Surface–Only Flux Algorithms Working Group Report

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Section One:

Validation and Subsequent Improvement of Surface–Only Flux Algorithms

Background (Part 1)

CERES uses several Surface–Only Flux Algorithms (SOFA) to compute SW and LW surface fluxes in addition to the more precise model used by SARB. The SOFA algorithms include:

LPSA/LPLA:
Langley Parameterized SW/LW Algorithm

		Model A	Model B	Model C
SW	Clear	Li et al.	LPSA	--
	All-Sky	--	LPSA	--
LW	Clear	Inamdar and Ramanathan	LPLA	Zhou-Cess
	All-Sky	--	LPLA	Zhou-Cess

SOFA References:

SW A: Li et al. (1993): *J. Climate*, **6**, 1764-1772.
SW B: Darnell et al. (1992): *J. Geophysical Research*, **97**, 15741-15760.
SW B: Gupta et al. (2001): *NASA/TP-2001-211272*, 31 pp.
LW A: Inamdar and Ramanathan (1997): *Tellus,* **49B**, 216-230.
LW B: Gupta et al. (1992): *J. Appl. Meteor.,* **31**, 1361-1367.
LW C: Zhou et al. (2007): *J. Geophysical Research*, **112**, D15102.
SOFA: Kratz et al. (2010): *J. Appl. Meteor. Climatology*, **49**, 164-180.
SOFA: Gupta et al. (2010): *J. Appl. Meteor. Climatology,* **49**, 1579-1589.
FLASH: Kratz et al. (2014): *J. Appl. Meteor. Climatology*, **53**, 1059-1079.

Background (Part 2)

- The SOFA LW and SW Models are based on fast, highly parameterized TOA to surface transfer algorithms, which are used to derive the surface fluxes on an instantaneous footprint basis.
- LW Model A (clear–sky only), LW Model B (all–sky) and SW Model A (clear–sky only) were incorporated at the start of the CERES project. SW Model B (all–sky) was incorporated into the CERES processing shortly thereafter.
- The Edition 2B LW and SW surface flux results underwent extensive validation [Kratz et al., 2010], which led to improvements to the LW models [Gupta et al., 2010].
- LW Model C (all-sky) [Zhou et al., 2007] was introduced into the Edition 4A processing to maintain two independent LW algorithms after the broadband LW Channel was chosen to replace the CERES Window Channel for CERES FM-6 and the next generation Radiation Budget Instrument (RBI).
- LW and SW Models B were incorporated into FLASHFlux [Kratz et al., 2014], an adjunct CERES effort designed to provide CERES–like Environmental Data Records within one week of observation. Details concerning FLASHFlux will be presented later this morning.

Recent and Future Improvements to the Surface-Only Flux Algorithms

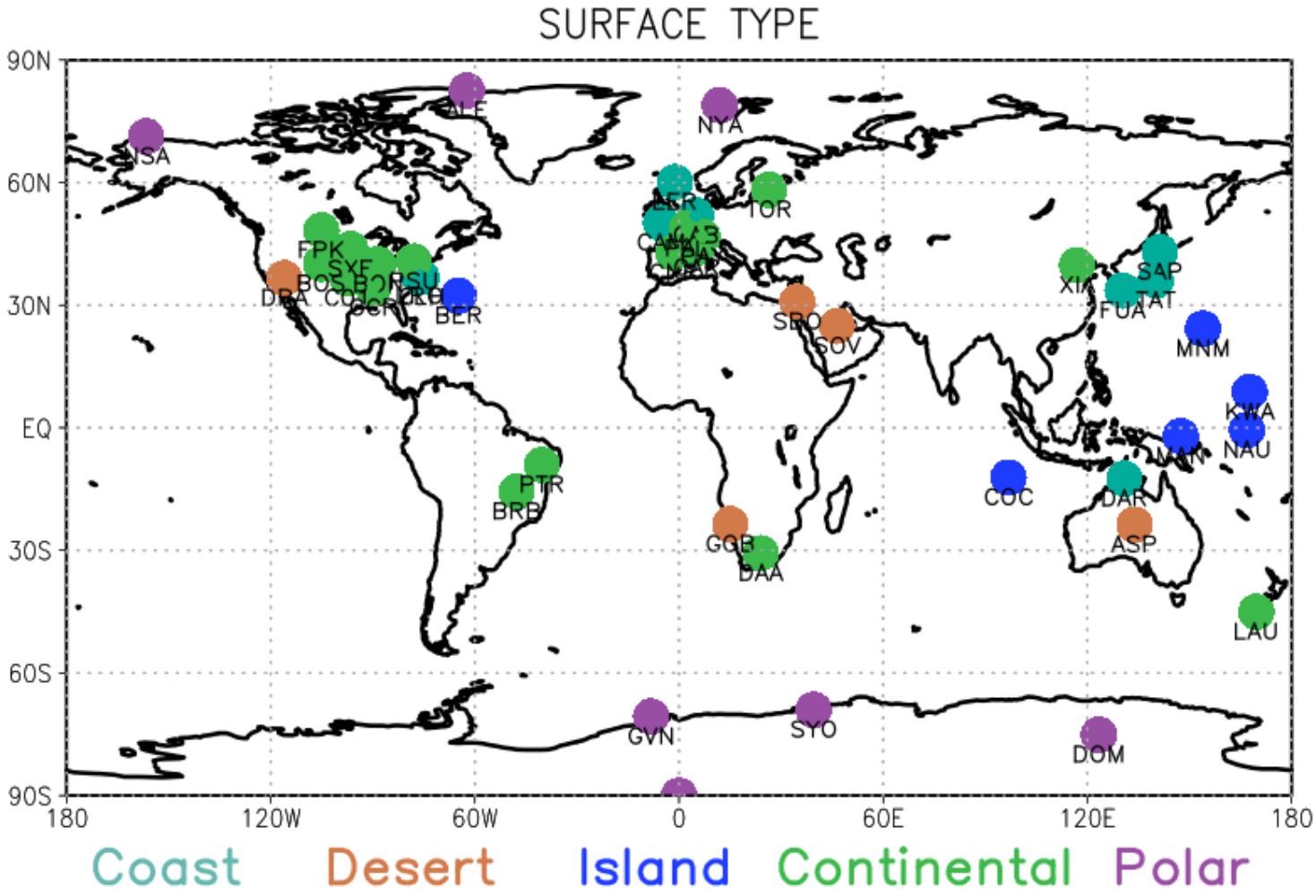
SW Model Improvements: 1) Replacing the ERBE albedo maps with the Terra maps greatly improved the SW retrievals, most notably for polar regions. 2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al., (1999) model significantly improved SW surface fluxes for clear conditions. 3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4A. 4) Using a revised empirical coefficient in the cloud transmission formula improved the SW surface fluxes for partly cloudy conditions. 5) Work continues on the improvement of the cloud transmission method for Edition 4+ clouds.

LW Model Improvements: 1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010). 2) Limiting the inversion strength to −10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

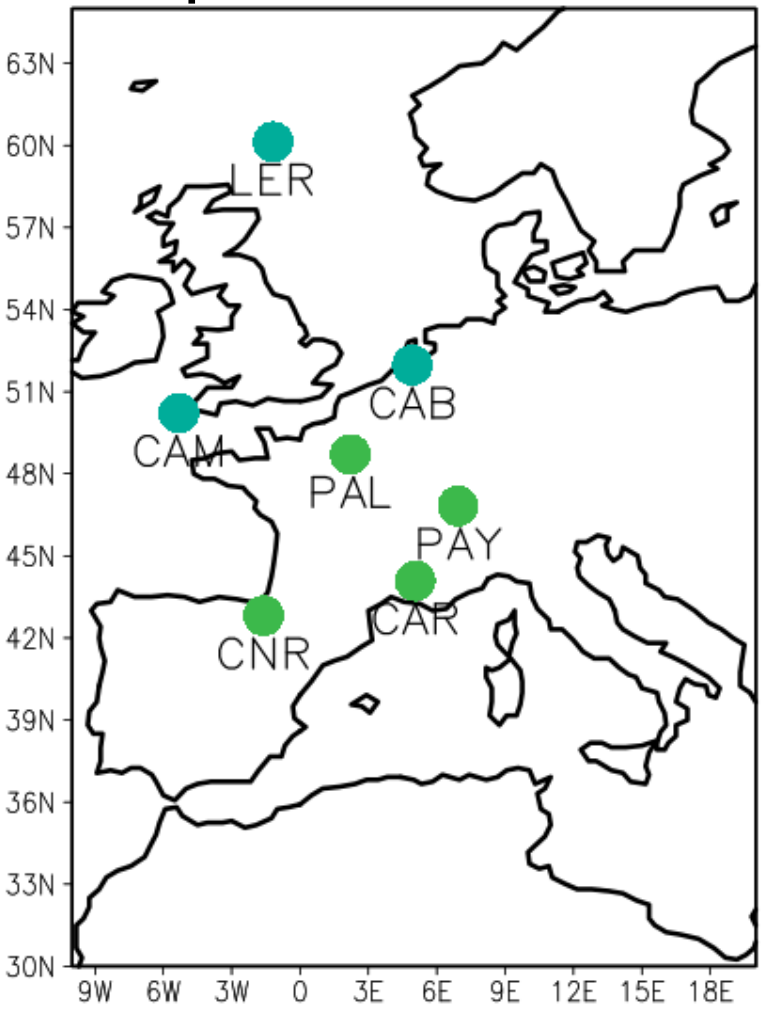
Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

