CERES Aqua Edition2A SSF
TOA Fluxes - Accuracy and Validation

CERES shortwave (SW), longwave (LW), and window (WN) channel radiative fluxes are derived from empirical Angular Distribution Models (ADMs) that convert a measured radiance in a given Sun-Earth-satellite viewing configuration to a top-of-atmosphere (TOA) radiative flux. The first set of CERES ADMs were developed from 9 months of CERES TRMM SSF measurements over the Tropics (Loeb et al., 2003a,b). These ADMs were used to generate TOA fluxes on the CERES TRMM Edition2B SSF product. The TRMM ADMs were also used to produce TOA fluxes for the CERES Terra Edition1A SSF product while a new set of global ADMs based on CERES Terra data were being developed. Once the new global CERES Terra ADMs were completed (Loeb et al., 2004), these were used to generate TOA fluxes on the CERES Terra Edition2B SSF product. Loeb et al. (2006) provide a detailed assessment of the uncertainties in CERES Terra Edition2B SSF fluxes.

The CERES Aqua Edition1B SSF data product used the CERES Terra ADMs while a new set of ADMs based on CERES Aqua data were being developed. The methodology used to develop the new Aqua ADMs is based on the same approach as that used to develop Terra ADMs (Loeb et al., 2004). The new Aqua ADMs are now complete and are being used to generate TOA fluxes on the CERES Aqua Edition2A SSF product. The new Aqua ADMs are based on 24 months (August 2002 - June 2004). The main features of the new Aqua ADMs are given below. For a more detailed description of the CERES Terra ADMs see Loeb et al. (2004).

- Empirical ADMs over snow and sea-ice.
- Increased angular resolution in nonpolar regions (2 degrees)
- Use of "continuous" SW and LW ADM scene types over ocean, land, and desert.
- Monthly 1 degree regional clear land+desert ADMs.
- Neural network scheme to improve TOA flux estimates for footprints with excessive "no retrievals". No retrievals can occur when imager data is missing or when the cloud algorithm cannot provide a physical retrieval. If the scene characteristics over 35% or more of a CERES FOV are unknown, TOA fluxes are estimated using a neural network scheme. Approximately 3% of the CERES data fall in this category.

While CERES *Terra* and CERES *Aqua* TOA flux errors are generally quite similar (Loeb et al., 2006), differences are observed in polar regions. Biases in daytime SW TOA fluxes from *Aqua* ADMs are significantly smaller than *Terra* fluxes over sea-ice. In contrast, when the new Aqua ADMs were first applied to infer LW TOA fluxes over the Antarctic Plateau, Aqua TOA flux errors were found to be significantly larger than those from Terra ADMs. The cause for these discrepancies is associated with differences between the *Terra* and *Aqua* CERES polar cloud mask applied to MODIS. To avoid the biases in Aqua LW TOA fluxes over the nighttime Antarctic Plateau, we've replaced the original Aqua nighttime LW permanent snow ADMs with those developed on Terra in Ed2A processing. A more detailed discussion of the differences is provided in Loeb et al. (2006).

The tables below provide additional details on Aqua ADM scene classification and validation results. Further details can be found in the following:

- CERES Aqua Angular Distribution Models (PDF)
- Loeb et al. (2006) paper (PDF)

CERES Aqua Shortwave Channel ADMs for Different Scene Types

Scene Type	Description
Clear Ocean	Function of wind speed; Correction for aerosol optical depth included.
Cloud Ocean	Function of cloud phase; Continuous function of cloud fraction and cloud optical depth (5-parameter sigmoid).
Land & Desert Clear	1°- regional monthly ADMs using Analytical Function of TOA BRDF (Ahmad and Deering, 1992).
Land & Desert Cloud	Function of cloud phase; continuous function of cloud cover and cloud optical depth; used 1°-regional clear-sky BRDFs to account for background albedo.
Permanent Snow	Function of Cloud Fraction, Surface Brightness, cloud optical depth
Fresh Snow	Function of Cloud Fraction, Surface Brightness, Snow Fraction, cloud optical depth
Sea-Ice	Function of Cloud Fraction, Surface Brightness, Ice Fraction, cloud optical depth

CERES Aqua Longwave and Window Channel ADMs for Different Scene Types

Scene Type	Description
Clear Ocean, Land, Desert	Function of Ocean, Forest, Cropland/Grass, Savanna, Bright Desert, Dark Desert, precip. water, lapse rate, skin temperature.

