P4.21 VALIDATION OF LANGLEY PARAMETERIZED ALGORITHMS USED TO DERIVE CERES/TRMM SURFACE RADIATIVE FLUXES

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1. INTRODUCTION

The Clouds and the Earth's Radiant Energy System (CERES) project, being conducted at NASA Langley Research Center (LaRC), is an investigation of cloud-radiation feedbacks in the Earth's climate system (Wielicki et al. 1996). Within this project, broadband shortwave (SW) and longwave (LW) radiances at the TOA are being measured with space-borne radiometers. The first in a series of CERES instruments was launched into a low-inclination (35°) orbit in November 1997 aboard the Tropical Rainfall Measuring Mission (TRMM) satellite. The CERES instrument on TRMM successfully operated from January until August 1998 and during March 2000. For developing a complete picture of the Earth-atmosphere system, deriving reliable estimates of SRB parameters is also an important objective of the CERES project. Since SRB cannot be directly and uniquely measured by satellite-borne instruments, the surface fluxes are being derived with several different methods using combinations of radiation models, data assimilation products, and satellite measurements. Along with other methods, the Langley Parameterized Shortwave Algorithm (LPSA; Darnell et al. 1992) and the Langley Parameterized Longwave Algorithm (LPLA; Gupta et al. 1992) are one set of algorithms being used in the CERES project for deriving surface SW and LW fluxes respectively.

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This paper presents validation of the instantaneous surface fluxes derived on a footprint basis with the Langley parameterized algorithms for both clear-sky and all-sky conditions. These fluxes were derived and archived as part of the Single Scanner Footprint (SSF) product of CERES processing. A brief description of the two models is presented in section 2. The sources and main characteristics of the validation datasets are described in section 3. Validation of all satellite retrieved fluxes and resulting error statistics are presented in section 4, and section 5 presents the concluding remarks.

2. THE MODELS

2.1. *SW model*

The SW model (LPSA) consists of physical parameterizations which account for the attenuation of solar radiation in simple terms separately for clear atmosphere and clouds. Surface insolation, F_{sd}, is computed as

$$F_{sd} = F_{toa}\ T_a\ T_c\,, \qquad (1)$$

where F_{toa} is the corresponding insolation at the TOA, T_a is the transmittance of the clear atmosphere, and T_c is the transmittance of the clouds. F_{toa} was computed using standard procedures available in textbooks. Clear-sky transmittance, T_a, was computed as

$$T_a = (1 + B)\exp(-\tau_z), \qquad (2)$$

where B represents the backscattering of surface reflected radiation by the atmosphere, and τ_z is the broadband extinction optical depth at solar zenith angle z which accounts for all absorption and scattering processes in the clear atmosphere. Cloud transmittance, T_c, was computed using a threshold method as

$$T_c = 0.05+0.95\,[(R_{ovc}-R_{meas})/(R_{ovc}-R_{clr})], \qquad (3)$$

where R_{ovc}, R_{clr}, and R_{meas} represent values of overcast, clear, and measured reflectances for the footprint respectively. R_{ovc} for the footprints was computed from an empirical relation developed from the International Satellite Cloud Climatology Project (ISCCP; Rossow and Schiffer 1991) data and R_{clr} was obtained from the monthly clear-sky reflectance climatologies developed from the Earth Radiation Budget Experiment (ERBE; Barkstrom et al. 1989) data. For a detailed description of LPSA, the reader is referred to Gupta et al. (2001).

2.2 *LW model*

The LW model (LPLA) is a fast parameterization developed from an accurate narrowband radiative transfer model (Gupta 1989) in which downward LW flux (DLF) is computed in terms of an "effective emitting temperature" of the atmosphere, column water vapor, fractional cloud amount, and cloud-base height for each footprint. The effective emitting temperature and column water vapor are computed from the temperature and humidity profiles available from the meteorological database called MOA (Meteorology, Aerosol, and Ozone) maintained for all CERES processing. Fractional cloud amount and cloud-base height are available in the CERES processing stream at the time of flux computation from the cloud subsystem where they are derived using high resolution imager data from the Visible/InfraRed Scanner (VIRS) which also flies aboard the TRMM satellite.