Dataset	CERES 2B	CERES 4A
Clear-Sky TOA albedo Terra	48 month ERBE	70 month Terra
Clear-Sky TOA albedo Aqua	46 month Terra	70 month Terra
Clear-Sky Surf. albedo	46 month Terra	70 month Terra
TOA to Surface albedo transfer	Instantaneous	Monthly average
Spec. Corr. Coef.	CERES 2B	CERES 4A
Cos (sza) dependence of Surface Flux	LPSA	Briegleb-type
Cloud Algorithm Terra	Terra Ed2	Terra/Aqua Ed4
Cloud Algorithm Aqua	Aqua Ed2	Terra/Aqua Ed4
SW aerosol dataset	WCP-55	MATCH/OPAC
Rayleigh Treatment	Original LPSA	Bodhaine et al (1999), JAOT.
Ozone Range Check	0 to 500 DU	0 to 800 DU
Twilight cutoff		New
Cloud transmission empirical coefficient	0.80	0.75
LW high temperature surface correction	No	Maximum Lapse Rate 10K/100hPa
LW Inversion correction	No	Maximum Inversion Strength -10K/100hPa

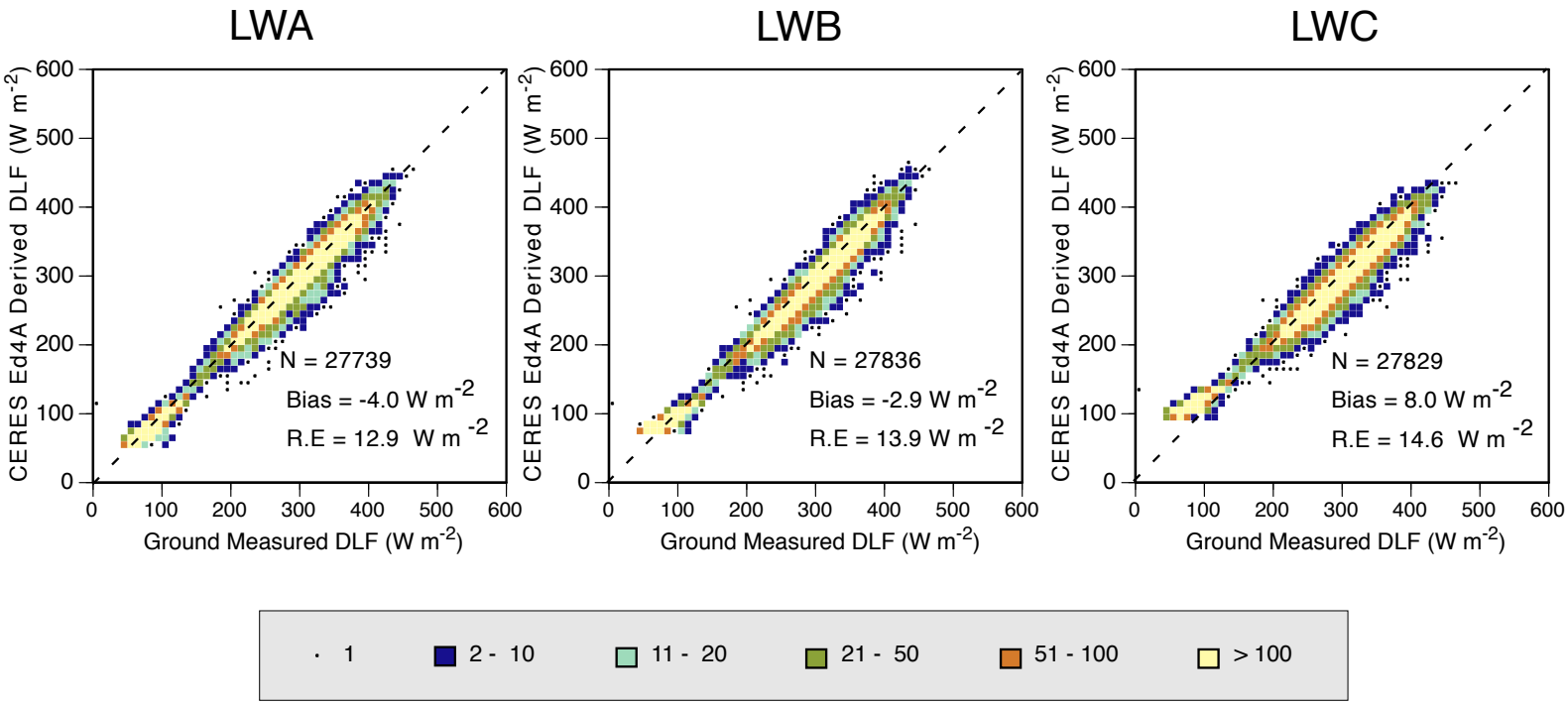
Surface Sites Available for Validation of Terra & Aqua Ed4A, and NPP Ed1A



European Sites Available for Validation of Terra & Aqua Ed4A, and NPP Ed1A

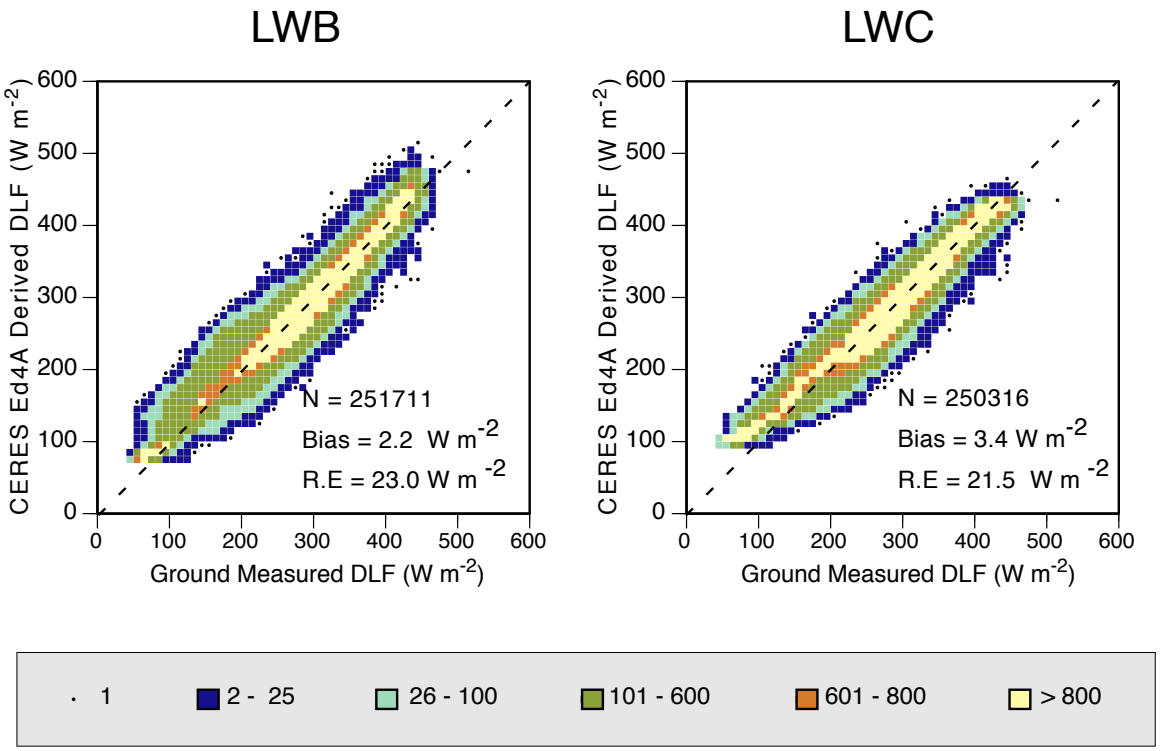


CERES Terra Edition 4A LW Ground Validation (Global) Clear–Sky



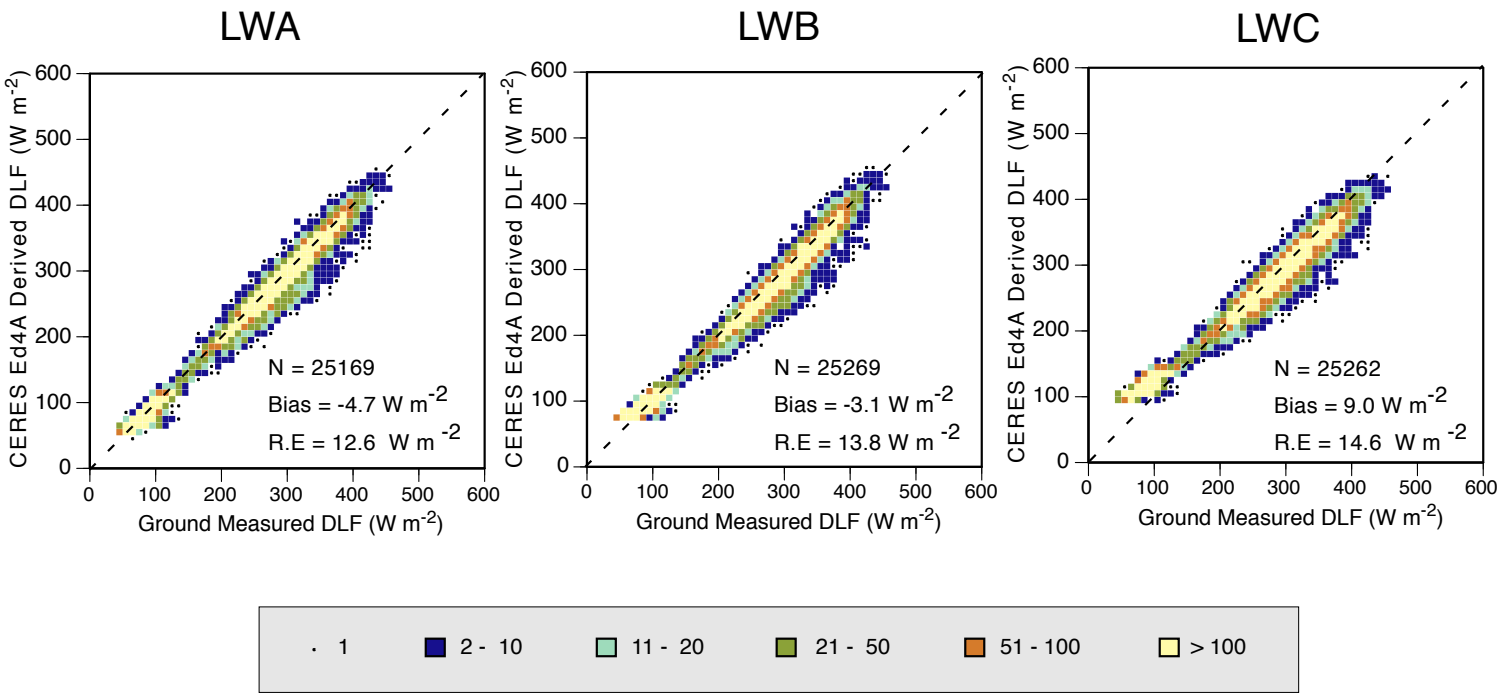
Combined LW Ground Validation for Terra (3/2000 through 2/2016).

