

Proudly Operated by Battelle Since 1965

An IPCC Perspective on Absorption

Steve Ghan

Direct Radiative Forcing by Black Carbon



Proudly Operated by Battelle Since 1965



where

F = global mean anthropogenic BC direct radiative forcing

E = global mean anthropogenic BC emissions

L = global mean lifetime = global mean anthropogenic BC burden B / E

MAC = global mean BC mass absorption cross section

= global mean anthropogenic BC absorption optical depth τ_{aBC} / B AFE = anthropogenic BC absorption forcing efficiency = F / τ_{aBC} (from models)

so
$$F = \tau_{a_{BC}} \times AFE$$

Estimating DRF



Model diagnostics of black carbon direct radiative forcing



Why use observed rather than simulated τ_{aBC} ?



Proudly Operated by Battelle Since 1965

AeroCom models underestimate τ_{aBC} in all seasons, particularly in Asia



Seasonal distribution of BC absorption aerosol optical depth

BC absorption aerosol optical depth (AAOD) and AAOD differences

But how is τ_{aBC} determined from AERONET retrievals?



Proudly Operated by Battelle Since 1965

- Method A (Bond et al., JGR 2013)
 - Use AERONET retrieved size distribution and τ_a
 - Assume all absorption by particles with diameter d>1 micron is by dust, all absorption by particles with d< 1 micron is by BC</p>
 - Estimate τ_{aD} from retrieved size distribution (d>1 micron) and prescribed dust refractive index

 $\tau_{aBC} = \tau_a - \tau_{aD}$

- Method B: as in Method A, but
 - Estimate τ_{aBC} from retrieved size distribution (d<1 micron) and retrieved refractive index

Size Resolved Chemical Composition



Proudly Operated by Battelle Since 1965





Proudly Operated by Battelle Since 1965

But how is τ_{aBC} determined from AERONET retrievals?

- Method C (Chung et al., PNAS 2012)
 - **Use spectral information about** τ_a from AERONET
 - Assume Angstrom dependence on wavelength λ

$$\tau_a(\lambda_{550}) \left(\frac{\lambda}{\lambda_{550}}\right)^{\beta} = \tau_{a_{CA}}(\lambda_{550}) \left(\frac{\lambda}{\lambda_{550}}\right)^{\beta_{CA}} + \tau_{a_D}(\lambda_{550}) \left(\frac{\lambda}{\lambda_{550}}\right)^{\beta_D}$$

Apply at $\lambda = \lambda_{550}$ and $\lambda = \lambda_{675}$ using retrieved τ_a and prescribed β_{CA} =1 and β_D =2.4 to solve for τ_{aCA} and τ_{aD} at $\lambda = \lambda_{550}$

Use same method to partition τ_{aCA} into τ_{aBC} and τ_{aOC}



All τ_{aBC} retrievals exceed simulations, but some much more than others

Industrial-era sources AeroCom, unscaled 0.00171 (Uncertainty is Aerocom model range) (0.0010 - 0.0035)only 0.00489 AeroCom median, scaled BC (Uncertainty in adjustment method) (0.00137 - 0.00783)Method A AeroCom median, scaled 0.00650 (Pre-industrial and industrial eras) (0.00226 - 0.00876)(Uncertainty in adjustment method) Sensitivity to assumptions Method B 0.00339 BC determined from fine mode only (x 0.52) (0.00188 - 0.00469)All BC sources Selection of stations (x 0.87 - 1.09) 0.0057 - 0.0071 All absorption due to BC (x 1.33) 0.00862 Method C Other adjusted studies 0.0077 BC Chung et al. [2012] Carbonaceous х 0.0095 Ramanathan and Carmichael [2008] х 0.0058 (based on model fields of Chung et al. [2005]) Sato et al. [2003] Х 0.0062 0.004 0.008 0 Bond et al. (2013) BC AAOD

Global BC AAOD inferred from observations and models

How ASR Can Help Resolve Retrieval Differences



- Focus on conditions with mixtures of dust and carbonaceous aerosol
- **Column** τ_a retrieval at multiple wavelengths
- Surface and aircraft measurements of
 - aerosol absorption at multiple wavelengths
 - size-resolved aerosol number and composition
- Constrain partitioning of retrieved τ_a into contributions from BC, OC, dust
- Constrain partitioning of local aerosol absorption into contributions from BC, OC, dust
- Test different partitioning methods