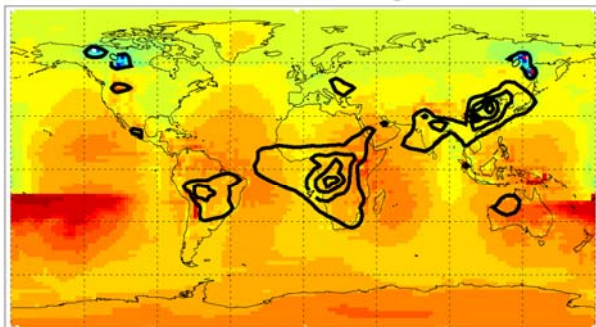
UIO-CTM 3.3 Wmg⁻¹



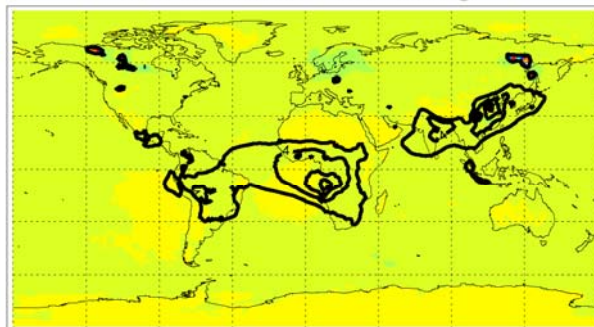
UIO-GCM 4.5 Wmg⁻¹



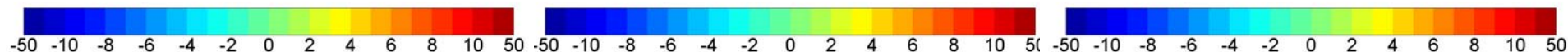
UMI 4.3 Wmg⁻¹



SPRINTARS 2.7 Wmg⁻¹



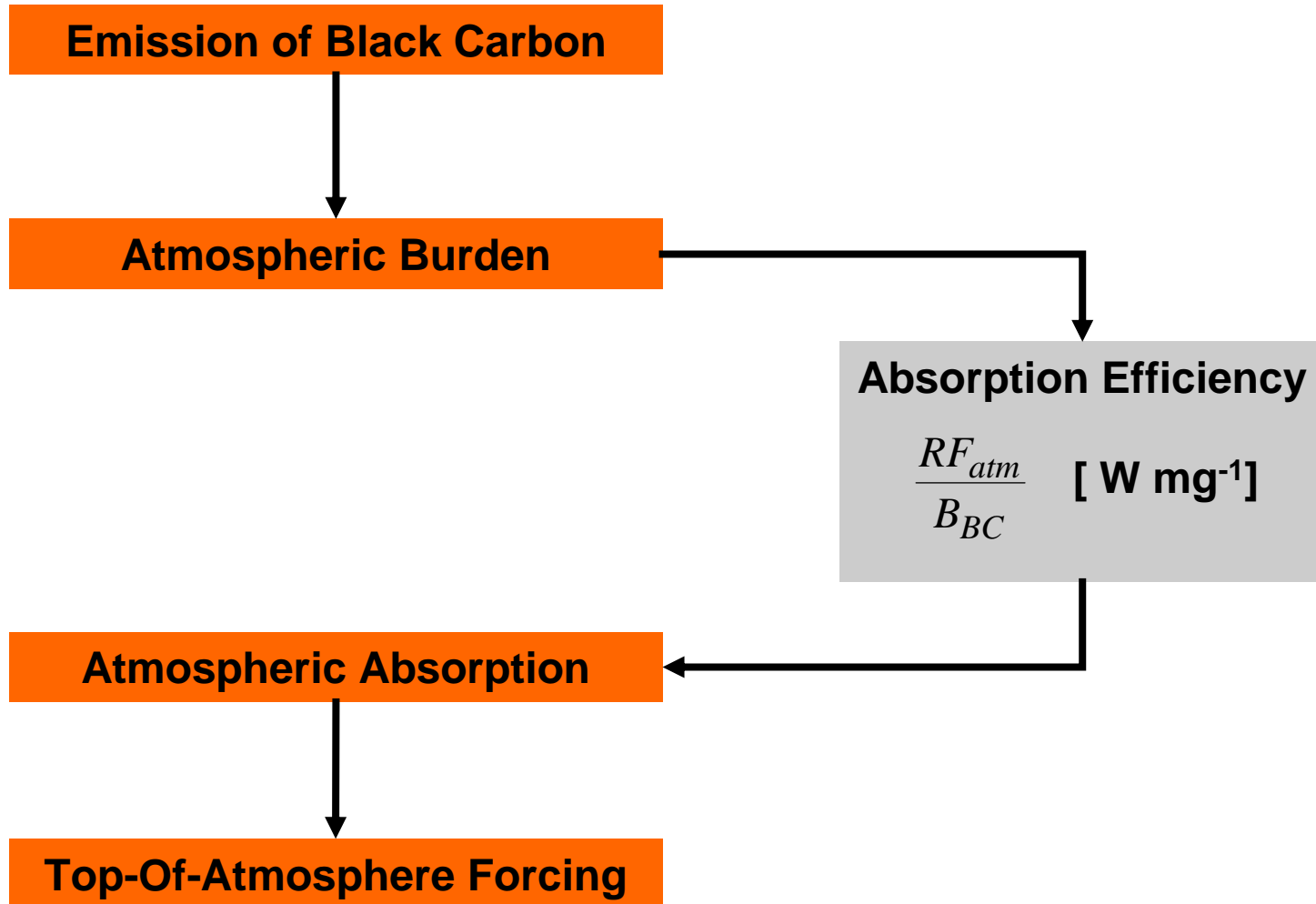
Contour lines: RF_{atm}



Method

Break down problem in individual steps

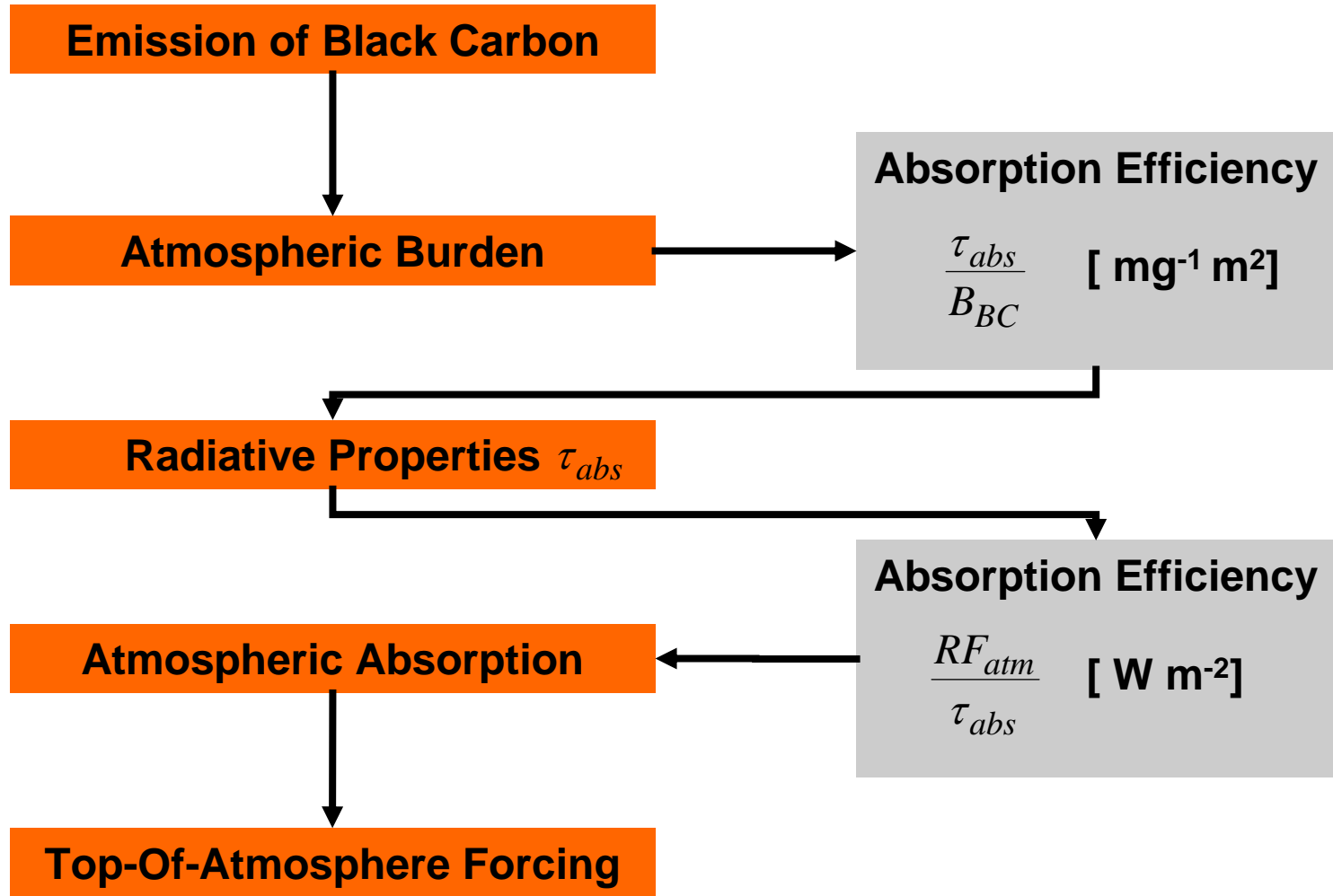
Traditionally:



Method

Break down problem in MORE individual steps

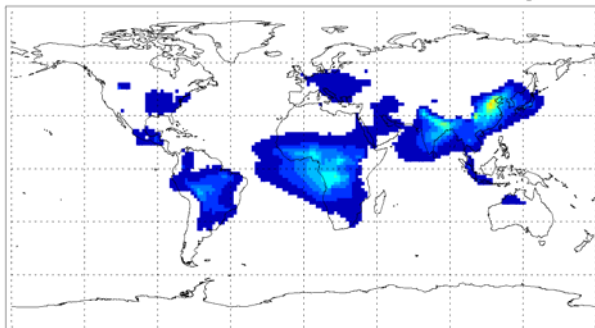
Establish physical connection – allows direct evaluation



