Direct Aerosol Forcing:
Calculation From Observables and Sensitivites to Inputs

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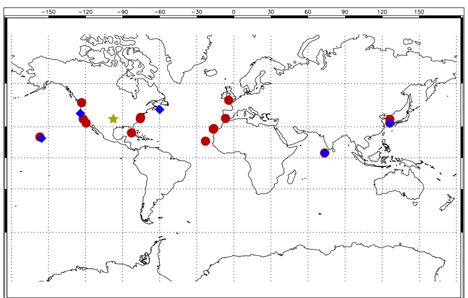
Abstract

Aerosol radiative forcing, the difference in net radiative flux with and without aerosol, and anthropogenic aerosol radiative forcing, the difference in net radiative flux with and without anthropogenic aerosol, are essential to understanding Earth's radiation budget and changes in this budget over the industrial period. These forcings are highly variable in space and time; locally and instantaneously they can be tens of watts per square meter. Characterization of aerosol direct forcing (the forcing in cloud-free sky) at a given time and location such as at ARM sites, generally relies on measured aerosol extensive and intensive properties and their dependence on wavelength. Extensive properties, which scale linearly with aerosol amount, include measurements of optical depth (extinction in the total column and its wavelength dependence, often characterized by the Ångström exponent); aerosol forcing is commonly characterized as a "forcing per optical depth." Intensive properties, independent of aerosol amount, are manifested in such measured aerosol properties including single scatter albedo and backscatter fraction as well as on situational variables such as solar zenith angle and surface reflectance (the latter also wavelength dependent). This poster examines the sensitivity of calculated aerosol radiative forcing and forcing per optical depth to extensive and intensive aerosol properties based on the uncertainties with which these are measurable.

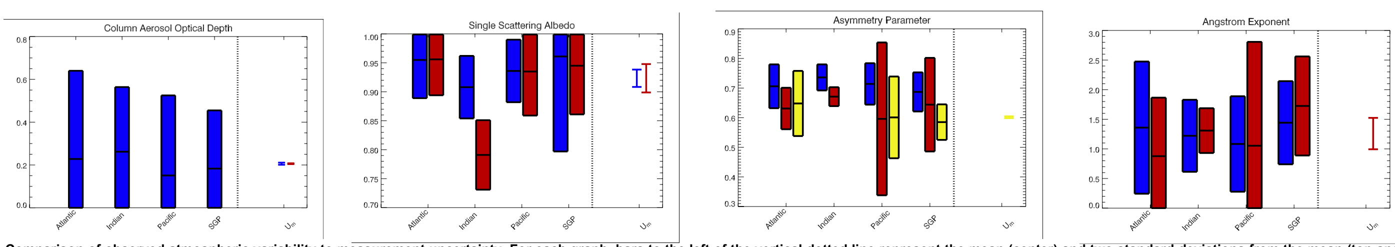


Optical properties from sites across the Northern Hemisphere are used as a basis for examining radiative forcing sensitivity. SGP values are given in comparison to other regions which consist of mostly oceanic and coastal sites.

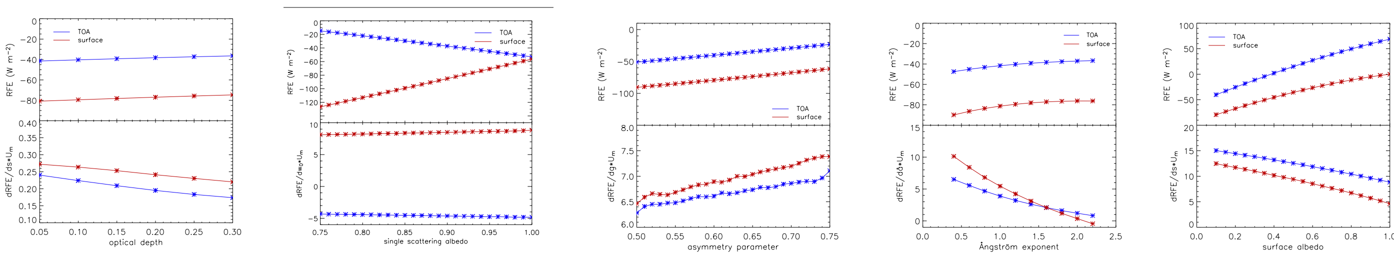
Reported uncertainty in measurement of aerosol properties by various instruments.

