Improvement in Clouds and the Earth's Radiant Energy System/Surface and Atmosphere Radiation Budget Dust Aerosol Properties, Effects on Surface Validation of Clouds and Radiative Swath

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Introduction

Within the Clouds and the Earth's Radiant Energy System (CERES) science team (Wielicki et al. 1996), the Surface and Atmospheric Radiation Budget (SARB) group is tasked with calculating vertical profiles of heating rates, globally, and continuously, beneath CERES footprint observations of Top of Atmosphere (TOA) fluxes. This is accomplished using a fast radiative transfer code originally developed by Qiang Fu and Kuo-Nan Liou (Fu and Liou 1993) and subsequently highly modified by the SARB team. Details on the code and its inputs can be found in Kato et al. (2005) and Rose and Charlock (2002). Among the many required inputs is characterization of the vertical column profile of aerosols beneath each footprint. To do this SARB combines aerosol optical depth information from the moderate-resolution imaging spectroradiometer (MODIS) instrument along with aerosol constituents specified by the Model for Atmosphere and Chemical Transport (MATCH) of Collins et al. (2001), and aerosol properties (e.g. single scatter albedo and asymmetry parameter) from Tegen and Lacis (1996) and OPAC (Hess et al. 1998). The publicly available files that include these flux profiles, called the Clouds and Radiative Swath (CRS) data product, available from the Langley Atmospheric Sciences Data Center (http://eosweb.larc.nasa.gov/). As various versions of the code are completed, publishable results are named "Editions." After CRS Edition 2A was finalized it was found that dust aerosols were too absorptive. Dust aerosols have subsequently been modified using a new set of properties developed by Andy Lacis and results have been released in CRS Edition 2B. This paper discusses the effects of changing desert dust aerosol properties, which can be significant for the radiation budget in mid ocean, a few thousand kilometers from the source regions. Resulting changes are validated via comparison of surface observed fluxes from the Saudi Solar Village surface site (Myers et al. 1999), and the E13 site at the Atmospheric Radiation Measurement (ARM), Southern Great Plains (SGP) central facility.

Improvements to Aerosol Scheme

After processing of CRS Edition 2A began, poor results arose when calculations included a large percentage of dust aerosols. Biases for computed shortwave (SW) fluxes in some desert regions were unacceptably high. The issue was significant enough to warrant improving dust properties and re-running the SARB code to produce a new version, Edition 2B. Beyond the effects on the radiation transfer calculation, the change in aerosol properties affected calculations of clear sky broadband surface albedo. Under clear skies, initial surface broadband albedo is determined from a look-up table based on the Langley Fu and Liou code having been run under a number of different conditions. It is, in essence, a parameterization of the radiation transfer code, which includes as independent variables, among others, clear sky CERES flux observations and aerosol optical depth. Using this approach with overly absorptive dust aerosols, the parameterization, to better match the CERES observations, compensated by increasing derived surface albedo. The new, less absorptive dust increased the values for computed shortwave insolation and reduced the initial surface albedo. A second benefit of re-running Edition 2A was that it allowed the use of a new "variable" scale height for each aerosol constituent included in the MATCH chemical transport model. Each aerosol species, instead of fixed scale heights, now has a vertical profile that changes over time. Table 1 lists the various aerosol constituents available during SARB processing and differences in those properties between Editions 2A and 2B.

Table 1. Aerosol properties available during SARB processing and changes between Editions 2A and 2B.

CRS Aerosol ID Number	MATCH Aerosol Type	CRS Aerosol Optics		Vertical Distribution	
		Ed 2A	Ed 2B	Ed 2A Scale Height	Ed 2B F(z)
1	Small dust particles	Dust < 1.0μm given by particle re =0.5μm Tegen -Lacis (1998)	Dust < 0.5μm given by particle re =0.3μm Lacis (2004 Personal Comm.)	3.0 km	Variable (Advected along with MATCH particles.)
2	Large dust particles	Dust > 1.0μm given by particle re =2.0μm Tegen -Lacis (1998)	Dust > 0.5μm given by particle re =2.0μm Lacis (2004 Personal Comm.)	1.0 km	Variable
3	Black carbon	Soot (OPAC)	Soot (OPAC)	3.5 km	Variable
4	Hydrophilic organic carbon	Soluble organic (OPAC)	Soluble organic (OPAC)	3.8 km	Variable
5	Hydrophobic organic carbon	Insoluble organic (OPAC)	Insoluble organic (OPAC)	3.8 km	Variable
6	Sulfate	Sulfate (OPAC)	Sulfate (OPAC)	3.5 km	Variable
7	Sea salt	Sea salt (OPAC)	Sea salt (OPAC)	0.5 km	Variable