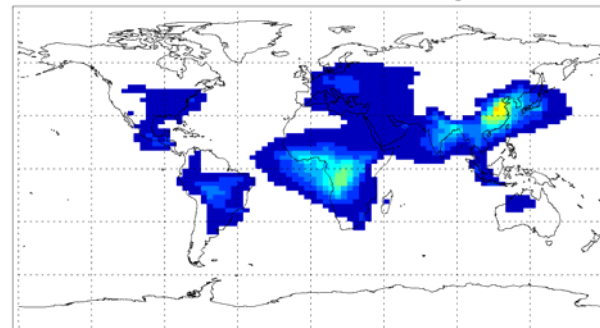
Black Carbon Burden

Annual-Mean
Anthropogenic
Black Carbon Burden

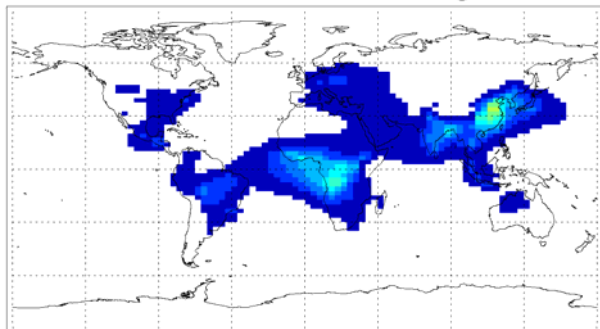
BC Burden ECHAM5-HAM 0.17 mg m^{-2}



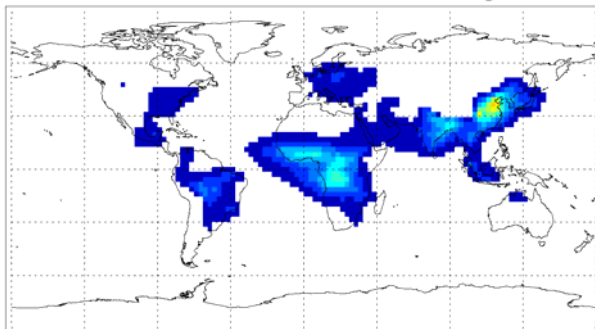
BC Burden LOA 0.25 mg m^{-2}



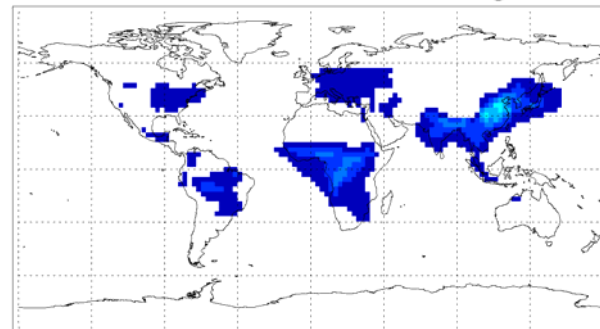
BC Burden LSCE 0.25 mg m^{-2}



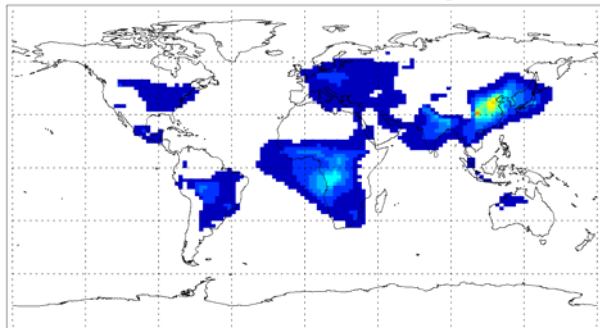
BC Burden UIO-CTM 0.19 mg m^{-2}



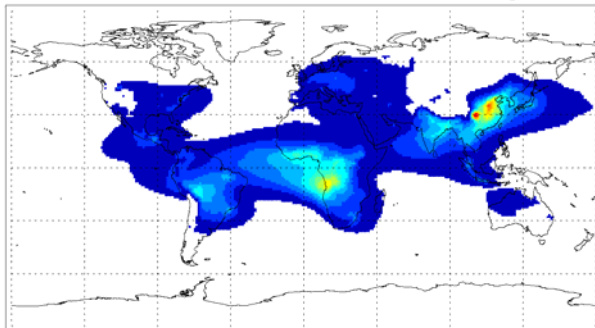
BC Burden UIO-GCM 0.18 mg m^{-2}



BC Burden UMI 0.19 mg m^{-2}



BC Burden SPRINTARS 0.36 mg m^{-2}



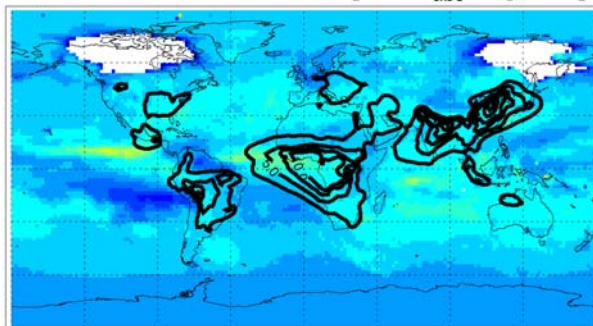
Aerosol Absorption Efficiency

Annual-Mean

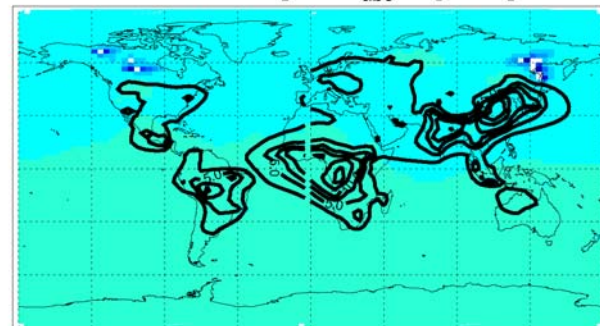
Anthropogenic

Absorption Efficiency = $\frac{\tau_{abs}}{B_{BC}}$
(τ_{abs}) at $\lambda=550$ nm

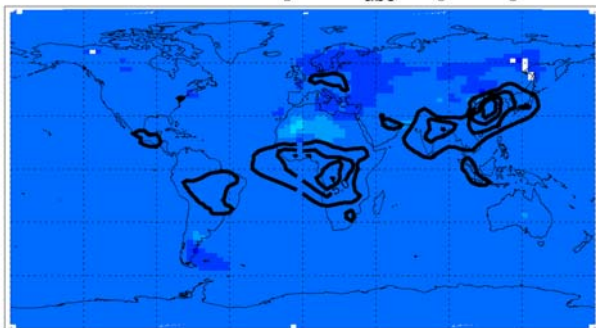
ECHAM5-HAM 7.1 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



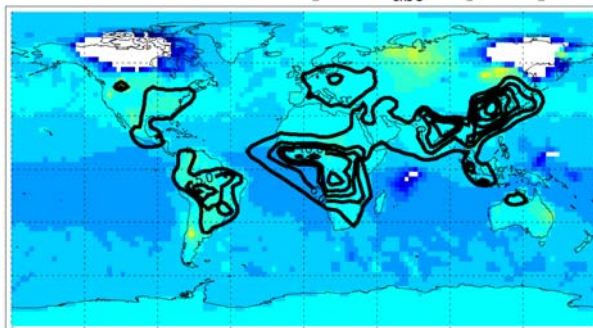
LOA 8.0 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



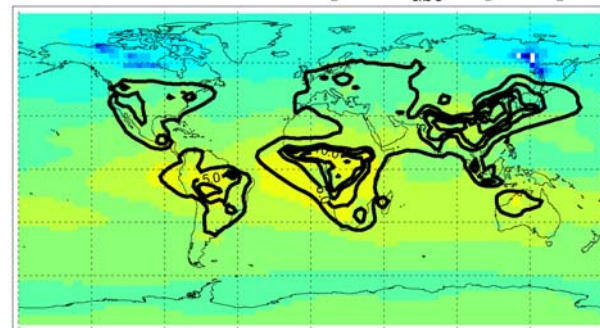
LSCE 4.4 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



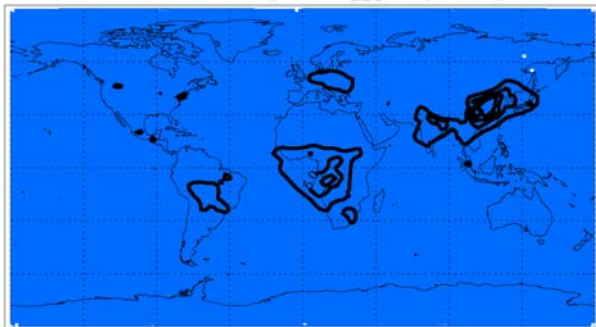
UIO-CTM 7.2 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



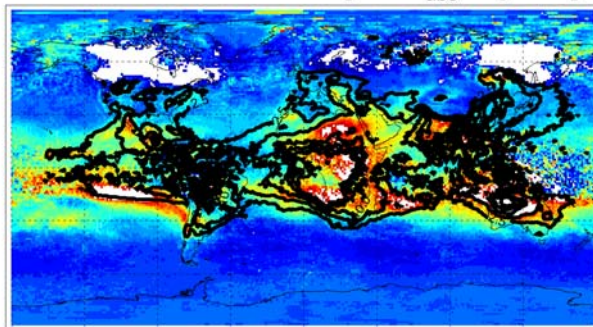
UIO-GCM 10.6 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



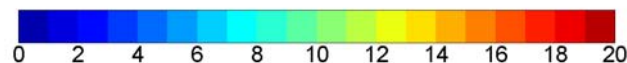
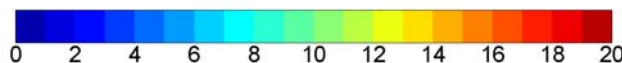
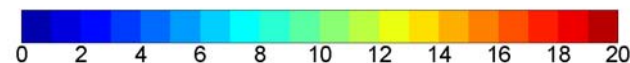
UMI 4.3 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



SPRINTARS 10.0 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]