3. SURFACE DATA FOR VALIDATION

Surface-based flux measurements for the validation of satellite retrievals were obtained from a number of sites belonging to different networks and organizations. Most important among these were the Atmospheric Radiation Measurement (ARM) program's Southern Great Plains (SGP) sites. These include the ARM central facility located near Lamont, Oklahoma, and a mesoscale network of about 20 extended facilities spread over central Oklahoma and southern Kansas. In addition, surface data were obtained from the Bermuda and Kwajalein (U.S. Marshall Islands) sites of the Climate Monitoring and Diagnostics Laboratory (CMDL/NOAA) network; and Florianopolis (Brazil), Alice Springs (Australia), and Tateno (Japan) sites of the Baseline Surface Radiation Network (BSRN). Note that the choice of validation sites was restricted to about 38° latitude in both hemispheres because of the limited coverage due to low inclination of the TRMM orbit. One-minute averages of downward SW and LW fluxes are available from all of these sites with the exception of Florianopolis, for which the averaging interval was two minutes. Temporal matching of the satellite and site fluxes was done at the highest resolution of the site data, i.e., one or two minutes. Spatial matching was done to a distance of 10 km between the location of the site and the center of the satellite footprint.

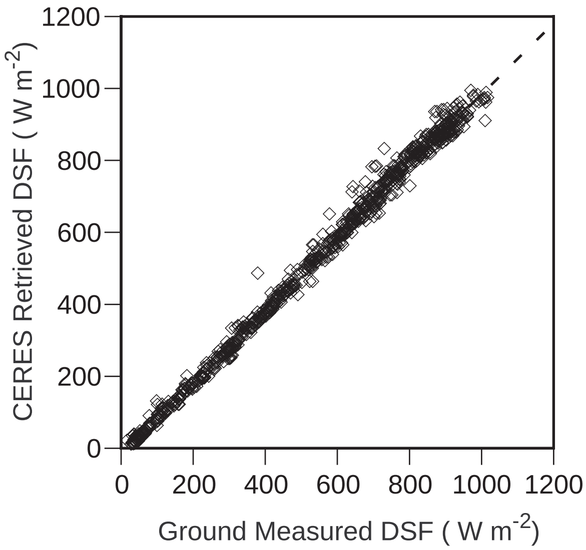

Fig. 1: Comparison of CERES clear-sky SW fluxes with surface measurements at the ARM/SGP central and extended facilities.

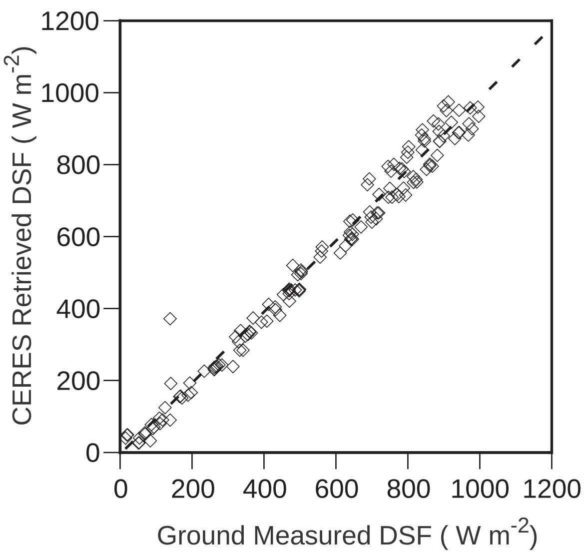

Fig. 2: Comparison of CERES clear-sky SW fluxes with surface measurements at the BSRN and CMDL sites.

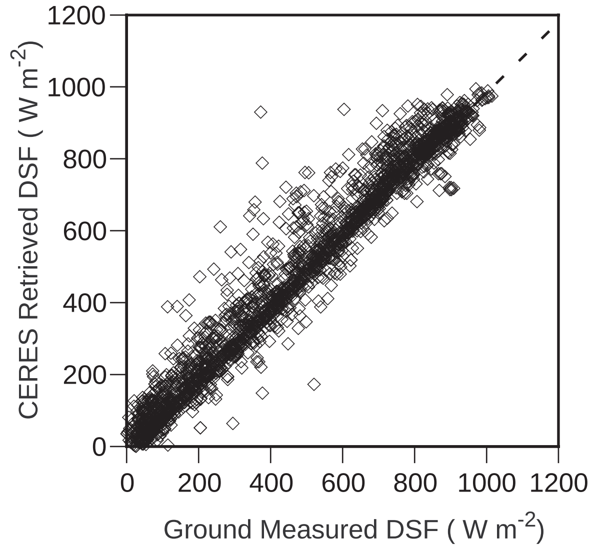

Fig. 3: Comparison of CERES all-sky SW fluxes with surface measurements at the ARM/SGP central and extended facilities.

