CERES Terra/Aqua Edition4A 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 Terra/Aqua ADMs were used for CERES Terra/Aqua Edition2 and Edition3 SSF data and a full description of these ADMs can be found in Loeb et al. (2004).

For CERES Terra/Aqua Edition4A SSF, ADMs described in Su et al. (2014) were used. These new ADMs improve upon the ADMs developed by Loeb et al. (2004). Most significant changes are over clear ocean, clear land, and over polar regions.

The tables below provide additional details on Terra/Aqua ADM scene classification and validation results. Further details can be found in Su et al. (2014) and the following CERES Science Team Meeting presentations:

- Updates on the CERES Edition 4 Angular Distribution Models - Spring 2013 (PDF)
- CERES Edition 4 Angular Distribution Models - Fall 2013 (PDF)
- Validation of the CERES Edition 4 Angular Distribution Models - Spring 2014 (PDF)

Table 1. CERES Terra/Aqua Shortwave Channel ADMs for Different Scene Types

Scene Type	Description
Clear Ocean	Function of wind speed, aerosol optical depth, and aerosol type.
Cloud Ocean	Function of cloud phase; Continuous 5-parameter sigmoid function of cloud fraction and cloud optical depth.
Land & Desert Clear	1°- regional monthly ADMs using modified Ross-Li 3-parameter fit for difference NDVI, $\cos\theta_0$ and surface roughness (θ_0 is solar zenith angle).
Land & Desert Cloud	Function of cloud phase; continuous 5-parameter sigmoid function of cloud cover and cloud optical depth; used 1°-regional clear-sky BRDFs to account for background albedo.
Permanent Snow	Clear Antarctica: use MISR data to develop ADMs that account for the effect of sastrugi Clear Greenland: one ADM
	Partly cloudy: cloud fraction (4).
	Overcast: cloud phase (2), and log optical depth bin (4).
Fresh Snow	1°- regional monthly ADMs using modified Ross-Li 3-parameter fit for difference NDVI, $\cos\theta_0$ and surface roughness (θ_0 is solar zenith angle).
	Cloudy: function of cloud fraction and snow fraction; for overcast consider surface brightness and cloud optical depth.
Sea-Ice	Clear: sea ice fraction (6), for 100% sea ice coverage use sea ice brightness index (3) to classify surface brightness.
	Partly cloudy: cloud fraction (4), for 100% sea ice coverage use sea ice brightness index (3) to classify surface brightness..
	Overcast: sea ice brightness index (5), phase (2), linear function of ln(cloud optical depth)

Table 2. CERES Terra/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.
Clear Permanent Snow, Fresh Snow, Sea-Ice	Discrete intervals of surface skin temperature.
Cloudy Permanent Snow, Fresh Snow, Sea-Ice	Function skin temp, sfc-cloud temp. diff; continuous function of parameterization involving cloud fraction, cloud and sfc emissivity, sfc and cloud temp.

Regional TOA Flux Uncertainties

Table 3. Regional mean all-sky SW TOA flux bias and RMS error for Terra 2002 and Aqua 2004 by season

	Terra		Aqua	
Season	Bias (W m^{-2})	RMS (W m^{-2})	Bias (W m^{-2})	RMS (W m^{-2})
January	0.06	0.79	0.11	0.87
April	0.08	0.67	-0.17	0.64
July	-0.20	0.91	0.11	0.77
October	0.02	0.58	0.15	0.66

Table 4. Regional mean all-sky LW TOA flux bias and RMS error for Terra 2002 and Aqua 2004 by season

	Terra		Aqua	
Season	Bias (W m^{-2})	RMS (W m^{-2})	Bias (W m^{-2})	RMS (W m^{-2})
January	0.37	0.55	0.29	0.51
April	0.47	0.54	0.37	0.43
July	0.44	0.57	0.37	0.41
October	0.40	0.48	0.36	0.46

Instantaneous TOA Flux Consistency Test (Nadir-viewing vs. Oblique-viewing [50°-60°])