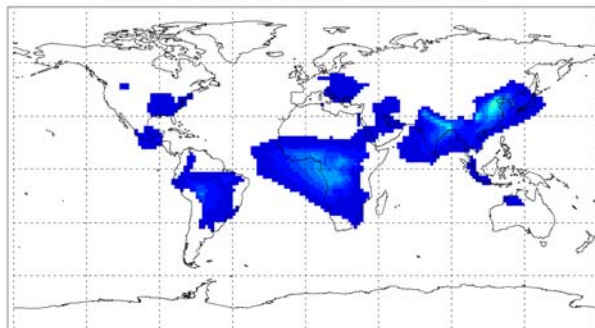
Contour lines: τ_{abs}



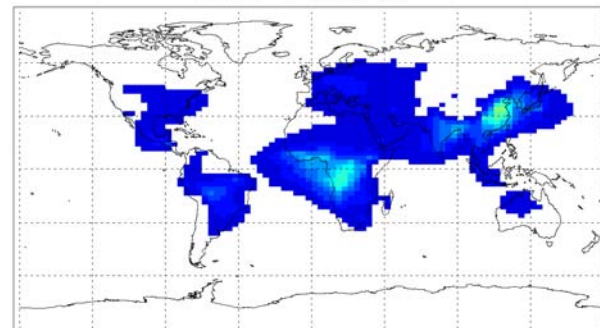
Aerosol Absorption Optical Depth

**Annual-Mean
Anthropogenic
Absorption Optical Depth
at $\lambda=550$ nm
[$\times 10^3$]**

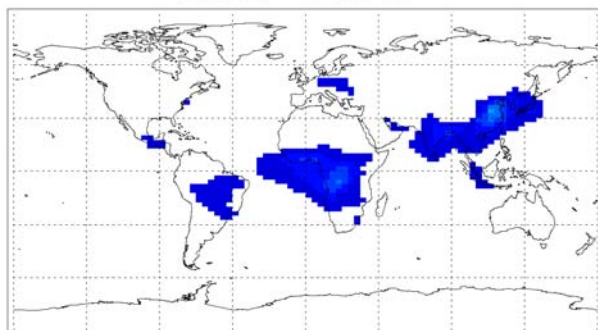
ECHAM5-HAM 1.3×10^{-3}



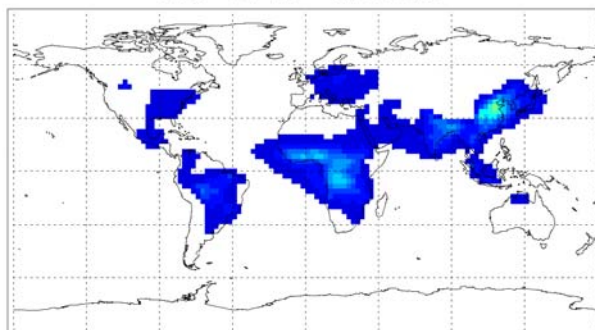
LOA 2.0×10^{-3}



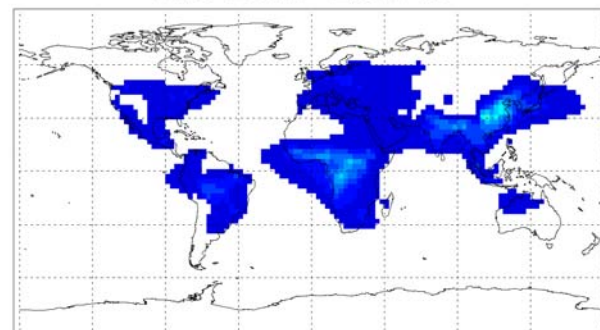
LSCE 1.1×10^{-3}



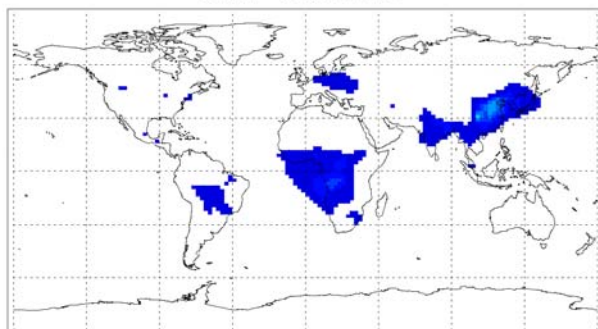
UIO-CTM 1.4×10^{-3}



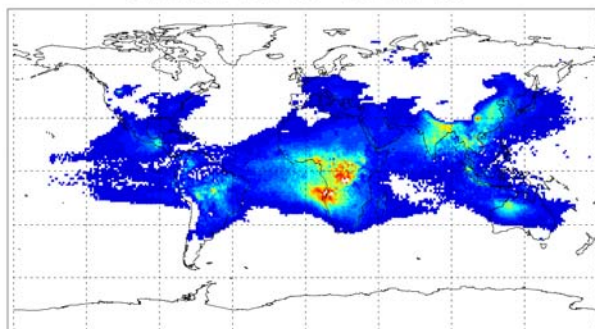
UIO-GCM 2.0×10^{-3}



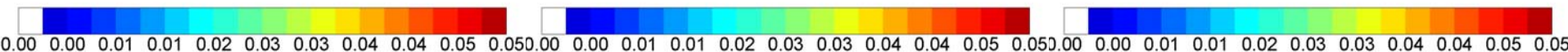
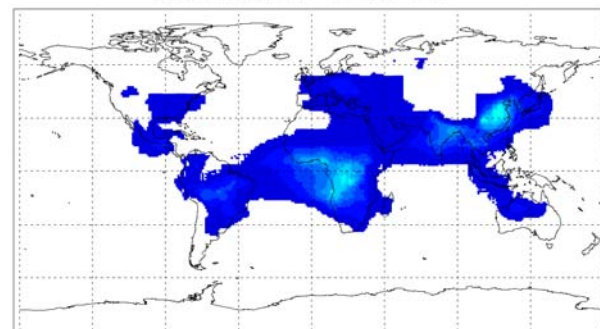
UMI 0.8×10^{-3}



