CERES SSF Surface Fluxes
S-NPP Edition-1A
Accuracy and Validation

One of the principal objectives for the CERES data products is to provide accurate estimates of surface fluxes (net and downward) for shortwave (SW) and longwave (LW) radiation. To achieve this objective, considerable effort has been focused upon obtaining consistent fluxes at the surface, within the atmosphere, and at the top of the atmosphere, all of which are produced as part of the CERES SARB data product using a detailed radiative transfer model and CERES Single Scanner Footprint (SSF) data as the input. The development and implementation of the SARB algorithm, however, proved to be a very complex undertaking, which required a considerable amount of time just to produce and validate the first SARB results. As an alternative, an effort was undertaken to use much simpler and faster models that were already available and validated, and which could quickly produce the surface fluxes. This data quality summary is concerned with these Surface-Only Flux Algorithms (SOFA) that either:

1. Associate surface fluxes directly with broadband CERES TOA fluxes using the methods provided by Li et al. (1993), or Darnell et al (1992) for the SW surface fluxes, and by Inamdar and Ramanathan (1997) for the clear- sky LW surface fluxes.
2. Or use a simple radiative parameterization to directly calculate the surface fluxes from meteorological parameters as provided by Gupta (1989) and in Gupta et al (1992) that utilize various retrieved meteorological parameters to estimate surface downward LW fluxes, which are effectively decoupled from the TOA fluxes for cloudy sky conditions.
3. Note that the Inamdar and Ramanathan (1997) algorithm will become unworkable when the 8-12 µm window channel is replaced by a broadband LW channel on future CERES and follow-on instruments. Therefore, another algorithm by Zhou et al. (2007), was introduced to maintain two independent algorithms to derive clear-sky and all-sky LW fluxes.

Consequently, these simpler SSF surface flux parameterizations are more comparable to results used in past analyses of surface radiation data sets such as those based on ERBE or geostationary data. In general, however, they are not expected to be as precise as the CERES SARB surface fluxes, though they do represent an independent method to acquire the more difficult surface flux estimates.

The CERES SSF Edition 4 data provides 5 products from surface flux algorithms:

1. Shortwave Flux Model A, Daytime, Clear-sky only
    - Net surface fluxes form Li et al. (1993).
    - Downward surface fluxes using net fluxes from Li et al. (1993) and clear-sky surface albedo from Li and Garand (1994).

2. Shortwave Flux Model B, Daytime only, Clear and All-sky
   - Net and downward surface fluxes from the Langley Parameterized Shortwave Algorithm (LPSA) as introduced by Darnell et al. (1992) and further revised by Gupta et al. (2001).
3. Longwave Flux Model A, Daytime and Nighttime, Clear-sky only
   - Net and downward surface fluxes from Inamdar and Ramanathan (1997).
4. Longwave Flux Model B, Daytime and Nighttime, Clear and All-sky
   - Net and downward surface fluxes from the Langley Parameterized Longwave Algorithm (LPLA) as described in Gupta (1989) and Gupta et al. (1992) and further refined in Gupta et al. (2010).
5. Longwave Flux Model C, Daytime and Nighttime, Clear and All-sky
   - Net and downward surface fluxes from the Zhou et al. (2007).

For Terra, Aqua, and S-NPP surface fluxes, clear-sky conditions are defined for CERES footprints with an imager determined cloud cover percentage less than 0.1%. Thus, to be consistent with the angular distribution models, our validation effort has also taken clear-sky to be defined as a CERES footprint with an imager determined cloud cover percentage less than 0.1%. The SSF surface fluxes are being validated using both theoretical analyses and simultaneous matching of satellite data to a range of surface sites. Preliminary results are discussed in the sections which follow.