Table 5. Relative RMS errors (%) between nadir-viewing and oblique-viewing SW fluxes for different cloud types over different surface types

		Partly cloudy			Mostly cloudy			Overcast			Clear	All
		Thin	Mod.	Thick	Thin	Mod.	Thick	Thin	Mod.	Thick		
						Ocean						
Single Layer	High	7.9	–	–	–	–	–	8.0	4.9	2.9	4.2	5.3
	Mid	–	–	–	–	–	–	8.3	5.7	4.2	–	–
	Low	8.1	–	–	8.8	7.8	–	10.0	3.5	2.5	–	–
Multi-Layer	High	–	–	–	13.7	–	–	9.7	6.8	5.1	–	–
	Mid	8.9	–	–	13.7	9.0	–	10.9	7.9	–	–	–
	Low	–	–	–	11.9	8.3	–	11.0	6.2	4.0	–	–
						Land						
Single Layer	High	4.3	–	–	9.7	–	–	10.2	5.6	3.6	3.4	5.2
	Mid	5.8	–	–	8.0	6.8	–	–	4.5	3.3	–	–
	Low	7.9	7.0	–	11.3	5.8	–	–	6.0	3.6	–	–
Multi-Layer	High	5.3	–	–	9.3	8.1	–	9.6	6.2	4.3	–	–
	Mid	7.6	–	–	8.3	7.7	–	–	–	–	–	–
	Low	–	–	–	9.2	6.6	–	–	–	3.2	–	–
						Snow/Ice						
Single Layer	High	–	8.5	7.5	8.7	12.1	10.2	7.8	8.6	8.6	3.0	6.7
	Mid	11.2	6.2	7.3	12.5	7.6	8.0	7.9	6.7	6.0	–	–
	Low	8.5	7.8	10.4	9.7	9.0	9.1	5.5	6.6	5.1	–	–
Multi-Layer	High	–	–	–	–	9.4	–	–	11.7	–	–	–
	Mid	–	–	–	–	11.7	–	7.6	11.8	–	–	–
	Low	–	8.0	13.6	8.8	9.0	7.3	7.4	7.4	5.8	–	–

Table 6. Relative RMS errors (%) between nadir-viewing and oblique-viewing daytime LW fluxes for different cloud types over different surface types

		Partly cloudy			Mostly cloudy			Overcast			Clear	All
		Thin	Mod.	Thick	Thin	Mod.	Thick	Thin	Mod.	Thick		
Ocean												
Single	High	1.4	–	–	–	–	–	5.0	6.0	4.3	0.9	2.5
Layer	Mid	–	–	–	–	–	–	5.0	4.1	2.9	–	–
	Low	1.6	1.3	–	2.1	2.3	–	2.4	2.1	1.8	–	–
Multi-	High	–	–	–	4.0	–	–	4.4	5.5	–	–	–
Layer	Mid	1.9	–	–	3.2	1.6	–	3.8	3.0	–	–	–
	Low	2.3	–	–	3.0	2.0	–	4.1	3.8	3.3	–	–
Land												
Single	High	2.5	–	–	–	–	–	–	6.6	4.2	1.3	1.6
Layer	Mid	2.4	–	–	–	–	–	–	4.0	3.1	–	–
	Low	1.8	1.8	–	2.5	2.4	–	–	2.4	2.1	–	–
Multi-	High	2.7	–	–	4.2	–	–	5.0	–	–	–	–
Layer	Mid	2.4	–	–	3.6	–	–	–	–	–	–	–
	Low	–	–	–	–	–	–	–	–	–	–	–
Snow/Ice												
Single	High	–	1.3	1.5	–	1.5	1.9	5.2	4.0	2.5	1.1	1.9
Layer	Mid	3.2	1.5	1.5	4.7	2.3	1.9	4.6	3.1	2.5	–	–
	Low	2.2	1.6	1.7	2.8	2.1	1.9	1.4	1.9	1.9	–	–
Multi-	High	–	–	–	–	1.7	–	–	2.1	–	–	–
Layer	Mid	–	–	–	–	1.8	–	4.7	3.5	–	–	–
	Low	–	1.5	–	2.9	2.3	2.3	4.0	3.2	3.7	–	–