SPRINTARS 3.7×10^{-3}



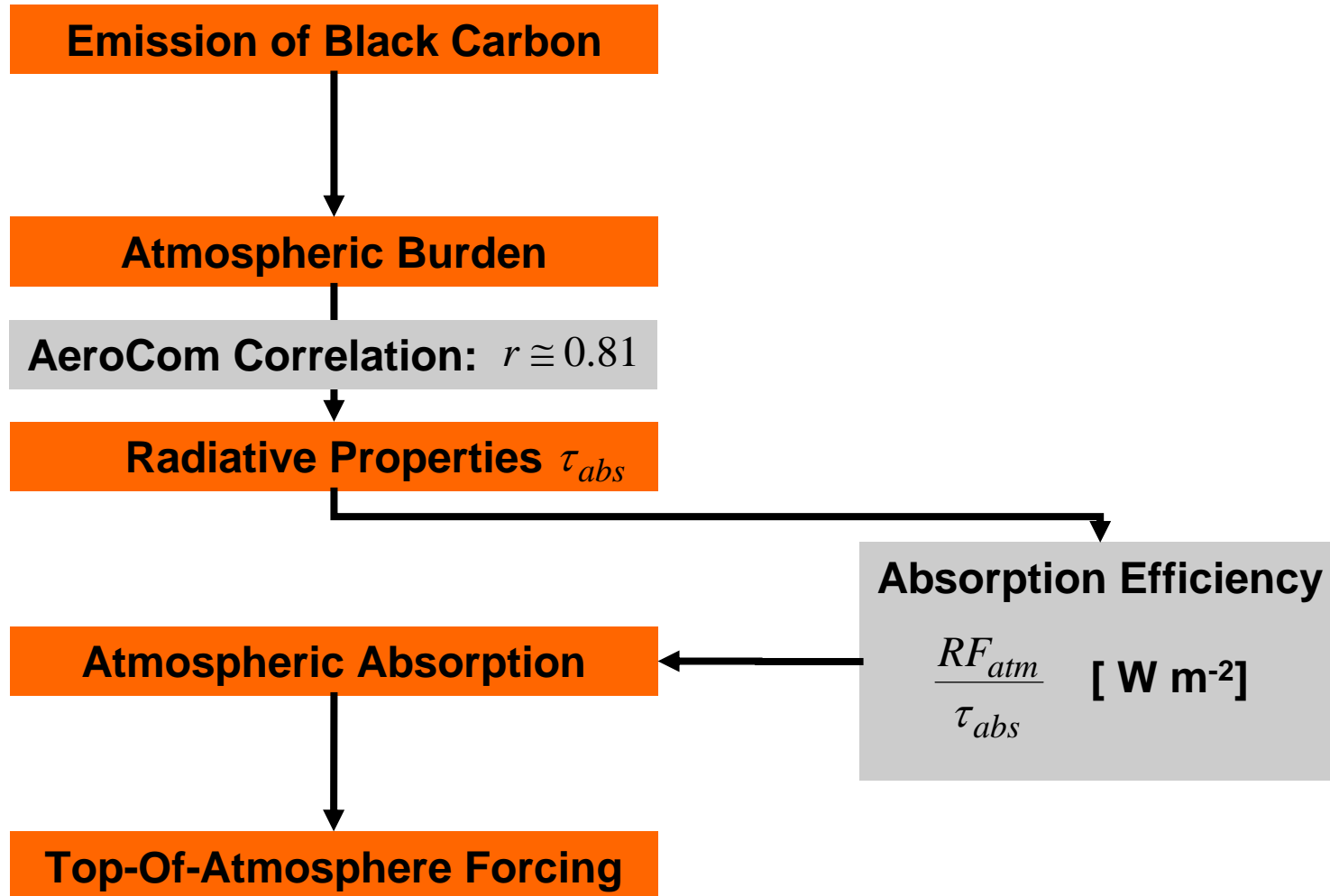
AeroCom 2.0×10^{-3}



Method

Break down problem in MORE individual steps

Establish physical connection – allows direct evaluation



Aerosol Absorption Efficiency

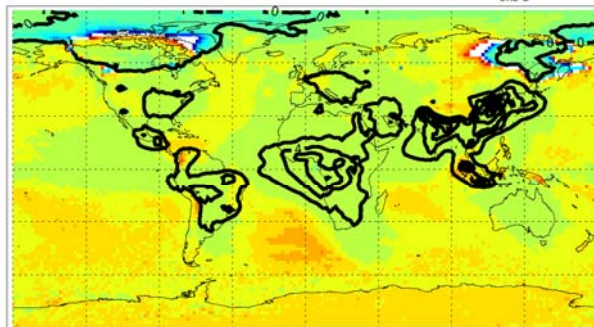
Annual-Mean

Anthropogenic

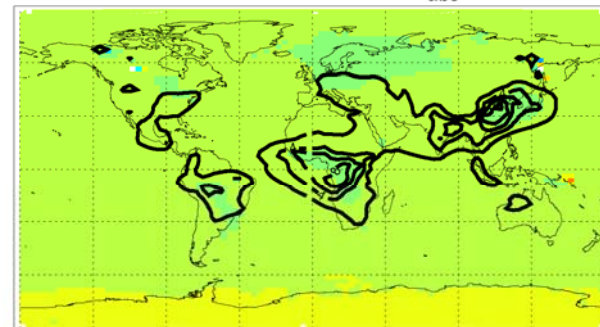
$$\text{Absorption Efficiency} = \frac{RF_{atm}}{\tau_{abs}}$$

Contour lines: RF_{atm}

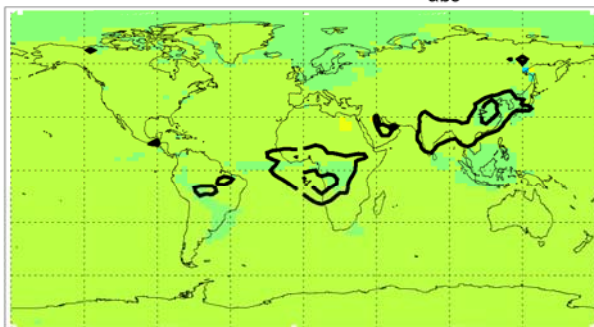
ECHAM5-HAM $754.4 \text{ Wm}^{-2} \tau_{abs}^{-1}$



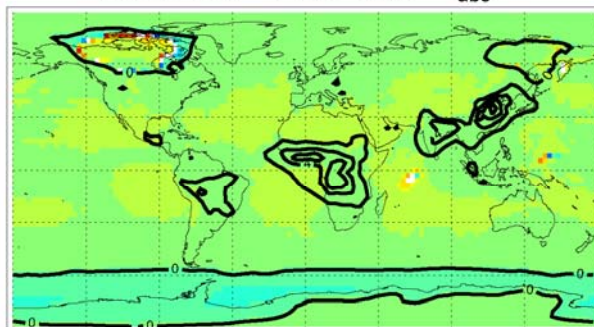
LOA $573.7 \text{ Wm}^{-2} \tau_{abs}^{-1}$



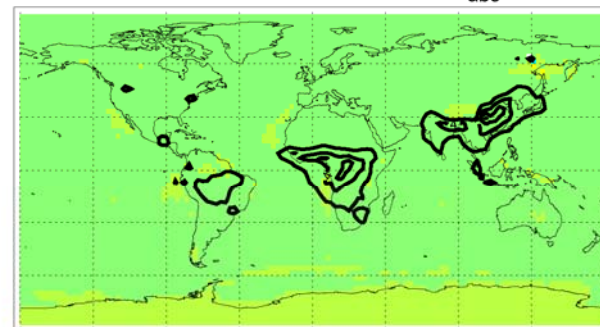
LSCE $586.4 \text{ Wm}^{-2} \tau_{abs}^{-1}$



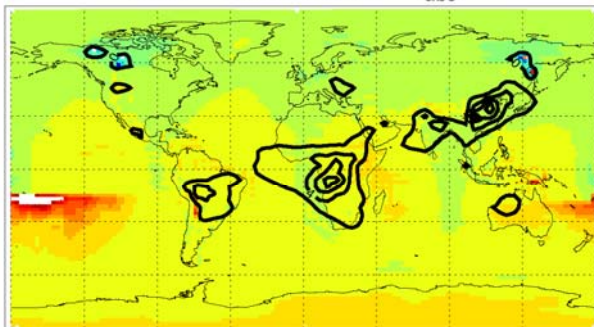
UIO-CTM $449.9 \text{ Wm}^{-2} \tau_{abs}^{-1}$



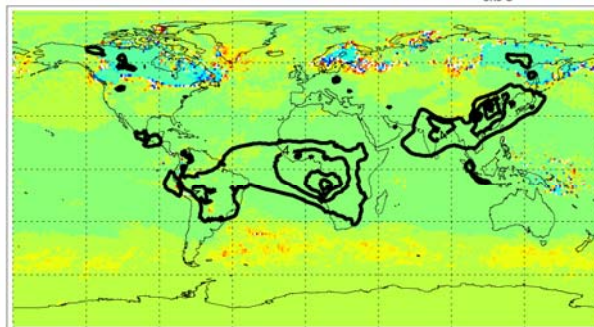
UIO-GCM $423.0 \text{ Wm}^{-2} \tau_{abs}^{-1}$



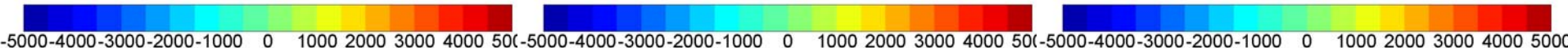
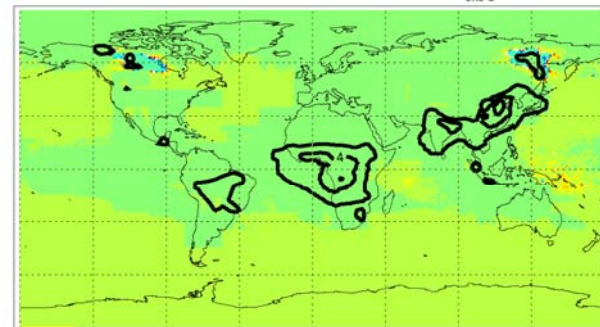
UMI $1007.8 \text{ Wm}^{-2} \tau_{abs}^{-1}$