The CERES SSF surface flux estimates for Edition 4A are derived using the Terra data starting with March 2000 and running through December 2014, the Aqua data starting with July 2002 and running through December 2014, and S-NPP data starting in January 2012 and running through December 2015. The coincident surface fluxes are nominally gathered from the Atmospheric Radiation Measurement (ARM) networks, which include the Southern Great Plains (SGP), the Tropical Western Pacific (TWP) and North Slope Alaska (NSA) sites, the Global Monitoring Division (GMD) of NOAA Earth System Research Laboratory (ESRL) network, the Baseline Surface Radiation Network (BSRN) and the NOAA Surface Radiation Budget (SURFRAD) Network. Note that the Tropical Western Pacific (TWP) sites of the ARM network have been taken out of service starting in 2013. Unless otherwise noted, surface site fluxes are 1 minute averages and are compared to the CERES footprint which includes the surface site.

A detailed discussion concerning the validation and inter-comparison studies involving the CERES Edition 2B data from both the Terra and Aqua satellites has been presented in "Validation of the CERES Edition 2B Surface-Only Flux Algorithms" by Kratz et al. (2010).

From lessons learned during the validation studies of the surface longwave flux algorithms used in the CERES processing, several improvements were developed, tested and then implemented for the longwave models. A detailed discussion concerning these efforts has been presented in "Improvement of Surface Longwave Flux Algorithms Used in CERES Processing" by Gupta et al. (2010)..

The validation results reported in this data quality summary compare Terra and Aqua Edition 4A, and S-NPP Edition 1A covering periods from the start for each satellite to the dates provided previously.

Shortwave Downward Flux Validation

CERES processing uses two very different models to produce the shortwave surface fluxes. While shortwave Model A was formulated to produce net shortwave surface fluxes for all-sky conditions, validation efforts demonstrated that this model could only reliably produce downward shortwave surface fluxes for clear-sky conditions. In contrast, shortwave Model B, which was formulated to produce downward shortwave surface fluxes for all-sky conditions, was found to have the capability to produce both downward and net shortwave surface fluxes reliably for all-sky conditions. These models are both part of our validation effort, and will be discussed separately.

Clear-sky Shortwave Downward Flux Validation: Model A

Validation studies of the TRMM Edition 2B surface fluxes from the earliest CERES results demonstrated that shortwave Model A overestimated surface insolation at the ARM Central Facility by approximately 30 W m-2. Considering that such biases were not observed for pristine high-latitude surface sites, it was hypothesized that the effects of aerosols could be the cause. Thus, an aerosol correction factor based on the Masuda et al. (1995) method, which uses the GFDL climatological aerosols described in Haywood et al. (1999) was incorporated into shortwave Model A. The use of the Masuda et al. (1995) method with the GFDL climatological aerosols was shown to produce a significant improvement in TRMM Edition 2B shortwave fluxes from Model A. For Terra and Aqua Edition 4A and S-NPP Edition 1A processing, daily aerosol properties from the Model for Atmospheric Transport and Chemistry (MATCH; Rasch et al. 1997) are used and those provide a further significant improvement.

Unlike many of the earlier versions of the SSF Data Quality Summary, this version groups together surface sites with similar characteristics: Coastal, Desert, Island, Continental and Polar, rather than grouping together surface sites from a single network. This allows for a better understanding of which surface and climatological types are the most problematic.

The following tables show the results for of the clear-sky shortwave Model A retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

SW Model A Clear-sky Terra_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	875	705.0	4.7 (0.7)	36.7 (5.2)
Desert	1726	817.8	-5.7 (-0.7)	51.4 (6.2)
Island	706	784.1	0.3 (0.0)	36.1 (4.6)
Continental	3449	745.5	-1.4 (-0.2)	32.7 (4.4)
Polar	1550	349.6	-54.0 (-13.4)	58.7 (14.5)
Combined	8306	686.3	-11.5 (-1.7)	43.6 (6.2)

SW Model A Clear-sky Aqua_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	599	693.7	7.8 (1.1)	31.2 (4.6)
Desert	1047	785.0	1.2 (0.2)	32.9 (4.2)
Island	519	740.0	3.0 (0.4)	35.1 (4.8)
Continental	2416	713.5	3.0 (0.4)	31.5 (4.4)
Polar	1822	333.5	-55.2 (-14.2)	63.1 (16.2)
Combined	6403	618.0	-13.4 (-2.1)	43.3 (6.9)