Figure 1 shows spectral plots of the changes in dust aerosol properties for large and small dust particles. The old were based on Tegen and Lacis (1998). The new are based on properties developed by Andy Lacis (Personal Communications 2004). Figures 1a, 1b, 1c, show normalized extinction, single scatter albedo and asymmetry parameters for small and large dust particles respectively as a

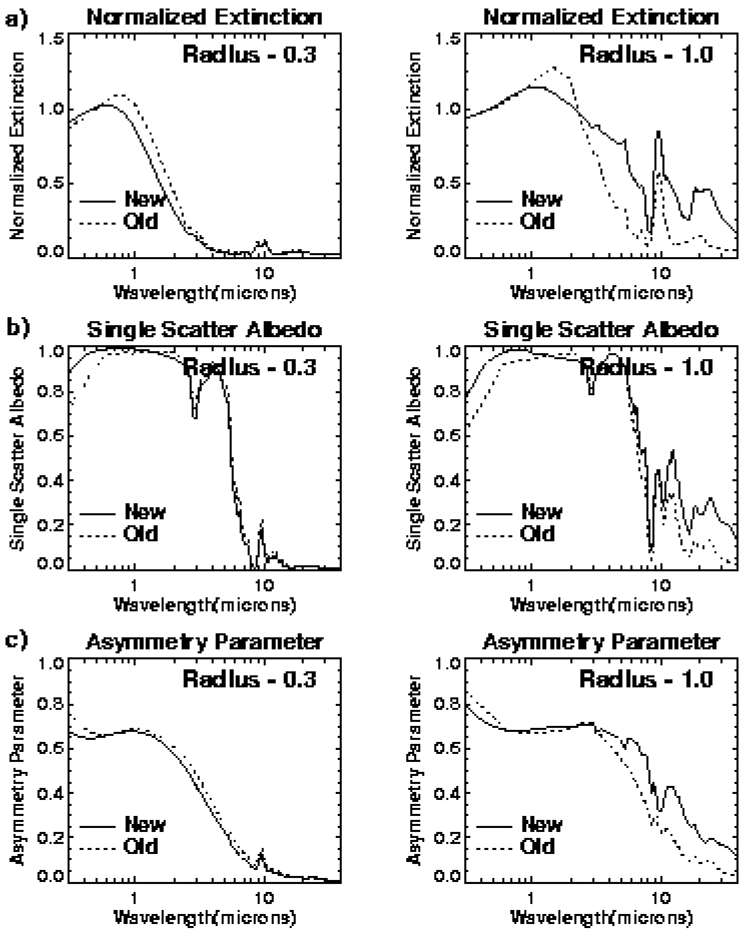

Figure 1. Old (Tegen and Lacis) and new (Lacis) properties for large and small dust particles used in SARB processing.

function of wavelength. Dashed lines show old dust properties, solid shows new. Figure 1 shows the increase in single scatter albedo and increase in backscatter indicative of less absorption by the dust particles, particularly in the visible and near IR region below 1 micron.

Effect on Radiation Transfer Results

As the Terra satellite passes over a surface site, at the same local times each day, a CERES instrument sweeps along perpendicular to the orbit track. The radiation transfer code is run for every other CERES footprint and every other scan line. Results from footprints within 15 km of a CERES validation site are subset for comparison with surface observations. (Complete CERES/SARB validation results for all surface validation sites can be found at http://www-cave.larc.nasa.gov/cave/valplot.) Surface observed fluxes are averaged up from 1 minute to 15 minutes. To account for differences in solar zenith angle within the 15 minute time span of surface flux averages, surface SW flux observations are adjusted by the ratio of surface 15 minute average solar zenith angle and footprint solar zenith angle at the satellite observation time. The adjustment of the surface observations is based only on the satellite "clock." No surface radiometric data are used as inputs for the SARB calculations. Results are shown from clear sky footprints where "clear" is defined as CERES footprints where all MODIS imager pixels (collocated within the larger CERES footprint) are determined cloud free via a cloud mask developed by Trepte et al. (1999).