CERES Terra Edition 4A LW Ground Validation (Global) All–Sky



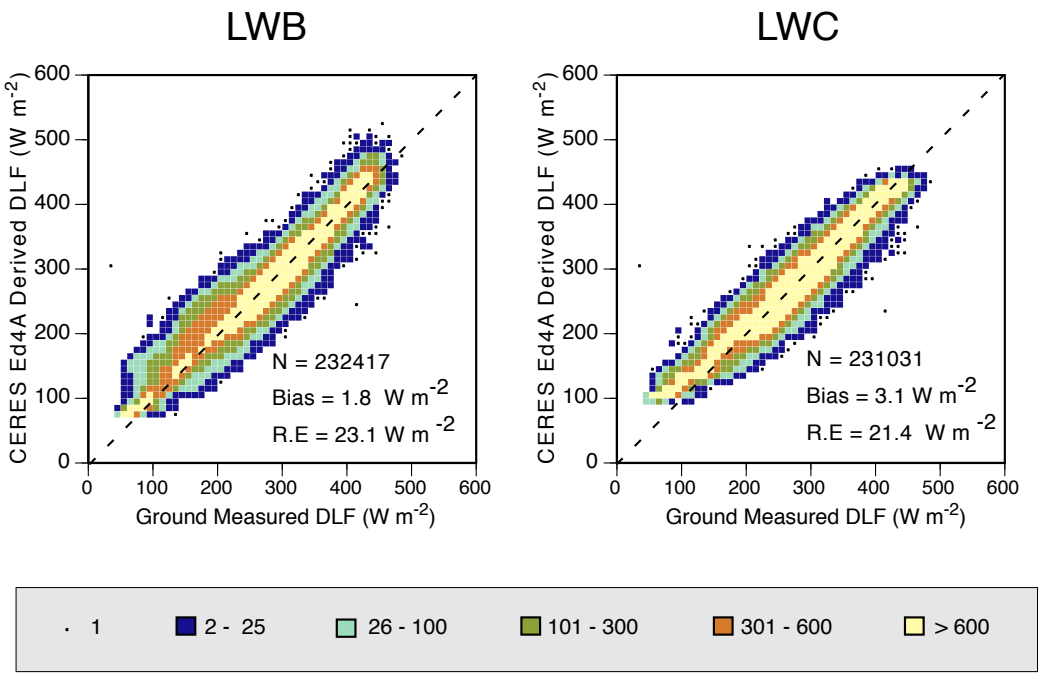
Combined LW Ground Validation for Terra (3/2000 through 2/2016).

CERES Aqua Edition 4A LW Ground Validation (Global) Clear–Sky



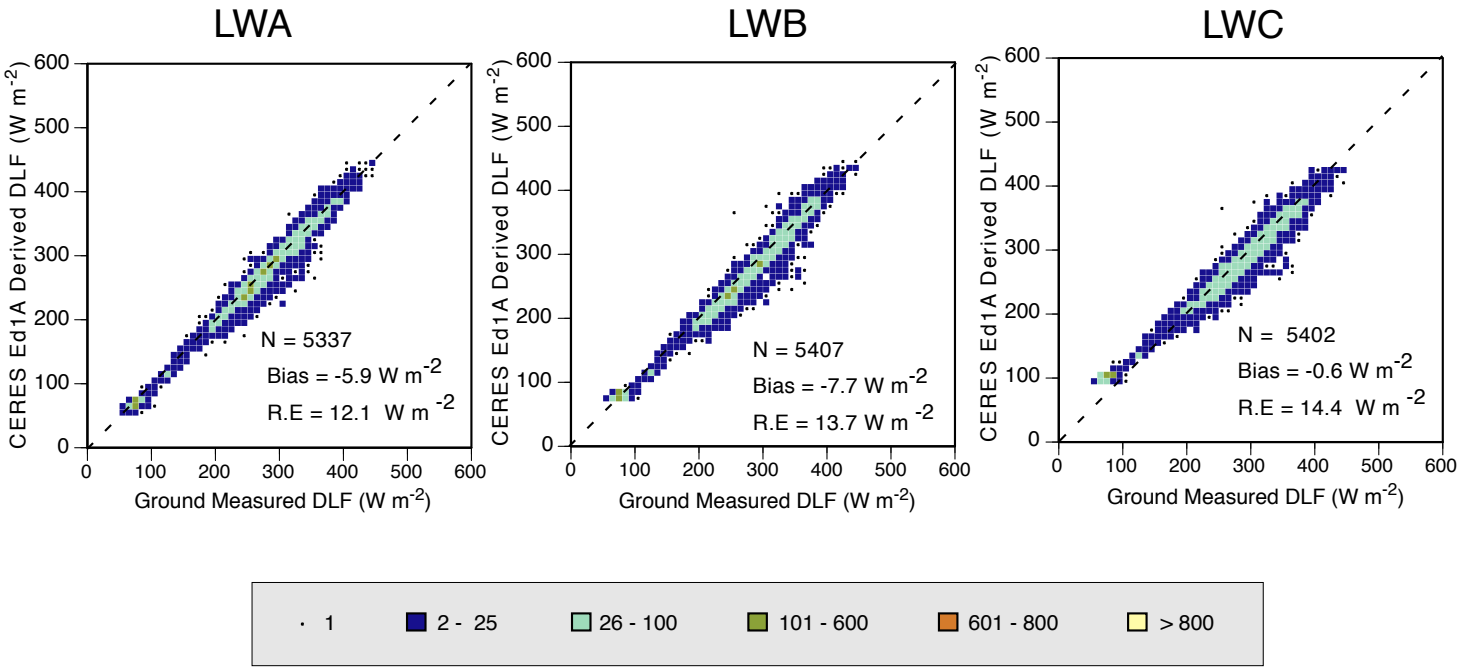
Combined LW Ground Validation for Aqua (7/2002 through 2/2016).

CERES Aqua Edition 4A LW Ground Validation (Global) All–Sky



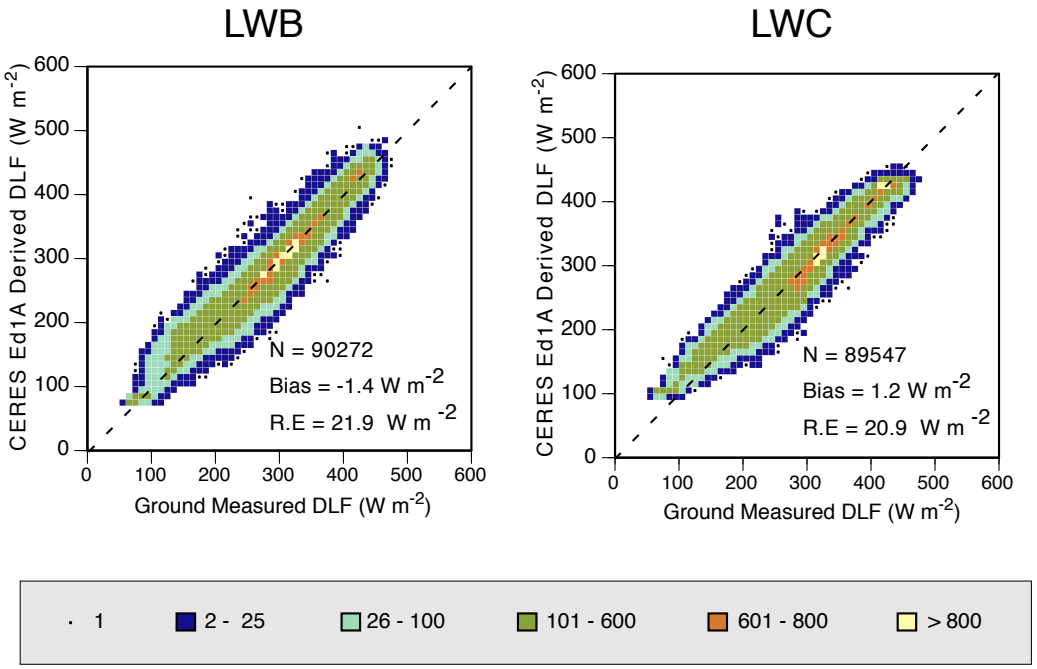
Combined LW Ground Validation for Aqua (7/2002 through 2/2016).

CERES NPP Edition 1A LW Ground Validation (Global) Clear–Sky



Combined LW Ground Validation for NPP (1/2012 through 12/2015).