Clouds Over Ocean, Land Desert	Function of precip. water, skin temp, sfc-cloud temp. diff; continuous function of parameterization involving cloud fraction, cloud and sfc emissivity, sfc and cloud temp.
Permanent Snow, Fresh Snow, Sea-Ice	Each a function of cloud fraction, sfc temp, sfc-cld temp diff

Instantaneous TOA Flux Consistency (nadir vs θ=50-60 deg)

No-Glint Ocean Scene Type SW TOA Flux RMS (%)

Aqua Ocean: All-sky RMS = 4.23% (6.04%)

CLR		PCL			MCL			OVC		
5.28	High							10.21	6.70	3.99
	Mid	16.01							5.62	4.20
	Low	8.33	10.06		10.63	6.13		25.50	3.78	3.61
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Ocean: All-sky RMS = 4.07% (5.21%)

CLR		PCL			MCL			OVC		
6.27	High							11.64	6.84	3.72
	Mid					10.73			5.65	4.15
	Low	7.77	9.68		7.31	5.28		28.51	3.06	3.56
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Land SW TOA Flux RMS (%)

Aqua Land: All-sky RMS = 6.58% (5.03%)

CLR		PCL			MCL			OVC		
3.05	High	3.01						9.79	8.11	4.65
	Mid	4.63				7.85			4.77	3.06
	Low	10.59	7.65			10.81			4.83	4.43
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Land: All-sky RMS = 5.77% (4.90%)

CLR		PCL			MCL			OVC		
4.12	High	4.09						23.27	6.01	3.92
	Mid	5.30	16.38			7.36			5.04	4.11
	Low	8.65	8.10		16.53	5.97			6.43	4.36
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Snow/Ice SW TOA Flux RMS (%)

Aqua Snow/Ice: All-sky RMS = 8.23% (7.40%)

CLR		PCL			MCL			OVC		
5.02	High	6.04						8.65	8.79	
	Mid	5.37	10.12		6.19	10.16		7.35	6.97	
	Low	9.79	17.50		11.54	14.18		8.85	5.17	
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Snow/Ice: All-sky RMS = 8.50% (8.17%)

CLR		PCL			MCL			OVC		
7.22	High				11.26			9.97	6.19	9.40
	Mid	6.21	12.42		7.08	9.54		10.28	4.87	15.27
	Low	10.05	17.01		9.04	10.77		8.50	5.98	6.47
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Ocean LW TOA Flux RMS (%)

Aqua Ocean: All-sky RMS = 2.39% (2.30%)

CLR		PCL			MCL			OVC		
1.06	High	1.05						6.04	7.69	5.97
	Mid	1.02							4.72	2.28
	Low	0.73	0.71		1.05	0.99			1.52	1.96
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Ocean: All-sky RMS = 2.66% (2.63%)

CLR		PCL			MCL			OVC		
0.97	High	1.95						6.35	7.79	7.31
	Mid					5.13			4.47	4.84
	Low	0.96	1.08		1.06	2.42		2.51	2.24	2.42
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Land LW TOA Flux RMS (%)

Aqua Land: All-sky RMS = 2.94% (1.97%)

CLR		PCL			MCL			OVC		
1.60	High	2.42						2.41	6.75	5.90
	Mid	2.15				3.42			3.77	3.35
	Low	1.57	1.53			1.18			1.35	1.64
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Land: All-sky RMS = 53.41% (2.09%)