SW Model A Clear-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	185	667.1	2.1 (0.3)	18.7 (2.8)
Desert	398	810.6	-0.1 (-0.0)	14.4 (1.8)
Island	172	739.0	0.8 (0.1)	57.6 (7.8)
Continental	1012	714.2	4.0 (0.6)	27.6 (3.9)
Polar	369	359.5	-41.7 (-10.4)	47.2 (11.8)
Combined	2136	669.3	-5.1 (-0.7)	32.9 (4.9)

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

CERES processing also makes use of a second shortwave model to produce surface fluxes. Unlike Model A, Model B produces fluxes for both clear and cloudy-sky conditions. The combination of clear and cloudy conditions is often referred to as all-sky conditions. Since Model B was formulated to be an all-sky model, this model has been applied to a wider range of sky conditions than Model A. Validation efforts have demonstrated that improvements are necessary for both clear-sky and cloud-sky retrievals with Model B. Thus, a number of improvements have been implemented into shortwave model B for the current processing. The following provides a list of Model B improvements implemented to date.

1. A correction has been made to a code limitation that prevented flux calculations for ozone column abundances that exceeded 500 Dobson Units.

2. A modification was made to the formulation to provide a more realistic dependence of the instantaneous surface albedo on the cosine of the solar zenith angle.

3. For Terra processing, the monthly climatology of clear-sky TOA albedos that had been based on 48 months of ERBE data were replaced by monthly climatology of clear-sky TOA albedos based on 10 years of Terra data. This substitution led to a significant improvement in the downward shortwave flux retrievals at the surface (See Kratz et al, 2010).

4. For Aqua processing, the monthly climatology of clear-sky TOA albedos that had been based on 46 months of Terra data were replaced by monthly climatology of clear-sky TOA albedos based on 10 years of Terra data.

The following tables show the results for of the shortwave Model B clear-sky retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

SW Model B Clear-sky Terra_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	877	696.1	-4.5 (-0.6)	35.5 (5.1)
Desert	1733	820.4	-3.4 (-0.4)	50.6 (6.1)
Island	708	785.4	1.7 (0.2)	34.2 (4.4)
Continental	3452	749.5	2.6 (0.3)	29.8 (4.0)
Polar	1726	352.3	-18.0 (-4.9)	22.6 (6.1)
Combined	8496	680.9	-3.8 (-0.6)	34.9 (5.1)

SW Model B Clear-sky Aqua_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	604	684.1	-1.5 (-0.2)	29.0 (4.2)
Desert	1048	786.4	2.4 (0.3)	32.4 (4.1)
Island	521	742.2	5.0 (0.7)	34.2 (4.6)
Continental	2418	716.5	6.1 (0.9)	28.0 (3.9)
Polar	1987	345.9	-18.0 (-5.0)	30.5 (8.4)
Combined	6578	614.7	-2.6 (-0.4)	30.1 (4.9)

SW Model B Clear-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	188	659.9	-5.8 (-0.9)	19.0 (2.8)
Desert	401	810.9	0.2 (0.0)	14.2 (1.8)
Island	172	741.5	3.2 (0.4)	56.9 (7.7)
Continental	1018	716.1	6.3 (0.9)	24.0 (3.4)
Polar	396	363.5	-17.6 (-4.6)	20.5 (5.4)
Combined	2175	667.0	-0.4 (-0.1)	26.0 (3.9)

Results are also presented for the Model B all-sky retrievals. To reduce the considerable variance introduced by broken cloud fields, the surface data is averaged over the 60 minutes centered on the time of the satellite overpass. Note, the variance that is introduced by broken cloud fields is far greater than that introduced by the temporal averaging.