CERES NPP Edition 1A LW Ground Validation (Global) All–Sky



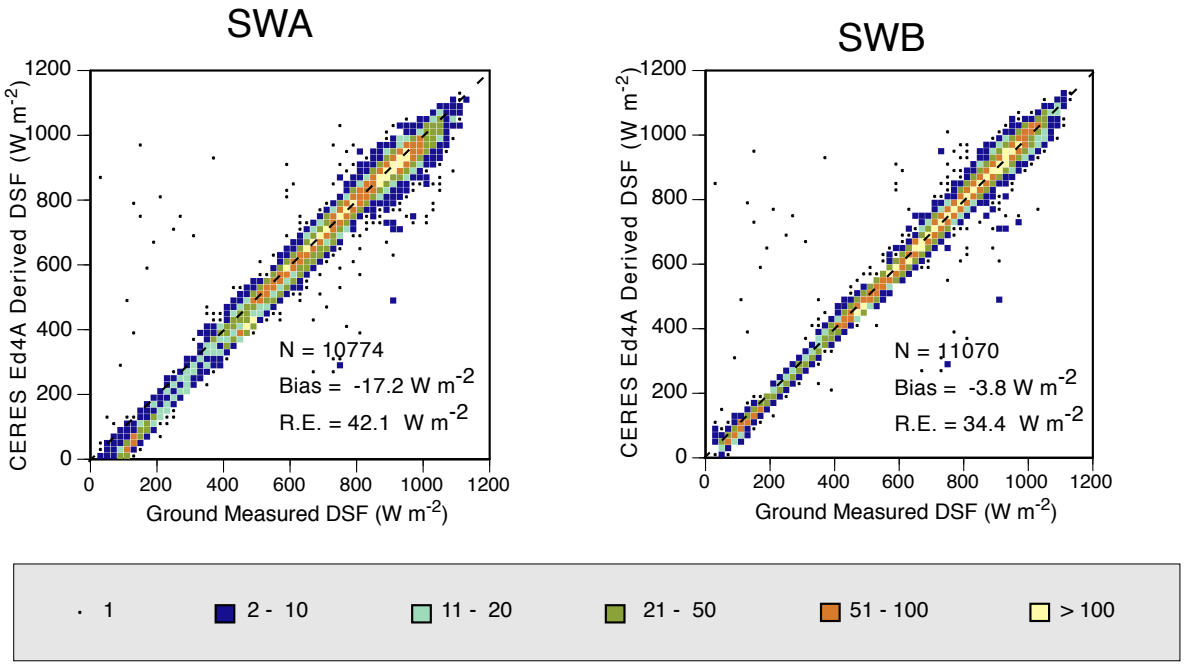
Combined LW Ground Validation for NPP (1/2012 through 12/2015).

LW Surface Flux Results

The Terra, Aqua and NPP LW fluxes derived for Clear Sky conditions show low biases ≈ ±8 W/m^2, and relatively low uncertainties ≈ 12 to 15 W/m^2.

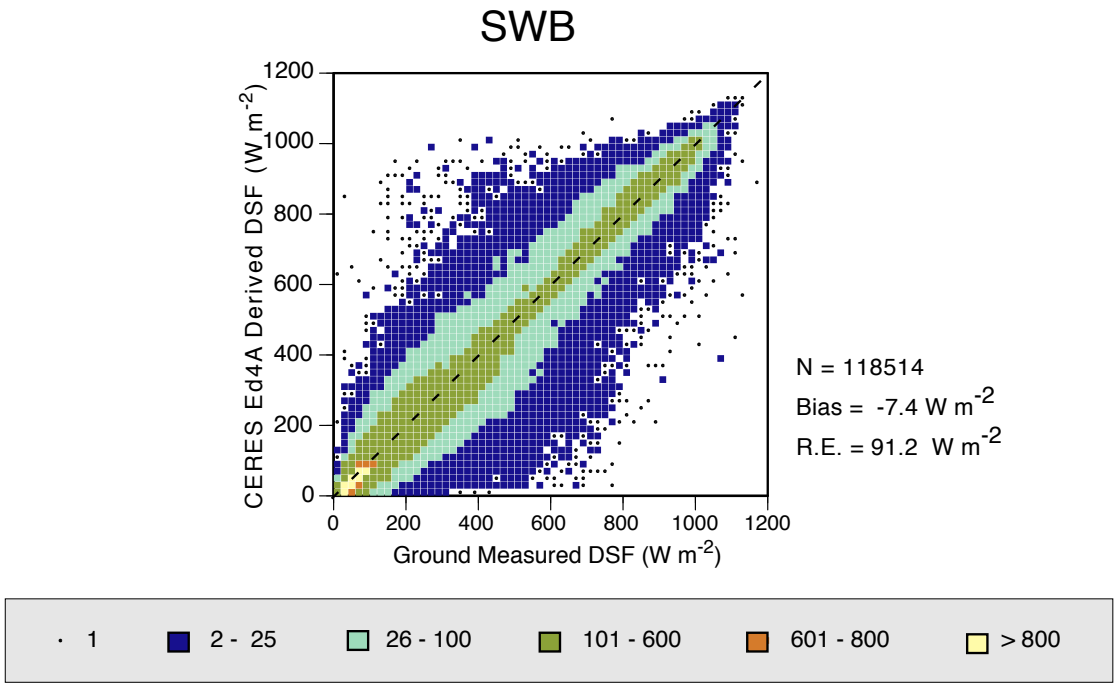
The Terra, Aqua and NPP LW fluxes derived for All Sky conditions show low biases ≈ ±3 W/m^2, and moderate uncertainties ≈ 20 to 23 W/m^2.

CERES Terra Edition 4A SW Ground Validation (Global) Clear–Sky



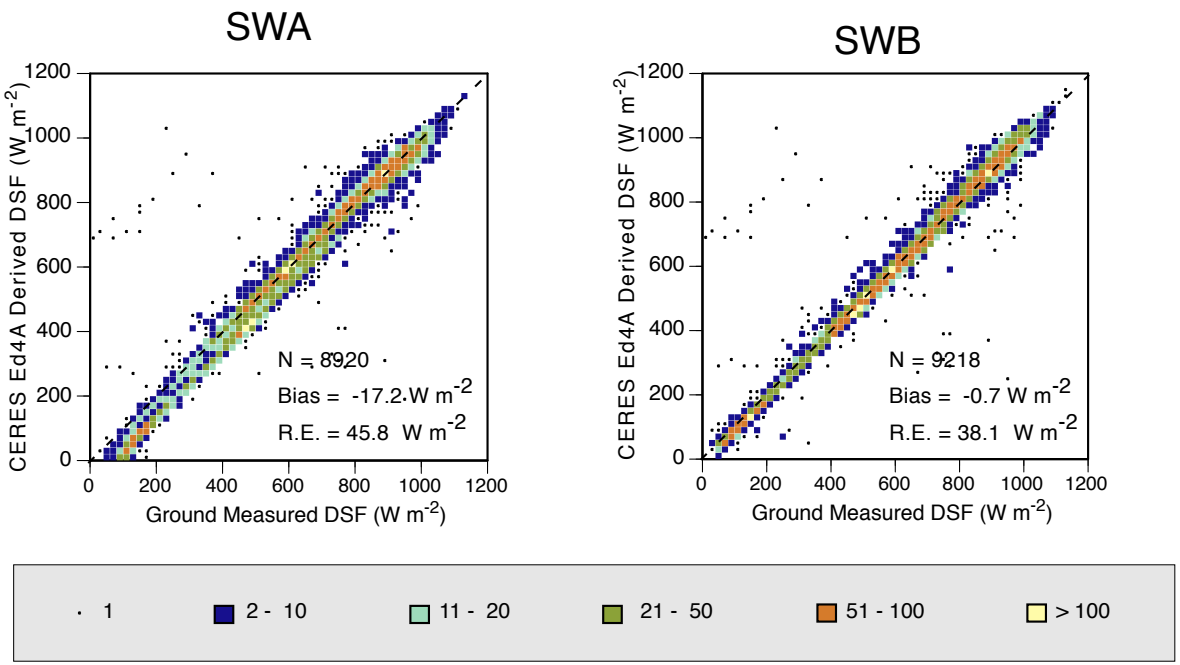
Combined SW Ground Validation for Terra (3/2000 through 2/2016).

CERES Terra Edition 4A SW Ground Validation (Global) All–Sky



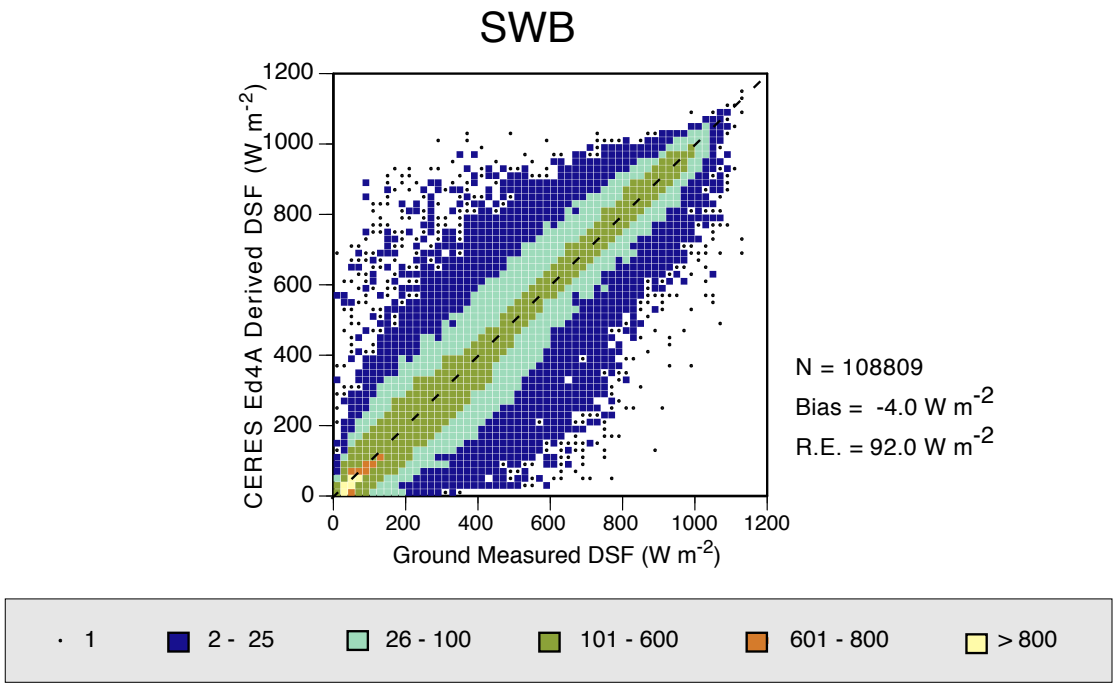
SWB Ground Validation for Terra (3/2000 through 2/2016).