CLR		PCL			MCL			OVC		
1.85	High	2.65						5.62	8.51	7.58
	Mid	2.00	1.88			3.69			3.94	2.07
	Low	2.00	1.96		3.26	1.43			1.27	2.25
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Snow/Ice LW TOA Flux RMS (%)

Aqua Snow/Ice: All-sky RMS = 2.13% (2.26%)

CLR		PCL			MCL			OVC		
2.27	High	2.20						5.01	7.46	
	Mid	2.96	1.52		2.05	2.50		1.84	3.40	
	Low	2.19	1.37		1.96	1.61		2.43	1.61	
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Snow/Ice: All-sky RMS = 2.78% (2.87%)

CLR		PCL			MCL			OVC		
2.85	High	2.58			2.39			5.15	5.16	4.10
	Mid	2.35	5.59		2.36	2.23		4.00	4.85	3.84
	Low	2.12	2.34		2.45	2.22		5.48	2.19	5.54
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Regional TOA Flux Uncertainties

Regional mean all-sky SW TOA flux bias and RMS error for Aqua and Terra by season for December 2002 - November 2003

	Aqua		Terra	
Season	**Bias (W m^{-2})**	**RMS (W m^{-2})**	**Bias (W m^{-2})**	**RMS (W m^{-2})**
January	0.13	0.75	0.11	0.98
April	-0.16	0.70	0.00	0.99
July	-0.02	1.08	0.02	1.37
October	-0.10	0.68	0.11	0.76

Regional mean all-sky LW TOA flux bias and RMS error for Aqua and Terra by season for December 2002 - November 2003

	Aqua		Terra	
Season	**Bias (W m^{-2})**	**RMS (W m^{-2})**	**Bias (W m^{-2})**	**RMS (W m^{-2})**
January	0.26	0.51	0.17	0.57
April	0.31	0.58	0.35	0.66
July	0.25	0.56	0.33	0.63
October	0.22	0.55	0.27	0.58

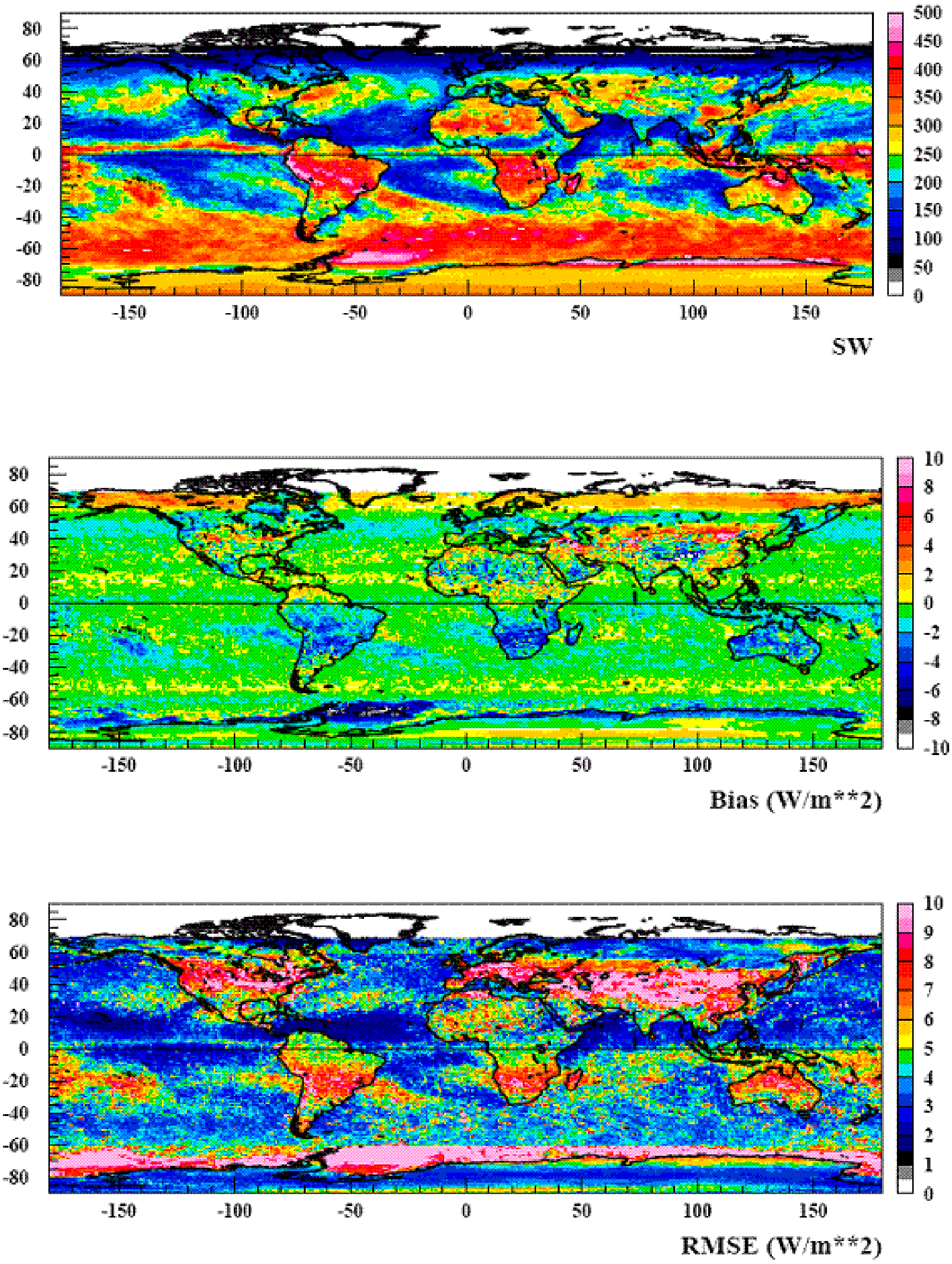
Regional mean all-sky WN TOA flux bias and RMS error for Aqua and Terra by season for December 2002 - November 2003.