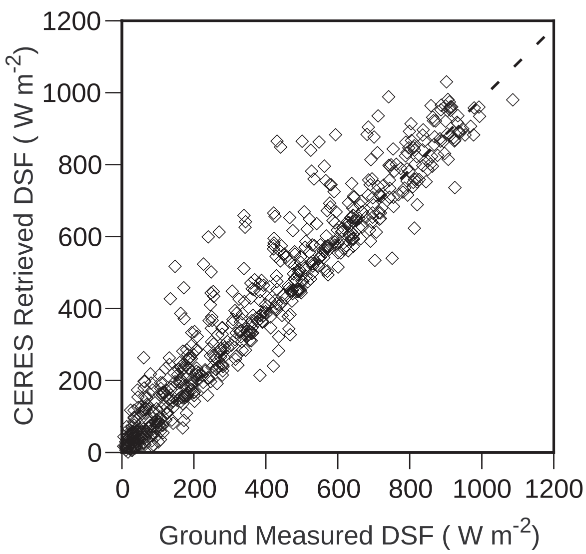

Fig. 4: Comparison of CERES all-sky SW fluxes with surface measurements at the BSRN and CMDL sites.

4. RESULTS AND DISCUSSION

Figure 1 shows a scatterplot of CERES-retrieved and ground-measured clear-sky SW fluxes for the ARM/SGP central and extended facilities combined together. Multiple sites have been combined on scatterplots in this section to limit the number of figures. A similar combined scatterplot of clear-sky SW fluxes for all BSRN and CMDL site is shown in Fig. 2. Corresponding scatterplots of all-sky SW fluxes for the ARM/SGP and BSRN/CMDL groups of sites are presented in Figs. 3 and 4 respectively. Ground-measured SW fluxes used in the all-sky comparisons were averaged over 60-minute intervals (for ±30 minutes from the satellite overpass time). The purpose of this operation was to compensate for the spatial variability of clouds by temporal averaging. Number of points in these scatterplots and error statistics from the comparisons are presented in Table 1.

Table 1 – Error statistics for comparisons of CERES-retrieved and ground-measured surface SW fluxes.

Clear-Sky SW Flux Statistics			
	# pts.	Bias (Wm^{-2})	RMS (Wm^{-2})
ARM/SGP	870	-12.4	24.3
BSRN/CMDL	139	-18.3	44.6
All-Sky SW Flux Statistics			
ARM/SGP	2236	8.4	61.1
BSRN/CMDL	674	21.5	84.2

These results show that bias and RMS at the ARM/SGP sites are considerably lower than at the BSRN and CMDL sites. That has also been true for many other comparisons made by the authors (not shown here) and is indicative of the generally high quality of the measurements made at the ARM/SGP sites, especially, at the central facility. Problems encountered in the past with data from the BSRN and CMDL sites were brought to the attention of the scientists from those organizations, and have mostly been corrected.

Corresponding scatterplots for LW fluxes at the ARM/SGP and BSRN/CMDL sites for clear-sky and all-sky conditions are presented in Figs. 5 – 8. Ground data used in all-sky LW comparisons remain at the available temporal

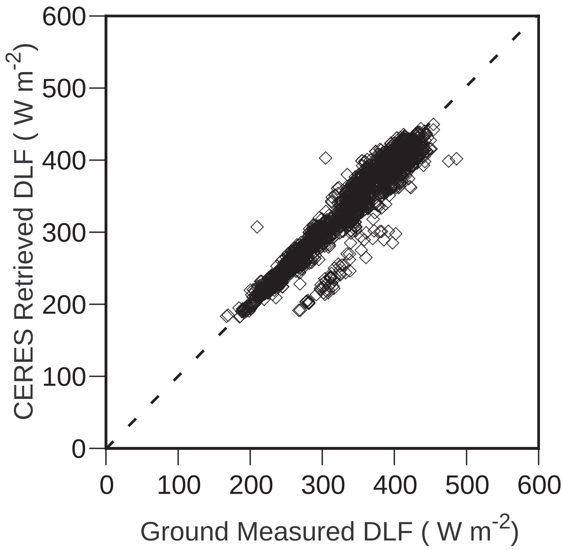

Fig. 5: Comparison of CERES clear-sky LW fluxes with surface measurements at the ARM/SGP central and extended facilities.

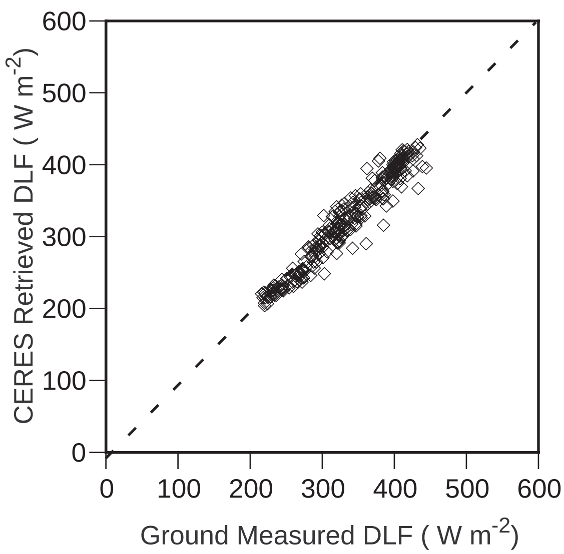

Fig. 6: Comparison of CERES clear-sky LW fluxes with surface measurements at the BSRN and CMDL sites.