The following tables show the results for the shortwave Model B all-sky retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

SW Model B All-sky Terra_Ed4A Hour Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	11029	507.2	15.7 (3.2)	89.6 (18.2)
Desert	5519	737.0	-4.4 (-0.6)	66.9 (9.0)
Island	11935	688.3	28.2 (4.3)	111.6 (16.9)
Continental	26419	533.0	10.0 (1.9)	87.5 (16.7)
Polar	41698	214.5	-38.1 (-15.1)	95.0 (37.6)
Combined	98298	423.4	-8.7 (-2.0)	93.3 (21.6)

SW Model B All-sky Aqua_Ed4A Hour Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	11587	470.7	13.1 (2.8)	84.8 (18.5)
Desert	4502	709.2	-2.5 (-0.3)	75.8 (10.6)
Island	10175	667.4	35.3 (5.6)	119.1 (18.9)
Continental	23012	517.1	12.5 (2.5)	87.4 (17.3)
Polar	36637	216.6	-34.6 (-13.8)	90.2 (35.9)
Combined	85913	412.8	-5.9 (-1.4)	92.2 (22.0)

SW Model B All-sky NPP_Ed1A Hour Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	8698	408.6	11.3 (2.8)	78.8 (19.8)
Desert	2138	716.8	-5.1 (-0.7)	73.9 (10.2)
Island	3189	674.5	35.0 (5.5)	118.9 (18.6)
Continental	13031	511.3	9.2 (1.8)	89.4 (17.8)
Polar	14721	198.8	-35.4 (-15.1)	97.1 (41.5)
Combined	41777	404.8	-5.6 (-1.2)	92.4 (22.4)

Longwave Downward Flux Validation

CERES processing uses three very different models to produce the longwave surface fluxes. Longwave Model A was specifically formulated to produce longwave surface fluxes for clear-sky conditions by taking advantage of the 8 to 12 µm window channel radiances produced by the CERES instrument. In contrast, longwave Model B was formulated to retrieve fluxes for all-sky conditions and thus, can provide fluxes irrespective of sky conditions. Since all future versions of the CERES and follow-on instruments will replace the window channel with a broadband LW channel, a third model, the LW Model C, which is not dependent on the window channel, has been introduced to maintain two independent models for use in the future. All these models are part of our validation effort, and will be discussed separately.

Despite their rather significant differences, all longwave models have been significantly improved through the implementation of a near-surface air-temperature constraint that manages conditions where the surface temperature greatly exceeds the overlying air temperatures as commonly occurs during daytime over desert areas (See Gupta et al, 2010). In addition, a second code modification was applied to all longwave models to manage temperature inversion conditions where the surface temperature falls far below the overlying air temperatures. Note that LW Model B was modified to calculate cloud effects correctly for high altitude regions such as Tibet, where cloud base heights were frequently unavailable from the SSF and were not correctly estimated in the original code.

Clear-sky Longwave Downward Flux Validation: Model A

Longwave Model A uses CERES-derived window and non-window TOA fluxes as well as the meteorological profiles to obtain surface fluxes for clear sky conditions. As demonstrated by the following tables, the results from longwave Model A are found to be in good agreement with the surface measurements for all land and ocean sites that were considered.

The following tables show the results for of the clear-sky longwave Model A retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

LW Model A Clear-sky Terra_Ed4A Minute Data

Type	N	Mean $W m^{-2}$	Bias $W m^{-2}$ (%)	RMS $W m^{-2}$ (%)
Coastal	2098	305.5	-0.4 (-0.1)	10.5 (3.4)
Desert	2696	304.2	-10.1 (-3.2)	16.1 (5.1)
Island	1478	324.7	1.5 (0.4)	11.2 (3.5)
Continental	8218	286.3	-6.9 (-2.4)	17.4 (5.9)
Polar	6434	88.1	-2.4 (-2.7)	8.6 (9.5)
Combined	20924	232.3	-4.8 (-2.0)	14.0 (5.9)

LW Model A Clear-sky Aqua_Ed4A Minute Data

Type	N	Mean $W m^{-2}$	Bias $W m^{-2}$ (%)	RMS $W m^{-2}$ (%)
Coastal	1585	299.7	-1.0 (-0.3)	10.4 (3.4)
Desert	1959	300.1	-12.3 (-3.9)	16.2 (5.2)
Island	1152	311.4	-0.2 (-0.1)	10.5 (3.4)
Continental	6794	280.5	-7.2 (-2.5)	17.3 (6.0)
Polar	6078	91.5	-1.6 (-1.7)	8.8 (9.4)
Combined	17568	221.0	-4.8 (-2.1)	13.8 (6.1)

