

Estimating Aerosol Effects on Cloud Radiative Forcing

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Ghan, S., 2013: Technical note: Estimating aerosol effects on cloud radiative forcing. *Atmos. Chem Phys.*, 13, 9971–9974, doi:10.5194/acp-13-9971-2013.

Ghan, S. J., X. Liu, R. C. Easter, R. Zaveri, P. J. Rasch, J.-H. Yoon, and B. Eaton, 2012: Toward a minimal representation of aerosols in climate models: Comparative decomposition of aerosol direct, semi-direct and indirect radiative forcing. *J. Climate*, 25, 6461-6476, doi:10.1175/JCLI-D-11-00650.1.

Distinguishing Direct and Indirect Effects



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Estimating indirect effects I

Easy method: $I = \Delta C$

$C = F - F_{\text{clear}}$ shortwave cloud radiative forcing

But if total aerosol forcing T is direct D + I,

this implies $D = \Delta F_{\text{clear}}$

which we know is biased cold because over a dark surface

- it overestimates cooling by scattering
- it underestimates warming by absorption

A More Representative Estimate

$$D = \Delta (F - F_{\text{clean}})$$

$I = \Delta (F_{\text{clean}} - F_{\text{clear, clean}}) = \Delta C_{\text{clean}}$ includes semi-direct effects

Total aerosol forcing $T = D + I + S$

where $S = \Delta F_{\text{clear, clean}}$ surface albedo forcing



Diagnostic Requirements

- ▶ F whole sky TOA flux with all aerosol
- ▶ F_{clean} aerosol set to zero for diagnostic radiation
- ▶ $F_{\text{clear, clean}}$ aerosol & cloud set to zero for diagnostic radiation

- ▶ If model already calculates F_{clear} along with F , just need a 2nd radiation call with aerosol set to zero.

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Longwave Radiation

- ▶ Anthropogenic aerosol particles are too small to affect longwave radiation much
- ▶ Difference between ΔC and ΔC_{clean} is less than 0.2 W m^{-2} locally and 0.01 W m^{-2} globally