CERES Aqua Edition 4A SW Ground Validation (Global) Clear–Sky



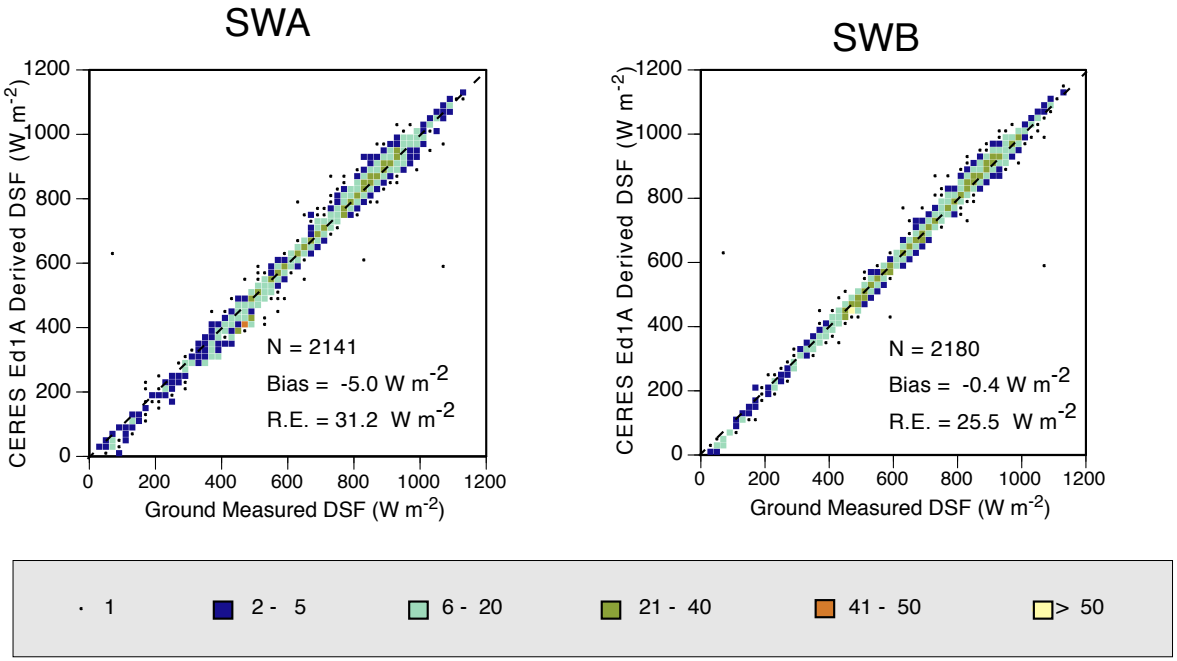
Combined SW Ground Validation for Aqua (7/2002 through 2/2016).

CERES Aqua Edition 4A SW Ground Validation (Global) All–Sky



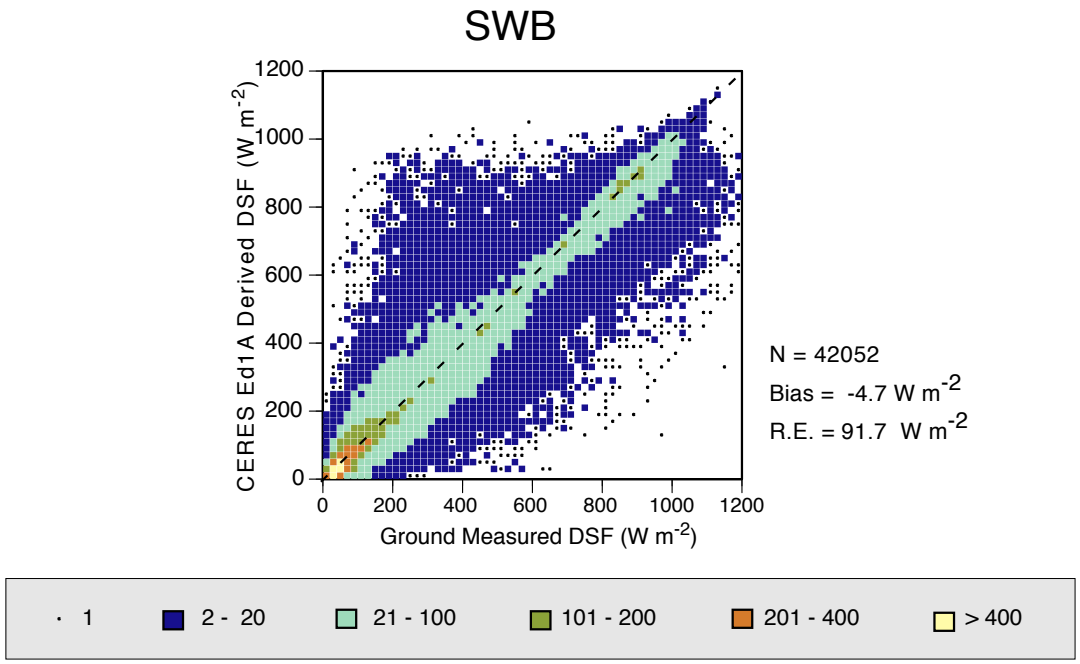
SWB Ground Validation for Aqua (7/2002 through 2/2016).

CERES NPP Edition 1A SW Ground Validation (Global) Clear–Sky



Combined SW Ground Validation for NPP (1/2012 through 12/2015).

CERES NPP Edition 1A SW Ground Validation (Global) All–Sky



SWB Ground Validation for NPP (1/2012 through 12/2015).

SW Surface Flux Results

The Terra, Aqua and NPP SW fluxes derived for Clear Sky conditions show relatively low biases ≈ –17 to 0 W/m^2, and moderate uncertainties ≈ 25 to 40 W/m^2.

The Terra, Aqua and NPP SW fluxes derived for All Sky conditions show low biases ≈ –4 to –8 W/m^2, but large uncertainties ≈ 90 W/m^2.

Our current effort is focused on finding methods to reduce the large uncertainties in the retrieved SW Cloudy Sky surface fluxes.

Conclusions for SOFA Ed4A algorithms

Validation studies have demonstrated that revisions to both the LW algorithms and the SW algorithms are working well, though further revisions to the cloud transmission method are underway to improve SW Model B.

An analysis of the LW and SW surface only flux algorithm results using the Edition 4A inputs, especially those from the Clouds Subsystem, has improved accuracies for most locations.

The Terra, Aqua and NPP flux retrievals show good agreement with the ground–based measurements.

Section Two:

Maintenance of Daily Total Solar Irradiance (TSI) Dataset
for Use in CERES Processing
(SSF 38A SW TOA flux downwards)

Part 1:
SORCE V15 based dataset for current Edition 4A Processing

Part 2:
SORCE V17 based dataset for processing future Editions.

Part 1: Total Solar Irradiance (TSI) Version 15

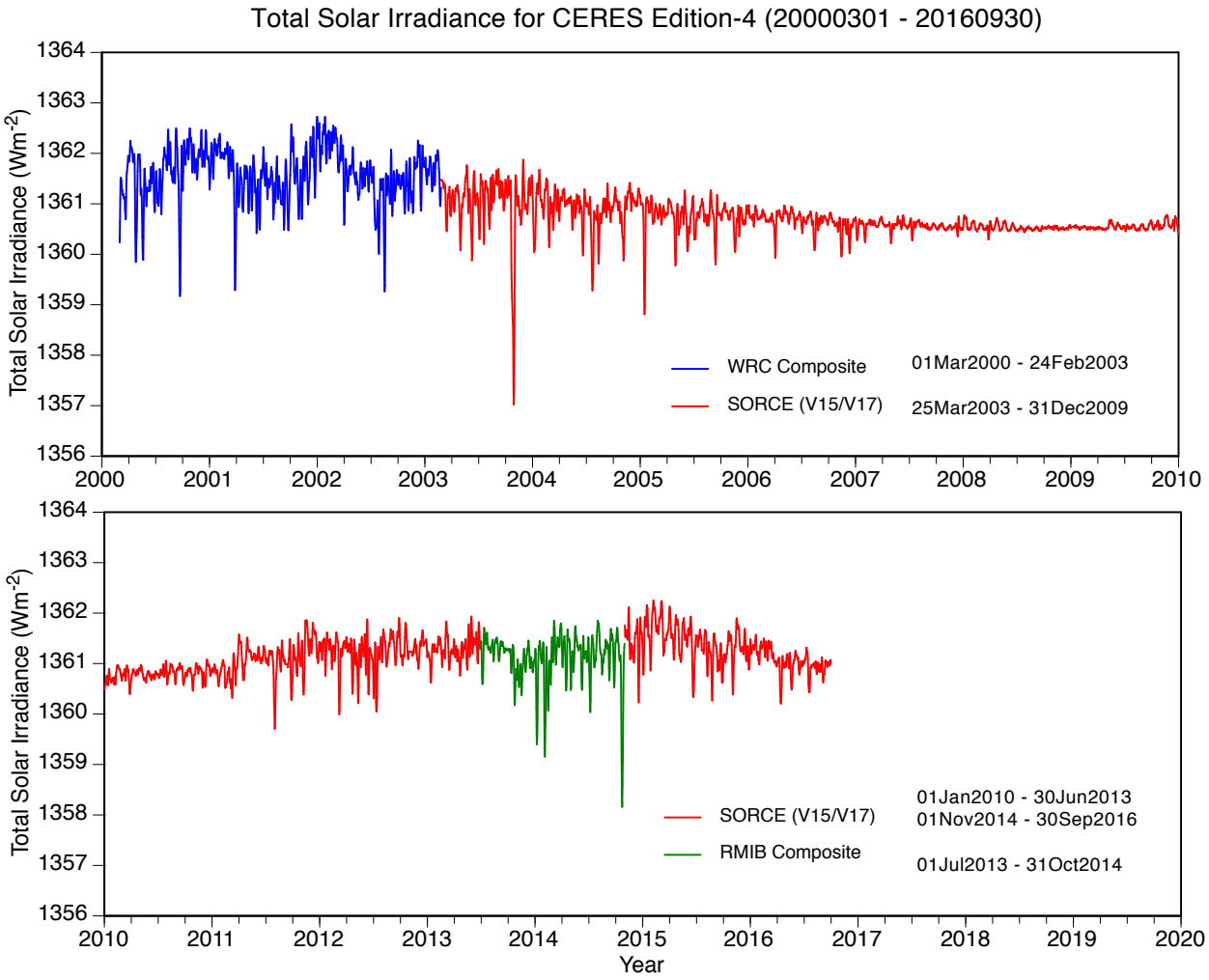
At the start of Edition 4A processing, the CERES team decided to use daily total solar irradiance from SORCE TIM Version 15. CERES Terra and Aqua began processing with 1 Mar 2000 and 1 Jul 2002, respectively. SORCE data production, however, did not start until 25 Feb 2003.