Table 7. Relative RMS errors (%) between nadir-viewing and oblique-viewing nighttime LW fluxes for different cloud types over different surface types

		Partly cloudy			Mostly cloudy			Overcast			Clear	All
		Thin	Mod.	Thick	Thin	Mod.	Thick	Thin	Mod.	Thick		
Ocean												
Single Layer	High	1.5	–	–	2.6	–	–	3.5	3.3	3.0	0.8	1.3
	Mid	0.9	–	–	1.4	–	–	2.7	1.9	1.2	–	–
	Low	0.7	0.6	–	0.7	0.6	–	1.5	0.8	0.8	–	–
Multi-Layer	High	1.5	–	–	2.3	–	–	2.9	3.2	–	–	–
	Mid	1.1	–	–	1.4	1.1	–	3.1	3.0	–	–	–
	Low	0.7	–	–	0.9	1.0	–	2.5	2.0	0.9	–	–
Land												
Single Layer	High	1.8	–	–	3.3	–	–	3.5	3.5	5.4	0.7	1.2
	Mid	–	0.8	–	–	1.4	–	–	1.6	1.0	–	–
	Low	0.9	1.0	–	–	1.1	–	–	0.9	–	–	–
Multi-Layer	High	1.6	–	–	2.5	–	–	3.4	–	–	–	–
	Mid	1.5	1.6	–	2.7	2.0	–	–	–	–	–	–
	Low	–	–	–	–	–	–	–	–	–	–	–
Snow/Ice												
Single Layer	High	2.1	1.3	–	2.4	2.5	–	2.3	3.0	–	1.3	1.6
	Mid	1.4	1.1	–	1.8	2.0	–	1.8	2.0	–	–	–
	Low	1.1	1.2	–	1.4	1.5	–	1.3	1.2	–	–	–
Multi-Layer	High	1.7	–	–	2.3	1.4	–	2.1	2.0	–	–	–
	Mid	2.0	1.1	–	2.3	1.7	–	2.4	4.5	–	–	–
	Low	1.2	1.0	–	1.6	1.5	–	1.6	1.6	0.8	–	–

Comparison Between Edition4A and Edition3 Terra/Aqua TOA Fluxes

Table 8. CERES Terra Edition4A mean instantaneous all-sky TOA flux and CERES Terra Edition4A minus Edition3 mean instantaneous all-sky TOA flux difference for January and July 2002

		Mean Flux (W m^{-2})	Mean Diff (W m^{-2})
January	SW	252.9	0.65
	Daytime LW	241.2	-0.47
	Nighttime LW	234.9	-0.13
July	SW	225.1	-0.07
	Daytime LW	250.9	-0.79
	Nighttime LW	242.5	-0.05

