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Aerosol direct radiative effects over the northwest Atlantic, northwest Pacific, and North Indian Oceans: estimates based on in-situ chemical and optical measurements and chemical transport modeling

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Abstract. The largest uncertainty in the radiative forcing of climate change over the industrial era is that due to aerosols, a substantial fraction of which is the uncertainty associated with scattering and absorption of shortwave (solar) radiation by anthropogenic aerosols in cloud-free conditions (IPCC, 2001). Quantifying and reducing the uncertainty in aerosol influences on climate is critical to understanding climate change over the industrial period and to improving predictions of future climate change for assumed emission scenarios. Measurements of aerosol properties during major field campaigns in several regions of the globe during the past decade are contributing to an enhanced understanding of atmospheric aerosols and their effects on light scattering and climate. The present study, which focuses on three regions downwind of major urban/population centers (North Indian Ocean (NIO) during INDOEX, the

Northwest Pacific Ocean (NWP) during ACE-Asia, and the Northwest Atlantic Ocean (NWA) during ICARTT), incorporates understanding gained from field observations of aerosol distributions and properties into calculations of perturbations in radiative fluxes due to these aerosols. This study evaluates the current state of observations and of two chemical transport models (STEM and MOZART). Measurements of burdens, extinction optical depth (AOD), and direct radiative effect of aerosols (DRE – change in radiative flux due to total aerosols) are used as measurement-model check points to assess uncertainties. In-situ measured and remotely sensed aerosol properties for each region (mixing state, mass scattering efficiency, single scattering albedo, and angular scattering properties and their dependences on relative humidity) are used as input parameters to two radiative transfer models (GFDL and University of Michigan) to constrain estimates of aerosol radiative effects, with uncertainties in each step propagated through the analysis. Constraining the radiative transfer calculations by observational inputs increases the clear-sky, 24-h averaged AOD (34±8%), top of atmosphere (TOA) DRE (32±12%), and TOA direct climate forcing of aerosols (DCF – change in radiative flux due to anthropogenic aerosols) (37±7%) relative to values obtained with "a priori" parameterizations of aerosol loadings and properties (GFDL RTM). The resulting constrained clear-sky TOA DCF is -3.3 ± 0.47, -14 ± 2.6, -6.4 ± 2.1 Wm^{-2} for the NIO, NWP, and NWA, respectively. With the use of constrained quantities (extensive and intensive parameters) the calculated uncertainty in DCF was 25% less than the "structural uncertainties" used in the IPCC-2001 global estimates of direct aerosol climate forcing. Such comparisons with observations and resultant reductions in uncertainties are essential for improving and developing confidence in climate model calculations incorporating aerosol forcing.

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