LW Model A Clear-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	548	292.8	-0.4 (-0.1)	9.4 (3.2)
Desert	834	311.0	-6.3 (-2.0)	11.1 (3.5)
Island	24	383.9	3.3 (0.9)	6.5 (1.7)
Continental	2932	281.3	-6.4 (-2.2)	15.5 (5.4)
Polar	993	114.5	-7.5 (-6.1)	10.9 (8.9)
Combined	5331	256.1	-5.8 (-2.2)	13.4 (5.1)

Theoretical studies and validation studies employing data from Central Equatorial Pacific Experiment (CEPEX), reported by Inamdar and Ramanathan (1997), are consistent with our results. The parameterization over land surfaces was initially developed using a limited set of emissivity data available from IRIS measurements aboard NIMBUS 4 and is described in Prabhakara and Dalu (1976). The current version of longwave Model A, however, was developed using the global emissivity maps developed by Wilber et al. (1999) and thus can be applied to the extra-tropics as well as to the tropics. Other possible sources of errors include:

1. Specification of the true radiating temperature (especially land surfaces);
2. Errors in scene identification;
3. Emissions from aerosols in the boundary layer. For instance, Inamdar and Ramanathan (1997) noted that sensitivity studies had revealed that thick haze in the boundary layer (visibilities less than 15 km) could increase the downward emissions by about 3 to 5 W m^{-2}.

Clear-sky and All-sky Longwave Downward Flux Validation: Model B

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

The following tables show the results for of the clear-sky longwave Model B retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

LW Model B Clear-sky Terra_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	2105	299.6	-6.2 (-2.0)	13.1 (4.3)
Desert	2709	300.1	-14.2 (-4.5)	20.1 (6.4)
Island	1483	322.5	-0.7 (-0.2)	11.5 (3.5)
Continental	8240	283.1	-10.1 (-3.5)	19.1 (6.5)
Polar	6450	96.6	6.0 (6.7)	12.1 (13.4)
Combined	20987	232.5	-4.7 (-2.0)	16.4 (6.9)

LW Model B Clear-sky Aqua_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	1591	294.1	-6.6 (-2.2)	13.2 (4.4)
Desert	1984	294.1	-18.4 (-5.9)	22.1 (7.1)
Island	1160	308.9	-2.8 (-0.9)	11.7 (3.8)
Continental	6825	277.0	-10.6 (-3.7)	19.2 (6.7)
Polar	6094	99.9	6.7 (7.2)	12.6 (13.6)
Combined	17654	221.4	-4.6 (-2.1)	16.7 (7.4)

LW Model B Clear-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	556	287.0	-6.2 (-2.1)	11.9 (4.1)
Desert	858	308.7	-8.0 (-2.5)	16.2 (5.1)
Island	25	386.8	5.9 (1.5)	9.2 (2.4)
Continental	2965	277.7	-9.9 (-3.4)	17.9 (6.2)
Polar	997	120.0	-2.1 (-1.8)	10.0 (8.2)
Combined	5401	256.7	-7.7 (-2.9)	15.8 (6.0)

The following tables show the results for of the all-sky longwave Model B retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

LW Model B All-sky Terra_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	25464	343.2	2.3 (0.7)	18.1 (5.3)
Desert	10901	322.7	1.0 (0.3)	21.8 (6.8)
Island	23989	400.0	5.7 (1.5)	17.7 (4.5)
Continental	51779	310.5	-4.6 (-1.5)	22.0 (7.0)
Polar	97059	217.3	6.1 (2.9)	27.7 (13.1)
Combined	209192	282.1	2.4 (0.9)	24.1 (8.6)