SPRINTARS $260.0 \text{ Wm}^{-2} \tau_{abs}^{-1}$



AeroCom $387.1 \text{ Wm}^{-2} \tau_{abs}^{-1}$



Aerosol Absorption Efficiency

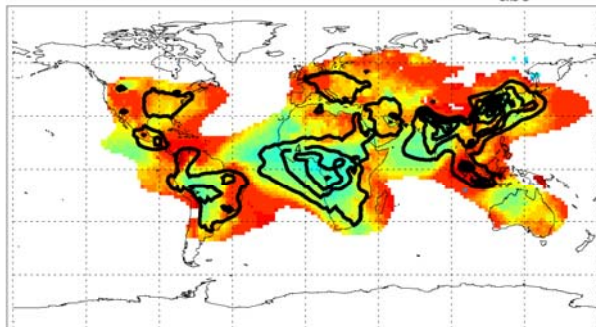
Annual-Mean

Anthropogenic

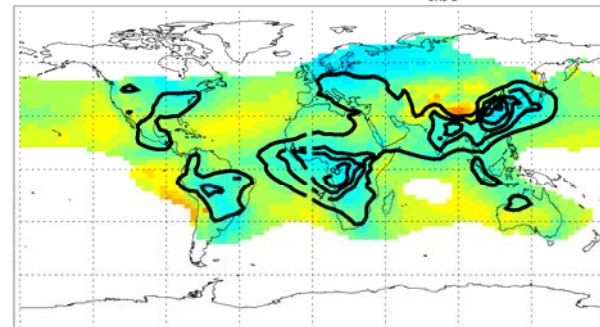
$$\text{Absorption Efficiency} = \frac{RF_{atm}}{\tau_{abs}}$$

Mask $RF_{atm} < 0.5 \text{ [W m}^{-2}\text{]}$

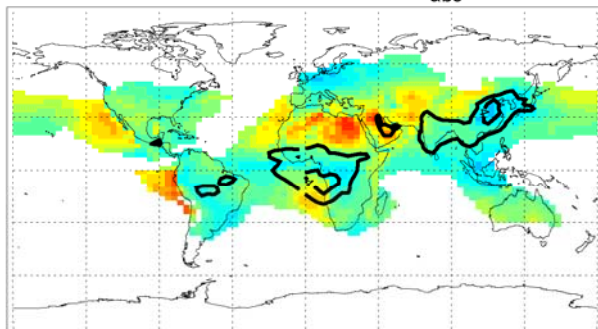
ECHAM5-HAM $749.3 \text{ Wm}^{-2} \tau_{abs}^{-1}$



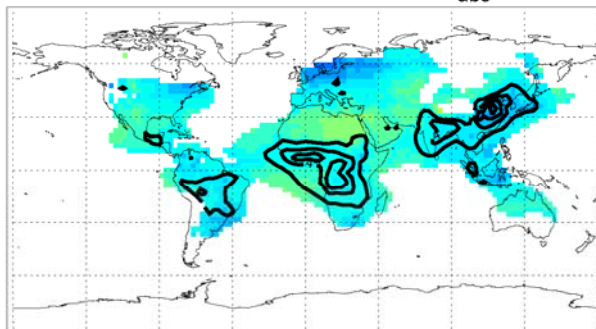
LOA $561.7 \text{ Wm}^{-2} \tau_{abs}^{-1}$



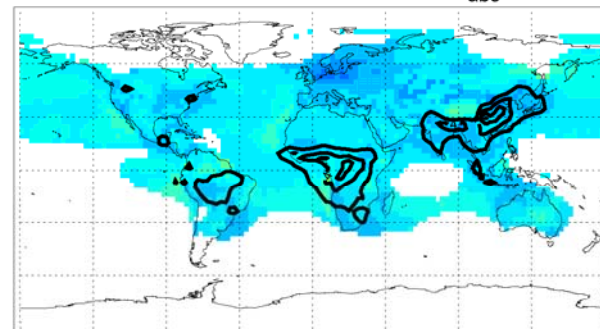
LSCE $581.2 \text{ Wm}^{-2} \tau_{abs}^{-1}$



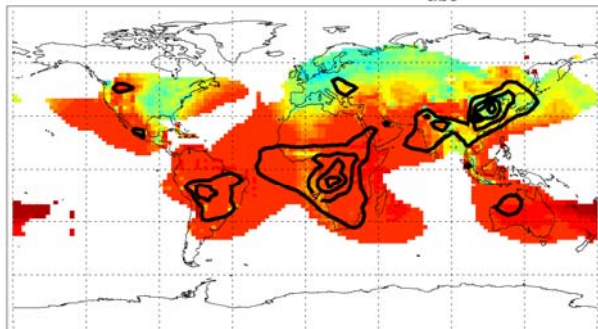
UIO-CTM $458.3 \text{ Wm}^{-2} \tau_{abs}^{-1}$



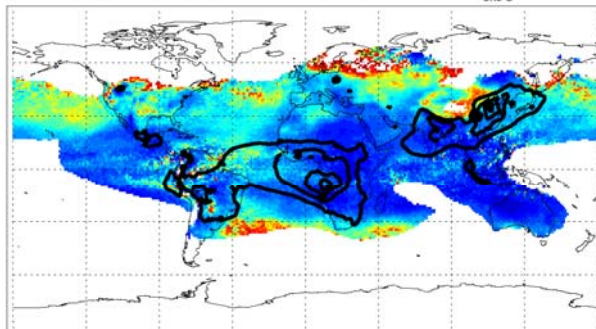
UIO-GCM $418.3 \text{ Wm}^{-2} \tau_{abs}^{-1}$



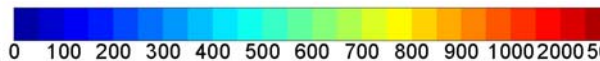
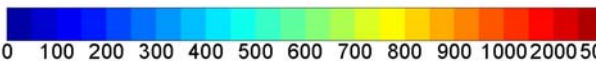
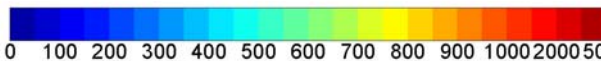
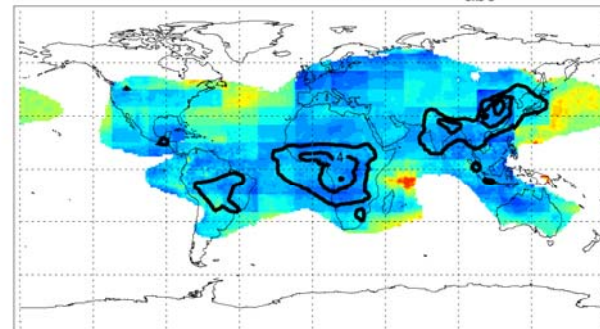
UMI $1010.2 \text{ Wm}^{-2} \tau_{abs}^{-1}$