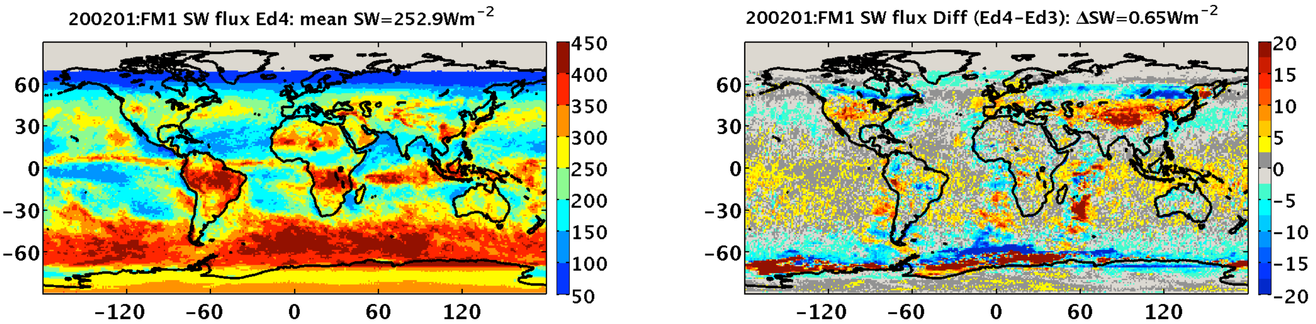

Figure 1. CERES Terra Edition4A mean all-sky SW TOA flux (left), CERES Terra Edition4A minus Edition3 mean all-sky SW TOA flux difference (right) for January 2002.

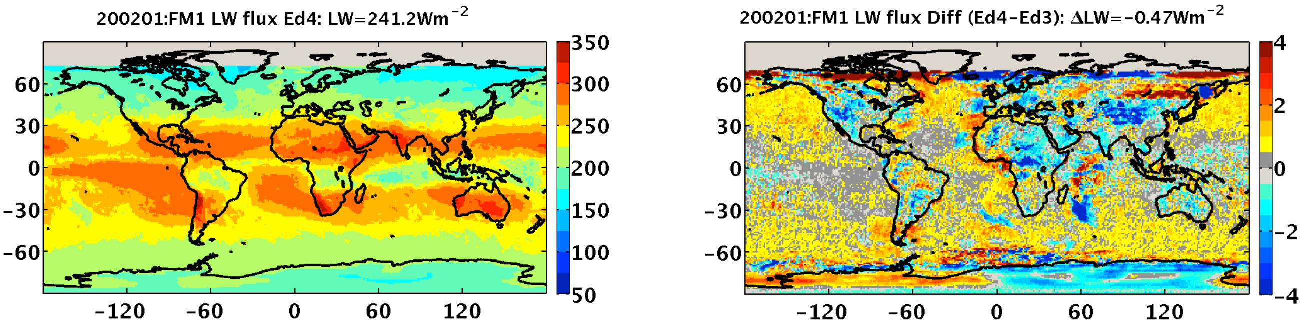

Figure 2. CERES Terra Edition4A mean all-sky daytime LW TOA flux (left), CERES Terra Edition4A minus Edition3 mean all-sky daytime LW TOA flux difference (right) for January 2002.

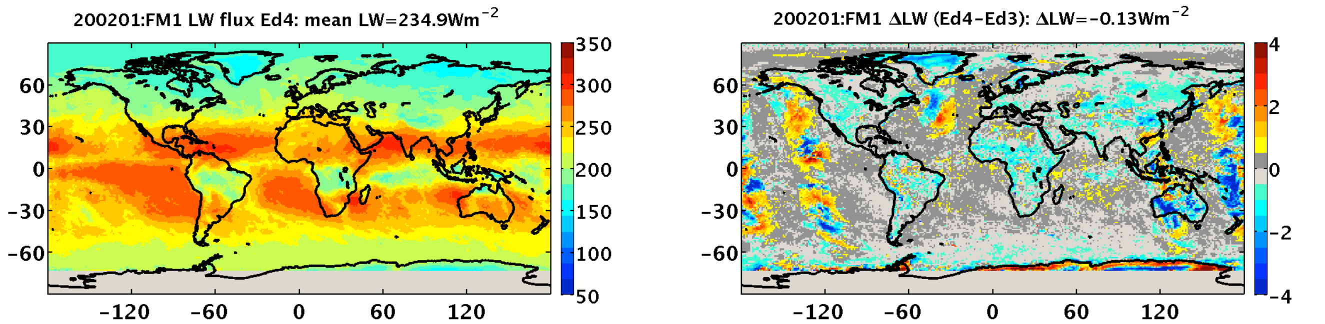

Figure 3. CERES Terra Edition4A mean all-sky nighttime LW TOA flux (left), CERES Terra Edition4A minus Edition3 mean all-sky nighttime LW TOA flux difference (right) for January 2002.