The early gap (Mar2000–Feb2003) was filled using data from the WRC file composite_d41_62_0906.dat after applying an offset recommended by the SORCE data providers.

The SORCE data stream was interrupted in July 2013 by a battery failure. Daily TSI data from RMIB-Composite was substituted for SORCE. An offset of 2.4447 W/m^2 was applied to the RMIB data in consultation with Steven Dewitte.

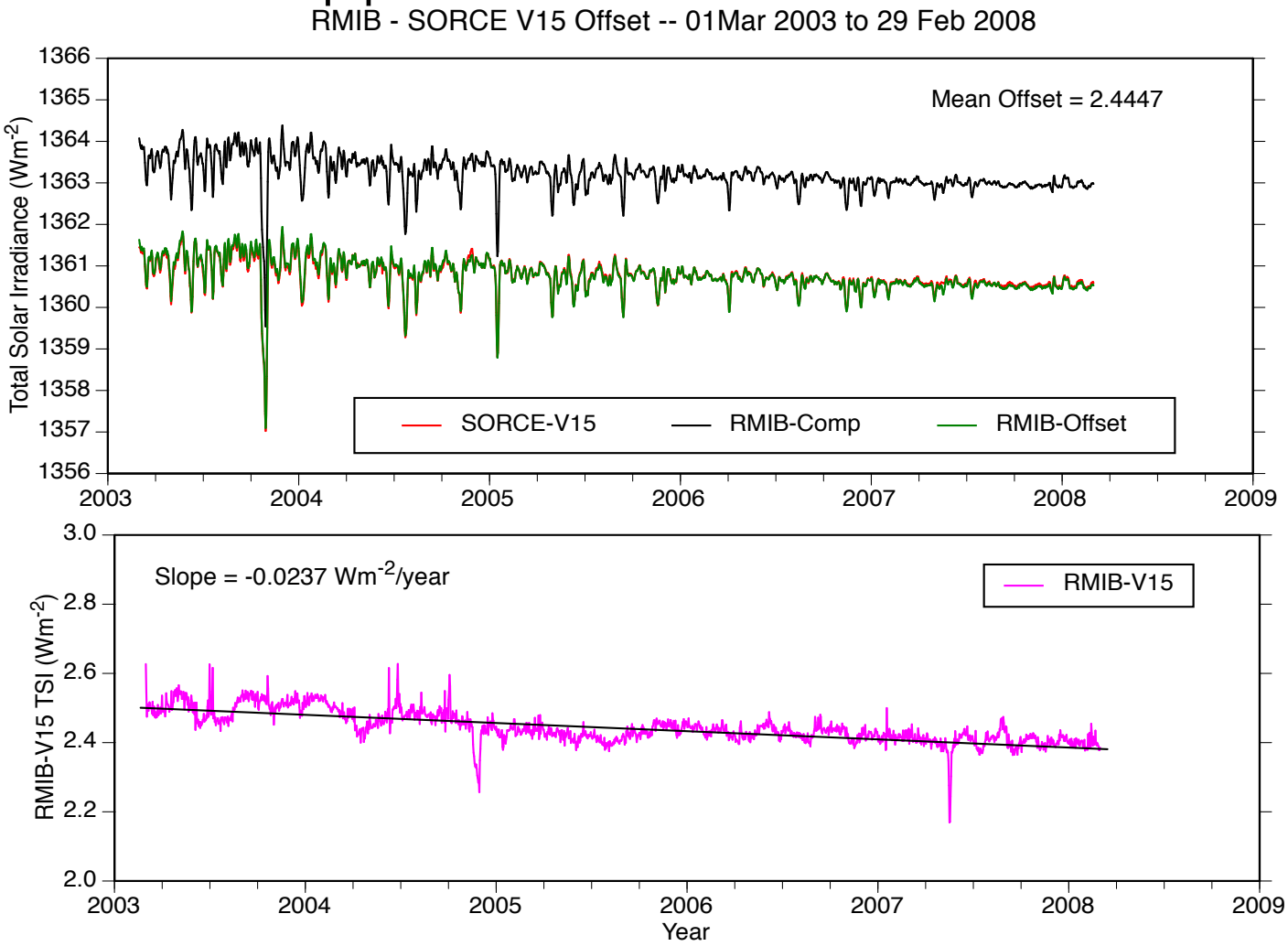
SORCE data production resumed in March 2014 but CERES continued to use RMIB data until October 2014. In November 2014, CERES resumed the use of SORCE data (now Version 17). A small offset (V15 – V17 = –0.0049 Wm^{-2}) was applied to bring V17 in line with V15. V17 data, with the above offset, continues to be used for CERES Ed4A and EBAF Ed2.8.

TSI composite data from WRC, SORCE(V15) and RMIB for the Timeframe of CERES Terra, Aqua & NPP



For CERES Ed 4A, all TSI data are offset to match SORCE TSI Version 15

Comparison of TSI data [SORCE(V15) versus RMIB] for the 5–year overlap period 1–Mar–2003 to 29–Feb–2008

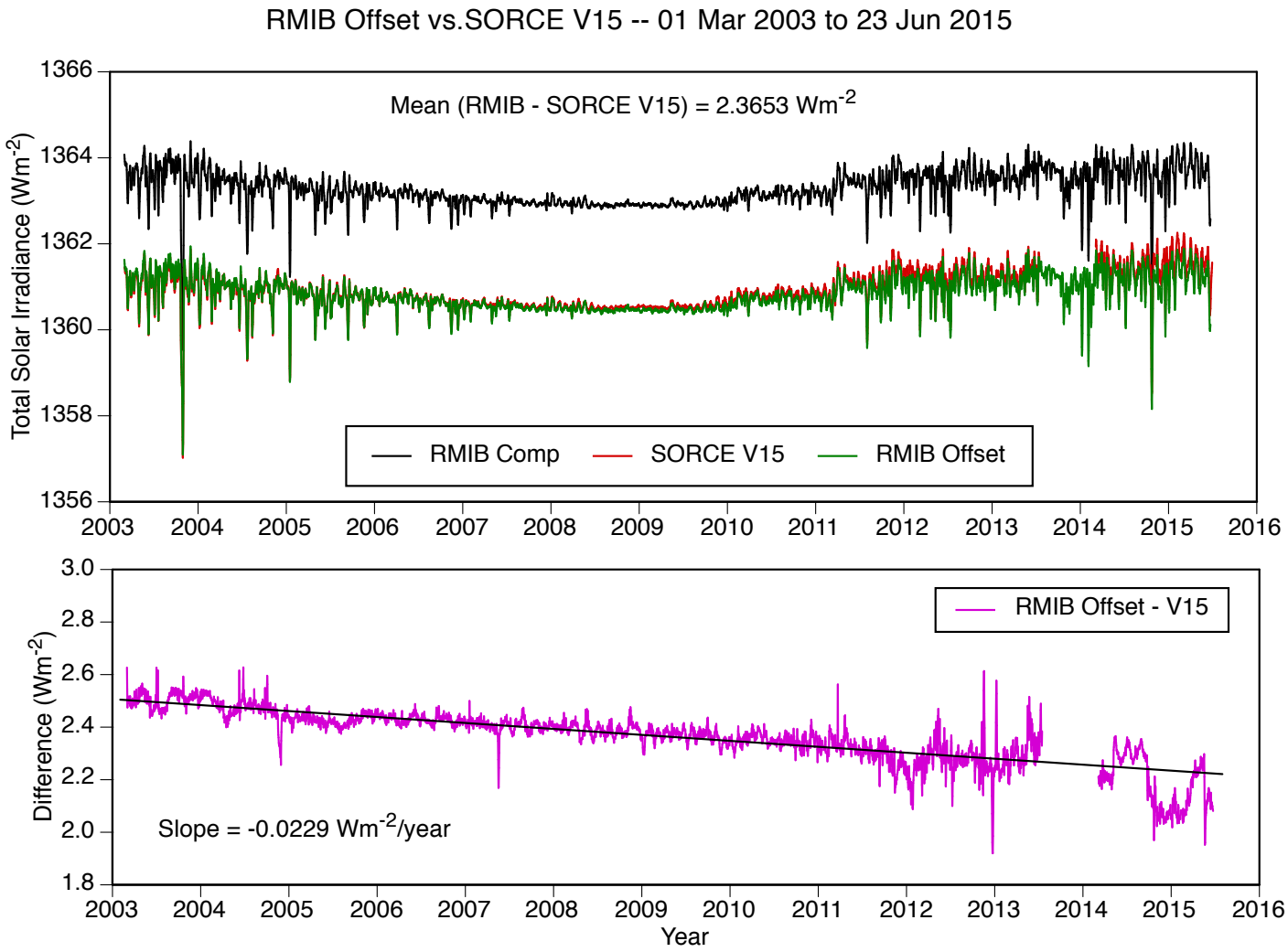


This timeframe corresponds to the first 60 months of the SORCE data record

Slope of RMIB vs. SORCE is −0.0237 W/m^2/y which yields an offset of 1 W/m^2 in 42.19 years