	Aqua		Terra	
Season	**Bias (W m^{-2})**	**RMS (W m^{-2})**	**Bias (W m^{-2})**	**RMS (W m^{-2})**
January	0.16	0.24	0.17	0.28
April	0.19	0.27	0.23	0.34
July	0.17	0.27	0.22	0.32
October	0.16	0.25	0. 20	0.29

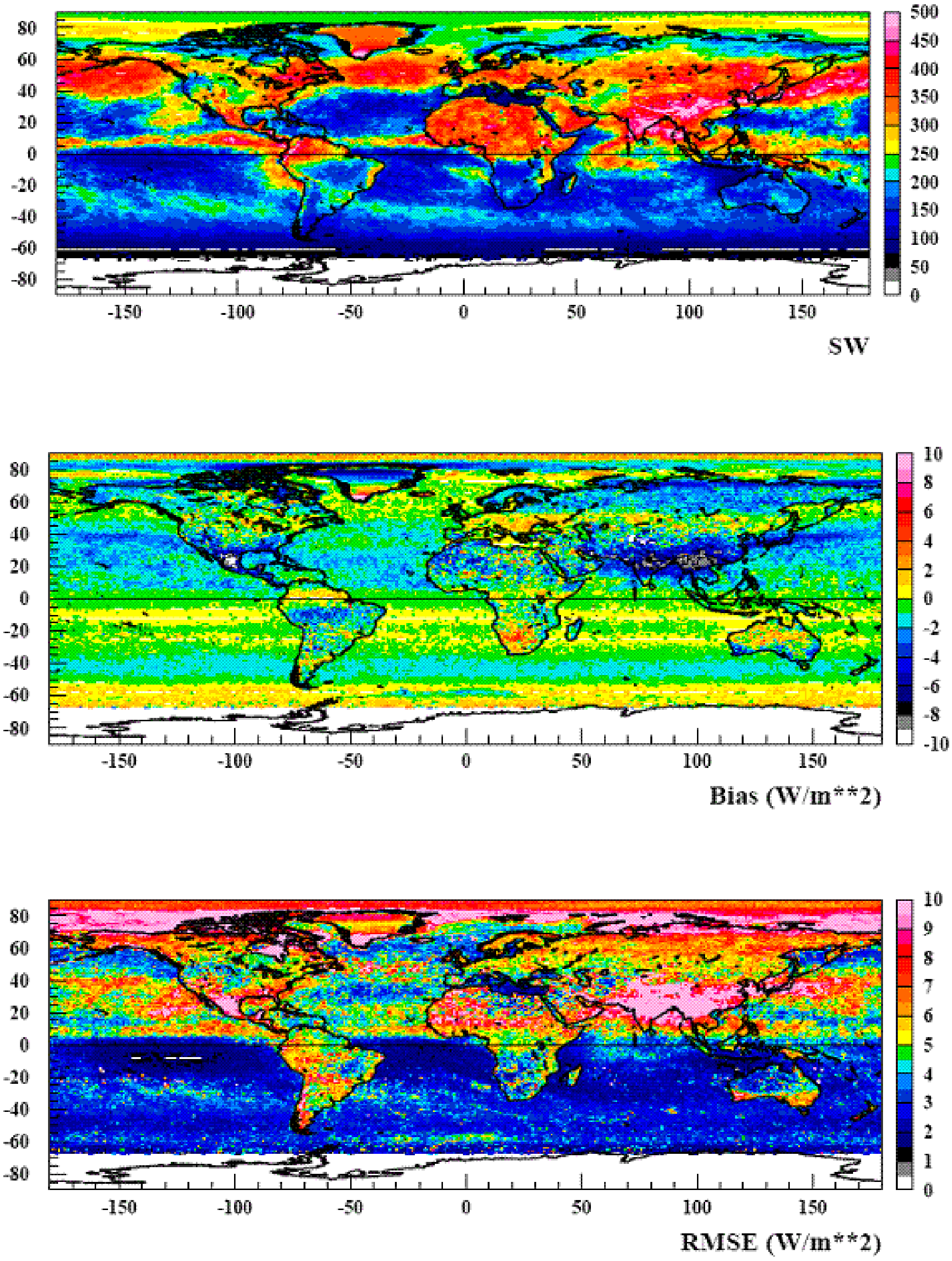
Comparison Between Edition1B and Edition2A Aqua TOA Fluxes

CERES Aqua Edition2A mean instantaneous all-sky TOA flux and CERES Aqua Edition1B minus Edition2A mean instantaneous all-sky TOA flux difference and RMS difference for January 2003 and July 2003