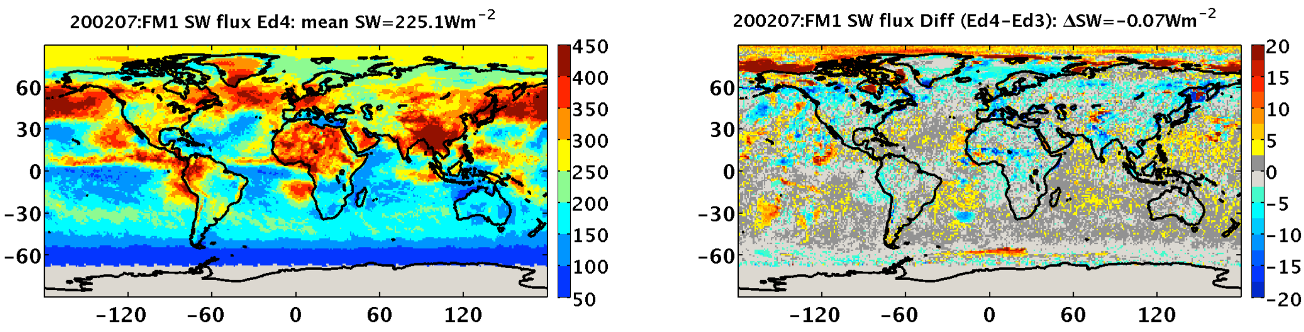

Figure 4. CERES Terra Edition4A mean all-sky SW TOA flux (left), CERES Terra Edition4A minus Edition3 mean all-sky SW TOA flux difference (right) for July 2002.

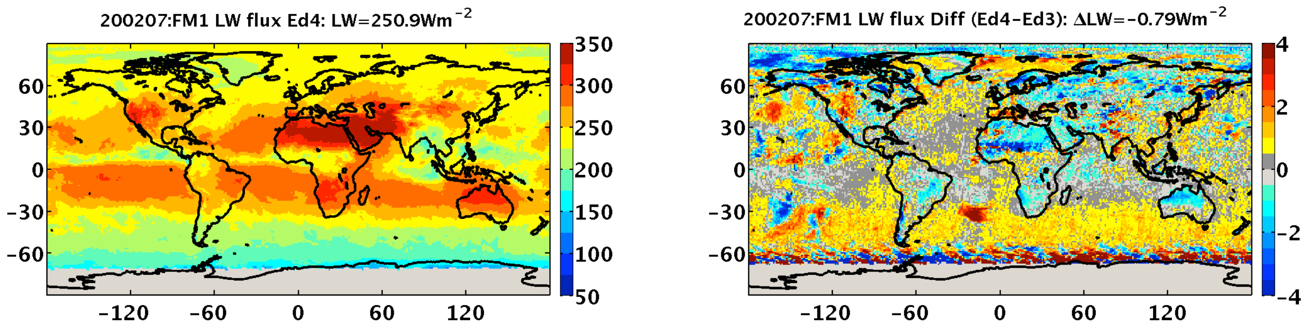

Figure 5. CERES Terra Edition4A mean all-sky daytime LW TOA flux (left), CERES Terra Edition4A minus Edition3 mean all-sky daytime LW TOA flux difference (right) for July 2002.