RMIB data was closely examined relative to SORCE

Comparison of SORCE(V15) and RMIB for the timeframe: 1–Mar–2003 to 23–Jun–2015



This timeframe corresponds to the first 148 months of the SORCE data record

RMIB offset by +2.3653 W/m^2 from SORCE

Slope of RMIB versus SORCE −0.0229 W/m^2/y corresponds to first 120 months and yields an offset of 1 W/m^2 in 43.67 years

Part 2: SORCE Upgrade to Version 17

- Current SORCE data being produced is Version 17
- Reasons for the upgrade:
- Calibration adjustments (cavity heater resistances corrected for varying temperatures; temperature coefficients of certain heater lead resistances changed; temperature weightings for heater lead resistances changed) for improved thermal corrections due to large temperature fluctuations with ongoing orbital power cycling.
- New dark model implemented for all cavities to better match existing dark (thermal background) measurements.
- Updates to instrument degradation using cavity inter-comparisons through 9 December 2014.

Upgraded Total Solar Irradiance (TSI)

1. A new timeseries of daily TSI values, based primarily on SORCE V17 data has been constructed for potential use in future CERES reprocessing.

2. Data for periods when SORCE data are not available: March 2000 to February 2003 and July 2013 to March 2014 were taken from World Radiation Center (WRC; aka PMOD) file ext_composite_42_65_1602.dat available from the WRC ftp site.

3. WRC TSI values are now quite close to SORCE TSI values but small differences persist (details follow). A closer examination of these differences between the two timeseries also showed a small trend between them.

4. Offset based on this trend analysis was applied to WRC TSI data in the two intervals before blending with the SORCE data to prepare a complete time series.

WRC's Rationale for Adjusting Their Data to Match With SORCE TIM

(From Documentation Accompanying the File ext_composite_42_65_1602.dat)

Comment: Since VIRGO version 6.4, a new way to analyze the degradation and other long-term changes in space is used and described in "Degradation of Radiometers in Space: Application to VIRGO TSI" available at:

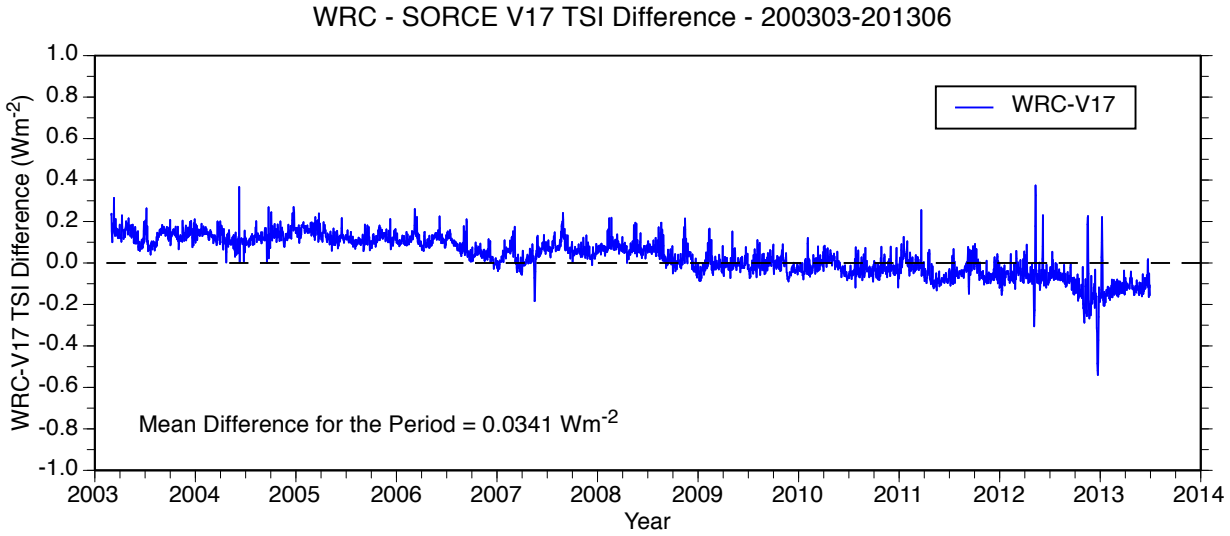
ftp://ftp.pmodwrc.ch/pub/Claus/VIRGO-TSI/VIRGO_TSI-vers64.pdf

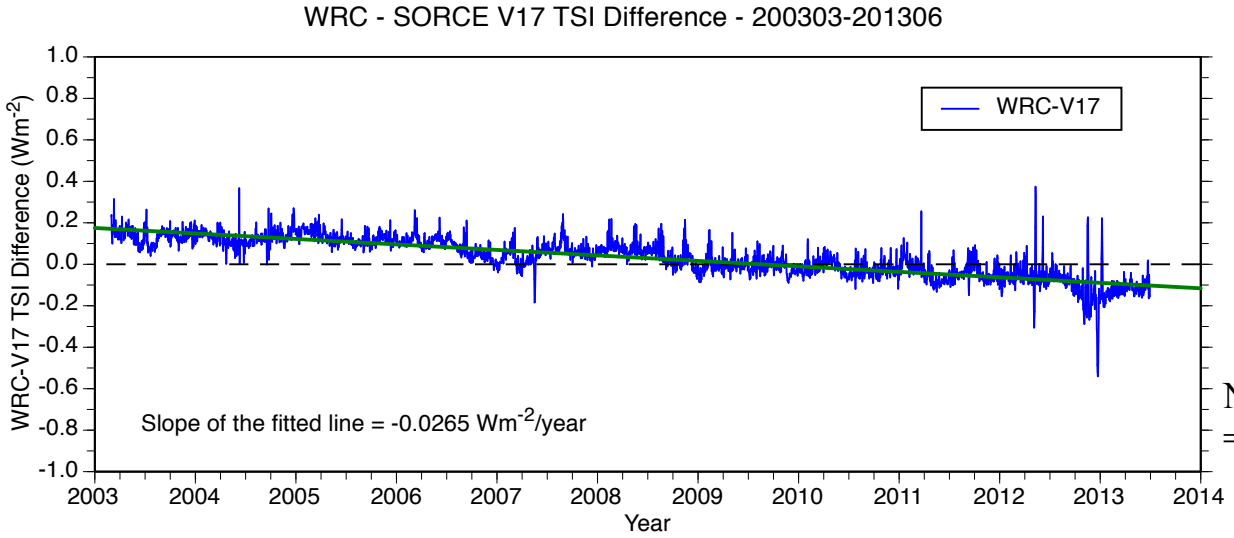
The difference in scale between TIM and the classical radiometers indicated a missing effect in the characterization of all classical radiometers and including PMO6V and DIARAD of VIRGO, which can now be corrected. This is described in "VIRGO Radiometry: An Update of the Characterization of PMO6V and DIARAD" available at:

ftp://ftp.pomdwrc.ch/pub/Claus/VIRGO-TSI/VIRGO_Char2Space.pdf

(A publication in the open literature is in preparation).
The factor for transforming the original scale of VIRGO (the basis for the PMOD Composite since version 42) to the new one is 0.9963812 and the new value is given in the first irradiance column.