SPRINTARS $257.8 \text{ Wm}^{-2} \tau_{abs}^{-1}$



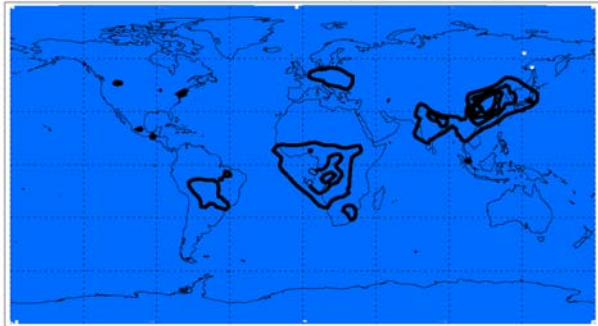
AeroCom $373.4 \text{ Wm}^{-2} \tau_{abs}^{-1}$



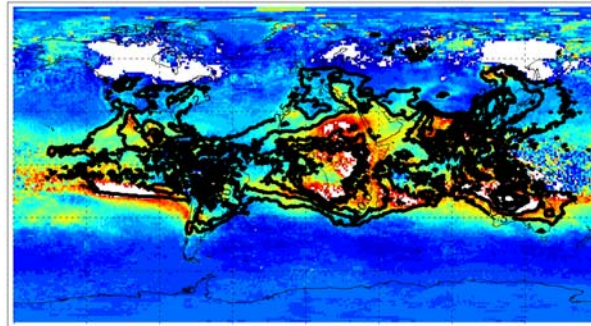
Aerosol Absorption Efficiency

Compensating Effects:

UMI 4.3 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]

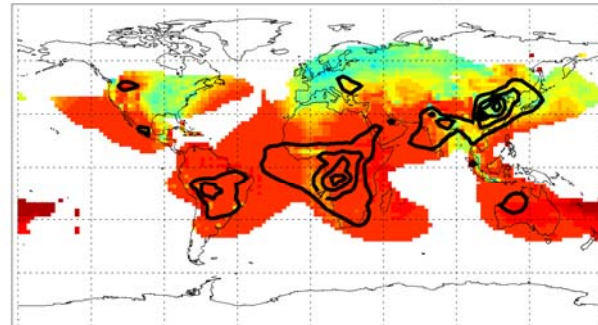


SPRINTARS 10.0 [$10^3 \tau_{abs} \text{ mg}^{-1} \text{ m}^2$]

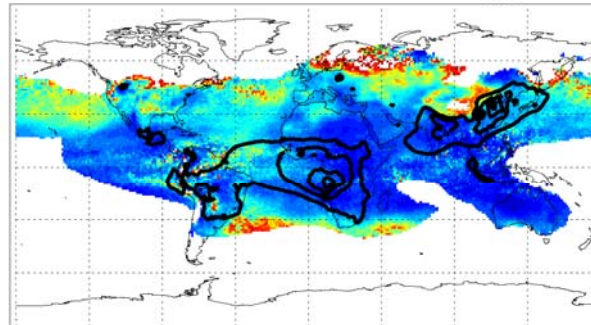


$$\frac{\tau_{abs}}{B_{BC}}$$

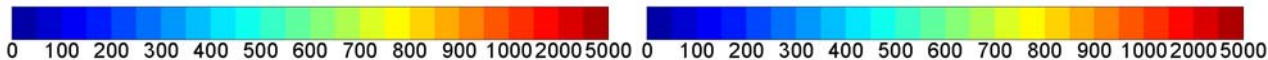
UMI 1010.2 $\text{Wm}^{-2} \tau_{abs}^{-1}$