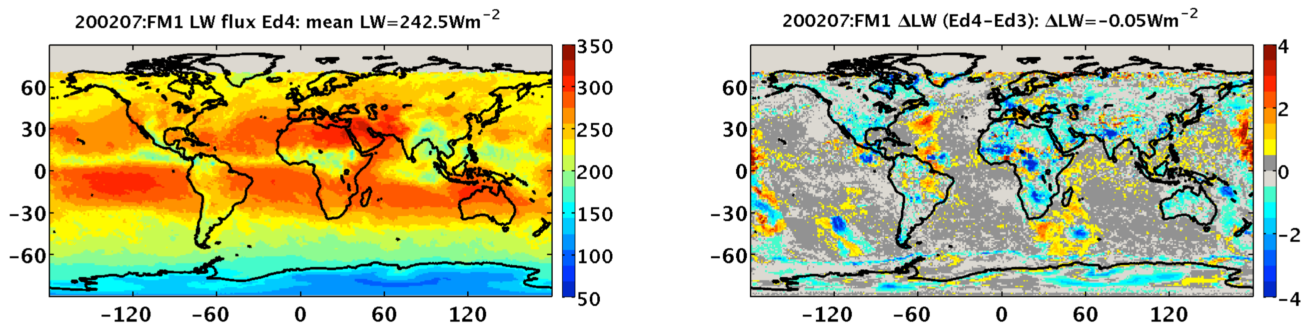

Figure 6. CERES Terra Edition4A mean all-sky nighttime LW TOA flux (left), CERES Terra Edition4A minus Edition3 mean all-sky nighttime LW TOA flux difference (right) for July 2002.

Table 9. CERES Aqua Edition4A mean instantaneous all-sky TOA flux and CERES Aqua Edition4A minus Edition3 mean instantaneous all-sky TOA flux difference for April and October 2004

		Mean Flux (W m^{-2})	Mean Diff (W m^{-2})
April	SW	240.1	0.27
	Daytime LW	242.7	0.00
	Nighttime LW	234.9	-0.07
October	SW	237.2	0.77
	Daytime LW	245.1	0.24
	Nighttime LW	236.6	-0.01

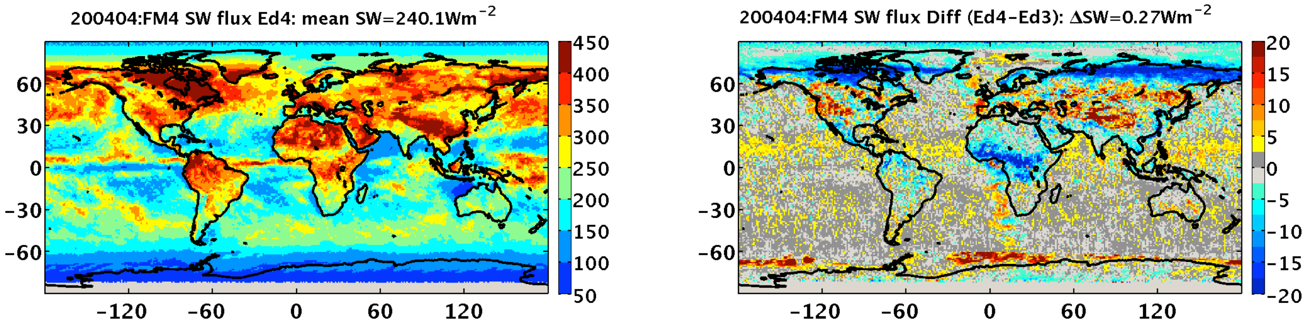

Figure 7. CERES Aqua Edition4A mean all-sky SW TOA flux (left), CERES Aqua Edition4A minus Edition3 mean all-sky SW TOA flux difference (right) for April 2004.