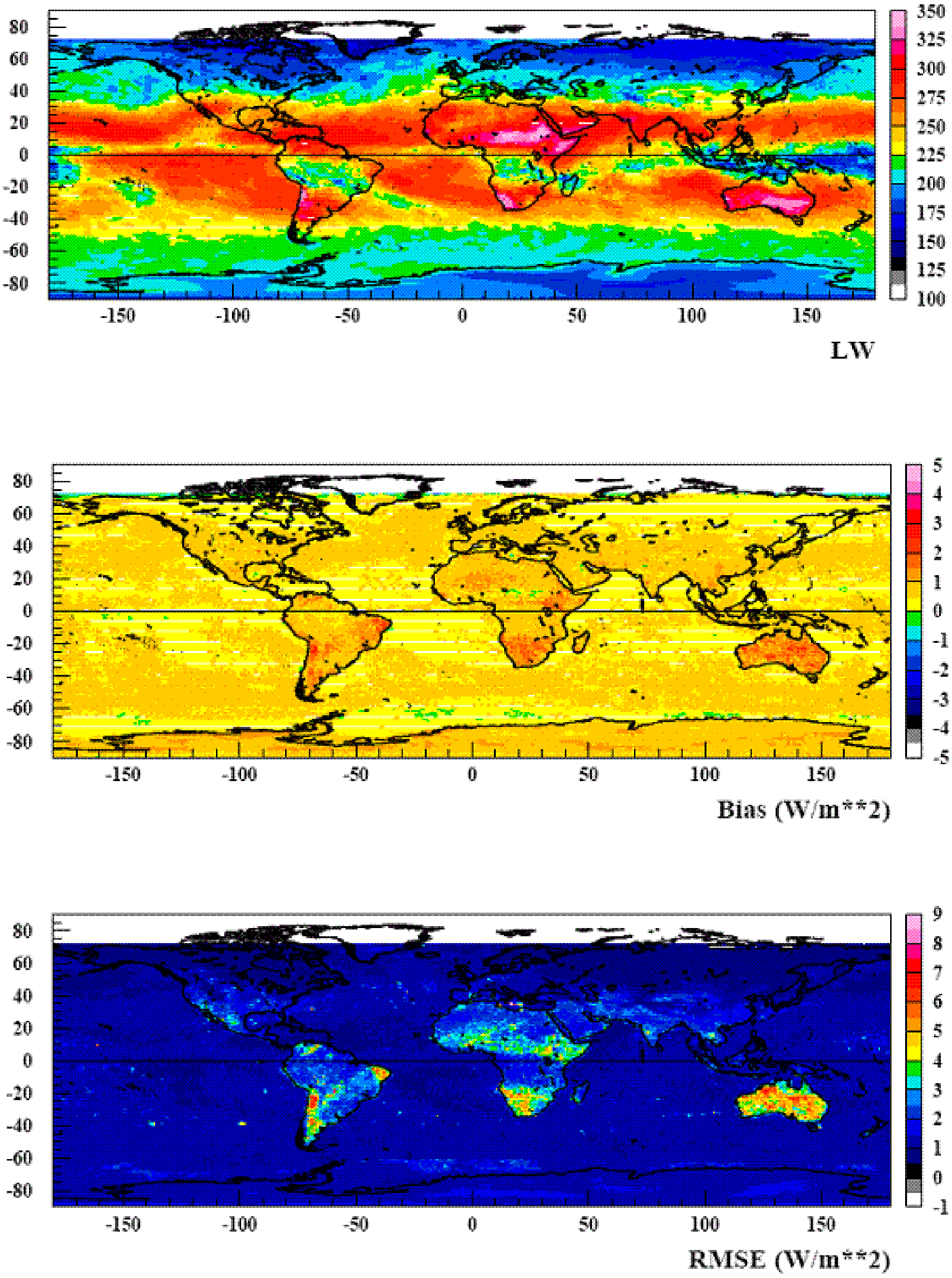
		Mean Flux (W m^{-2})	**Mean Diff (W m^{-2})**	**RMS Diff (W m^{-2})**
January 2003	SW	248.6	-0.53	1.5
	LW	240.3	0.55	0.61
	WN	66.8	-0.043	0.092
July 2003	SW	222.5	-0.82	1.8
	LW	248.3	0.57	0.63
	WN	71.1	-0.047	0.094