SPRINTARS 257.8 $\text{Wm}^{-2} \tau_{abs}^{-1}$

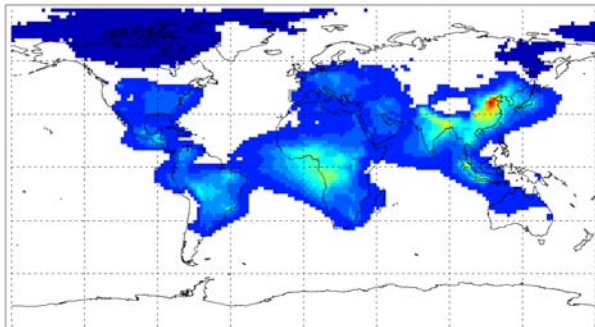


$$\frac{RF_{atm}}{\tau_{abs}}$$

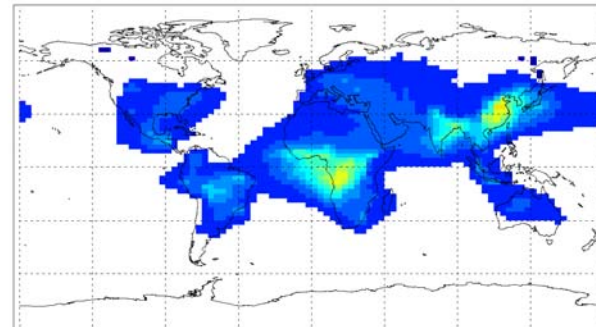


Direct Aerosol Radiative Forcing – Atmospheric Column

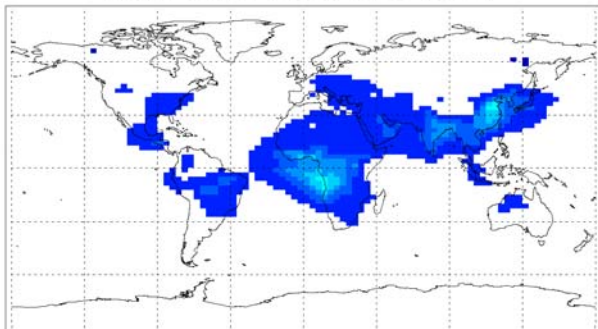
Total-Sky ECHAM5-HAM 0.95 Wm^{-2}



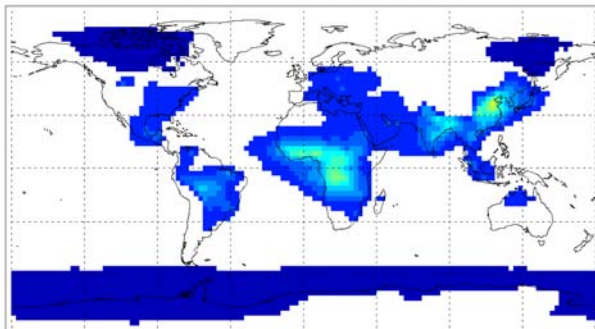
Total-Sky LOA 1.14 Wm^{-2}



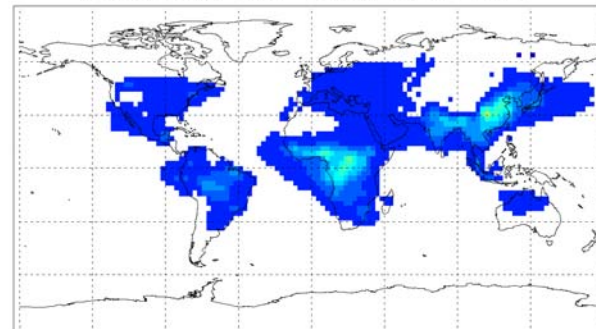
Total-Sky LSCE 0.65 Wm^{-2}



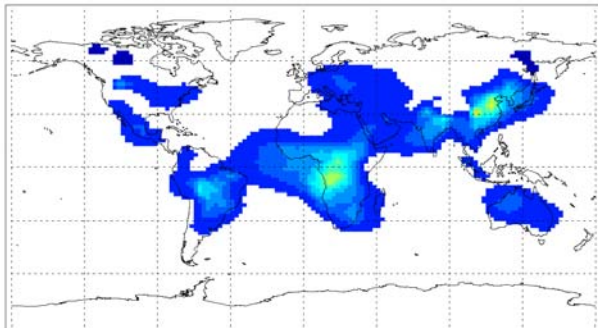
Total-Sky UIO-CTM 0.61 Wm^{-2}



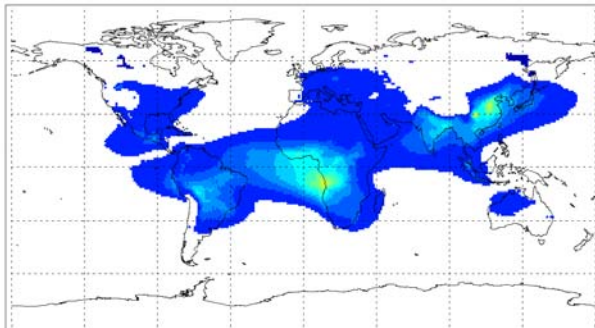
Total-Sky UIO-GCM 0.83 Wm^{-2}



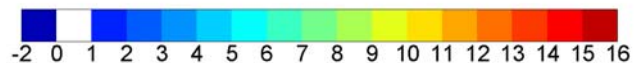
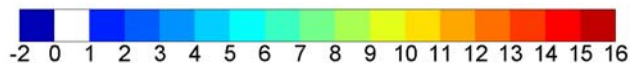
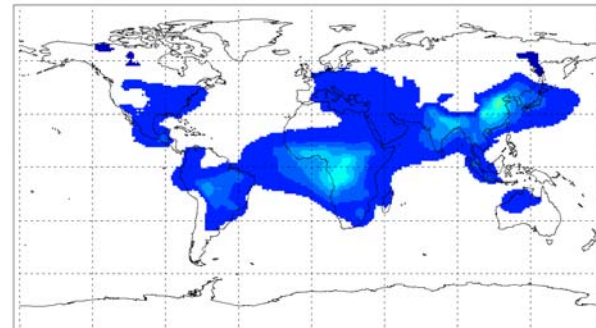
Total-Sky UMI 0.84 Wm^{-2}



Total-Sky SPRINTARS 0.96 Wm^{-2}



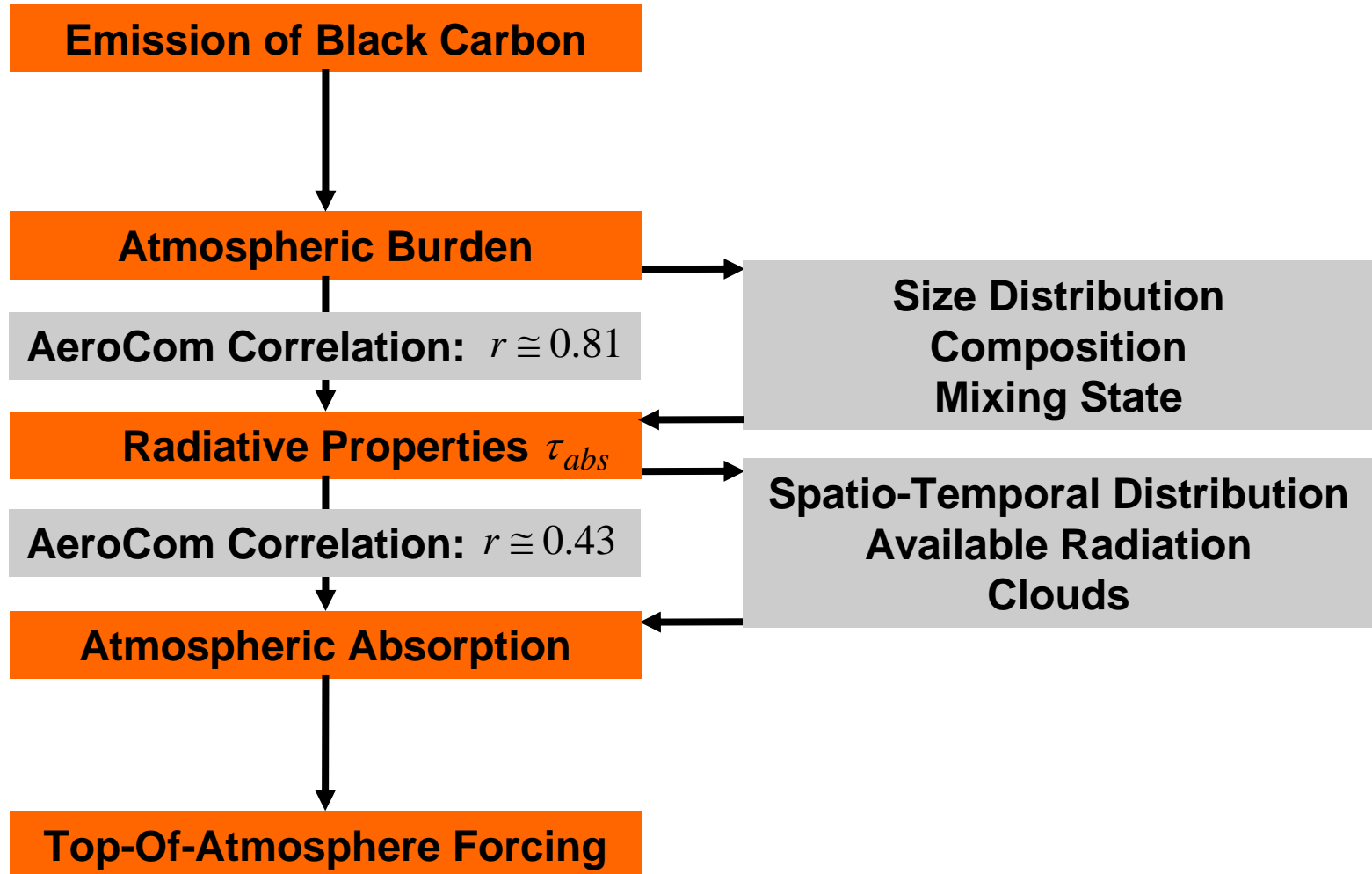
Total-Sky AeroCom 0.76 Wm^{-2}



Method

Break down problem in MORE individual steps

Establish physical connection – allows direct evaluation



Conclusions

Analysis of global annual mean radiative properties and effects creates little physical understanding

- Essential to break down the problem to a physical basis (This works only at the local scale)
- Reduction in complexity allows direct evaluation

Aerosol absorption important contribution to direct forcing

- Cloudy-sky contribution significant
- Additional diagnostics needed...

Uncertainty not limited to aerosol radiative properties

- Link to actual absorption and forcing equally important (and uncertain)
- AeroCom experiment could include forcing calculation with prescribed AOD / AAOD

This is work in progress...

Acknowledgements

- **AeroCom Modellers contributing to the forcing experiment**
- **Michael Schulz and Stefan Kinne**
- **John H. Seinfeld**
- **NASA EOS-IDS**
- **Max Planck Institute for Meteorology**
- **German High Performance Computing Centre for Climate and Earth System Research**