CERES TRMM-PFM-VIRS Beta2 SSF Surface Fluxes - Accuracy and Validation

One of the objectives for the CERES data products is to provide improved estimates of the surface fluxes (net and downward) for shortwave (SW) and longwave (LW) radiation. The main effort is to obtain consistent fluxes for the surface, within the atmosphere, and for the top of atmosphere. These fluxes will be produced as part of the CERES CRS data product using the Edition 2 SSF as input data. The initial CRS surface fluxes, however, will not be available until Spring 2002. Thus, a second effort uses simpler algorithms that:

- derive the surface fluxes from the broadband CERES TOA fluxes using the Li et al. (1993) for clear-sky SW surface fluxes, the Staylor and Wilbur (1990) models for clear and cloudy-sky SW surface fluxes, and the Inamdar and Ramanathan (1997) model for clear-sky LW surface fluxes,
- and estimate the surface LW fluxes for all-sky sky conditions using the Gupta (1989) and Gupta, Darnell, and Wilber (1992) transfer parameterizations which assume that the TOA and surface fluxes are decoupled.

While these simpler parameterization for the SSF surface fluxes are more comparable to results used in past analyses of surface radiation data sets based on ERBE and geostationary data, and they are not expected to be as precise as the CERES CRS surface fluxes, they do represent an independent method to get to the more difficult surface flux estimates.

The CERES SSF data product provides 4 surface flux algorithm results:

1. Shortwave Flux Model A Clear-sky only: Net surface flux uses Li et al. (1993); Downward surface flux uses Li et al. (1993) for net and Li and Garand (1994) for surface albedo
2. Shortwave Flux Model B Cloudy and Clear-sky: Net surface flux uses Staylor and Wilber (1990); Downward surface flux uses Staylor and Wilber (1990) for net and surface albedo
3. Longwave Flux Model A Clear-sky only: uses Inamdar and Ramanathan (1997)
4. Longwave Flux Model B Cloudy and Clear-sky: uses Gupta (1989) and Gupta, Darnell, and Wilber (1992).

In Edition 1, only limited surface fluxes were available as shown below. Edition 2 will have new angular models for TOA all-sky fluxes which will enable surface shortwave all-sky results for model B shortwave. For the surface-only routines, the present Beta version of Edition 2 (Beta 2) has the same abilities as Edition 2. Subsequent references to Edition 2 will therefore also refer to Beta 2. In Edition 1, clear-sky is defined as a CERES footprint with an imager determined cloud cover percentage less than 0.1%. In Edition 2, clear-sky will be defined as having a cloud cover percentage less than 5%.

Available Surface Fluxes

	Clear-sky	**All-Sky**
SW Model A	Edition1, Edition2	-
SW Model B	Edition2	Edition2
LW Model A	Edition1, Edition2	-
LW Model B	Edition1, Edition2	Edition1, Edition2

The SSF surface fluxes have been validated using both theoretical analyses and simultaneous matching of TRMM satellite and a range of surface sites.

The CERES SSF surface flux estimates were obtained using Tropical Rainfall Measuring Mission (TRMM) satellite data for January through August of 1998. The coincident surface fluxes were then gathered from the 21 sites of the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) network, the 6 sites of the Climate Modeling and Diagnostic Laboratory (CMDL) network, and the 4 sites of the Baseline Surface Radiation Network(BSRN). Surface site fluxes are averaged for 30 minutes and are compared to the CERES footprint nearest the surface site. TRMM overpass time must fall within the 30 minute period.

Clear-sky Shortwave Downward Flux Validation: Model A and B

For the shortwave, two models have been used to produce the surface fluxes. Both of these shortwave models are part of our validation effort. Early results demonstrated that the shortwave models were unsatisfactory for cloudy-sky conditions. Thus, we first concentrated on clear-sky conditions. Suitable modifications have since been made to model B to handle cloudy-sky conditions. The modifications to model B will be implemented into the Edition 2 data set.

As can be seen in the following tables, for clear sky conditions the shortwave models are found to be in reasonably good agreement with the surface measurements at the ARM/CART SGP sites, and to a lesser extent with the surface measurements at the CMDL and BSRN sites. These discrepancies are under investigation. In addition, model A shows a persistent 30 W m^{-2} bias with relationship to model B. Meanwhile model B has a very small bias when compared to the ATM/CART data from the Central Facility.

Downward Shortwave Model A Comparisons, Clear-Sky

Site	# of Points	Mean Bias	RMS Difference
ARM Central Facility	57	34.1 W m^{-2}	51.2 W m^{-2}
Arm Extended Facilities	960	41.7 W m^{-2}	67.5 W m^{-2}
CMDL Facilities	51	64.4 W m^{-2}	82.7 W m^{-2}
BSRN Facilities	62	53.9 W m^{-2}	76.9 W m^{-2}

Downward Shortwave Model B Comparisons, Clear-Sky

Site	# of Points	Mean Bias	RMS Difference
ARM Central Facility	60	2.9 W m^{-2}	35.0 W m^{-2}
Arm Extended Facilities	989	11.1 W m^{-2}	49.3 W m^{-2}
CMDL Facilities	57	51.8 W m^{-2}	78.0 W m^{-2}
BSRN Facilities	65	23.5 W m^{-2}	54.8 W m^{-2}

All-sky Longwave Downward Flux Validation: Model B

Longwave model B uses the meteorological profiles and CERES VIRS-derived cloud properties, but not the CERES-measured TOA fluxes, to obtain surface fluxes for clear and cloudy sky conditions. As demonstrated by the following table, the results from longwave model B are found to be in good agreement with the surface measurements at all the sites.

Downward Longwave Model B Comparisons, All-Sky

Site	# of Points	Mean Bias	RMS Difference
ARM Central Facility	285	2.8 W m^{-2}	21.9 W m^{-2}
Arm Extended Facilities	4065	0.8 W m^{-2}	21.1 W m^{-2}
CMDL Facilities	699	-3.0 W m^{-2}	14.3 W m^{-2}
BSRN Facilities	769	-5.8 W m^{-2}	23.7 W m^{-2}

Clear-sky Longwave Downward Flux Validation: Model A

In theoretical error analysis, the standard errors of estimate for the surface LW model A clear-sky fluxes (see Inamdar and Ramanathan, 1997) are:

	Open Ocean (Tropics: 30 N - 30 S)	4.4 W m^{-2}

	Open Ocean (Extra-tropics: 30 degree to pole)	3.2 W m^{-2}
	Land	6.2 W m^{-2}

Validation studies employing data from Central Equatorial Experiment (CEPEX), reported in the study cited above, reveal good agreement consistent with the above error estimates. The parameterization over the land surfaces have been developed using a limited set of emissivity data available from IRIS measurements aboard NIMBUS 4 (Prabhakara and Dalu, 1976). Other possible sources of errors are:

1. Specification of the true radiating temperature (especially land surfaces);
2. Errors in scene identification;
3. Emissions from aerosols in the boundary layer. For example, sensitivity studies have shown that thick haze in the boundary layer (visibilities less than 15 km) can increase the downward emissions by about 3 - 5 W m^{-2}.

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