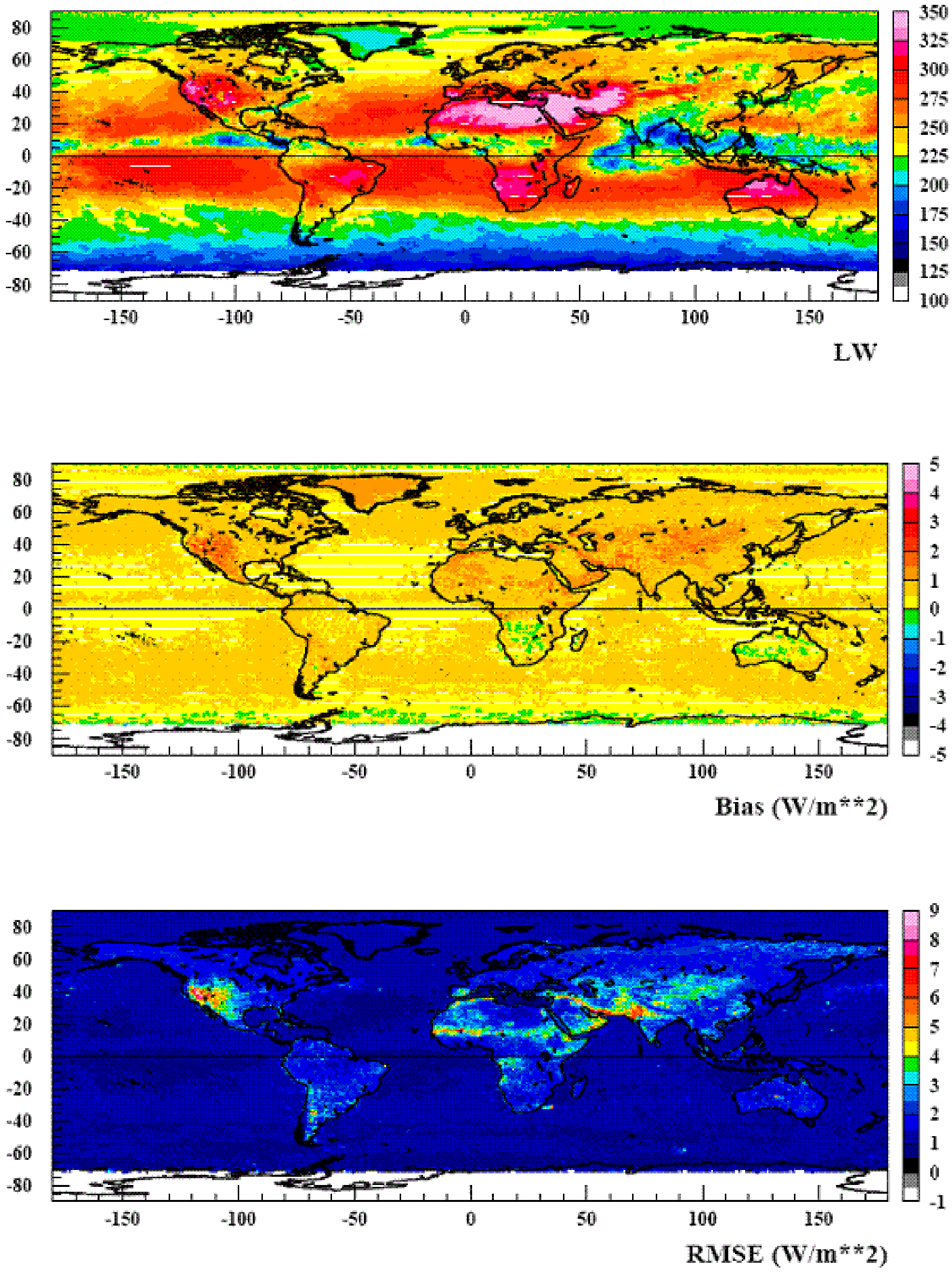
CERES Aqua Edition2A mean all-sky SW TOA flux (top),
CERES Aqua Edition1B minus Edition2A mean all-sky SW TOA flux difference (middle)
and RMS difference (bottom) for January 2003.



CERES Aqua Edition2A mean all-sky SW TOA flux (top),
CERES Aqua Edition1B minus Edition2A mean all-sky SW TOA flux difference (middle)
and RMS difference (bottom) for July 2003.



CERES Aqua Edition2A mean all-sky LW TOA flux (top),
CERES Aqua Edition1B minus Edition2A mean all-sky LW TOA flux difference (middle)
and RMS difference (bottom) for January 2003 (daytime only).



CERES Aqua Edition2A mean all-sky LW TOA flux (top),
CERES Aqua Edition1B minus Edition2A mean all-sky LW TOA flux difference (middle)
and RMS difference (bottom) for July 2003 (daytime only).

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