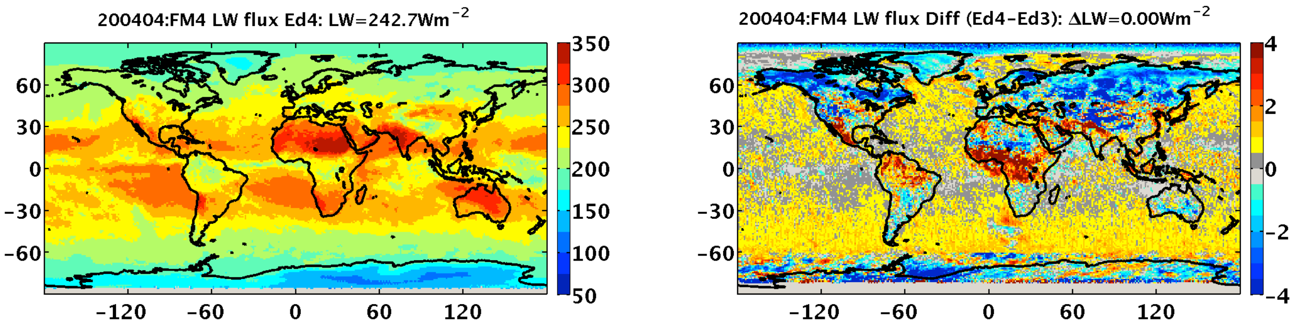

Figure 8. CERES Aqua Edition4A mean all-sky Daytime LW TOA flux (left), CERES Aqua Edition4A minus Edition3 mean all-sky daytime LW TOA flux difference (right) for April 2004.

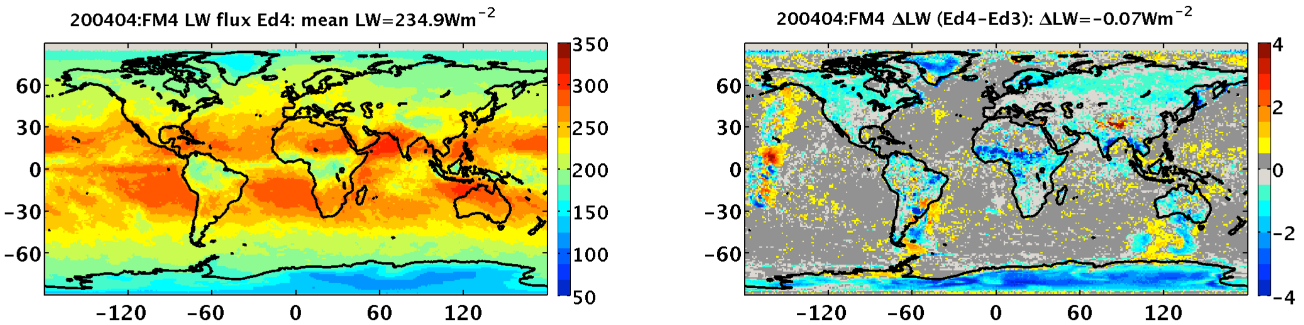

Figure 9. CERES Aqua Edition4A mean all-sky nighttime LW TOA flux (left), CERES Aqua Edition4A minus Edition3 mean all-sky nighttime LW TOA flux difference (right) for April 2004.

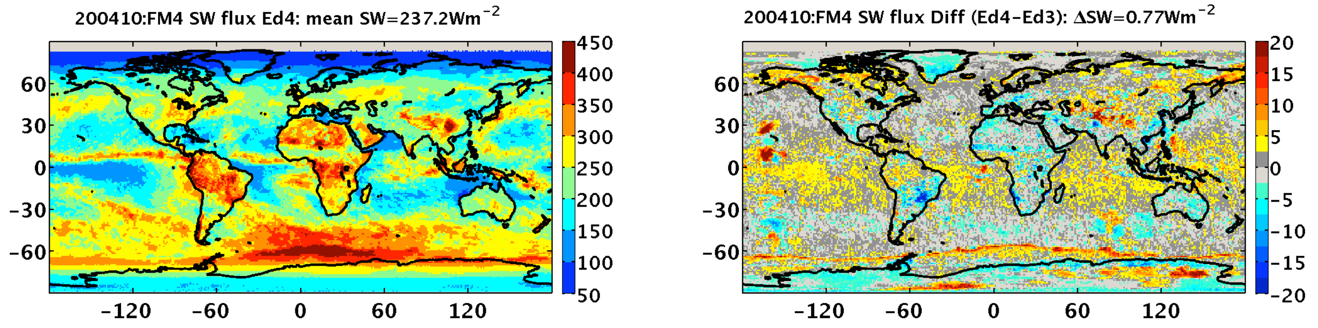

Figure 10. CERES Aqua Edition4A mean all-sky SW TOA flux (left), CERES Aqua Edition4A minus Edition3 mean all-sky SW TOA flux difference (right) for October 2004.