LW Model B All-sky Aqua_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	22939	345.0	1.6 (0.5)	18.3 (5.3)
Desert	9032	320.5	-3.1 (-1.0)	19.7 (6.1)
Island	20639	399.7	4.9 (1.2)	16.7 (4.2)
Continental	46154	309.3	-5.0 (-1.6)	22.1 (7.1)
Polar	84956	218.7	6.7 (3.1)	28.0 (13.2)
Combined	183720	282.1	2.4 (0.9)	24.1 (8.6)

LW Model B All-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	15192	336.7	-0.1 (-0.0)	18.5 (5.5)
Desert	6505	330.3	3.8 (1.2)	19.6 (6.0)
Island	5096	422.8	4.8 (1.1)	14.9 (3.5)
Continental	27791	312.9	-5.3 (-1.7)	21.2 (6.7)
Polar	35291	217.1	-0.6 (-0.3)	25.7 (11.8)
Combined	89875	287.1	-1.3 (-0.5)	22.3 (7.7)

Clear-sky and All-sky Longwave Downward Flux Validation: Model C

Longwave Model C (Zhou et al., 2007) derives clear-sky downward LW fluxes using surface upward LW fluxes computed from surface temperature, and column water vapor. Cloud effect computation makes use of cloud liquid water and ice water paths available from CERES cloud properties retrievals. As demonstrated by the following tables, the results from longwave Model C are found to be in good agreement with the surface measurements at all the sites.

The following tables show the results for of the clear-sky longwave Model C retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes

LW Model C Clear-sky Terra_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	2104	307.2	1.4 (0.4)	13.4 (4.4)
Desert	2709	299.3	-15.0 (-4.8)	22.5 (7.2)
Island	1482	324.2	1.0 (0.3)	14.4 (4.4)
Continental	8240	288.6	-4.6 (-1.6)	17.2 (5.9)
Polar	6449	118.9	28.4 (31.4)	31.0 (34.3)
Combined	20984	242.3	5.1 (2.2)	22.6 (9.5)

LW Model C Clear-sky Aqua_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	1590	302.1	1.4 (0.5)	13.7 (4.5)
Desert	1984	292.3	-20.1 (-6.4)	25.0 (8.0)
Island	1159	311.5	-0.2 (-0.1)	14.5 (4.6)
Continental	6824	282.9	-4.7 (-1.6)	17.3 (6.0)
Polar	6093	122.4	29.1 (31.3)	31.9 (34.3)
Combined	17650	232.4	6.1 (2.7)	23.8 (10.5)

LW Model C Clear-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	556	295.8	2.6 (0.9)	12.9 (4.4)
Desert	857	304.9	-11.8 (-3.7)	18.3 (5.8)
Island	25	388.0	7.1 (1.9)	8.6 (2.3)
Continental	2962	283.6	-4.0 (-1.4)	16.0 (5.6)
Polar	996	139.2	17.1 (14.1)	21.3 (17.4)
Combined	5396	262.2	-0.6 (-0.2)	17.1 (6.5)

The following tables show the results for of the all-sky longwave Model C retrievals as compared to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

LW Model C All-sky Terra_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	25252	345.9	4.8 (1.4)	20.0 (5.8)
Desert	10817	318.5	-3.2 (-1.0)	21.3 (6.6)
Island	23952	396.1	1.7 (0.4)	16.3 (4.1)
Continental	51393	314.0	-1.3 (-0.4)	21.5 (6.8)
Polar	96553	217.6	6.3 (3.0)	27.3 (12.9)
Combined	207967	283.5	3.1 (1.1)	23.7 (8.4)

LW Model C All-sky Aqua_Ed4A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	22816	347.2	3.8 (1.1)	19.8 (5.8)
Desert	8982	316.5	-7.2 (-2.2)	21.4 (6.6)
Island	20586	395.9	0.9 (0.2)	15.5 (3.9)
Continental	45790	312.7	-1.9 (-0.6)	21.5 (6.8)
Polar	84387	219.1	6.9 (3.2)	27.3 (12.9)
Combined	182561	282.8	2.9 (1.0)	23.6 (8.4)