The effect of changes in the dust aerosols at both the TOA (left plot) and the surface (right plot) are clearly found in changes to bias (model minus observed fluxes) in Figure 2. Results shown are for clear sky footprints for all 12 months of 2001. The decrease in the TOA model reflected SW with respect to the CERES observation was more than 12 W/m^{-2}. This follows directly from a decrease in initial clear sky surface albedo. When dust aerosols were made less absorptive, more radiation was allowed to the surface. This allowed for a decrease in model derived surface albedo, which in turn lets the radiation transfer model, better match the TOA observations.

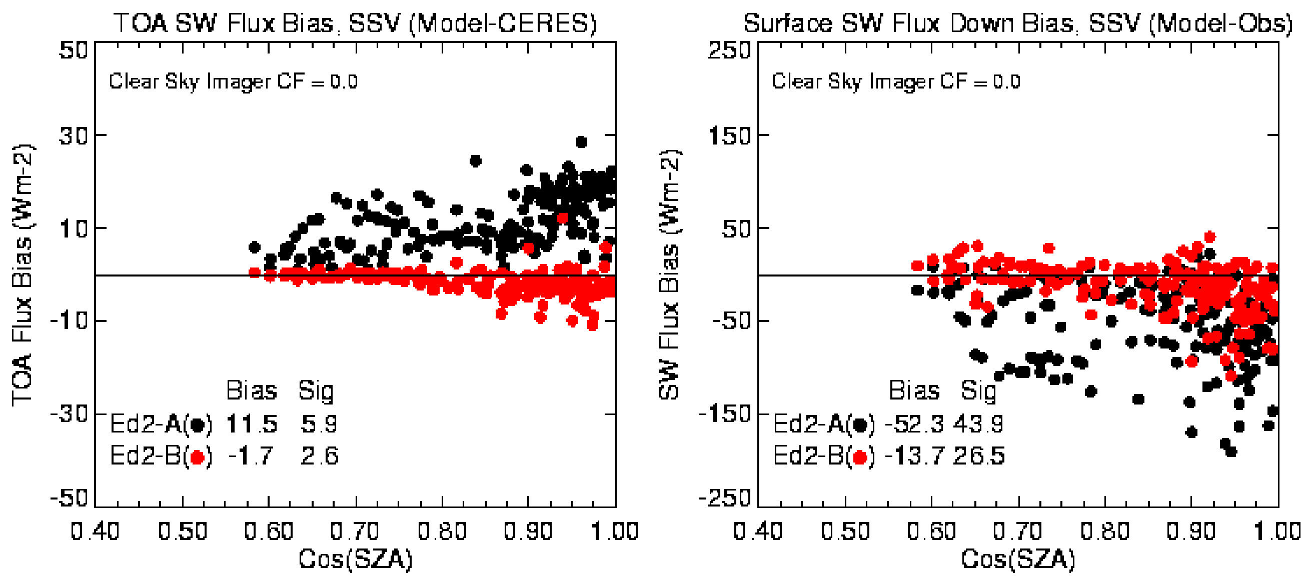

Figure 2. Top of atmosphere and surface observed broadband shortwave flux biases for CERES/CRS results from Editions 2A(black) and 2B(red) for clear sky CERES footprints during 2001 collocated within 10 km of the Saudi Solar Village surface site.

Figure 3 shows flux biases in a manner similar to Figure 2 for the year 2001, but for CERES footprints collocated near the ARM/SGP Central Facility. Calculated downwelling SW fluxes are compared to surface observed SW fluxes obtained from the E13 suite of radiometers. Effects of the change in dust aerosol properties on calculated biases are similar to those found at SSV but of substantially smaller magnitude. At TOA, SW flux biases decrease from +1Wm^{-2} to ~-1Wm^{-2} whereas at the surface there is an increase in the solar insolation bias of 1Wm^{-2} indicating that dust particles play a minor role in results in and around the ARM central facility in Oklahoma.