resolution (1 or 2 minutes). It was not found necessary to average all-sky fluxes over longer time intervals because of the lower sensitivity of surface LW fluxes to cloud variability. A small fraction of points in Figs. 5-8 indicate a significant underestimation of DLF by the satellite algorithm. An investigation of this disrepancy showed that most of these points were related to cloud contamination in the footprints which were regarded as cloud-free by the satellite cloud algorithm. This discrepancy was found to occur more frequently during the nights when cloud detection algorithm was based entirely on infrared radiances. Table 2 presents the number of points and error statistics for the LW comparisons.

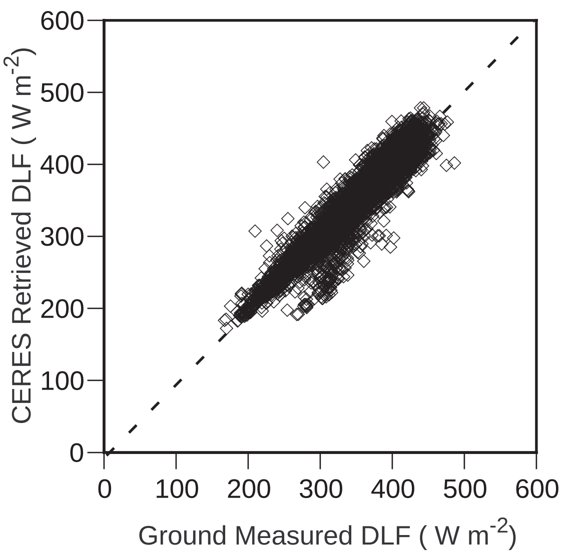

Fig. 7: Comparison of CERES all-sky LW fluxes with surface measurements at the ARM/SGP central and extended facilities.

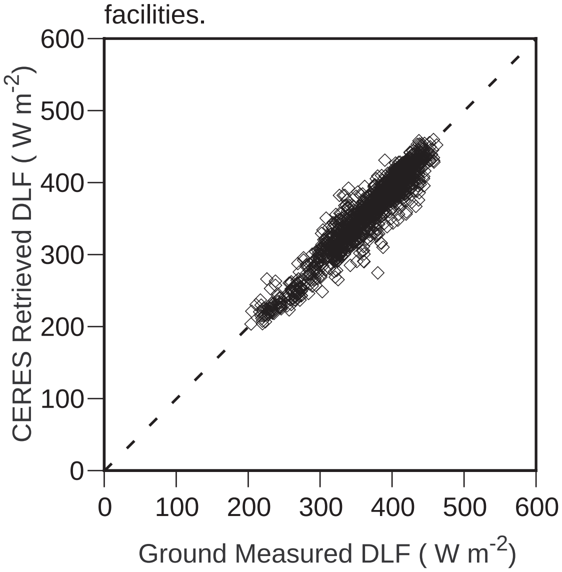

Fig. 8: Comparison of CERES all-sky LW fluxes with surface measurements at the BSRN and CMDL sites.

Table 2 – Error statistics for comparisons of CERES-retrieved and ground-measured surface LW fluxes.

Clear-Sky LW Flux Statistics			
	# pts.	Bias (Wm^{-2})	RMS (Wm^{-2})
ARM/SGP	2061	-4.6	20.6
BSRN/CMDL	306	-11.9	18.9
All-Sky LW Flux Statistics			
ARM/SGP	4787	-2.1	20.8
BSRN/CMDL	1364	-8.3	18.6

Here, the biases at the ARM/SGP sites are considerably lower than at the BSRN/CMDL sites while the RMS values for the two groups are comparable.

5. CONCLUDING REMARKS

Surface SW and LW fluxes from CERES processing presented here were retrieved using satellite-derived cloud properties, meteorological parameters from reanalyses, and fast radiative parameterizations. Error statistics obtained from clear-sky and all-sky comparisons with ground data are presented in Tables 1 and 2 for SW and LW fluxes respectively. The desired accuracy goal for instantaneous surface fluxes for climate research is ±20 Wm^{-2} (Suttles and Ohring 1986). Results in Table 2 show that we are close to meeting this accuracy goal for surface LW fluxes. However, as shown in Table 1, biases and random errors in SW fluxes remain higher. The errors in clear-sky SW fluxes may be coming in part from errors in CERES cloud detection. Spatial and temporal variability of clouds and the fact that the fields-of-view of the satellite and the ground-based instrument seldom match completely may contribute to the all-sky errors. Efforts are underway to address these problems.

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