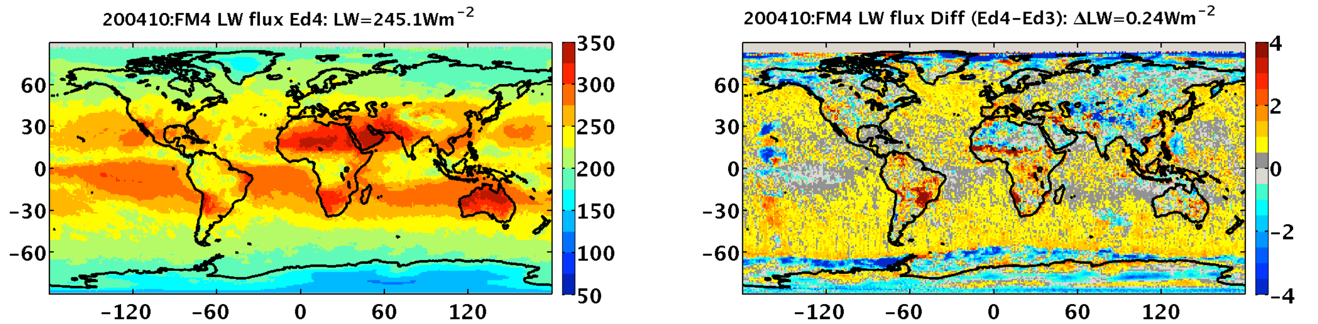

Figure 11. CERES Aqua Edition4A mean all-sky Daytime LW TOA flux (left), CERES Aqua Edition4A minus Edition3 mean all-sky daytime LW TOA flux difference (right) for October 2004.

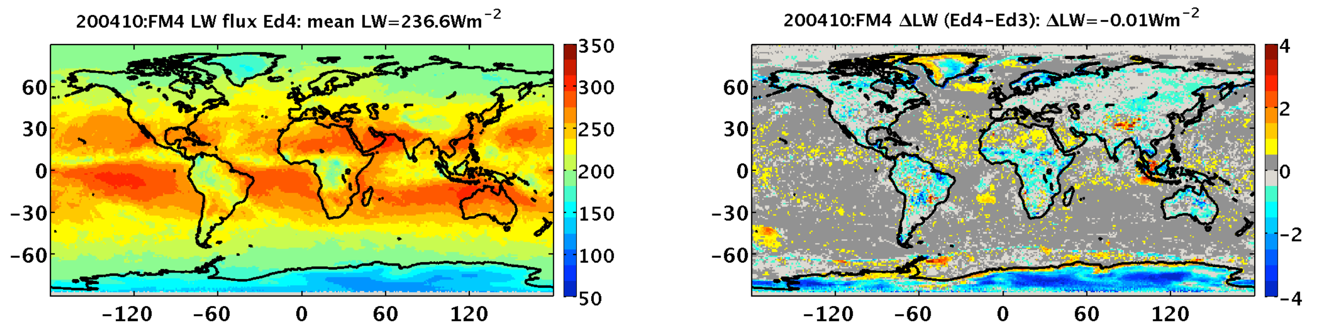

Figure 12. CERES Aqua Edition4A mean all-sky Daytime LW TOA flux (left), CERES Aqua Edition4A minus Edition3 mean all-sky nighttime LW TOA flux difference (right) for October 2004.

Wenying Su, Joseph Corbett, Zachary Eitzen, Lusheng Liang, Next-Generation Angular Distribution Models for Top-of-Atmosphere Radiative Flux Calculation from the CERES Instruments: Methodology, Atmos. Meas. Tech. Disscuss., 7, doi:10.5194/amtd-7-8817-2014, 8817-8880, 2014.

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