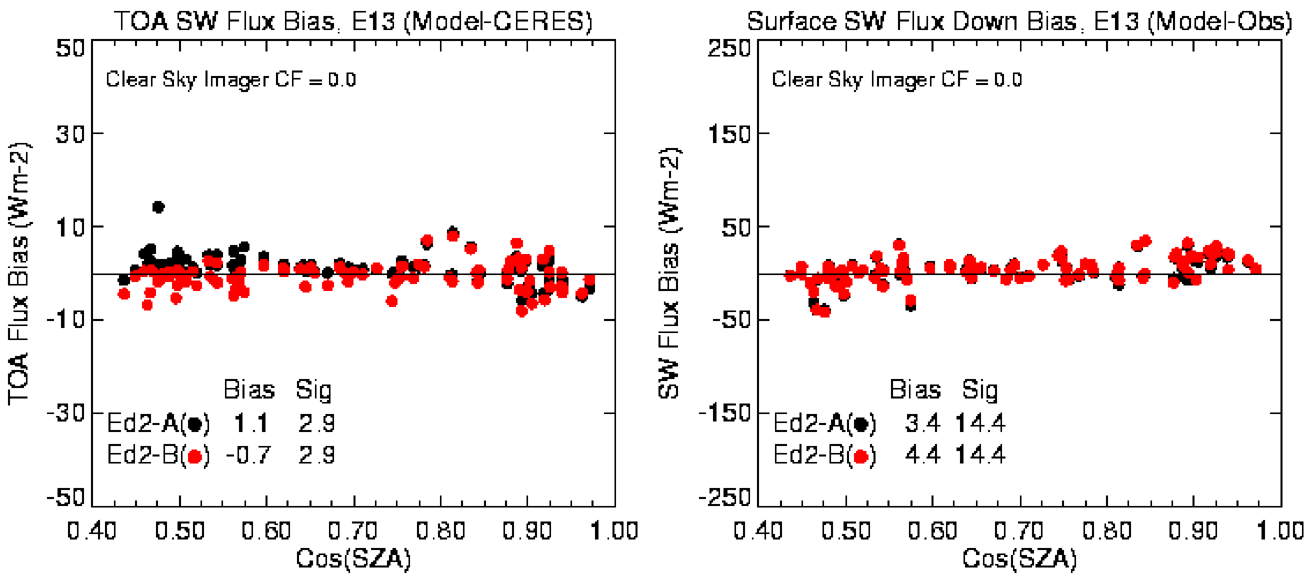

Figure 3. Same as Figure 2 but for CERES footprints collocated within 15 km of the ARM/SGP central facility.

CERES CRS results are validated at nearly 50 surface sites around the globe. To summarize overall surface validation, Table 2 gives a more global look at downward longwave (LW) and SW surface flux bias and RMS for groupings of sites based on surface characteristics. In this table all results are for CRS Edition 2B for the years 2001 for "Tuned" CRS results and include the "All-Sky" results. Here, all–sky implies both cloudy and clear footprints lumped together. Cloud properties themselves come from an analysis of MODIS pixels collocated within the larger CERES footprints. The CERES cloud properties retrieved with MODIS (Minnis et al. 2002) are vital inputs for the all-sky calculations. The sense of the bias is model minus observation. As these numbers are for instantaneous comparisons, not daily averages, LW, which is observed both day and night, represents a 24-hour average. SW fluxes are daytime only observations and are subsequently halved from the numbers shown in the bottom row of Table 2.

Table 2. Surface SW & LW bias CERES/SARB tuned model results minus surface observations.

Downward Surface Flux (Tuned Model-Obs) Bias(RMS) (W/m^2), 2001				
	All Sky		Clear Sky	
	Longwave	Shortwave	Longwave	Shortwave
ARM/SGP	-9(18)	+13(86)	-10(15)	+4(20)
Island Sites	-4(12)	+39(164)	-4(10)	+7(50)
Polar Sites	-6(31)	+14(66)	-7(14)	-7(20)
SURFRAD	-8(20)	+17(105)	-8(17)	-1(24)
Coastal	+3(20)	+36(109)	+4(13)	-3(32)
Desert	-11(22)	+9(75)	-11(19)	-3(39)
All Available	-7(21)	+19(98)	-9(17)	-0(30)
24-Hr Avg.	-7(21)	+9(49)	-9(17)	-0(15)

Acknowledgements

ARM data is made available through the US Department of Energy as part of the Atmospheric Radiation Measurement Program. Climate Monitoring and Diagnostics Laboratory (CMDL) data is made available through the National Oceanic and Atmospheric Administration (NOAA)/CMDL Solar and Thermal Radiation group. Surface Radiation Budget Network data is made available through NOAA's Air Resources Laboratory/Surface Radiation Research Branch. COVE data is made available through National Aeronautics and Space Administration (NASA) Langley Research Center's, Atmospheric Sciences Competency, CERES Surface and Airborne Radiometry Calibration group. CERES data is made available from NASA Langley's Atmospheric Sciences Data Center at http://eosweb.larc.nasa.gov/.

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