LW Model C All-sky NPP_Ed1A Minute Data

Type	N	Mean W m^{-2}	Bias W m^{-2} (%)	RMS W m^{-2} (%)
Coastal	15102	341.9	4.9 (1.5)	20.4 (6.1)
Desert	6334	325.0	-2.4 (-0.7)	19.6 (6.0)
Island	5077	417.1	-1.0 (-0.2)	12.8 (3.0)
Continental	27570	318.0	-0.3 (-0.1)	20.4 (6.4)
Polar	35070	219.6	1.8 (0.8)	25.2 (11.6)
Combined	89153	289.1	1.3 (0.4)	22.1 (7.7)

References

Darnell, W. L., W. F. Staylor, S. K. Gupta, N. A. Ritchey, and A. C. Wilber, 1992: Seasonal variation of surface radiation budget derived from ISCCP-C1 data. *J. Geophys. Res.*, **97**, 15 741-15 760.

Gupta, S. K., 1989: A parameterization for longwave surface radiation from Sun-synchronous satellite data. *J. Climate,* **2**, 305-320.

Gupta, S. K., W. L. Darnell, and A. C. Wilber, 1992: A parameterization for longwave surface radiation from satellite data: Recent improvements. *J. Appl. Meteor.,* **31**, 1361-1367.

Gupta, S. K., D. P. Kratz, P. W. Stackhouse Jr., and A. C. Wilber, 2001: The Langley Parameterized Shortwave Algorithm (LPSA) for surface radiation budget studies (Version 1.0). *NASA/TP-2001-211272*, 31 pp. [Available online at http://techreports.larc.nasa.gov/ltrs/ltrs.html]

Gupta, S. K., D. P. Kratz, P. W. Stackhouse, A. C. Wilber, T. Zhang, and V. E. Sothcott, 2010: Improvement of Surface Longwave Flux Algorithms Used in CERES Processing. J. Appl. Meteor. Climatol., 49, 1579-1589. doi: 10.1175/2010JAMC2463.1

Haywood, J. M., V. Ramaswamy, and B. J. Soden, 1999: Tropospheric aerosol climate forcing in clear-sky satellite observations over the oceans, *Science*, **283**, 1299-1303.

Inamdar, A. K., and V. Ramanathan, 1997: On monitoring the atmospheric greenhouse effect from space. *Tellus*, **49B**, 216-230.

Kratz, D. P., S. K. Gupta, A. C. Wilber, and V. E. Sothcott, 2010: Validation of the CERES edition 2B Surface-Only Flux Algorithms. J. Appl. Meteor. Climatol., 49, 164-180. doi: 10.1175/2009JAMC2246.1.

Li, Z., and L. Garand, 1994: Estimation of surface albedo from space: A parameterization for global application. *J. Geophys. Res*., **99**, 8335-8350.

Li, Z., H. G. Leighton, and R. D. Cess, 1993: Surface net solar radiation estimated from satellite measurements: Comparisons with tower observations. *J. Climate*, **6**, 1764-1772.

Masuda, K., H. G. Leighton, and Z. Li, 1995: A new parameterization for the determination of solar flux absorbed at the surface from satellite measurements. J. Climate., 8, 1615-1629.

Prabhakara, C., and G. Dalu, 1976: Remote sensing of surface emissivity at 9 micron over the globe. J. Geophys. Res., **81**, 3719-3724.

Rasch, P. J., N. M. Mahowald, and B. E. Eaton, 1997: Representations of transport, convection, and the hydrologic cycle in chemical transport models: Implications for the modeling of short-lived ands soluble species, J. Geophys. Res., **102**, 28127-28138.

Wilber, A. C., D. P. Kratz, and S. K. Gupta, 1999: Surface emissivity maps for use in satellite retrievals of longwave radiation. NASA/TP-1999-209362, 35 pp. [Available online at http://techreports.larc.nasa.gov/ltrs/ltrs.html]

Zhou Y., D. P. Kratz, A. C. Wilber, S. K. Gupta, and R. D. Cess, 2007: An improved algorithm for retrieving surface downwelling longwave radiation from satellite measurements. *J. Geophys. Res*., **112**, D15102, doi:10.1029/2006JD008159.

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