Parameter Instrument	*Uncertainty**	*Wavelength*	*Source*
Tau			
CIMEL	±0.01	340-1020 nm	Holben et al. 1998
MFRSR	±0.02	415-940 nm	Mitchell and Forgan 2003
ω_0			
CIMEL	±0.03		Dubovik et al. 2000
Neph+PSAP	<1 µm ±0.014-0.029** 1-10 µm ±0.008-0.023	550 nm	Anderson et al. 1999
	±0.036-0.049***	550 nm	Sheridan et al. 2002
g			
CIMEL			
Fiebig	1%	450, 550, 700 nm	Fiebig and Ogren 2005
å			
CIMEL			
Neph	<1 µm ±0.33-0.45** 1-10 µm ±0.70-0.84	450 nm / 700 nm	Anderson et al. 1999
	±0.49-0.53***	550 nm	Sheridan et al. 2002

***Total size range, all wavelengths unless otherwise noted**
****For a range of airmasses**
*****For a range of scattering coefficients (58-6 Mm-1)**



Comparison of observed atmospheric variability to measurement uncertainty. For each graph, bars to the left of the vertical dotted line represent the mean (center) and two standard deviations from the mean (top and bottom) for regions in the Northern Hemisphere and SGP. Blue bars represent properties from the Cimel Sunphotometer and Dubovik retrievals (Dubovik and King 2000) at 441 nm. Red bars represent properties from *in situ* nephelometer observations and, for asymmetry parameter, the Henyey-Greenstein relationship to backscatter fraction (Wiscombe and Grams 1976) at 550 nm. The yellow bars represent asymmetry parameter from a new inversion (Fiebig and Ogren 2005) using *in situ* data, also at 500 nm. Error bars to the right of the vertical dotted line represent reported measurement uncertainties (U_m) as cited in the table above.



Model Constants
wavelength: 0.3-3.0µm
SZA: diurnally averaged over Spring Equinox
latitude: 35°
standard atmosphere: mid-latitude summer
surface albedo (s): 0.1
single scatter albedo (ω_0): 0.92
asymmetry parameter (*g*): 0.6
Ångström exponent (å): 1.2
number of streams: 8

The sensitivity of aerosol direct radiative forcing to observed aerosol properties and to measurement uncertainties is demonstrated above. A radiative transfer model is used to compute fluxes at the top of atmosphere and surface, varying one property at a time while the others are held constant. Sensitivity to the range of observed values is expressed as radiative forcing efficiency (RFE), the direct radiative forcing per unit optical depth (top panes). Sensitivity to measurement uncertainty is expressed as the derivative of RFE with respect to the variation of the aerosol property of interest times its measurement uncertainty (U_m). The measurement uncertainty used here is the largest for each property from the table above. The aerosol property of interest and surface albedo are varied over the range in observations shown in the bar graphs while all others are held at the mean value. The means are listed in the model constants. Solar zenith angle is diurnally average over the day of the Spring equinox to avoid solar angle effects. Results for the range of latitudes (-90°,90°) has been computed and those for 35° are presented here.

Future Work

An approach to examining the sensitivity of aerosol direct radiative forcing to observed variability and measurement uncertainty has been presented. The current analysis is limited in scope by several factors. Aerosol properties and surface albedo are specified in the model at one wavelength only; the effect of wavelength dependence of the properties on radiative forcing has not been shown. Surface albedo is modeled here as a lambertian surface which is not representative of natural materials in the Earth system. For a more comprehensive discussion of the effects of surface albedo see Ricchiazzi et al. (this session). The properties examined here are those of first order importance to calculating aerosol direct radiative forcing: optical depth, single scattering albedo, asymmetry parameter, angstrom exponent, and surface albedo. These properties in turn depend on others that are regularly measured such as backscatter fraction and f(RH). In the future, the effect of additional properties on the radiaitve forcing can be examined through use of the chain rule.

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