Difference SORCE V17 minus WRC March 2003 – June 2013

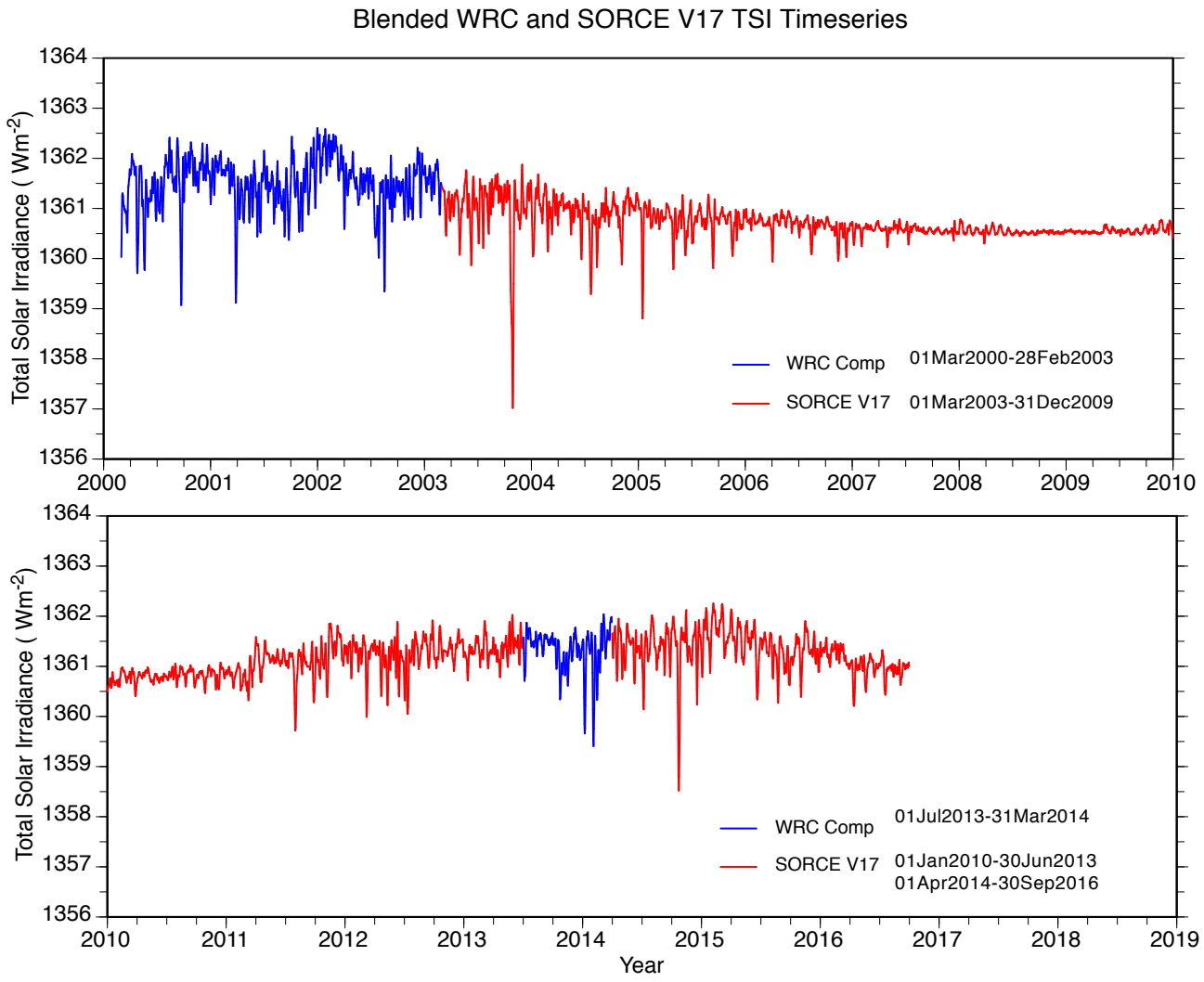




Note: 0.0265 W/m^2/year = 1 W/m^2 in 37.74 years

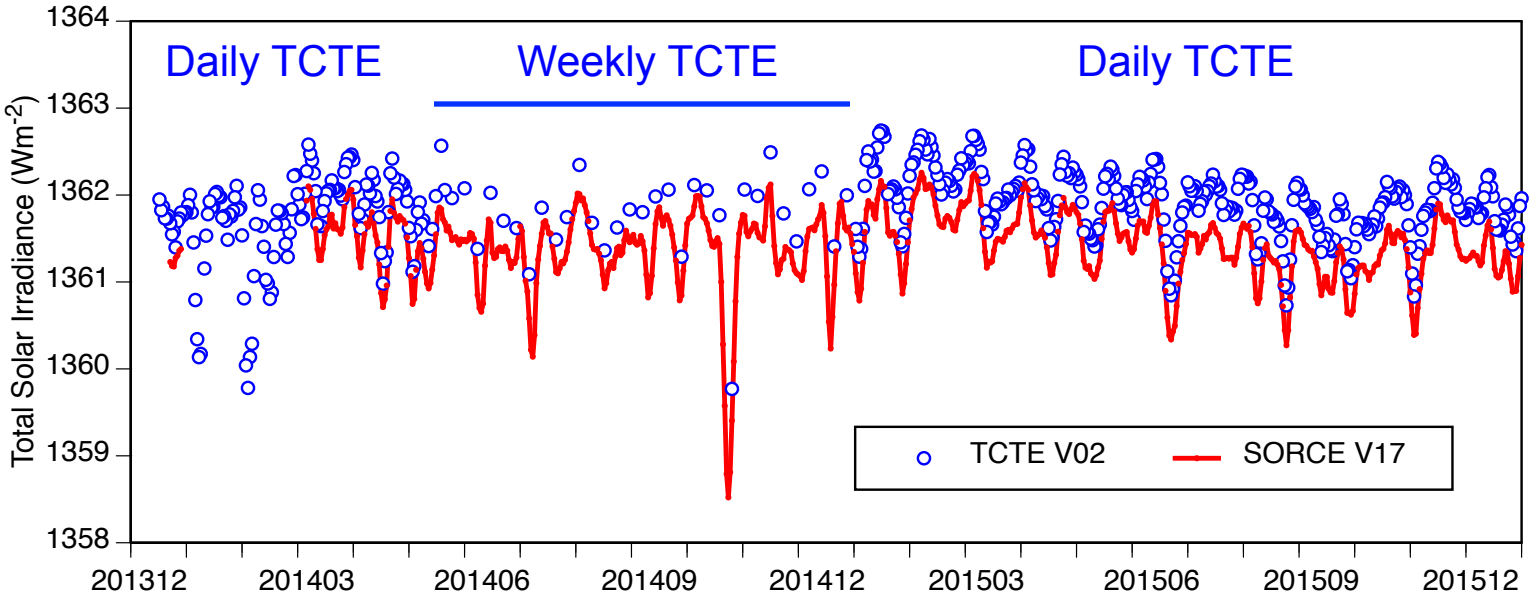
The period above is the longest continuous common period between V17 and WRC.

TSI composite data from SORCE V17 and WRC



Comparison of SORCE(V17) and TCTE(V02) Daily/Weekly Total Solar Irradiance Retrievals

TSI Comparison: SORCE V17 vs. TCTE V02 (16 Dec 2013 to 31 Dec 2015)

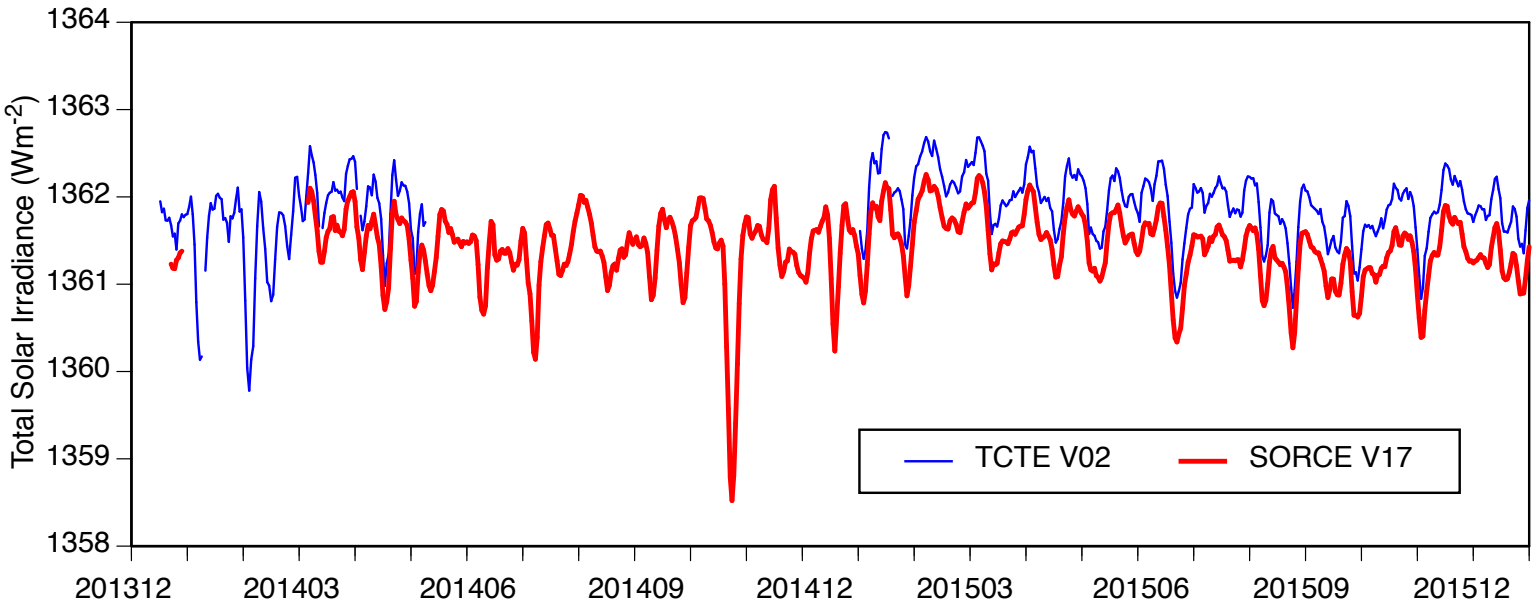


SORCE: 1 value/day, Dec 22, 2013 through Dec 28, 2013, and 1 value/day Mar 5, 2014 through Mar 31, 2016; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

TCTE: 1 value/day, Dec 16, 2013 through May 8, 2014, 1 value/week May 11, 2014 through Dec 31, 2014, 1 value/day Jan 1, 2015 through Sep 30, 2016; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

SORCE minus TCTE (Jan 1, 2015 to Dec 31, 2015) is −0.4879 ± 0.0599 W/m^2
SORCE minus TCTE (Jan 1, 2015 to Sep 30, 2016) is −0.4999 ± 0.0536 W/m^2

Comparison of SORCE(V17) and TCTE(V02) Daily Total Solar Irradiance Retrievals



SORCE: 1 value/day, Dec 22, 2013 through Dec 28, 2013, and 1 value/day Mar 5, 2014 through Mar 31, 2016; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

TCTE: 1 value/day, Dec 16, 2013 through May 8, 2014, 1 value/week May 11, 2014 through Dec 31, 2014, 1 value/day Jan 1, 2015 through Sep 30, 2016; Absolute Accuracy: ±0.48 W/m^2 at 1361 W/m^2

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